RACER Trust

In Situ Chemical Reduction with Zero Valent Iron Pilot Study Workplan

Pontiac North Campus, Former Fiero Property

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In Situ Chemical Reduction with Zero Valent Iron Pilot Study Workplan

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Acronyms and Abbreviations

Arcadis	Arcadis of Michigan, LLC.
bgs	below ground surface
cis-1,2 DCE	cis-1,2 dichloroethene
CVOC	chlorinated volatile organic compound
DO	dissolved oxygen
DQO	data quality objective
EGLE	Michigan Department of Environment, Great Lakes, and Energy
ft	feet
GFL	Green for Life
ISCR	in situ chemical reduction
ITRC	Interstate Technology Regulatory Council
lbs	pounds
mg/L	milligrams per liter
µg/L	micrograms per liter
LCS	laboratory control samples
LOD	limit of detection
LOQ	limit of quantitation
MDL	method detection limit
MS/MSD	matrix spike and spike duplicate
MW	monitoring well
ORP	oxidation-reduction potential
PCE	tetrachloroethene
Plan	Work Plan for Remedial Action
PRB	permeable reactive barrier
psi	pounds per square inch
QA/QC	quality assurance/quality control
RACER	Revitalizing Auto Communities Environmental Response
ROI	radius of influence
SDS	Safety Data Sheet
SOP	standard operating procedures
TCE	trichloroethene
TGI	Technical Guidance Instruction
USEPA	United States Environmental Protection Agency
VAP	Vertical Aquifer Profile
VI	vapor intrusion
VOCs	volatile organic compounds
ZVI	zero valent iron

1 Introduction

On behalf of RACER Trust (RACER), Arcadis of Michigan, LLC (Arcadis) has prepared this Work Plan (Plan) for pilot-scale direct-push injections of zero valent iron (ZVI) at the former Fiero assembly property at Pontiac North Campus (Site). Information collected during this pilot test will provide a basis for evaluating possible future applications of ZVI if deemed necessary based on monitoring data, evaluation of risks, and other corrective measure options. At the current time, a full-scale application of injected ZVI (or any other remedy) is not warranted.

2 Site Description

The Site is a former automobile manufacturing facility located in Pontiac, Michigan. The Site is currently occupied by Green for Life (GFL), a waste management company. **Figure 1** shows the site layout and distribution of tetrachloroethane (PCE) and trichloroethane (TCE) in the groundwater. The proposed pilot test location is located near the center of the site (**Figure 2**).

The lithology of the pilot test area is an interbedded mixture of sands and silts from zero to 25 feet below ground surface (bgs), then a fine sand unit from 25 to 40 feet bgs, underlaid by a clay aquitard (**Figure 3A**). Depth to groundwater at the pilot test location ranges from approximately 20 to 25 feet bgs. Boring logs for the nearby wells are included in **Appendix A**. Additional Site characterization information can be found in the 2022 Fiero Site Investigation Report.

3 In Situ Chemical Reduction with Zero Valent Iron

In situ chemical reduction (ISCR) with ZVI was selected for pilot testing based on its ability degrade chlorinated volatile organic compounds (CVOCs) abiotically. The proposed pilot test will evaluate the efficacy of treatment of PCE and TCE with ZVI. Because potential offsite migration of groundwater above site specific residential vapor intrusion criteria is a concern at the Site, ISCR with ZVI is ideal because it limits the potential for generation of daughter products that can result in vapor intrusion concerns associated with biological degradation of CVOCs. To ensure there are no vapor intrusion concerns, the pilot test will evaluate the potential for generation of daughter products with low vapor intrusion criteria (e.g., vinyl chloride). ZVI can be emplaced into the subsurface a variety of ways, including trenching, soil mixing, or direct-push injections. Direct-push injections was selected as the preferred alternative based on its small installation footprint, quick installation, and easy field adaptability, which is important based on the uncertainty of ongoing/future construction and redevelopment activities at the Site. The distribution of ZVI in the subsurface is important to ensure robust treatment and will be evaluated as part of the pilot test. The longevity of the ZVI reactivity depends on many factors including the size of ZVI particles injected (i.e., micro-scale), groundwater geochemistry, CVOC loading, and contact. ZVI is not soluble in water and cannot migrate downgradient in the way that a soluble amendment (e.g., oxidant) can. The longevity of treatment will be assessed as part of the ongoing monitoring at the Site. The details of how the pilot test will be implemented is described in Section 4 and the performance monitoring plan to meet the pilot test objectives is detailed in Section 5.

4 Data Quality Objectives

The data quality objective (DQO) process was developed by the United States Environmental Protection Agency (USEPA) to “serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of a study” (USEPA 2006). This section is organized around the key steps in the DQO process which include:

1. State the problem.
2. Identify the goals of the study.
3. Identify information inputs.
4. Define the boundaries of the study.
5. Develop analytical approach.
6. Specify performance or acceptance criteria.
7. Develop the detailed plan for obtaining data.

4.1 State the Problem

The problem is to evaluate the effectiveness of an injected ZVI barrier as a potential remedy to address CVOCs, specifically PCE, TCE, and cis-1,2 dichloroethene (cis-1,2 DCE) in groundwater at the Site.

4.2 Identify the Goals of the Study

The overall objective of this effort is to collect information necessary to further evaluate and possibly design an injected ZVI barrier as a potential remedy at the Site.

4.3 Identify Information Inputs

This Plan has been specifically designed to collect the information inputs necessary to evaluate the effectiveness of and complete a design of a ZVI barrier including:

- Quantitatively evaluate treatment of CVOCs onsite utilizing an injected ZVI barrier by monitoring upgradient and downgradient monitoring wells.
- Quantitatively evaluate treatment longevity of an injected ZVI wall by monitoring upgradient and downgradient monitoring wells.
- Verify the radius of influence (ROI) of the injected ZVI in the subsurface utilizing confirmatory borings after all injections are complete to verify there is overlap of ROIs between points and a continuous treatment barrier.
- Evaluate the potential for chlorinated by-product generation (e.g., vinyl chloride) to create vapor intrusion (VI) risks to offsite receptors by monitoring upgradient and downgradient monitoring wells.

4.4 Define the Boundaries of the Study

The pilot test is focused on the proposed ZVI barrier transect area (**Figure 2**), as well as the monitoring wells directly upgradient and downgradient of the injected ZVI barrier, as described in this Plan. Key information required to evaluate and potentially design an injected ZVI barrier is its ability to treat PCE and TCE. Therefore, the pilot test is specifically located where both PCE and TCE are present in groundwater at concentrations high enough to evaluate treatment. The pilot test is also located away from the property boundary so that the potential for by-product generation (e.g., vinyl chloride) can be assessed without risk to offsite receptors. In addition, the pilot test location is along the core of the plume that appears to reach the property line and can provide treatment in a key location. The vertical boundaries of the pilot study are from the top of the saturated sand to the top of the basal clay, approximately 20 to 25 feet bgs to 40 feet bgs.

4.5 Develop the Analytical Approach

Information derived from performance monitoring will be used to evaluate the effectiveness of the injected ZVI barrier to treat PCE and TCE in groundwater. Groundwater concentration trend graphs will be developed to track changes in concentrations of PCE, TCE and chlorinated daughter products, and will be used to assess treatment performance.

4.6 Specify Performance or Acceptance Criteria

Field activities described in this Plan will be executed in accordance with Technical Guidance Instruction (TGI) documents referenced and included in **Appendix B**. Acceptance criteria for data will be governed by satisfactory adherence to TGIs and data validation procedures. Acceptance criteria will also include percent completion of planned data collection of 95% or greater.

4.7 Develop the Detailed Plan for Obtaining Data

This Plan provides the detailed plan for obtaining the required data and is presented in Sections 5 and 6 below.

5 Pilot Study Implementation

The residence time required to degrade the PCE and TCE to below residential VI criteria was evaluated with calculations consistent with Interstate Technology Regulatory Council (ITRC) Guidance modified for an injected ZVI barrier (ITRC, 2011). Several simplifying and conservative assumptions were made to complete this assessment for the proposed injected ZVI approach, with the resulting estimates indicating the proposed ZVI barrier has over 2 times the required residence time to degrade PCE, TCE, and cis-1,2-DCE to below residential VI criteria.

As described in the IRTC guidance, first order reaction rates for ZVI from the literature were used to calculate the required reaction (residence time) within the injected ZVI barrier. Calculations were performed using a PCE half-life of 0.2 hours, TCE half- life of 0.6 hours, and cis-1,2-DCE half-life of 3.1 hours. Residence times were calculated using the maximum expected PCE, TCE and cis 1,2-DCE concentrations of 560, 42, and 112 µg/L, respectively. The resulting required residence times were: 0.42 hours for PCE,1.95 hours for TCE, and 2.36 hours for cis 1,2-DCE. Required lateral ZVI treatment zone was calculated based on the following assumptions:

- Groundwater velocity of 1 foot per day,
- ZVI fracture height of 0.5 inches,
- Fractures emplaced every 2 feet vertically,
- Two, off-set rows of injection points,
- Injection points spaced 7 feet apart in each row,

- A radius of influence for each ZVI injection of 5 feet; and,
- A 2:1 porosity ratio for ZVI to the native geology.

Using the conservative assumption that the required residence times for PCE, TCE, and cis-1,2-DCE treatment are additive (they are not), the required lateral treatment zone was calculated to be 7.1 feet of ZVI. There will be approximately 17 feet of lateral ZVI treatment zone available in the pilot test layout proposed in Section 4.2 below.

These design calculations suggest that ZVI reaction kinetics should not be a limiting factor in contaminant degradation and that performance will generally be dependent on effective contact between injected ZVI and PCE and TCE in groundwater.

5.1 Injection Reagent Loading

ZVI will be applied at a rate of 0.5% of the weight of soil within the target treatment volume. Assuming a conservatively low 5-foot ROI, soil bulk density of 110 pounds (lbs) per cubic foot, and a 2-foot emplacement injection interval, a total of approximately 80 lbs of ZVI will be applied at each emplacement. The estimates and assumptions made to develop the ZVI mass loading rate are based on industry standards, ZVI vendor recommendations, injection subcontractor input, and ITRC guidance (ITRC, 2011) to achieve a technically effective, implementable, and cost-efficient design. One of the pilot test objectives is to confirm that these assumptions are appropriate for the Site-specific conditions to meet Site-specific objectives.

For each emplacement, the ZVI will be mixed with approximately 20 gallons of water and approximately 5 pounds of guar to help suspend the ZVI in a slurry and facilitate distribution. The slurry will be mixed in a mixing tank and will be fairly viscous. Guar is a polysaccharide that is used for its thickening and stabilizing properties. Based on its properties, it is often used in food applications. Guar has no adverse impact on groundwater quality, treatment effectiveness of the ZVI, and biodegrades rapidly. Safety Data Sheets (SDSs) for guar and ZVI are included in **Appendix C**. Assuming a two-foot interval between emplacements, and eight emplacements per injection location, this equates to 640 lbs of ZVI and 160 gallons of slurry per location.

The actual slurry volume may vary from the specifications above based on field conditions.

5.2 Injection Locations and Depth Intervals

The proposed pilot test area (**Figure 2**) was chosen due to the proximity to nearby upgradient and downgradient monitoring wells, the selected location has both PCE and TCE present in groundwater allowing for evaluation of treatment of both compounds, and the distance from the property line where the limited potential for by-product generation can be safely monitored away from the off-site residential structures. In addition, this pilot test location is also along the core of the plume that appears to reach the property line and can provide treatment in a key location. Six vertical aquifer profile (VAP) borings were completed in August 2022 to define the extent of the PCE and TCE plumes, VAP-29-22 through VAP-34-22 (**Figure 1**). This data was used to define the length and vertical treatment interval of the proposed injected ZVI barrier (**Figure 2**). Boring logs for the VAPs are included in **Appendix A**.

ZVI injections are conservatively expected to achieve at least a 5-foot ROI around each point based on subcontractor experience injecting ZVI into similar geologic settings and the ITRC guidance (ITRC, 2011). In order to achieve a robust treatment transect, injection points will be installed at a 7-foot spacing resulting in an expected overlap of 3 feet between injection points. Injection points will be installed in two adjacent transects of staggered points (**Figure 2**). Approximately 26 injection locations are planned based on the August 2022 VAP investigation.

The target treatment zone is approximately 15 feet thick (**Figures 3A, 3B and 3C)**, generally from 25 ft bgs to approximately 40 feet bgs. To achieve delivery, the reagent will be injected as a slurry (described in Section 4.2) into target emplacement intervals. A Geoprobe will advance push rods with a pressure activated injection probe to the top target depth. The reagent will be pumped with a diaphragm pump (or equivalent) that can deliver the pressure required to push the thick slurry through the pressure activated injection probe and into the subsurface. The probe is designed to allow placement of material into the target interval and prevent backflow reducing the potential for surfacing of reagent. Once the target volume has been injected at the top target depth, the probe will be advanced two feet to the next target depth for the next emplacement. The ZVI slurry will be injected every two feet across the treatment zone, with approximately eight emplacements per point. Each location will be completed using a top-down approach, with tooling advanced to the subsequent deeper interval following delivery of the emplacement-specific target volume. Each emplacement will create a ZVI filled fracture in the soil that will provide for contact between the ZVI and impacted groundwater. The exact number and depth of emplacements may be adjusted in the field based on conditions encountered. Field staff will carefully monitor the injection area during implementation for surfacing of the injection slurry. The injections will be completed in non-consecutive points to avoid potential over-pressurization that may negatively impact the injection performance (injection pressure, rate and ROI). If surfacing of injection slurry is observed, injection at that interval will be discontinued. Each injection point will be filled with bentonite following the injection. A preliminary example of emplacements for a target treatment zone of 25 to 40 ft bgs is shown below.

Depth of ZVI Emplacement (ft bgs)	
Line 1	**Line 2**
25	26
27	28
29	30
31	32
33	34
35	36
37	38
39	40

5.3 Utilities

A full utility clearance will be performed prior to initiating any subsurface work at the Site. Activities include:

- Identification of public utility lines servicing the Site (811), and
- A private utility locator in the areas identified for subsurface work.

All utilities will be avoided as part of the injection of the ZVI material. Any utilities outside of the injection area will remain unaffected since the ZVI is not soluble in water and cannot migrate downgradient in the way that a soluble amendment (e.g., oxidant) can. Injected ZVI will not contact or interact with the utilities in any way.

6 Performance Monitoring

As detailed in **Table 1**, five monitoring wells (MW-13-22, MW-14-22, MW-15-22, MW-16-22, and MWF16-16) are included in the performance monitoring program. These wells are located upgradient and downgradient of the ZVI Pilot Injection location. Six vertical aquifer profile (VAP) borings were completed in October 2022 to determine the best location for additional downgradient performance monitoring wells, VAP-35-22 through VAP-40-22 to supplement existing downgradient monitoring wells MW-13-22 and MW-14-22 (**Figure 1**). Placement of the new downgradient performance monitoring wells were completed as follows:

- Monitoring well MW-15-22 was screened from 31.3-36.6’ bgs based on the PCE/TCE concentrations at VAP-38-22 at 33-36’bgs.
- Monitoring well MW-16-22 was screened from 26-31’ bgs based on PCE/TCE concentrations at VAP-37-22 at 27-30’ bgs.

VAP analytical results summary and boring logs for VAP-35-22 through VAP-40-22 and well construction logs for MW-15-22 and MW-16-22 are included in **Appendix A**. Further details on the October 2022 VAP investigation and performance monitoring well installation will be provided as part of the Fiero Site Investigation Report.

Baseline groundwater samples will be collected from all five monitoring wells prior to the completion of the ZVI injections using low-flow sampling techniques. The monitoring well samples will be analyzed for CVOCs via USEPA Method 8260 and field parameters using a flow-through cell. Quarterly sampling will be conducted post-injection for up to eight quarters (**Table 1**). Prior to collecting groundwater samples, gauging will be conducted during each monitoring event to evaluate localized groundwater flow direction. All performance monitoring field activities will be completed following the applicable Arcadis technical guidance instructions (TGIs) are included in **Appendix B**. Laboratory standard operating procedures and Arcadis TGIs included in **Appendix B**.

The goal of the performance monitoring is to capture the expected cycle of decreasing, stabilizing, and increasing concentrations over time. It is expected that downgradient well concentrations will decrease as treated water migrates, will stabilize once the clean waterfront reaches the downgradient wells, then may increase as the ZVI becomes passivated. The frequency of monitoring will be re-assessed based on observations over the first year to efficiently capture this cycle. For example, if concentrations at downgradient wells are not changing fast enough to warrant quarterly sampling, frequency may be reduced to semi-annual. Conversely if concentrations are changing very quickly and higher resolution data provides value to the assessment of performance, more frequent sampling may be completed

6.1 Treatment of COCs

Groundwater analytical data collected during the post-injection monitoring events will be used to evaluate the relative change in concentrations compared to baseline using trend graphs for each monitoring well in the performance monitoring program. Changes in concentrations will be compared to historical results and performance monitoring data to evaluate PCE and TCE treatment at the Site.

6.2 Reagent Distribution

Spacing of the injection points assumes a 5-foot ROI, with three feet of overlap between points. Two confirmatory soil borings will be installed within the ROI of the injection points immediately following ZVI injections. Soil borings will be completed at the maximum distance from each injection point. Based on an anticipated spacing of 7 feet, the soil borings will be completed approximately 3.5 feet from injection points. However, the locations will be determined based on field conditions, biased toward locations where injections were more difficult. Core samples from these borings will be used to confirm distribution of ZVI within the injection area. Specifically, the field geologist will visually check the core samples and use a magnet to field screen for ZVI to verify the target ROI and emplacement depths of ZVI have been achieved. This will be documented on the soil boring and with photographs.

6.3 Byproduct Formation

ZVI injections abiotically degrade TCE and PCE so the potential for daughter product formation with vapor intrusion concerns (e.g., vinyl chloride) is low. The guar utilized as part of the injection slurry has the potential to act as a carbon source and, under reducing conditions, could trigger biological degradation of PCE and TCE in the short term. The small amount of guar being used should not result in strong, widespread, or long-lasting reducing conditions. Performance monitoring will include an evaluation of the potential generation of by-products that could present vapor intrusion concerns (e.g., vinyl chloride). Concentrations of chlorinated daughter products will be monitored downgradient of the treatment zone.

6.4 Reagent Longevity

Any ZVI application has a finite life span that is directly related to groundwater flux and chemical composition of groundwater passing through the reactive zone. Numerous competing reactions are expected, and the longevity of ZVI is partly determined by consumption of nontarget compounds (Arcadis, 2017). One competing reaction is the oxic reaction, which is likely to occur in the upgradient interface between the ZVI mass and influent groundwater, and results in dissolved iron (Fe^{2+}) and peroxide ions (OH^-). Nontarget reactions (e.g., with oxygen, nitrate, and sulfate) are expected to account for a high proportion of ZVI consumption.

In addition, the ZVI surfaces may become coated with minerals that inhibit contact between the impacted groundwater and the ZVI. Dissolved calcium (Ca^{2+}) and carbonate (CO_3^{2-}) concentrations in the groundwater suggests there is a potential for precipitation if the pH increases above the neutral baseline conditions, which is expected to occur within the immediate vicinity of the reactive ZVI. Alkalinity data reviewed from the Site suggests this should be relatively minor and not significantly impact the performance and longevity of ZVI in this application. Passivation or loss of effectiveness will be evaluated over the study period using field parameter and CVOC results.

Performance monitoring results will be evaluated for evidence of reduced treatment of CVOCs over time which could be indicative of aging of the ZVI barrier. Reduced treatment of PCE, TCE and cis-1,2-DCE noted downgradient of the ZVI barrier will be used as the indicator that passivation of the ZVI may be occurring.

The primary objective of the pilot test is to evaluate the efficacy of reducing CVOC concentrations in groundwater to below residential VI criteria using an injected ZVI barrier. If adequate reductions in CVOCs are not observed the remedy would not be carried forward for further consideration. Lack of CVOC treatment could be due to limitations of in situ distribution of the ZVI, interaction from non-target compounds, or a combination of both. It would be difficult to cost effectively determine the root cause of performance issues during the field pilot. If ZVI were to be considered in the future in a trenched permeable reactive barrier (PRB) application, eliminating the in situ distribution concern, a laboratory column test would be completed to test passivation potential as described in the IRTC PRB guidance.

6.5 Analytical Methods and Quality Control

Merit Laboratories Inc. of East Lansing, Michigan will be the laboratory company supporting the environmental sample analyses for this project.

6.5.1 Laboratory Analytical Methods

Groundwater samples will be analyzed for VOCs by the project laboratory by Method 8260 B (**Table 1**). Relevant laboratory SOPS are summarized in **Table 2** and provided in **Appendix B**.

Table 2: Index of Standard Operating Procedures (SOP) and TGIs

Laboratory SOP	Purge and Trap for Aqueous and High and Low Concentration Soil Samples Method 5030C/5035A
	Volatile Organic Compounds by Gas Chromatography/ Mass Spectrometry Method SW-846 8260C/ EPA 624.1
	Determination of the Method Detection Limit (MDL), Limit of Detection (LOD), and Limit of Quantitation (LOQ)
Arcadis TGI	Monitoring Well Installation
	Groundwater and Soil Sampling Equipment Decontamination
	Low Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
	Manual Water Level and NAPL Monitoring
	Sample Chain of Custody
	Soil Drilling and Sample Collection
	Vertical Aquifer Profile (VAP) Sampling

Samples will be preserved, handled and shipped according to the requirements in **Table 3**. Laboratory analysis limits (lower control limit and upper control limit) for VOCs are documented in the Merit SOPs in **Appendix B**.

6.5.2 Quality Assurance/Quality Control Procedures

Field Quality Assurance / Quality Control

Field Quality Assurance/Quality Control Procedures (QA/QC) samples will be collected during field sampling include:

- Equipment blank samples to determine the existence and magnitude of sample contamination resulting from ambient conditions or sampling procedures.
- Equipment blank samples will be collected at a frequency of one per day, following sampling equipment decontamination procedures. These samples will be collected by routing laboratory-provided deionized water through decontaminated sampling equipment. Equipment blank samples will be analyzed to check procedural contamination and/or ambient conditions and/or sample container contamination at the Site that may cause sample contamination.
- Field duplicate samples will be collected at a minimum frequency of 1 per 10 or fewer investigative samples. Field duplicate samples will be analyzed to assess the precision of the field sample collection procedures.
- Sufficient sample volume will be provided to the laboratory (as necessary) for matrix spike and spike duplicate (MS/MSD) analyses. The data from MS/MSD analyses provide an indication of the precision and accuracy of the analytical method relative to the sample matrix. Samples for MS/MSD analysis will be designated at a minimum frequency of 1 per 20 or fewer samples.

Samples will be collected and packed in laboratory supplied containers and transported in accordance with the laboratory container, preservation, shipping, and packaging requirements.

Laboratory Quality Assurance / Quality Control

Laboratory QA/QC requirements for the analysis of soil samples includes analyzing method blanks, initial calibration verification standards, continuing calibration verification standards, MS/MSD samples, and laboratory Control Samples (LCS). The analysis frequency for these QA/QC samples is identified in the applicable laboratory SOP provided in **Appendix B**. The acceptance criteria for these QC checks will be consistent with the analytical methods and laboratory SOP.

Laboratory Report Deliverables

Laboratory reports for samples collected will consist of the following data deliverables:

1. Case Narrative:
    a. Date of issuance
    b. Project name and number
    c. Any deviations from intended analytical strategy
    d. Condition of samples "as received"
    e. Discussion of whether or not sample holding times were met
    f. Discussion of technical problems or other observations that may have created analytical difficulties
    g. Discussion of any laboratory quality control checks that failed to meet project criteria
2. Chemistry Data Package
    a. Dates of sample collection, receipt, preparation, and analysis
    b. Cross-reference of laboratory to project sample identification numbers
    c. Description of data qualifiers used

d. Methods of sample preparation and analysis
e. Sample results in tabular format
f. Method blank data, surrogate data, LCS data, duplicate sample data, MS/MSD data,
g. Fully executed chain-of-custody document

6.5.3 Data Review and Validation

Upon receipt of the final data packages from the project laboratory the data will be reviewed and validated. The data review will evaluate the final analytical results, holding time period compliance, equipment blank sample data, field duplicate sample data, method blank data, LCS data, laboratory duplicate data, surrogate compound spike data, and MS/MSD sample data. Validation of the data will consist of evaluating the QA/QC data based on the applicable review criteria specified in "National Functional Guidelines for Inorganic Superfund Methods Data Review", EPA 540-R-2017-001, January 2017 and "National Functional Guidelines for Organic Superfund Methods Data Review", EPA 540-R-2017-002, January 2017. The results of the data review and validation process will be documented in memoranda that identify all limitations on the usability of the analytical data.

7 Reporting

A ZVI pilot test report will be submitted following implementation of the ZVI injections and the first quarterly monitoring event. The initial report will include details on the field implementation, including a layout of injection locations, boring logs for the ROI confirmatory borings, mass and volumes injected at each point, and baseline and first quarter monitoring data. Data from subsequent quarterly performance monitoring events will be included in the quarterly groundwater reports for the Site. Evaluation of the data, including an assessment of the longevity of the ZVI, will be discussed in the monitoring report after the initial four quarterly events. Any modifications to the proposed monitoring program will be recommended, as necessary, in that report. Information collected during this pilot test will provide a basis for evaluating possible future applications of injected ZVI if deemed necessary based on monitoring data, evaluation of risks, and other corrective measure options. At the current time, a full-scale application of injected ZVI (or any other remedy) is not warranted.

8 Contingency Plan

Based on the nature of the proposed ZVI injection (i.e., the injected ZVI stays in place and does not migrate with groundwater, and minimal potential for and impacts from generation of unwanted byproducts), no contingency plans outside of the proposed monitoring are proposed. If the pilot test does not meet the proposed objectives, alternate remedies will be considered, as needed, to meet the overall corrective action objectives of the Site.

9 References

Arcadis, 2017. Remediation Engineering Design Concepts, 2nd Edition. CRC Press.

ITRC, 2011. Permeable Reactive Barrier: Technology Update.

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4.

USEPA 540-R-2017-001, 2017. National Functional Guidelines for Inorganic Superfund Methods Data Review

USEPA 540-R-2017-002, 2017. National Functional Guidelines for Organic Superfund Methods Data Review

Tables

Table 1
Monitoring Well Details and Sampling Plan
RACER Trust Pontiac North Campus
Pontiac, Michigan

Sampling Locations	Location	Screen Interval (ft bgs)	Parameter (Analysis)	Frequency
MWF16-16	Upgradient	22-32	**Field Parameters:** pH, DO, specific conductivity, turbidity, ORP (field multi-meter) **Laboratory:** VOCs (Method 8260)	One baseline event and quarterly post injection events for up to 8 quarters. Post injection frequency subject to change based on results.
MW-13-22	Downgradient	22-27		
MW-14-22	Downgradient	30-35		
MW-15-22	Downgradient	31.5-36.5		
MW-16-22	Downgradient	26-31		

Abbreviations:
ft bgs - feet below ground surface
DO - dissolved oxygen
ORP - oxidation-reduction potential

Table 3
Container Preservation, Shipping, and Packaging Requirements
RACER Trust Pontiac North Campus
Pontiac, Michigan

Analyses	Sample Containers	Preservation	Maximum Holding Time From Sample Collection	Volume of Sample	Shipping	Normal Packaging
VOCs	Three 40 mL VOAs	HCl, Iced, 4+/-2 deg C	14 days	120 mL	Overnight or Hand Deliver	Bubble-wrap

Abbreviations:

VOCs - Volitile Organic Compounds

HCl - Hydrochloric Acid

deg C - Degrees Celsius

mL - Mililiters

Figures

CITY: LANSING DIV: ENV DB: D.AKENS PIC:S.INSALACO PM: B. SAUNDERS TM: L. CRISP TR: PROJECT NUMBER: 30112891.0005 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
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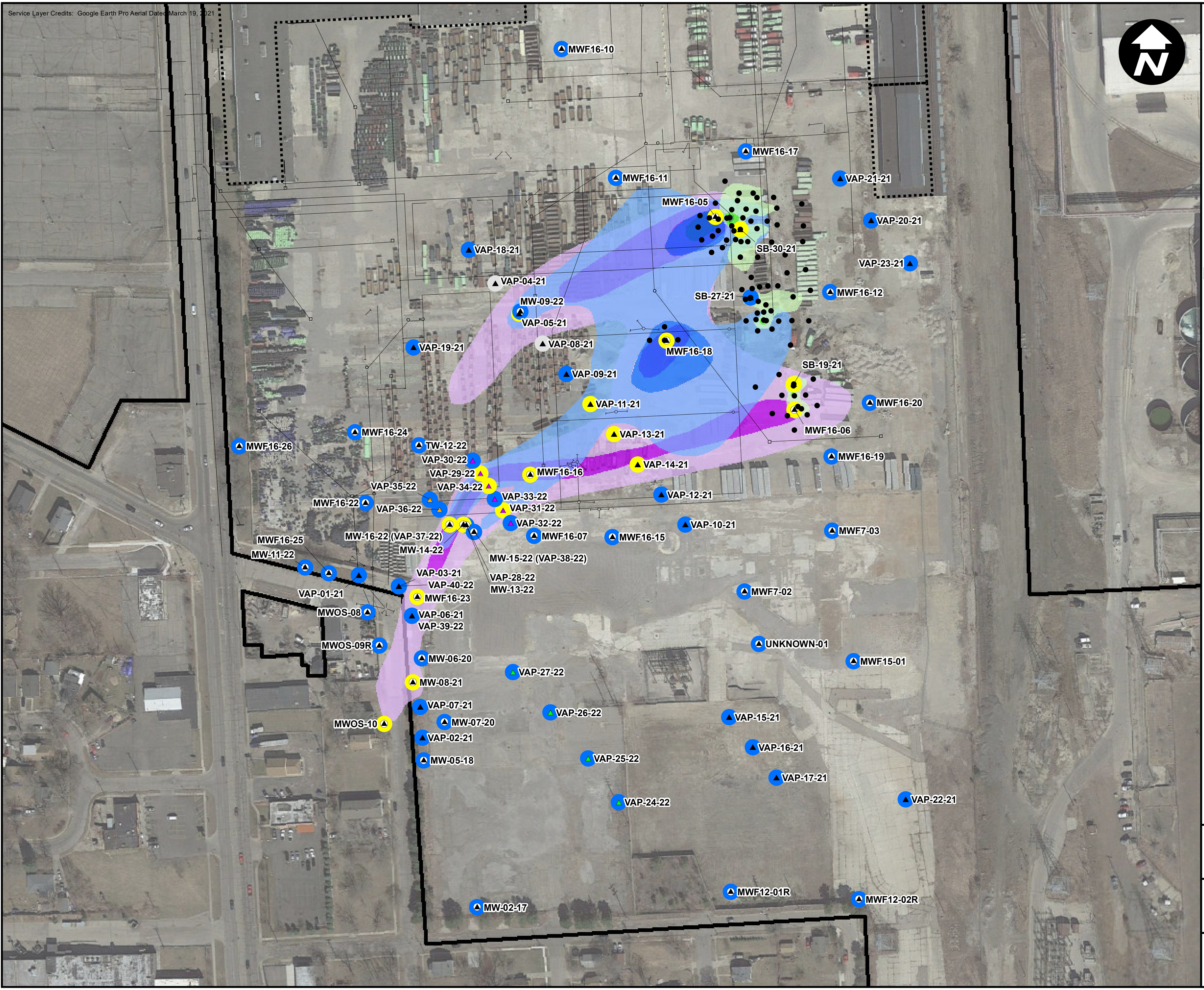


LEGEND

●	SOIL BORING
◬	MONITORING WELL
▲	VERTICAL AQUIFER PROFILE (VAP, ARCADIS OCTOBER 2021)
▲	VERTICAL AQUIFER PROFILE (VAP, ARCADIS FEBRUARY 2022)
▲	VERTICAL AQUIFER PROFILE (VAP, ARCADIS JUNE 2022)
▲	VERTICAL AQUIFER PROFILE (VAP, ARCADIS SEPTEMBER 2022)
●	EXCEEDS RESIDENTIAL FIERO SSVIAC BASEMENT (TCE >8.1 µg/L, PCE >130 µg/L)
●	DOES NOT EXCEED RESIDENTIAL FIERO SSVIAC BASEMENT (TCE <8.1 µg/L, PCE <130 µg/L)
●	UNABLE TO COLLECT VAP SAMPLE
······	PROPOSED OR EXISTING BUILDING
——	PROPOSED OR EXISTING UTILITY
▭	CURRENT OR FORMER RACER PROPERTY

CONCENTRATION OF TETRACHLOROETHYLENE IN SOIL

🟩	1,000 - 5,000 µg/kg
🟩	5,000 - 10,000 µg/kg
🟩	10,000 µg/kg

CONCENTRATION OF TETRACHLOROETHYLENE IN GROUNDWATER

🟦	130 - 500 µg/L
🟦	>500 µg/L

CONCENTRATION OF TRICHLOROETHYLENE IN GROUNDWATER

🟪	8.1 - 20 µg/L
🟪	20 - 35 µg/L
🟪	>35 µg/L

NOTES:

1. ALL CONCENTRATIONS ARE PRESENTED IN MICROGRAMS PER LITER (µg/L)
2. < - NOT DETECTED ABOVE THE LABORATORY REPORTING LIMIT
3. E - CONCENTRATION EXCEEDS CALIBRATION RANGE
4. SSVIAC - SITE SPECIFIC VOLATILIZATION TO INDOOR AIR CRITERIA
5. U - COMPOUND WAS ANALYZED BUT NOT DETECTED. THE ASSOCIATED VALUE IS THE COMPOUND QUANTITATION LIMIT.
6. Y - ELEVATED REPORTING LIMIT DUE TO HIGH TARGET CONCENTRATION
7. CONCENTRATION SHOWN REPRESENTS THE MOST RECENT MONITORING WELL SAMPLE OR THE MAXIMUM VALUE DETECTED AT VERTICAL AQUIFER PROFILE BORINGS.
8. CRITERIA FROM DEPARTMENT OF ENVIRONMENT, GREAT LAKES AND ENERGY (EGLE) DEVELOPED SITE-SPECIFIC VOLATIZATION TO INDOOR AIR CRITERA FOR THE FORMER FIERO ASSEMBLY, APRIL 21, 2020.

0 170 340

SCALE IN FEET

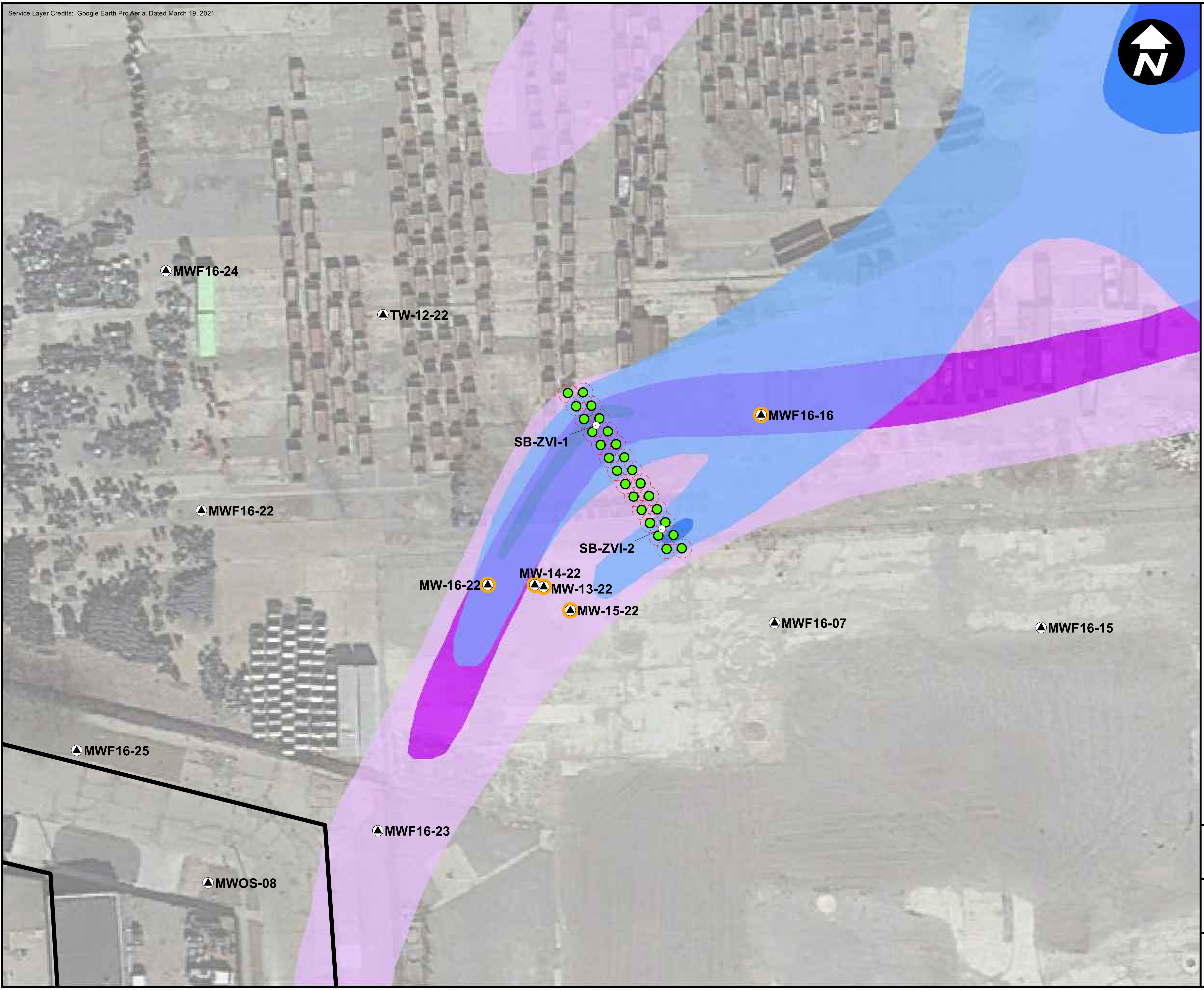
RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

DISTRIBUTION OF TETRACHLOROETHENE AND TRICHLOROETHYLENE IN GROUNDWATER, CONCENTRATION OF TETRACHLOROETHENE IN SOIL

ARCADIS

FIGURE
1

CITY: LANSING DIV: ENV DB: D.AKENS PIC:S.INSALACO PM: B. SAUNDERS TM: L. CRISP TR: PROJECT NUMBER: 30112891.0005 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
D:\GIS\Project Files\MotorsLiquidationCompany\PontiacNorthCampus\Documents\Former_Fiero_PropertySiteInvestigation_2021\ZVI_Pilot_rev3.mxd PLOTTED: 11/9/2022 2:23:45 PM BY: TYarbrough



LEGEND

○ CONFIRMATORY SOIL BORINGS
● PROPOSED ZVI PILOT INJECTION POINT
- - - - RADIUS OF INFLUENCE (5 FEET)
● PERFORMANCE MONITORING WELL
▲ MONITORING WELL
▭ CURRENT OR FORMER RACER PROPERTY

CONCENTRATION OF TETRACHLOROETHYLENE IN GROUNDWATER

🟦 130 - 500 µg/L
🟦 >500 µg/L

CONCENTRATION OF TRICHLOROETHYLENE IN GROUNDWATER

🟪 8.1 - 20 µg/L
🟪 20 - 35 µg/L
🟪 >35 µg/L

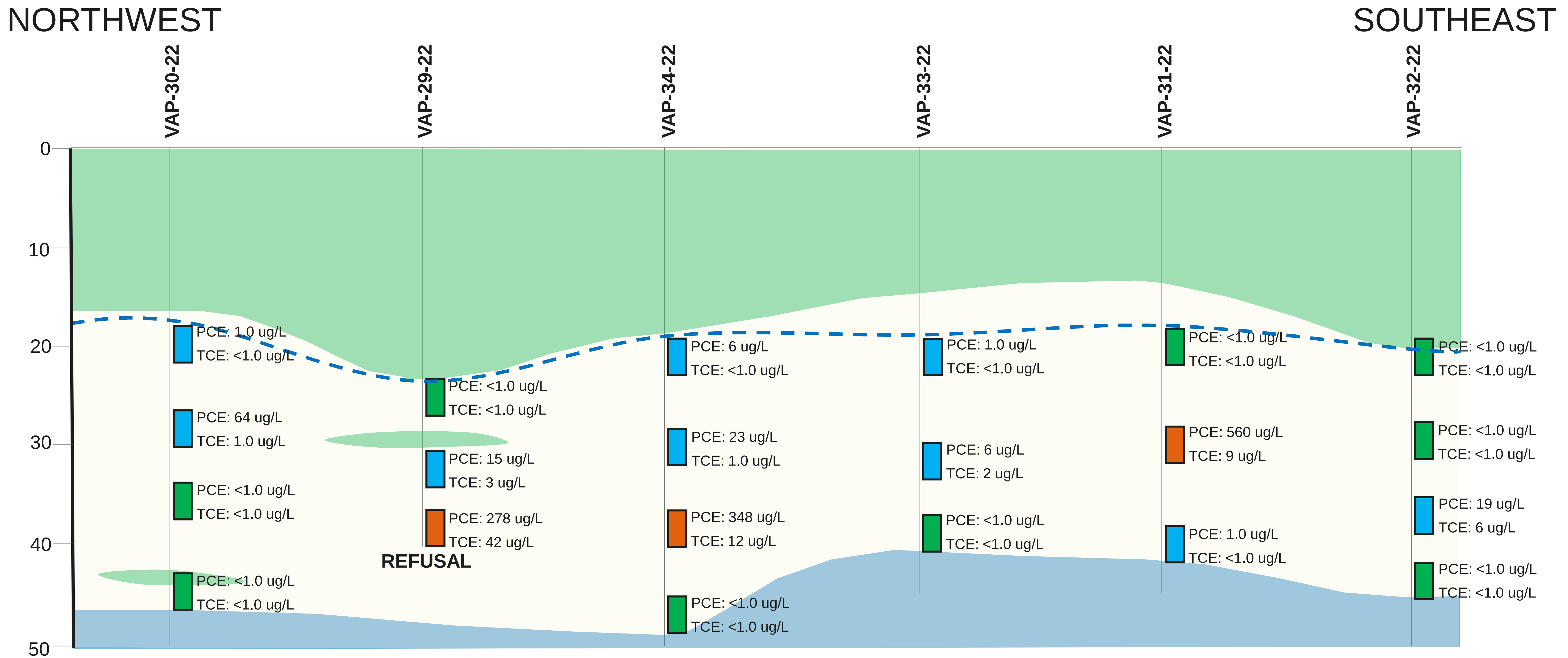
0 50 100
SCALE IN FEET

RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

FIERO PLANT PROPOSED ZVI PILOT LAYOUT

ARCADIS

FIGURE
2



GEOLOGIC UNITS

🟩 Interbedded

⬜ Sand

🟦 Clay

BORING

Water Table (approximate) - - -

🟩 VAP Sample Interval (non-detect)

🟦 VAP Sample Interval (below criteria)

🟧 VAP Sample Interval (above criteria)

NOTES:

1. Scale is approximate.
2. Ground surface elevation is assumed to be flat.
3. Results compared to residential SSVIAC (PCE – 130 ug/L and TCE – 8.1 ug/L)

VAP – vertical aquifer profile

ug/L – micrograms per liter

SCALE

10 FEET

10 FEET

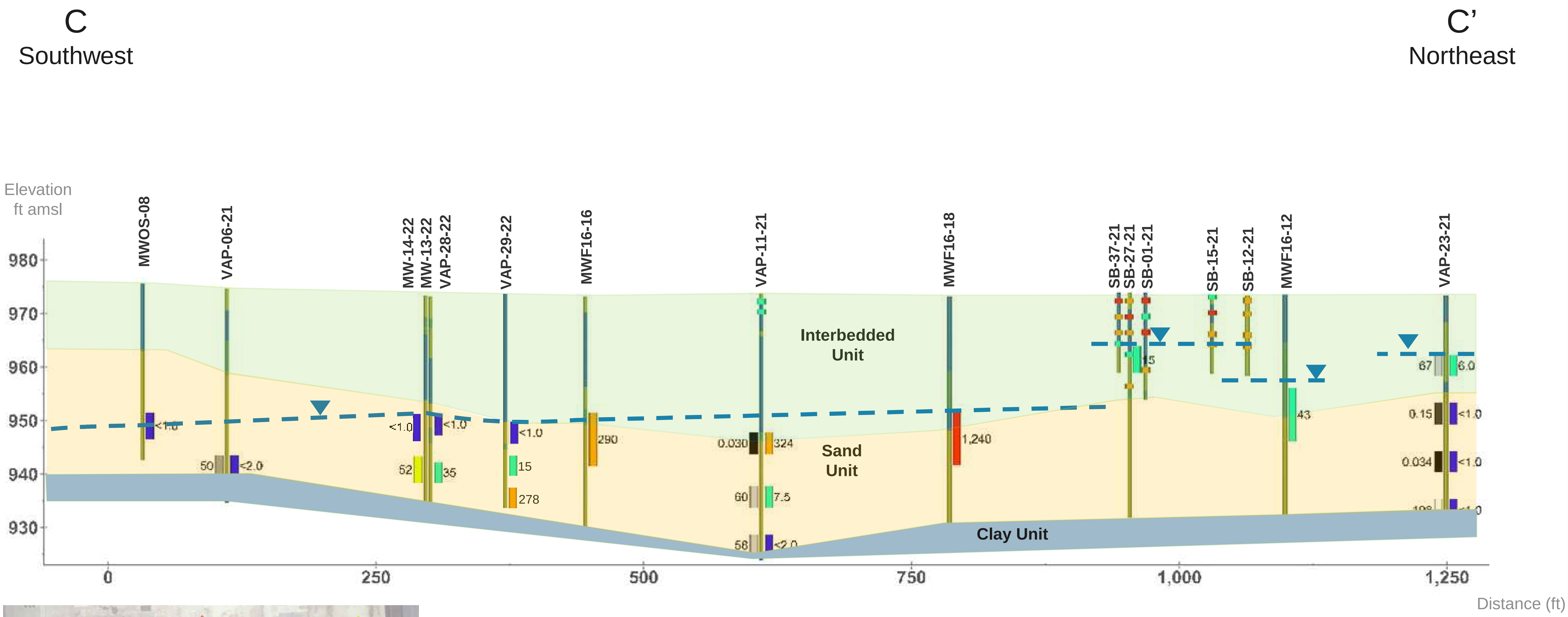
RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

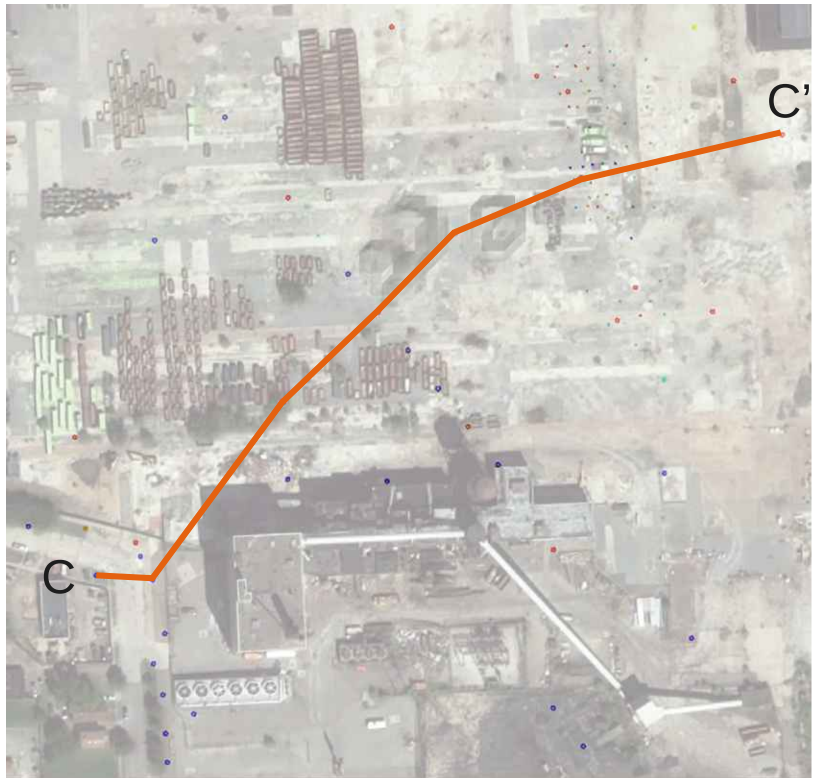
FORMER FIERO PLANT 2022 VERTICAL AQUIFER PROFILE CROSS SECTION

ARCADIS

FIGURE
3A

10/26/2022 11:41:13 AM





Graphical Legend

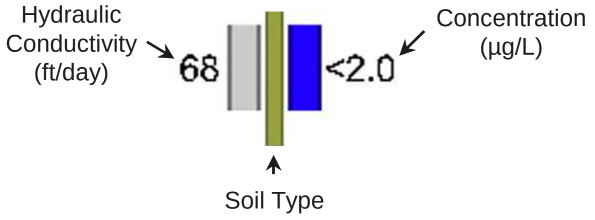
Hydraulic Conductivity
- ⬜ >100 ft/day
- ⬜ 75 – 100 ft/day
- ⬜ 50 – 75 ft/day
- ⬜ 25 – 50 ft/day
- ⬛ 1.0 – 25 ft/day
- ⬛ 0.1 – 1.0 ft/day
- ⬛ <0.1 ft/day

GEOLOGIC UNITS
- 🟩 Interbedded
- ⬜ Sand
- 🟦 Clay

PCE Concentrations
- 🟪 >10,000 µg/L
- 🟥 1,000 – 10,000 µg/L
- 🟧 100 – 1,000 µg/L
- 🟨 50 – 100 µg/L
- 🟩 5 – 50 µg/L
- 🟦 <5 µg/L

Notes
1. Vertical Exaggeration = 5x

▼ — Approximate Water Table



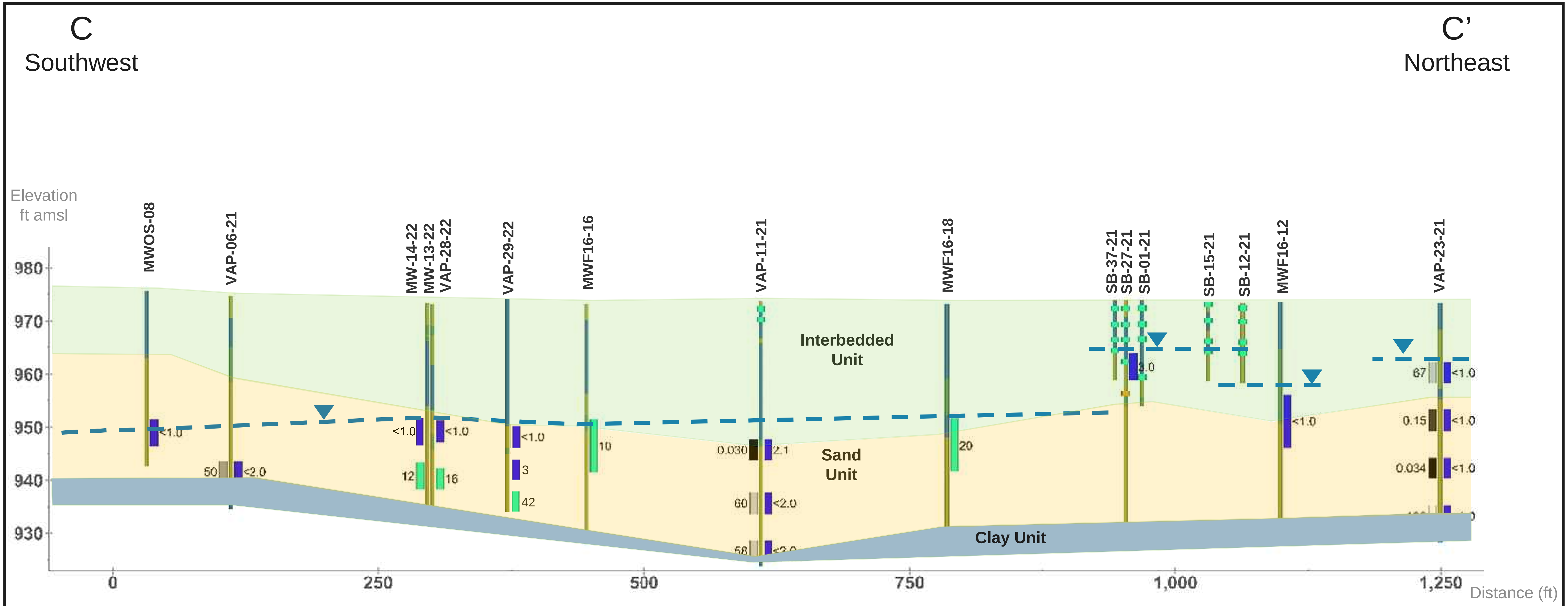
RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

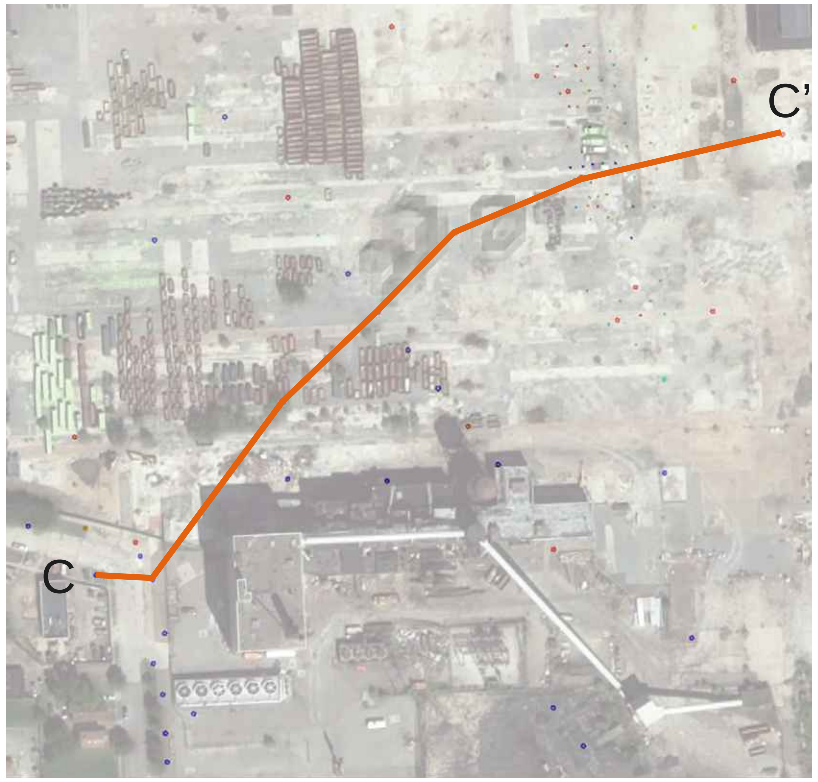
CROSS SECTION C-C' - TETRACHLOROETHYLENE

ARCADIS

FIGURE
3B

10/26/2022 11:41:15 AM





Graphical Legend

Hydraulic Conductivity

- >100 ft/day
- 75 – 100 ft/day
- 50 – 75 ft/day
- 25 – 50 ft/day
- 1.0 – 25 ft/day
- 0.1 – 1.0 ft/day
- <0.1 ft/day

GEOLOGIC UNITS

- Interbedded
- Sand
- Clay

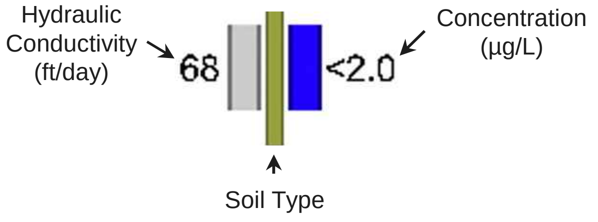
PCE Concentrations

- >10,000 µg/L
- 1,000 – 10,000 µg/L
- 100 – 1,000 µg/L
- 50 – 100 µg/L
- 5 – 50 µg/L
- <5 µg/L

Notes

1. Vertical Exaggeration = 5x

▼ — Approximate Water Table



RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

CROSS SECTION C-C'
TRICHLOROETHYLENE

ARCADIS

FIGURE
3C

10/26/2022 11:41:15 AM

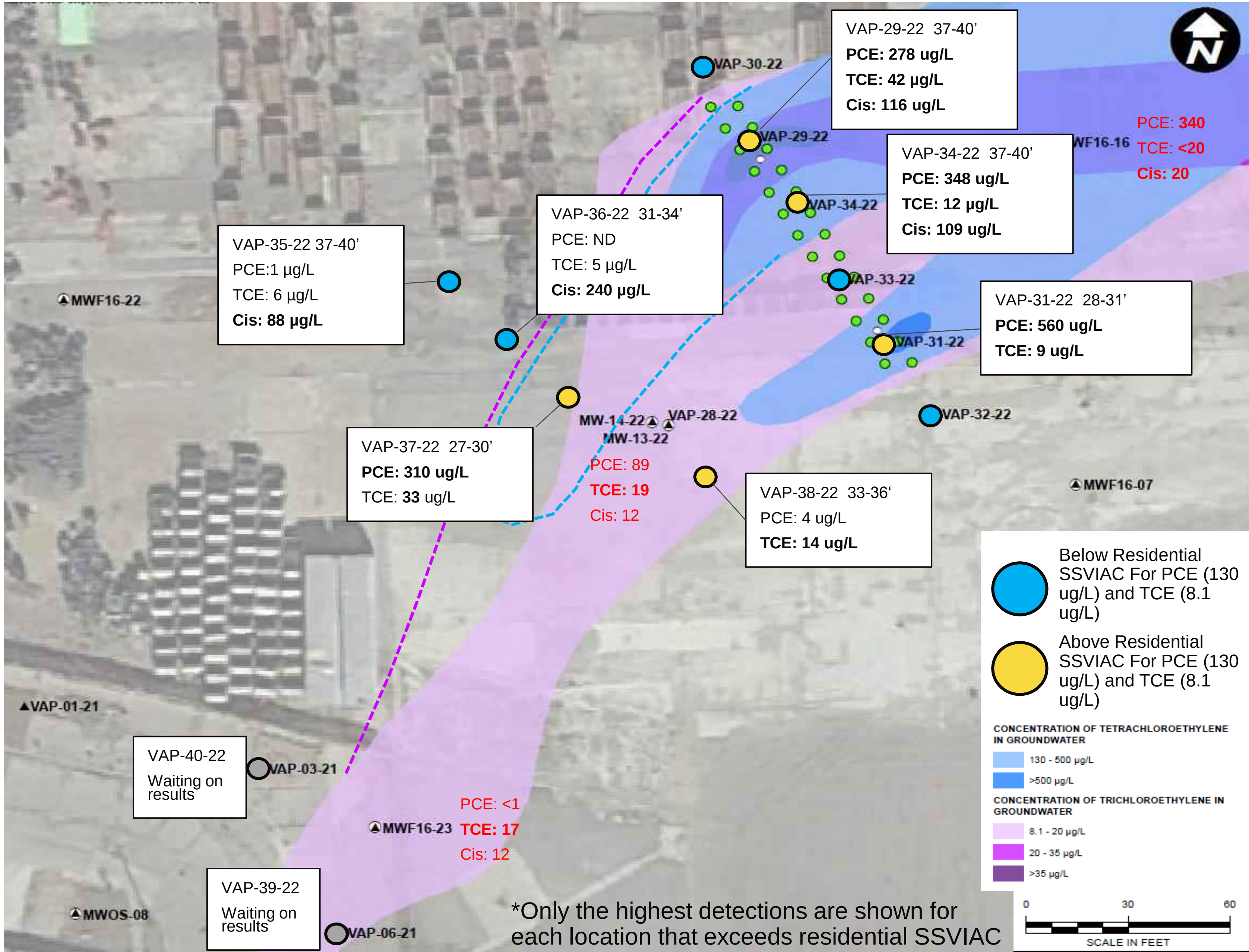
Appendix A

Boring Logs and Well Construction Diagrams

Fiero ZVI VAP Investigation

Investigation Summary:

- Completed four VAP borings
- Locations VAP-35-22 and VAP-36-22 are below the criteria for PCE and TCE; exceed SSVIAC for cis-1,2-DCE (62 µg/L).
- Performance monitoring wells will be installed at locations VAP-37-22 and VAP-38-22



VAP-29-22 37-40'
PCE: 278 ug/L
TCE: 42 µg/L
Cis: 116 ug/L

PCE: **340**
TCE: **<20**
Cis: 20

VAP-34-22 37-40'
PCE: 348 ug/L
TCE: 12 µg/L
Cis: 109 ug/L

VAP-36-22 31-34'
PCE: ND
TCE: 5 µg/L
Cis: 240 µg/L

VAP-35-22 37-40'
PCE:1 µg/L
TCE: 6 µg/L
Cis: 88 µg/L

VAP-31-22 28-31'
PCE: 560 ug/L
TCE: 9 ug/L

VAP-37-22 27-30'
PCE: 310 ug/L
TCE: **33** ug/L

PCE: 89
TCE: 19
Cis: 12

VAP-38-22 33-36'
PCE: 4 ug/L
TCE: 14 ug/L

Below Residential SSVIAC For PCE (130 ug/L) and TCE (8.1 ug/L)

Above Residential SSVIAC For PCE (130 ug/L) and TCE (8.1 ug/L)

VAP-40-22
Waiting on results

PCE: <1
TCE: 17
Cis: 12

VAP-39-22
Waiting on results

*Only the highest detections are shown for each location that exceeds residential SSVIAC

Date Start: 2/14/2022
Date Finish: 2/14/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Geoprobe/Direct Push
Sampling Method: Macrocore
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 6.0
Water Level Finish (ft. btoc.): 40.0

Northing: 424887.225
Easting: 13410700.038
Casing Elevation: NA

Borehole Depth (ft. bgs.): 40.0
Surface Elevation: 972.622

Descriptions By: E Redner

Well/Boring ID: MW-13-22

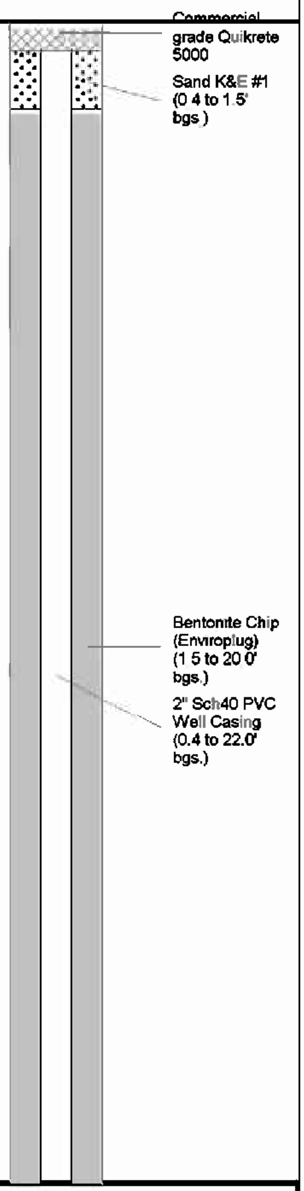
Client: RACER

Location: RACER PNC

Weather Conditions: 8 F, Partly Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)
	0				0.0			(0.0-4.0') SAND, very fine to very coarse, subangular to subrounded; some silt; little clay, low plasticity, rapid dilatancy; moist; poorly sorted; very dark gray (10YR 3/1) NOTE: cobbles and re-bar at surface and ground is icy/frozen	
					0.0				
		1	0.0-5.0'	3.2	0.0				
					0.0				
					0.0			(4.0-6.0') SILT; some clay, low to medium plasticity, rapid dilatancy; little very fine to fine sand; soft; moist; brown (10YR 5/3). NOTE: 3" clay and silt seam at 4.8' bgs.	
5	-5				0.0				▼
					0.0			(6.0-7.0') SAND, very fine to medium, subangular to subroumnded; trace silt; poorly sorted; wet; yellowish brown (10YR 5/4).	
		2	5.0-10.0'	3.0	0.0			(7.0-7.5') SAND, very fine to fine; little silt; well sorted; moist; black (10YR 2/1). (7.5-11.5') SAND, very fine to very coarst, subangular to subrounded; poorly sorted; wet, gray (10YR 6/1)	
					0.0				
					0.0				
10	-10				0.0			NOTE: heavily saturated from 10.0 to 11.0' bgs.	
					0.0			(11.5-20.0') CLAY, medium to high plasticity, slow dilatancy; little silt; trace very fine sand to small pebbles, subangular to susrbourded; medium stiff to stifdf; moist; hgray (10YR 5/1)	
		3	10.0-15.0'	5.0	0.0				
					0.0				
					0.0				
15	-15				0.0				
					0.0				
		4	15.0-20.0'	1.8	0.0				
					0.0				
					6.0				

Well/Boring Construction



ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Hit concrete at 3.0' bgs, stepped approximately 2' south and resumed drilling.
Unable to hand auger due to ice/cobbles

Location: 11' south of fence; 20' northwest of MW-10-22

Overdrilled to install well. Concrete used for flushmount was commercial grade Quickrete 5000.

Date Start: 2/14/2022
Date Finish: 2/14/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Geoprobe/Direct Push
Sampling Method: Macrocore
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 6.0
Water Level Finish (ft. btoc.): 40.0

Northing: 424887.225
Easting: 13410700.038
Casing Elevation: NA

Borehole Depth (ft. bgs.): 40.0
Surface Elevation: 972.622

Descriptions By: E Redner

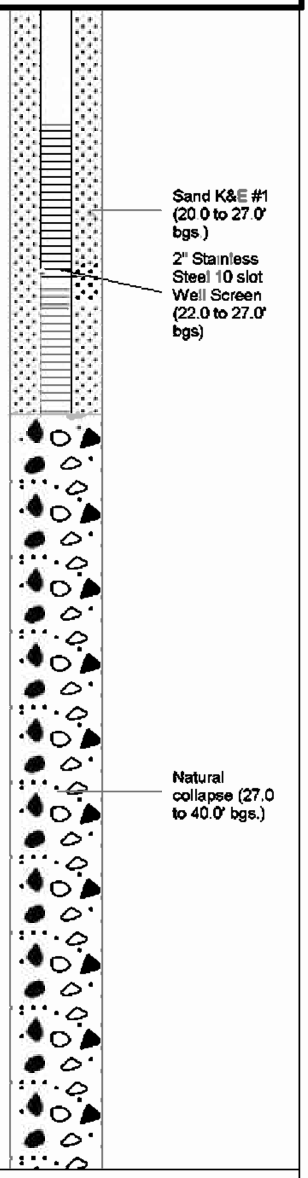
Well/Boring ID: MW-13-22

Client: RACER

Location: RACER PNC

Weather Conditions: 8 F, Partly Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		5	20.0-25.0	2.5	0.0 0.0 0.0 0.0 0.0			(20.0-21.0') SAND, very fine to granule, angualr to subrounded; some silt; little clay, low plasticity, rapid dilatancy; poorly sorted; wet; dark gray (10YR 5/1) (21.0-24.5') SAND, very fine to coarse; some silt; well sorted; wet; gray (10YR 5/1). NOTE: heavily saturated from 21.0 to 27.5' bgs. (24.5-27.5') SILT, no plasticity, rapid dilatancy, and SAND, very fine to fine; very soft; wet; gray (10YR 5/1)		
25	-25	6	25.0-30.0	3.3	0.1 0.0 0.0 0.0 0.0			(27.5-28.5') SAND, very fine to medium, subangular to subrounded; poorly sorted; wet, gray (10YR 5/1) (28.5-35.5') SAND, fine to medium, subrounded; well sorted; wet; dark yellowish brown (10YR 4/6) to grayish brown (10YR 5/2).		
30	-30	7	30.0-35.0	2.4	0.0 0.0 0.0 0.0 0.0					
35	-35	8	35.0-40.0	2.7	0.0 0.0 0.0 0.0 0.0			(35.5-40.0') SAND, fine to granule, subangular to subrounded; poorly sorted; wet; dark yellowish brown (10YR 4/6) to gray (10YR 4/1). NOTE: large pebble at 39.8' bgs.		
40	40							End of boring at 40.0' bgs.		



ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Hit concrete at 3.0' bgs, stepped approximately 2' south and resumed drilling.
Unable to hand auger due to ice/cobbles

Location: 11' south of fence; 20' northwest of MW-10-22

Overdrilled to install well. Concrete used for flushmount was commercial grade Quickrete 5000.

Date Start: 3/18/2022
Date Finish: 3/18/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Geoprobe
Sampling Method: Macrocore
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 22.01
Water Level Finish (ft. btoc.): NA

Northing: 424888.267
Easting: 13410695.304
Casing Elevation: NA

Borehole Depth (ft. bgs.): 40.0
Surface Elevation: 972.71

Descriptions By: A Westhuis

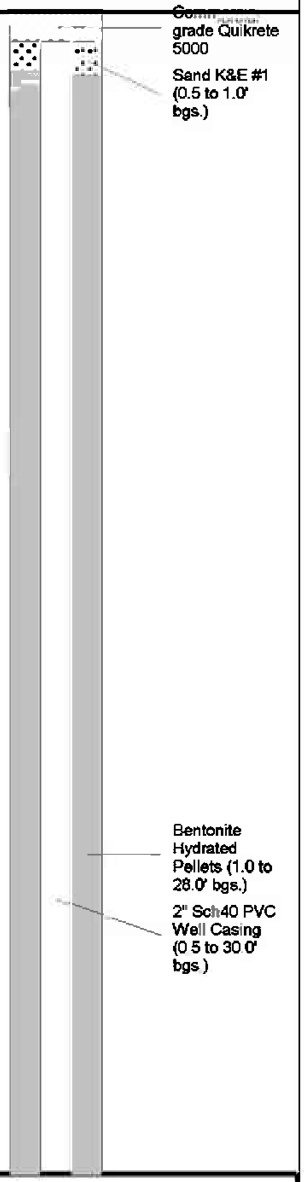
Well/Boring ID: MW-14-22

Client: RACER

Location: RACER PNC

Weather Conditions: 45 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0	1	0.0-5.0'	5.0	0.0 0.0 0.0 0.0 0.0			(0.0-0 5') CONCRETE (0 5-4 0') SAND, very fine to coarse, subrounded; some silt; little clay, low plasticity, slow dilatancy; poorly sorted; moist; pale brown (10YR 6/3). (4.0-6 0') SILT, some clay, low plasticity, no dilatancy; little very fine to fine sand, subrounded, soft; moist; grayish brown (10YR 5/2).		
5	-5	2	5.0-10.0'	3.5	0.0 0.0 0.0 0.0 0.0			(6.0-6.3') SAND, very fine to fine, subrounded; little silt; trace clay; well sorted; moist; grayish brown (10YR 5/2). (6.3-7 0') SILT, some clay, low plasticity, no dilatancy; little very fine to fine sand, subrounded; soft; moist; grayish brown (10YR 5/2). (7.0-7 3') SAND, very fine to fine, subrounded; little silt; trace clay; well sorted; moist; grayish brown (10YR 5/2). (7 3-19 5') CLAY, little silt, medium to high plasticity, no dilatancy; trace very fine to fine sand, subrounded; trace granules to small pebbles, subrounded; stiff; dry to moist; gray (10YR 5/1)		
10	-10	3	10.0-15.0'	4.7	0.0 0.0 0.0 0.0 0.0					
15	-15	4	15.0-20.0'	4.0	0.0 0.0 0.0 0.0 0.0			(19.5-25 0') SAND, very fine, some silt; well sorted, wet; grayish brown (10YR 5/2).		



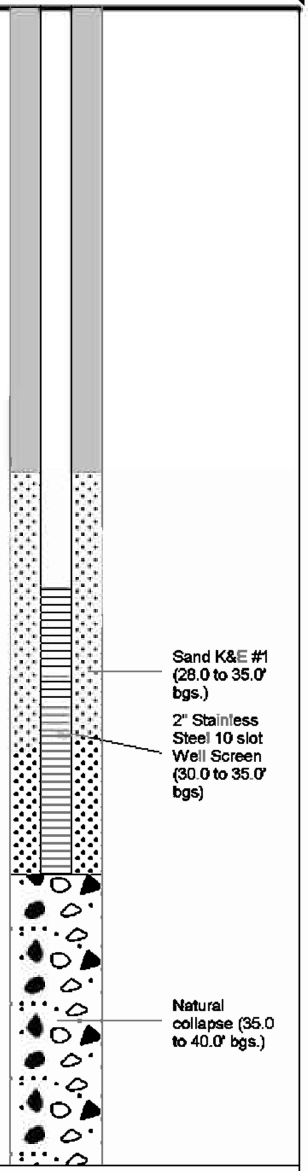
ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 3/18/2022	**Northing:** 424888.267	Well/Boring ID: MW-14-22
Date Finish: 3/18/2022	**Easting:** 13410695.304	Client: RACER
Drilling Company: Fibertec	**Casing Elevation:** NA	**Location:** RACER PNC
Driller's Name: N Wiseman	**Borehole Depth (ft. bgs.):** 40.0	**Weather Conditions:** 45 F, Sunny
Drilling Method: Hand Auger/Geoprobe	**Surface Elevation:** 972.71	
Sampling Method: Macrocore	**Descriptions By:** A Westhuis	
Rig Type: Geoprobe		
Water Level Start (ft. bgs.): 22.01		
Water Level Finish (ft. btoc.): NA		

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)
					0.0				
					0.0				▼
		5	20.0-25.0	3.7	0.0				
					0.0				
					0.0				
25	-25				0.0			(25.0-27.5') SAND, very fine to medium, subrounded, trace granules, subrounded; litte silt; poorly sorted, wet, pale brown (10YR 6/3).	
					0.0				
		6	25.0-30.0	3.5	0.0			(27.5-35.5') SAND, fine to medium, subrounded, well soted, wet; pale brown (10YR 6/3).	
					0.0				
					0.0				
30	-30				0.0				
					0.0				
		7	30.0-35.0	3.0	0.0				
					0.0				
					0.0				
35	-35				0.0			(35.5-40.0') SAND, very fine to fine, subrounded; trace medium sand, subrounded; trace granules, subrounded; trace silt; poorly sorted; wet; gray (10YR 5/1).	
					0.0				
		8	35.0-40.0	3.5	0.0				
					0.0				
					0.0				
40	40							End of boring at 40.0' bgs.	

Well/Boring Construction



ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start/Finish: 4/21/2005
Drilling Company: Altech
Driller's Name: Phil MCclaskey
Drilling Method: Direct Push
Sampler Size: 5' acetate liners
Rig Type: 6610DT Trackmount Geoprobe

Northing: 424976.0032
Easting: 13410786.52
Casing Elevation: 973.223708

Borehole Depth: 45.0'
Surface Elevation: 973.5

Descriptions By: Wayne Patterson

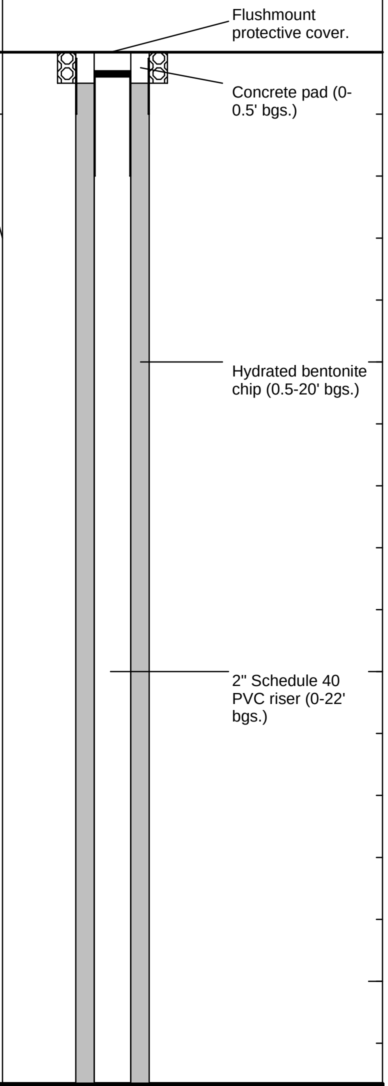
Well ID: MWF16-16

Client: General Motors

Location: Pontiac North Campus
Pontiac, Michigan

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	USCS Code	Stratigraphic Description
	975						
0							Concrete
		1	1-5'	3.0'	10.8	SP	Fill- Gray and brown fine SAND, little angular Gravel, few Clay, dry.
	970					CL	Fill- Dark gray brown LEAN CLAY WITH SILT, little fine to coarse subangular Sand, trace fine subangular to angular Gravel, low plasticity, stiff, dry to moist.
5		2	5-10'	5.0'	1.0		
	965						
10		3	10-15'	4.5'	3.1		
	960						
15							Dark gray brown LEAN CLAY WITH SILT, little fine to coarse subangular Sand, trace fine subangular to angular Gravel, low plasticity, stiff, dry to

Well Construction



EEC
Encore Environmental Consortium, LLC

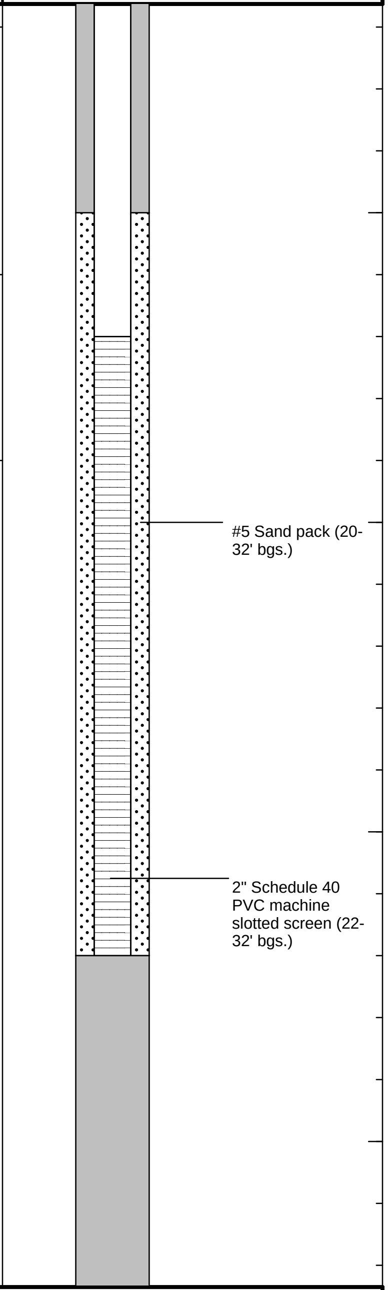
Remarks: NA= not available\not applicable
bgs= below ground surface

Client:
General Motors
Site Location:
GM Pontiac North Campus

Boring ID: MWF16-16
Borehole Depth: 45.0'

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	USCS Code	Stratigraphic Description
						CL	moist.
		4	15-20'	3.0'	2.3	SP	Brown fine POORLY GRADED SAND, medium dense, dry.
	955						
20							
		5	20-25'	3.5'	0.0	SM	Gray fine SILTY SAND, few Silt and Clay layers 2-3" thick, medium dense, Silt is wet.
	950						
						SP	Brown fine to medium POORLY GRADED SAND, medium dense, laminations of iron oxidation at 24-24.5' bgs, dry. 25.0' bgs- Wet.
25							
		6	25-30'	4.5'	0.0		
	945						
30							
		7	30-35'	3.0'	0.0		
	940						
35							
							Brown fine to medium POORLY GRADED SAND, medium dense, wet, laminations of iron oxidation at 24-24.5' bgs.

Well
Construction



EEC
Encore Environmental Consortium, LLC

Remarks: NA= not available\not applicable
bgs= below ground surface

Project: 64411.120
Data File:MWF16-16.dat
Template:I:\rockware\logplot\logfiles\Template\PontiacEEC_1.ldf
Date: 5/2/2005

Client:
General Motors

Site Location:
GM Pontiac North Campus

Boring ID: MWF16-16

Borehole Depth: 45.0'

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	USCS Code	Geologic Column	Stratigraphic Description	Well Construction
		8	35-40'	4.5'	0.0	SP			Bentonite chip (32-45' bgs.)
	935								
40									
		9	40-45'	4.0'	0.0				
	930					CL		Dark gray LEAN CLAY WITH SILT, few fine to coarse subangular Sand, trace Gravel, moderately plastic, medium stiff, moist.	
45									
	925								
50									
	920								
55									

Remarks: NA= not available\not applicable
bgs= below ground surface

Project: 64411.120
Data File:MWF16-16.dat

Template:I:\rockware\logplot\logfiles\Template\PontiacEEC_1.ldf
Date: 5/2/2005

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 17.5
Water Level Finish (ft. btoc.): NA

Northing: 425001.706365
Easting: 13410711.666010
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-30-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0	1	0.0-5.0'	5.0	0.0 0.0 0.0 0.0 0.0			(0.0-0.5') CONCRETE. (0.5-13.5') CLAY, medium to high plasticity, no dilatancy; little silt; little coarse sand, subangular to subrounded; trace very coarse sand to medium pebbles, subangular to subrounded; stiff to very stiff; poorly sorted; moist; grayish brown (10YR 5/2).		
5	-5	2	5.0-10.0'	4.4	0.0 0.0 0.0 0.0 0.0					
10	-10	3	10.0-15.0'	4.3	0.0 0.0 0.0 0.0 0.0			(13.5-16.0') CLAY, medium to high plasticity, no dilatancy; little silt; little medium sand, subangular to subrounded; trace coarse sand to small pebbles, subangular to subrounded; stiff to very stiff; poorly sorted; moist; gray (10YR 5/1).		
15	-15				0.0 0.0			(16.0-27.0') SAND, fine to medium, subangular to subrounded; trace coarse sand to small pebbles, subangular to subrounded, poorly sorted, moist to wet; brown (10YR 5/3).		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 17.5
Water Level Finish (ft. btoc.): NA

Northing: 425001.706365
Easting: 13410711.666010
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-30-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		4	15.0-20.0'	4.2	0.0 0.0 6.0			NOTE: wet at 17.5' bgs.	▼	
20	-20	5	20.0-25.0	3.9	0.0 0.0 0.0 0.0 0.0					Borehole backfilled with bentonite chips.
25	-25	6	25.0-30.0	4.2	0.1 0.0 0.0 0.0 0.0			(27.0-43.0') SAND, medium, subangular to subrounded; some coarse sand, subangular to subrounded; trace very coarse sand to granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
30	-30	7	30.0-35.0	4.0	0.0 0.0 0.0 0.0 0.0					

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Remarks: bgs = below ground surface

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 17.5
Water Level Finish (ft. btoc.): NA

Northing: 425001.706365
Easting: 13410711.666010
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-30-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					0.0	X				
					0.0					
		8	35.0-40.0	4.0	0.0					
					0.0			NOTE: color change at 39.0' bgs to gray (10YR 5/1).		
					0.0					
40	40				0.0					
					0.0					
		9	40.0-45.0'	4.3	0.0					
					0.0			(43.0-44.0') SILT, low to medium plasticity, slow to rapid dilatancy; and SAND, very fine to medium, poorly sorted; wet; gray (10YR 5/1).		
					0.0	X		(44.0-46.0') SAND, medium, subangular to subrounded; some coarse sand, subangular to subrounded; trace very coarse sand to granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
45	45				0.0					
					0.0			(46.0-50.0') CLAY, high plasticity, no dilatancy; little silt; trace very fine to medium sand, subangular to subrounded; very stiff; poorly sorted; moist; gray (10YR 5/1).		
		10	45.0-50.0'	4.5	0.0					
					0.0					
					0.0					
50	50							End of boring at 50.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 18.0
Water Level Finish (ft. btoc.): NA

Northing: 424913.972441
Easting: 13410765.318898
Casing **Elevation:** NA

Borehole Depth (ft. **bgs.**): 45.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: **VAP-31-22**
Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.5') SAND, medium to very coarse, subangular to subrounded; and GRANULES to large pebbles, subangular to subrounded; poorly sorted; dry; gray (10YR 5/1). NOTE: concrete pieces; gravel fill		
					0.2			(0.5-5.0') CLAY, medium to high plasticity, no dilatanc; little silt; little small pebbles, subangular to subrounded, stiff, poorly sorted; moist; brown (10YR 5/3).		
					151.1					
		1	0.0-5.0'	5.0	163.2					
					170.3					
					158.6					
5	-5							(5.0-6.0') CLAY, medium to high plasticity, no dilatancy; some medium to medium pebbles, subangular to subrounded; stiff; poorly sorted; moist; brown (10YR 5/3).		
					152.3					
								(6.0-13.5') CLAY, medium to high plasticity, no dilatancy; some silt; some medium sand, trace coarse sand to granules, subangular to subrounded, medium stiff; poorly sorted; moist; black (10YR 2/1) to gray (10YR 5/1).		
					150.1					
		2	5.0-10.0'	5.0	142.9					
					137.8					
					139.5					
10	-10									
					131.0					
					128.3					
		3	10.0-15.0'	4.9	120.1					
					120.0			(13.5-18.0') SAND, very fine to fine; some medium sand, subangular to subrounded; trace coarse sand, subangular to subrounded; poorly sorted; moist; light grayish brown (10YR 6/2).		
					118.3					
15	-15									
					119.7					
					112.6					

Remarks: bgs = below ground surface

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Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013
Data File: VAP-31-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 18.0
Water Level Finish (ft. btoc.): NA

Northing: 424913.972441
Easting: 13410765.318898
Casing **Elevation:** NA

Borehole Depth (ft. **bgs.):** 45.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-31-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		4	15 0-20.0'	4 6	110.4			NOTE: wet at 18.0' bgs.		
					60.6			(18 0-41 0') SAND, medium, subangular to subrounded; some coarse sand, subangular to subrounded; little very coarse sand to granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3) to grayish brown (10YR 5/2).	▼	
					30.4	X				
20	-20									
					15.2					
					1.2					
		5	20.0-25.0	3.8	0.0					Borehole backfilled with bentonite chips.
					0.0					
					0.0					
25	-25									
					0.0					
					0.0					
		6	25.0-30.0	4.0	0.0					
					0.0					
					0.0	X				
30	-30									
					0.0					
					0.0					
		7	30.0-35.0	4.2	0.0					
					0.0					
					0.0					

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Remarks: bgs = below ground surface

Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013
Data File: VAP-31-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/08/2022
Date Finish: 8/08/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 18.0
Water Level Finish (ft. btoc.): NA

Northing: 424913.972441
Easting: 13410765.318898
Casing **Elevation:** NA

Borehole Depth (ft. **bgs.**): 45.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-31-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					0.0					
					0.0					
		8	35.0- 40.0	4.2	0.0					
					0.0					
					0.0					
40	40				0.0					
					0.0			(41.0-45.0') CLAY, high plasticity, no dilatancy; little silt; trace very fine to medium sand; stiff to very stiff; poorly sorted; moist; gray (10YR 5/1).		
		9	40.0- 45.0'	4.6	0.0					
					0.0					
					0.0					
45	45							End of boring at 45.0' bgs.		
50	50									

Remarks: bgs = below ground surface

Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013 *Page: 3 of 3*
Data File: VAP-31-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/16/2022
Date Finish: 8/16/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 15
Water Level Finish (ft. btoc.): NA

Northing: 424890.952756
Easting: 13410779.061352
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-32-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.5') CONCRETE.		
					NM			(0.5-4.5') CLAY, medium plasticity, no dilatancy; some silt; some very fine to medium sand; little granules to large pebbles, subangular to subrounded; medium stiff; poorly sorted; moist; brown (10YR 5/3).		
					0.0					
		1	0.0-5.0'	5.0	0.0					
					0.0					
					0.0			(4.5-15.0') CLAY, high plasticity, no dilatancy; little very fine to medium sand, subangular to subrounded, trace silt; trace small pebbles, subangular to subrounded, medium stiff; poorly sorted, moist; gray (10YR 5/1).		
5	-5									
					0.0					
					0.0					
		2	5.0-10.0'	4.5	0.0					
					0.0					
					0.0					
10	-10									
					0.0					
					0.0					
		3	10.0-15.0'	4.3	0.0					
					0.0					
					0.0					
15	-15							(15.0-17.0') CLAY, medium plasticity, slow dilatancy; and SAND, very fine to medium; soft to medium stiff; poorly sorted; wet; dark gray (10YR 4/1).	▼	
					0.0					
					0.0					

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Remarks: bgs = below ground surface
NM = not measured

Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013 *Page: 1 of 3*

Data File: VAP-32-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/16/2022
Date Finish: 8/16/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 15
Water Level Finish (ft. btoc.): NA

Northing: 424890.952756
Easting: 13410779.061352
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: **VAP-32-22**

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		4	15.0-20.0'	4.0	0.0		▨	(17.0-19 5') CLAY, high plasticity, no dilatancy; little very fine to medium sand, subangular to subrounded, trace silt, trace small pebbles, subangular to subrounded, medium stiff, poorly sorted, moist; gray (10YR 5/1).		
					0.0					
					6.0		⁘	(19 5-28 5') SAND, very fine to fine; little medium sand; trace silt; poorly sorted; wet; gray (10YR 5/1).		
20	-20									
					0.0	☒				
					0.0					
		5	20.0-25.0	4.0	0.0					
					0.0					
					0.0					
25	-25									Borehole backfilled with bentonite chips
					0.1					
					0.0					
		6	25.0-30.0	3.8	0.0					
					0.0		⁘	(28.5-45.0') SAND, medium, subangular to subrounded, little coarse sand to granules, subangular to subrounded; poorly sorted, wet; gray (10YR 5/1) to yellowish brown (10YR 5/4).		
					0.0					
30	-30									
					0.0					
					0.0					
		7	30.0-35.0	3.6	0.0					
					0.0	☒				
					0.0					

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 8/16/2022
Date Finish: 8/16/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 15
Water Level Finish (ft. btoc.): NA

Northing: 424890.952756
Easting: 13410779.061352
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-32-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs.)	Well/Boring Construction
		8	35.0-40.0	3.3	0.0 0.0 0.0 0.0 0.0	×	⁙			
40	-40	9	40.0-45.0'	3.2		×	⁙	NOTE: color change to gray (10YR 5/1) at 43.5' bgs.		
45	-45	10	45.0-50.0'	3.75			▨	(45.0-50.0') CLAY, high plasticity, no dilatancy; little silt; trace very fine sand to small pebbles, subangular to subrounded; stiff; poorly sorted; moist; gray (10YR 5/1).		
50	-50							End of boring at 50.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013 *Page: 3 of 3*
Data File: VAP-32-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/16/2022
Date Finish: 8/16/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 19.0
Water Level Finish (ft. btoc.): 40.5

Northing: 424933.659777
Easting: 13410750.735564
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: **VAP-33-22**

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.5') TOPSOIL; GRASS; ORGANICS.		
					0.0			(0.5-8.0') CLAY, medium plasticity, no dilatancy; some silt; some very fine to medium sand; little granules to large pebbles, subangular to subrounded; medium stiff; poorly sorted; dry to moist; brown (10YR 5/3).		
					0.0					
		1	0.0-5.0'	5.0	0.0					
					0.0					
					0.0					
5	-5									
					0.0					
					0.0					
		2	5.0-10.0'	4.75	0.0					
					0.0			(8.0-14.8') CLAY, high plasticity, no dilatancy; little very fine to medium sand; trace silt; trace small pebbles, subangular to subrounded; medium stiff; poorly sorted; moist; grayish brown (10YR 5/2).		
					0.0					
10	-10									
					0.0					
					0.0					
		3	10.0-15.0'	5.0	0.0					
					0.0					
					0.0			(14.8-15.0') SAND, fine; little silt; little medium sand, subangular to subrounded; poorly sorted; moist; brown (10YR 5/3)		
15	-15							(15.0-17.5') CLAY, high plasticity, no dilatancy; little very fine to medium sand; trace silt; trace small pebbles, subangular to subrounded, medium stiff; poorly sorted; moist; grayish brown (10YR 5/2).		
					0.0					
					0.0					

Remarks: bgs = below ground surface

ARCADIS Design & Consultancy for natural and built assets

Date Start: 8/16/2022 **Date Finish:** 8/16/2022 **Drilling Company:** Fibertec **Driller's Name:** N Wiseman **Drilling Method:** Hand Auger/Direct Push **Sampling Method:** Continuous **Rig Type:** Geoprobe **Water Level Start (ft. bgs.):** 19.0 **Water Level Finish (ft. btoc.):** 40.5	**Northing:** 424933.659777 **Easting:** 13410750.735564 **Casing Elevation:** NA **Borehole Depth (ft. bgs.):** 45.0 **Surface Elevation:** NA **Descriptions By:** M Olender	**Well/Boring ID:** **VAP-33-22** **Client:** RACER **Location:** RACER PNC **Weather Conditions:** 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		4	15.0-20.0'	4.8	0.0			(17.5-23.0') SAND, fine; little medium sand; trace coarse sand, subangular to subrounded, poorly sorted; moist to wet; brown (10YR 5/3).		
					0.0			NOTE: wet from 19.0 to 40.5' bgs.	▼	
					0.0					
20	-20				0.0	☒				
					0.0					
		5	20.0-25.0	3.8	0.0					Borehole backfilled with bentonite chips.
					0.0			(23.0-28.0') SAND, medium, subangular to subrounded; little coarse sand to granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
					0.0					
25	-25				0.0					
					0.0					
		6	25.0-30.0	4.2	0.0					
					0.0			(28.0-40.5') SAND, medium, subangular to subrounded; some coarse sand, subangular to subrounded; little granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
					0.0					
30	-30				0.0					
					0.0	☒				
		7	30.0-35.0	4.3	0.0					
					0.0					
					0.0			NOTE: color change to gray (10YR 5/1) at 34.0' bgs.		

Remarks: bgs = below ground surface

ARCADIS Design & Consultancy for natural and built assets

Date Start: 8/16/2022	Northing: 424933.659777
Date Finish: 8/16/2022	Easting: 13410750.735564
Drilling Company: Fibertec	Casing Elevation: NA
Driller's Name: N Wiseman	
Drilling Method: Hand Auger/Direct Push	Borehole Depth (ft. bgs.): 45.0
Sampling Method: Continuous	Surface Elevation: NA
Rig Type: Geoprobe	
Water Level Start (ft. bgs.): 19.0	Descriptions By: M Olender
Water Level Finish (ft. btoc.): 40.5	

Well/Boring ID: VAP-33-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					0.0		●			▒
					0.0		●			▒
		8	35.0-40.0	3.9	0.0		●			▒
					0.0	X	●			▒
					0.0		●			▒
40	-40									
					0.0		▨	(40.5-45.0') CLAY, high plasticity, no dilatancy; little silt; trace very fine sand to small pebbles, subangular to subrounded; stiff to very stiff, poorly sorted; moist; gray (10YR 5/1).		▒
					0.0		▨			▒
		9	40.0-45.0'	4.0	0.0		▨			▒
					0.0		▨			▒
					0.0		▨			▒
45	-45							End of boring at 45.0' bgs.		
50	-50									

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Project: 30112891.00004 Template: ARCADIS_Analytical Boring-Well 2013 *Page: 3 of 3*

Data File: VAP-33-22.dat Date: 10/2/2022 Created/Edited by: C. Jeffers

Date Start: 8/16/2022	**Northing:** 424956.993110	Well/Boring ID: VAP-34-22
Date Finish: 8/16/2022	**Easting:** 13410739.798228	Client: RACER
Drilling Company: Fibertec	**Casing Elevation:** NA	**Location:** RACER PNC
Driller's Name: N Wiseman	**Borehole Depth (ft. bgs.):** 50.0	
Drilling Method: Hand Auger/Direct Push	**Surface Elevation:** NA	
Sampling Method: Continuous	**Descriptions By:** M Olender	
Rig Type: Geoprobe		
Water Level Start (ft. bgs.): 13.5		**Weather Conditions:** 81 F, humid, cloudy
Water Level Finish (ft. btoc.): 49.0		

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.5') SAND, coarse to very coarse, and PEBLES, small to large, subangular to subrounded; poorly sorted; dry; gray (10YR 5/1) NOTE: gravel; concrete chuncks.		
					NM			(0.5-10.0') CLAY, medium plasticity, no dilatancy; some silt; some very fine to medium sand; little granules to large pebbles, subangular to subrounded; medium stiff; poorly sorted; dry to moist; brown (10YR 5/3).		
					0.0					
		1	0.0-5.0'	5.0	0.0					
					0.0					
					0.0					
5	-5									
					0.0					
					0.0					
		2	5.0-10.0'	4.5	0.0					
					0.0					
					0.0					
10	-10							(10.0-13.5') CLAY, high plasticity, no dilatancy; little very fine tomedium sand; trace silt; trace small pebbles, subangular to subrounded; medium stiff to stiff; poorly sorted; moist; grayish brown (10YR 5/2).		
					0.0					
					0.0					
		3	10.0-15.0'	5.0	0.0					
					0.0			(13.5-15.0') SAND, fine to medium; llittle silt; poorly sorted; wet; brown (10YR 5/3).		
					0.0					
15	-15							(15.0-19.0') CLAY, high plasticity, no dilatancy; little very fine tomedium sand; trace silt; trace small pebbles, subangular to subrounded; medium stiff to stiff; poorly sorted; moist; grayish brown (10YR 5/2).		
					0.0					
					0.0					

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 8/16/2022
Date Finish: 8/16/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 13.5
Water Level Finish (ft. btoc.): 49.0

Northing: 424956.993110
Easting: 13410739.798228
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: M Olender

Well/Boring ID: VAP-34-22

Client: RACER

Location: RACER PNC

Weather Conditions: 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		4	15.0-20.0'	4.6	0.0		▨			
					0.0		▨		▼	
					6.0		●	(19.0-20.0') SAND, fine to medium; little coarse sand to granules, subangular to subrounded; trace small pebbles, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
20	-20				0.0	☒	●	(20.0-28.0') SAND, fine; little medium sand; trace coarse sand, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3).		
					0.0		●			
		5	20.0-25.0	4.0	0.0		●			
					0.0		●			
					0.0		●			
25	-25				0.1		●			Borehole backfilled with bentonite chips.
					0.0		●			
		6	25.0-30.0	3.0	0.0		●			
					0.0		●	(28.0-49.0') SAND, medium, subangular to subrounded; some coarse sand, subangular to subrounded; trace granules, subangular to subrounded; poorly sorted; wet; brown (10YR 5/3)		
					0.0	☒	●			
30	-30				0.0		●			
					0.0		●			
		7	30.0-35.0	2.5	0.0		●			
					0.0		●			
					0.0		●			

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 8/16/2022	**Northing:** 424956.993110	Well/Boring ID: VAP-34-22
Date Finish: 8/16/2022	**Easting:** 13410739.798228	Client: RACER
Drilling Company: Fibertec	**Casing Elevation:** NA	
Driller's Name: N Wiseman		
Drilling Method: Hand Auger/Direct Push	**Borehole Depth (ft. bgs.):** 50.0	**Location:** RACER PNC
Sampling Method: Continuous	**Surface Elevation:** NA	
Rig Type: Geoprobe		
Water Level Start (ft. bgs.): 13.5	**Descriptions By:** M Olender	
Water Level Finish (ft. btoc.): 49.0		**Weather Conditions:** 81 F, humid, cloudy

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		8	35.0-40.0	3.2	0.0 0.0 0.0 0.0 0.0	X		NOTE. color change to gray (10YR 5/1) at 35.0' bgs.		
40	40	9	40.0-45.0'	2.9	0.0 0.0 0.0 0.0 0.0					
45	45	10	45.0-50.0'	2.9	0.0 0.0 0.0 0.0 0.0	X		(49.0-50.0') CLAY, high plasticity, no dilatancy; little silt; trace very fine sand to small pebbles, subangular to subrounded; stiff to very stiff; poorly sorted; moist; gray (10YR 5/1).		
50	50							End of boring at 50.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface

Date Start: 10/03/2022 **Date Finish:** 10/03/2022 **Drilling Company:** Fibertec **Driller's Name:** N Wiseman **Drilling Method:** Hand Auger/Direct Push **Sampling Method:** Continuous **Rig Type:** Geoprobe **Water Level Start (ft. bgs.):** 18.2 **Water Level Finish (ft. btoc.):**	Northing: Easting: Casing Elevation: NA Borehole Depth (ft. bgs.): 45.0 Surface Elevation: NA Descriptions By: C. Weaver	Well/Boring ID: **VAP-35-22** Client: RACER **Location:** RACER PNC **Weather Conditions:** 48 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.5') BRICK (0.5-14.4') CLAY, medium plasticity, slow dilatancy; some medium sand, subrounded to subangular; trace small pebbles, subrounded to subandulat; soft, dry, brown (10YR 5/3).		
		1	0.0-5.0'	5.0	0.2 1.2 0.0 0.0 0.0					
5	-5	2	5.0-10.0'	5.0	0.0 0.0 0.0 0.0 0.0			NOTE: trace medium pebbles, subrounded to angular after 7.0' bgs.		
10	-10	3	10.0-15.0'	5.0	0.0 0.0 0.0 0.0 0.0			(14.4-17.2') SAND, fine to medium, subrounded to subangular; little silt; well sorted; dry; light yellowish brown (10YR 5/4).		
15	-15	4	15.0-20.0'	5.0	0.0 0.0 0.0 0.0 0.0			(17.2-20.0') SAND, fine, subrounded to subangular; some silt; well sorted; dry to wet; pale brown (10YR 6/3). NOTE: boring appears wet at 18.2' bgs; small clay seam ~1" thick at 19.8' bgs.	▼	
20	-20	5	20.0-25.0	5.0	0.0 0.0 0.0 0.0			(20.0-39.0') SAND, fine to medium, subrounded to subangular; trace small pebbles, subrounded to subangular; well sorted; moist to wet; light brownish gray (10YR 6/2).		Borehole backfilled with bentonite chips.

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/03/2022
Date Finish: 10/03/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 18.2
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: C. Weaver

Well/Boring ID: **VAP-35-22**

Client: RACER

Location: RACER PNC

Weather Conditions: 48 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					0.0					
25	-25	6	25.0-30.0	3.0	NM NM 0.0 0.0 0.0	☒				
30	-30	7	30.0-35.0	2.6	0.0 0.0 0.1 0.0 0.0	☒				
35	-35	8	35.0-40.0	2.4	NM NM 0.0 0.0 0.0	☒		(39.0-40.0') SAND, fine to very coarse, subrounded to subangular; some small pebbles, subrounded to subangular; little medium to large pebbles, subrounded to subangular; poorly sorted; moist to wet; pale brown (10YR 6/3).		
40	-40	9	40.0-45.0'	4.3	0.0 0.0 0.0 0.0 0.0			(40.0-45.0') CLAY, high plasticity, slow dilatancy; trace medium sand, subrounded to subangular; trace small pebbles, subrounded; stiff; dry; gray (10YR 5/1). NOTE: small cobble, subrounded at 41' bgs.		
45	-45							End of boring at 45.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/03/2022 **Date Finish:** 10/03/2022 **Drilling Company:** Fibertec **Driller's Name:** N Wiseman **Drilling Method:** Hand Auger/Direct Push **Sampling Method:** Continuous **Rig Type:** Geoprobe **Water Level Start (ft. bgs.):** 18.0, 27.0 **Water Level Finish (ft. btoc.):**	Northing: Easting: Casing Elevation: NA Borehole Depth (ft. bgs.): 45.0 Surface Elevation: NA Descriptions By: C. Weaver	Well/Boring ID: **VAP-36-22** Client: RACER **Location:** RACER PNC **Weather Conditions:** 55 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs.)	Well/Boring Construction
0	0							(0.0-0.5') BRICK		
					NM		▨	(0.5-15.0') CLAY, medium plasticity, slow dilatancy; little fine to medium sand, subrounded to subangular; trace small pebbles, subrounded to subangular; soft; dry; grayish brown (10YR 5/1) to dark gray (10YR 4/1).		
					0.0					
		1	0.0-5.0'	5.0	0.0					
					0.0					
5	-5				0.0					
					0.0					
					0.0					
		2	5.0-10.0'	5.0	0.0					
					0.0					
10	-10				0.0					
					0.0					
					0.0					
		3	10.0-15.0'	3.75	0.0					
					0.0					
15	-15				0.0					
					0.0		⁘	(15.0-22.5') SAND, fine to medium, subrounded to subangular; some silt, nonplastic, rapid dilatancy; dry to wet, well sorted, light yellowish brown (10YR 6/4) to pale brown (10YR 6/3).		
					0.0					
		4	15.0-20.0'	3.2	0.0			NOTE: boring appears wet at 18.0' bgs.	▼	
					0.0					
20	-20				0.0					
					0.0			NOTE: boring changes to dry at 21.0' bgs.		
					0.0					
		5	20.0-25.0	2.5	0.0		⁘	(22.5-39.0') SAND, fine to medium, subrounded to subangular; well sorted, moist to dry to wet; brownish yellow (10YR 6/8) to pale brown (10YR 6/3).		Borehole backfilled with bentonite chips.
					0.0					

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/03/2022
Date Finish: 10/03/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 18.0, 27.0
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: C. Weaver

Well/Boring ID: **VAP-36-22**
Client: RACER

Location: RACER PNC

Weather Conditions: 55 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					0.0					
25	-25	6	25.0-30.0	2.6	0.0 0.0 0.0 0.0 0.0	☒		NOTE: boring changes moist at 25.0' bgs and wet at 27.0' bgs.	▼	
30	-30	7	30.0-35.0	2.5	0.0 0.0 0.0 0.0 0.0	☒				
35	-35	8	35.0-40.0	2.9	0.0 0.0 0.0 0.0 0.0	☒		(39.0-40.0') SAND, fine to very coarse, subrounmded to subangular; some small pebbles to granules, subrounded to subangular; little to trace medium pebbles, subrounded to subangular; poorly sorted; wet; pale brown (10YR 6/3)		
40	-40	9	40.0-45.0'	4.0	0.0 0.0 0.0 0.0 0.0			(40.0-45.0') CLAY, high plasticity, slow dilatancy; trace sand, subrounded to subangular; trace small pebbles, subrounded to subangular; stiff; dry; gray (10YR 5/1).		
45	-45							End of boring at 45.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Project: 30112891.00005 Template: ARCADIS_Analytical Boring-Well 2013 *Page: 2 of 2*
Data File: VAP-36-22.dat Date: 10/20/2022 Created/Edited by: C. Jeffers

Date Start: 10/03/2022
Date Finish: 10/03/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 24.0
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: C Weaver

Well/Boring ID: VAP-37-22/MW-16-22

Client: RACER

Location: RACER PNC

Weather Conditions: 60 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample
0	0	1	0.0-5.0'	5.0	NM 0.0 0.0 0.0 0.0	
5	-5	2	5.0-10.0'	3.6	0.0 0.0 0.0 0.0 0.0	
10	-10	3	10.0-15.0'	2.0	NM NM 0.0 0.0 0.0	
15	-15	4	15.0-20.0'	2.2	0.0 0.0 0.0 NM NM	
20	-20	5	20.0-25.0'	3.2	0.0 0.0 0.0 0.0	X

Stratigraphic Description

(0.0-0 5') CONCRETE

(0 5-1 0') SAND, fine to coarse, subrounded to subangular; little small pebbles, subrounded to subangular; well sorted, dry; dark gray (10YR 4/1

(1.0-7 0') CLAY, medium plasticity, slow dilatancy; little sand, subrounded to subangular; soft; dry; brown (10YR 5/3).

NOTE: brick fragments at 1 0' and 4 5' bgs.

(7.0-8 0') SAND, fine to medium, subrounded to subangular; trace small pebbles, subrounded to subangular; well sorted; dry; light brownish gray (10YR 6/2).

(8.0-15.0') CLAY, medium to high plasticity, slow dilatancy; trace small pebbles, subrounded to subangular; moist; soft; dark gray (10YR 4/1)

NOTE: wood fragments at 8.8' bgs.

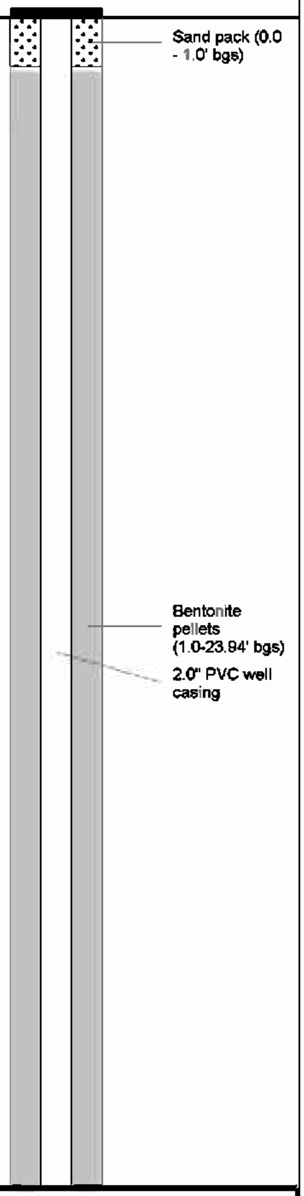
(15.0-19 0') SAND, fine to medium, subrounded to subangular; some silt; well sorted, dry to moist; brownish yellow (10YR 6/6) to pale brown (10YR 6/3).

(19.0-23 0') SILT, nonplastic, rapid dilatancy; some fine to medium sand, subrounded to subangular; soft; moist; gray (10YR 6/1)

(23.0-42 0') SAND, fine to medium, subrounded to subangular; well sorted, moist to wet; brownish yellow (10YR 6/6) to pale brown (10YR 6/3).

Water Level (ft bgs.)

Well/Boring Construction



Remarks: bgs = below ground surface
NM = not measured

ARCADIS Design & Consultancy for natural and built assets

Project: 30112891.00005
Template: ARCADIS_Analytical Boring-Well 2013

Data File: VAP-37-22/MW-16-22.dat
Date: 10/20/2022 Created/Edited by: C. Jeffers

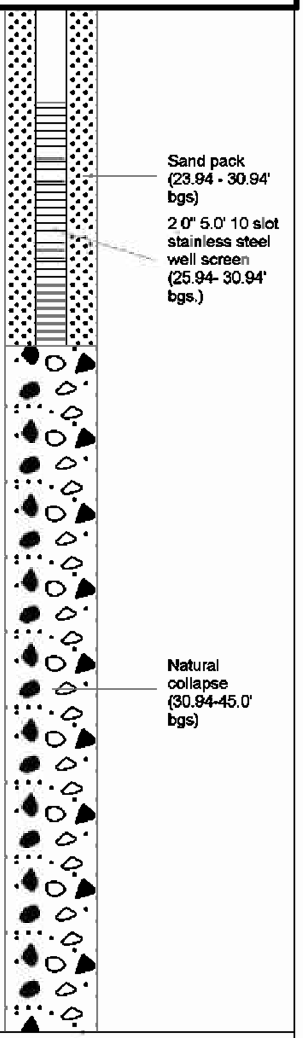
Date Start: 10/03/2022
Date Finish: 10/03/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 24.0
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA
Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA
Descriptions By: C. Weaver

Well/Boring ID: VAP-37-22/MW-16-22
Client: RACER
Location: RACER PNC
Weather Conditions: 60 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Stratigraphic Description
					0.0		
25	-25	6	25.0-30.0	2.75	0.0 0.0 0.0 0.0 0.0	✕	NOTE: boring appears wet at 24.0' bgs.
30	-30	7	30.0-35.0	2.9	0.0 0.1 0.0 0.0 0.0	✕	NOTE: color change from pale brown (10YR 6/3) to gray (10YR 6/1) at 34.0' bgs.
35	-35	8	35.0-40.0	3.75	0.0 0.0 0.0 0.0 0.0		
40	-40	9	40.0-45.0'	4.0	0.0 0.0 0.0 0.0 0.0	✕	(42.0-43.5') CLAY, high plasticity, slow dilatancy; little to trace small pebbles, subrounded to subangular; stiff; dry; gray (10YR 5/1). (43.5-44.0') SAND, fine to medium, subrounded to subangular; well sorted, trace medium pebbles, subrounded to subangular; dry; gray (10YR 6/1). (44.0-45.0') CLAY, high plasticity, slow dilatancy; trace small pebbles, subrounded to subangular; stiff; dry; gray (10YR 5/1).
45	-45						End of boring at 45.0' bgs.

Well/Boring Construction



Remarks: bgs = below ground surface
NM = not measured

ARCADIS Design & Consultancy for natural and built assets

Project: 30112891.00005 Template: ARCADIS_Analytical Boring-Well 2013
Data File: VAP-37-22/MW-16-22.dat Date: 10/20/2022 Created/Edited by: C. Jeffers

Date Start: 10/04/2022
Date Finish: 10/04/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 27.2
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

Descriptions By: C. Weaver

Well/Boring ID: VAP-38-22/MW-15-22

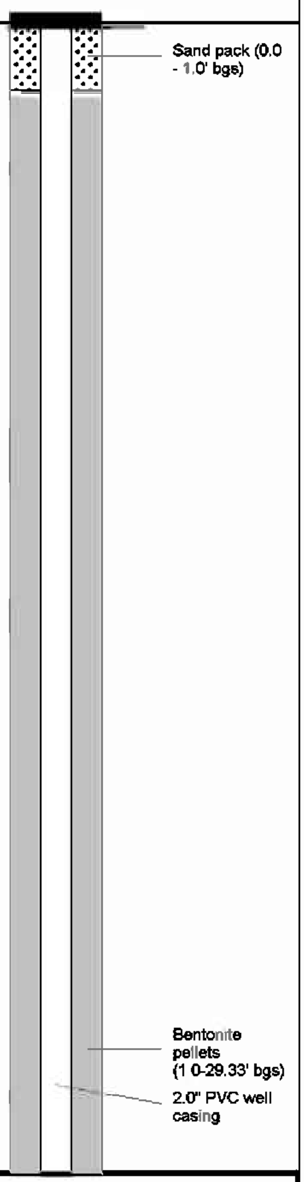
Client: RACER

Location: RACER PNC

Weather Conditions: 50 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)
0	0							(0.0-0.5') CONCRETE	
					0.0			(0.5-1.0') SAND, fine to coarse, subrounded to subangular; some small to medium pebbles, subroumded to subangular; poorly sorted, dry; gray (10YR 6/1).	
					0.0			(1.0-2.0') SILT, low plasticity, rapid dilatancy; little fine sand, subrounded to subangular; trace clay; soft; dry; light yellowish brown (10YR 6/4).	
		1	0.0-5.0'	5.0	0.0			(2.0-6.0') CLAY, high plasticity, slow dilatancy; trae fine to medium sand, subrounded to subangular; trace small pebbles, subrounded to subangular; soft; dry; light yellowish brown (10YR 6/4).	
					0.0				
					0.0				
5	-5								
					0.0				
					0.0			(6.0-8.2') SILT, low plasticity, rapid dilatancy; some fine sand; trace clay; soft; moist; light grayish brown (10YR 6/2).	
		2	5.0-10.0'	3.75	0.0				
					0.0			(8.2-11.0') CLAY, high plasticity, rapid dilatancy; some silt; little fine sand; soft to stiff; moist to dry; gray (10YR 6/1). NOTE: black (10YR 2/1) from 8.8 to 9.2' bgs.	
					0.0				
10	-10								
					0.0				
					0.0			(11.0-12.0') SILT, low plasticity, rapid dilatancy; some fine to medium sand, subronded to subangular; little clay; soft; moist; gray (10YR 6/1).	
		3	10.0-15.0'	5.0	0.0			(12.0-27.2') CLAY, high plasticity, slow dilatancy; trace small pebbles, subrounded to subangular; trace fine tomedium sand, subrounded to subangular; soft to medium stiff; gray (10YR 6/1)	
					0.0				
					0.0				
15	-15								
					0.0				
					0.0				

Well/Boring Construction



ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/04/2022
Date Finish: 10/04/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 27.2
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 50.0
Surface Elevation: NA

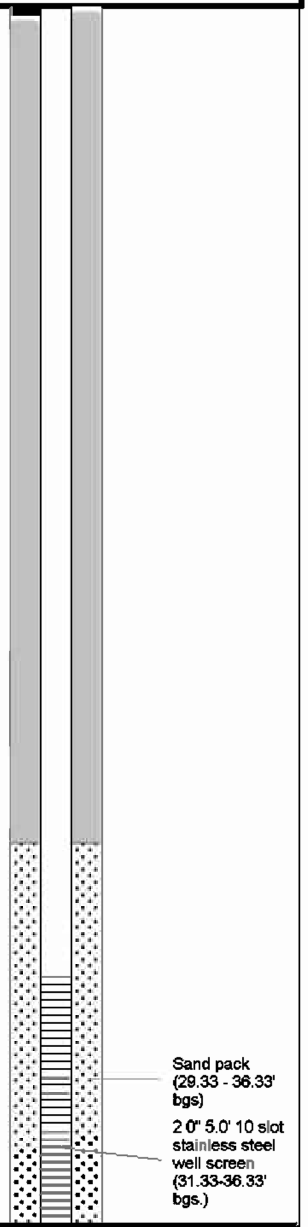
Descriptions By: C. Weaver

Well/Boring ID: VAP-38-22/MW-15-22
Client: RACER

Location: RACER PNC

Weather Conditions: 50 F, Sunny

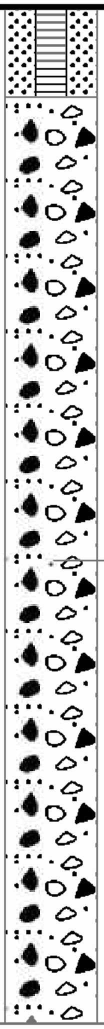
DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft. bgs)	Well/Boring Construction
		4	15.0-20.0'	4.0	0.1					
					0.0					
					0.0					
20	-20									
					0.0					
					0.0					
		5	20.0-25.0	5.0	0.0					
					0.0					
					0.0					
25	-25									
					0.0					
					0.0					
		6	25.0-30.0	3.4	0.0			(27.2-48.0') SAND, fine to medium, subrounded to subangular; trace small pebbles, subrounded to subangular; welll sorted, wet; pale brown (10YR 6/3) to gray (10YR 6/1).	▼	
					0.0	X				
					0.0					
30	-30									
					0.0					
					0.0					
		7	30.0-35.0	3.25	0.0					
					0.0					
					0.0	X				



ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/04/2022 **Date Finish:** 10/04/2022 **Drilling Company:** Fibertec **Driller's Name:** N Wiseman **Drilling Method:** Hand Auger/Direct Push **Sampling Method:** Continuous **Rig Type:** Geoprobe **Water Level Start (ft. bgs.):** 27.2 **Water Level Finish (ft. btoc.):**	Northing: Easting: Casing Elevation: NA Borehole Depth (ft. bgs.): 50.0 Surface Elevation: NA Descriptions By: C. Weaver	Well/Boring ID: VAP-38-22/MW-15-22 Client: RACER **Location:** RACER PNC **Weather Conditions:** 50 F, Sunny



DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
		8	35.0-40.0	1.7	NM NM NM NM 0.0			NOTE: poor recovery 35.0 to 40.0' bgs due to jammed liner loss and compaction during extraction. NOTE: color change to gray (10YR 6/1) at 39.0' bgs.		
40	-40	9	40.0-45.0'	0.8	0.0 NM NM NM NM	X		NOTE: poor recovery from 40.0 to 45.0' bgs due to liner break in sample tube when extracting, sediments lost.		Natural collapse (36.33-50.0' bgs)
45	-45	10	45.0-50.0'	4.6	0.0 0.0 0.0 0.0 0.0	X		(48.0-50.0') CLAY, high plasticity, slow dilatancy; trace small pebbles, subrounded to subangular; dry; stiff; gray (10YR 6/1).		
50	-50							End of boring at 50.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Date Start: 10/05/2022
Date Finish: 10/05/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 25.0
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: C Weaver

Well/Boring ID: VAP-39-22

Client: RACER

Location: RACER PNC

Weather Conditions: 50 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
0	0							(0.0-0.3') ASPHALT		
					0.0			(0.3-2.0') CLAY, high plasticity, slow dilatancy; little fine to medium sand, subrounded to subangular; trace small pebbles, subrounded to subangular; soft; dry to moist; yellowish brown (10YR 5/4).		
					0.0					
		1	0.0-5.0'	5.0	0.0			(2.0-4.0') SAND, fine to medium, subrounded to subangular; trace granules, subrounded to subangular; well sorted; dry; yellowish brown (10YR 5/4).		
					0.0					
5	-5				0.0			(4.0-10.0') CLAY, high plasticity, slow dilatancy; trace fine to medium sand, subrounded to subangular; trace small pebbles, subrounded to subangular; very soft to stiff; dry to wet; dark yellowish brown (10YR 4/1).		
					0.0					
					0.0					
		2	5.0-10.0'	3.9	0.0					
					0.0			NOTE: boring appears wet at 8.5' bgs.		
10	-10				0.0					
					0.0			(10.0-12.5') SILT, nonplastic, rapid dilatancy; trace fine to medium sand; moist to wet; very soft; yellowish brown (10YR 5/6).		
					0.0					
		3	10.0-15.0'	2.2	0.0			(12.5-35.0') SAND, fine to medium, subrounded to subangular; trace silt; well sorted; moist to wet; brownish yellow (10YR 6/8) to light yellowish brown (10YR 6/4).		
					NM					
15	-15				NM					
					0.0					
					0.0					
		4	15.0-20.0'	2.0	NM					
					NM					
20	-20				NM					
					0.0					
					NM					
		5	20.0-25.0	0.8	NM					Borehole backfilled with bentonite chips.
					NM					

Remarks: bgs = below ground surface
NM = not measured

ARCADIS Design & Consultancy for natural and built assets

Date Start: 10/05/2022
Date Finish: 10/05/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 25.0
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 45.0
Surface Elevation: NA

Descriptions By: C. Weaver

Well/Boring ID: VAP-39-22

Client: RACER

Location: RACER PNC

Weather Conditions: 50 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)	Well/Boring Construction
					NM	✕				
25	-25	6	25.0-30.0	1.3	0.0				▼	
					0.0					
					NM					
					NM					
					NM	✕				
30	-30	7	30.0-35.0	2.4	0.0					
					0.0					
					0.0					
					NM					
					NM	✕		(35.0-35.2') SAND, medium to very coarse, subrounded to subangular; little small pebbles, subangular to subrounded; poorly sorted; wet; black (10YR 2/1).		
35	-35	8	35.0-40.0	3.2	0.0			(35.2-40.0') CLAY, medium plasticity, rapid dilatancy; some silt; moist; soft; dark gray (10YR 4/1).		
					0.0					
					0.0					
					NM					
					NM					
40	-40	9	40.0-45.0'	5.0	0.0			(40.0-45.0') CLAY, high plasticity, slow dilatancy; little fine to medium sand, subrounmded to subangular; trace small to medium pebbles, subrouded to subangular; medium stiff, dry to moist; grayish brown (10YR 5/2).		
					0.0					
					0.0					
					0.0					
					0.0			NOTE: very large pebble at 45.0' bgs.		
45	-45							End of boring at 45.0' bgs.		

ARCADIS Design & Consultancy for natural and built assets

Remarks: bgs = below ground surface
NM = not measured

Project: 30112891.00005 Template: ARCADIS_Analytical Boring-Well 2013 Page: 2 of 2
Data File: VAP-39-22.dat Date: 10/19/2022 Created/Edited by: C. Jeffers

Date Start: 10/05/2022
Date Finish: 10/05/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 28.5
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 40.0
Surface Elevation: NA

Descriptions By: C. Weaver/S. Guy

Well/Boring ID: VAP-40-22

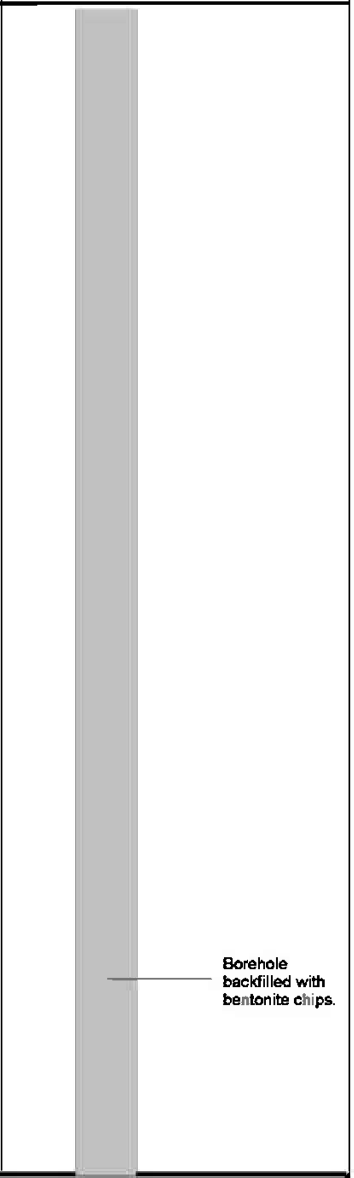
Client: RACER

Location: RACER PNC

Weather Conditions: 66 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft bgs)
0	0								
					0.0			(0.0-0.8') CONCRETE (0.8-1.0') SAND, fine to medium, subrounded to subangular; trace small to medium pebbles, subrounded to subangualr, well sorted, dry, brown (10YR 5/3)	
					0.0			(1.0-2.0') CLAY, high plasticity, slow dilatancy; little fine to medium sand, subangular to subroumnded; trace small pebbles, subrounded to subangular; soft; dry; brown (10YR 5/3).	
		1	0.0-5.0'	5.0	0.0			(2.0-8.0') SAND, fine to medium, subrounded to subangular; trace small pebbles, subrounded to subangular; well sorted, dry; pale brown (10YR 6/3).	
					0.0				
5	-5				0.0				
					0.0				
					0.0				
		2	5.0-10.0'	2.6	0.0				
					0.0			(8.0-13.0') CLAY, high plasticity, slow dilatancy; trace fine to medium sand, subangular; trace small pebbles, subrounded to subangular; soft; dry; brown (10YR 5/3)	
10	-10				0.0				
					0.0				
					0.0				
		3	10.0-15.0'	2.3	0.0				
					NM			(13.0-19.0') SILT, nonplastic, rapid dilatancy; trace fine sand, soft; dry; light yellowish brown (10YR 6/4).	
15	-15				NM				
					0.0				
					0.0				
		4	15.0-20.0'	1.25	NM				
					NM				
20	-20				NM			(19.0-34.2') SAND, fine to medium, subrounded to subangular; well sorted; dry; very pale borwn (10YR 7/4) to yellowish brown (10YR 5/6).	
					0.0				
					NM				
		5	20.0-25.0	1.2	NM				
					NM				

Well/Boring Construction



Remarks: bgs = below ground surface
NM = not measured

ARCADIS Design & Consultancy for natural and built assets

Project: 30112891.00005 Template: ARCADIS_Analytical Boring-Well 2013
Data File: VAP-40-22.dat Date: 10/20/2022 Created/Edited by: C. Jeffers

Date Start: 10/05/2022
Date Finish: 10/05/2022
Drilling Company: Fibertec
Driller's Name: N Wiseman
Drilling Method: Hand Auger/Direct Push
Sampling Method: Continuous
Rig Type: Geoprobe
Water Level Start (ft. bgs.): 28.5
Water Level Finish (ft. btoc.):

Northing:
Easting:
Casing Elevation: NA

Borehole Depth (ft. bgs.): 40.0
Surface Elevation: NA

Descriptions By: C. Weaver/S. Guy

Well/Boring ID: VAP-40-22

Client: RACER

Location: RACER PNC

Weather Conditions: 66 F, Sunny

DEPTH (feet bgl)	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Water Level (ft. bgs)	Well/Boring Construction
					NM			NOTE: boring appears moist at 24.0' bgs.		
25	-25				0.0					
					0.0					
		6	25.0-30.0	2.25	NM					
					NM			NOTE: boring appears wet @ 28.5' bgs.	▼	
					NM					
30	-30				0.0					
					0.0					
		7	30.0-35.0	2.3	NM			NOTE: trace granules, subrounded to subangular at 34.0' bgs.		
					NM			(34.2-35.0') SAND, fine to coarse, subrounded to subangular; and GRANULES, subrounded to subangular, some small to medium pebbles; poorly sorted; wet; brown (10YR 5/3).		
					NM					
35	-35				0.0			(35.0-35.2') SAND, fine to medium, subrounded to subangular; well sorted; wet; yellowish brown (10YR 5/4).		
					0.0			(35.2-40.0') CLAY, high plasticity, rapid dilatancy; some silt; soft; moist to dry; gray (10YR 6/1).		
		8	35.0-40.0	4.2	0.0					
					0.0					
					0.0					
40	-40							End of boring at 40.0' bgs.		
45	-45									

Remarks: bgs = below ground surface
NM = not measured

Appendix B

Standard Operating Procedures

STANDARD OPERATING PROCEDURE

PURGE AND TRAP FOR AQUEOUS AND HIGH AND LOW CONCENTRATION SOIL SAMPLES
METHOD 5030C/5035A

APPROVALS:

Barbara Ball

02/16/2021

QA Officer — Date

02/16/2021

Technical Director — Date

Number	**Description of Change**	**Date**
001-005	Previous changes were not documented	
006	Updated to comply with DoD QSM and ISO 17025 standards.	6/3/11
007	Updated SOP for Method 5035A high and low level soil prep	6/14/12
008	Updated SOP for Method 5030C	9/03/13
009	Updated to comply with DoD QSM 5.0 standards.	04/01/16
010	Updated to comply with DoD QSM 5.1 standards.	01/16/18
011	DOD Audit Corrective Action	09/29/2020
012	2020 Internal Audit revisions	02/16/2021
013		
014		
015		
016		

1.0 SCOPE AND APPLICATION

This SOP describes a purge-and-trap procedure for the analysis of volatile organic compounds (VOCs) in aqueous samples and water miscible liquid samples. It also describes the analysis of low and high concentration soil and waste sample extracts prepared in Method 5035A. The method is applicable to Gas Chromotography/Mass Spectrometry (GC/MS) Method 8260B. Method 5030C can be used for most volatile organic compounds that have boiling points below 200°C and are insoluble or slightly soluble in water. Volatile water-soluble compounds can be included in this analytical technique; however, quantitation limits (by GC or GC/MS) are approximately ten times higher because of poor purging efficiency. The method is also limited to compounds that elute as sharp peaks from a GC column packed with graphitized carbon lightly coated with a carbowax or a coated capillary column. Such compounds include low molecular weight halogenated hydrocarbons, aromatics, ketones, nitriles, acetates, acrylates, ethers, and sulfides. Water samples can be analyzed directly for volatile organic compounds by purge-and-trap extraction and gas chromatography. Higher concentrations of these analytes in water can be determined by direct injection of the sample into the chromatographic system or by dilution of the sample prior to the purge-and-trap process. This method is restricted to use by or under the supervision of trained analysts. Each analyst must demonstrate the ability to generate acceptable results with this method. This SOP is not for use with samples that come into the lab for OHIO VAP work.

2.0 SUMMARY OF METHOD

Aqueous Samples: An inert gas is bubbled through a portion of the aqueous sample at ambient temperature, and the volatile components are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent column where the volatile components are adsorbed. After purging is completed, the sorbent column is heated and backflushed with inert gas to desorb the components onto a gas chromatographic column. High Concentration Extracts from Method 5035A: An aliquot of the extract prepared in Method 5035A is combined with organic free reagent water in the purging chamber. It is then analyzed by purge-and-trap GC or GC/MS. Low Concentration Soils: An aliquot of the soil is combined with organic free reagent water in the purging chamber. It is then analyzed by purge-and–trap GC or GC/MS. Air samples in Tedlar Bags: A volume of air is extracted from the Tedlar Bag using a gas tight syringe and is introduced to a vial of reagent water. An inert gas is bubbled through a portion of the aqueous sample at ambient temperature. The vapor is swept through a sorbent column where the volatile components are adsorbed. After purging is completed, the sorbent column is heated and backflushed with inert gas to desorb the components onto a gas chromatographic column.

3.0 INTERFERENCES

Impurities in the purge gas, and from organic compounds out-gassing from the plumbing ahead of the trap, account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks. The use of non-polytetrafluoroethylene (non-PTFE) plastic coating, non-PTFE thread sealant, or flow controllers with rubber components in the purging device must be avoided, since such materials out-gas organic compounds which will be concentrated in the trap during the purge operation. These compounds will result in interferences or false positives in the determinative step.

Samples can be contaminated by diffusion of volatile organics (particularly methylene chloride and fluorocarbons) through the septum seal of the sample vial during shipment and storage. A trip blank prepared from organic-free reagent water and carried through sampling and handling protocols serves as a check on such contamination.

Contamination by carryover can occur whenever high-concentration and low-concentration samples are analyzed sequentially. Whenever an unusually concentrated sample is analyzed, it must be followed by an analysis of organic-free reagent water to check for cross-contamination. The trap and other parts of the system are subject to contamination. Therefore, frequent bake-out and purging of the entire system may be required.

The laboratory where volatiles analysis is performed must be completely free of solvents. Special precautions must be taken to determine methylene chloride. The analytical and sample storage areas must be isolated from all atmospheric sources of methylene chloride. Otherwise random background levels will result. Since methylene chloride will permeate through PTFE tubing, all GC carrier gas lines and purge gas plumbing must be constructed of stainless steel or copper tubing. Laboratory workers' clothing previously exposed to methylene chloride fumes during common liquid/liquid extraction procedures can contribute to sample contamination. The presence of other organic solvents in the laboratory where volatile organics are analyzed will also lead to random background levels and the same precautions must be taken.

4.0 APPARATUS AND MATERIALS

Microsyringes - 10-µL, 25-µL, 100-µL, 250-µL, and 500-µL.

Gas tight 5ml syringes.

Vials – 40-mL, for GC autosampler (Archon).

Magnetic stir bars.

Scale capable of displaying weight to the nearest hundredth of a gram.

Purge-and-trap device. The purge-and-trap device consists of three separate pieces of equipment: the sample purger, the trap, and the desorber.

- The Vocarb3000 trap by Supelco is used. It is preconditioned at 270°C for 60 minutes upon installment as suggested by supplier.

Gas Chromatograph.

Mass Spectrometer.

pH paper.

Class A Volumetric Flasks (10, 50 & 100 ml)

Disposal Pipettes

Graduated Pipettes

5.0 REAGENTS

Organic-free reagent water - All references to water in this method refer to organic-free reagent water.

Purge and Trap grade methanol.

Sodium Bisulfate.

Hydrochloric Acid (HCl)

See SOP ORL-007 for specifications on internal and surrogate standards.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

Aqueous Samples

- Samples must be stored in capped bottles, with minimum headspace, at (4 ± 2)°C in an area free of solvent fumes.

- All samples must be analyzed within 14 days of collection. Samples not analyzed within this period must be noted and data are considered minimum values. The pH of the samples is checked with pH strips after the sample has been prepared for the autosampler. If the pH is greater than 2 as determined by the pH strip the fact is noted. If the sample with pH > 2 is not analyzed within seven days of the collection date then it is noted on the report that the sample was not properly preserved. The pH is recorded on the volatile sample prep log (Figure 1).

Soil Samples

- High concentration soil samples collected and preserved in the field.
  - The following steps apply to the preparation of vials used in the collection of high concentration soil samples to be preserved in the field with methanol and analyzed by the aqueous purge-and-trap equipment.

  - Add 10 mL of methanol to each vial. Seal the vial with the screw-cap and septum seal. Affix a label to each vial. This eliminates the need to label the vials in the field and assures that the tare weight of the vial includes the label. (The weight of any markings added to the label in the field is negligible). Weigh the prepared vial to the nearest 0.01g, record the tare weight, and write it on the label.

  - (10 ± 0.5)g of sample are weighed out and added to the vial in the field.
  - Upon arrival to the lab, samples are stored at (4 ±2)°C.

- High concentration soil samples collected without a preservative.
  - When high concentration soil samples are collected without the use of a preservative, an EnCore sample container/sampler is employed.

    - The EnCore sampler has not been thoroughly evaluated by the EPA as a sample storage device. Preliminary results indicate that storage in the EnCore device may be appropriate for up to 48 hours, and so samples collected this way must be preserved in methanol within 48 hours of the sampling time. This preservation is documented in the High Level Extraction Sheet (Figure 3).

  - Weigh out (10 ±0.5)g of soil sample into a 40-mL vial and add 10-mL of Methanol.
  - Sonicate for twenty minutes.
  - Sample extracts are transferred to 4 ml vials and stored at (4 ± 2)°C.
  - Frozen samples are not acceptable for all OHIO VAP samples.

- Low concentration soil samples collected and preserved in the field.
  - The following steps apply to the preparation of vials used in the collection of low concentration soil samples to be preserved in the field with sodium bisulfate and reagent water and analyzed by the aqueous purge-and-trap equipment described in this SOP. Note: The sampling and preservation techniques required for low concentration analysis vary widely by state and regulating agency. The end-use of the data must be considered before selecting a sampling and preservation technique and may include procedures not in this SOP.

  - Add 5 mL of reagent water and a magnetic stir bar to each vial as well as 0.2g of sodium bisulfate for every 1g of sample to be collected. Seal the vial with the screw-cap and septum seal. Affix a label to each vial. This eliminates the need to label the vials in the field and assures that the tare weight of the vial includes the label. (The weight of any markings added to the label in the field is negligible). Weigh the prepared vial to the nearest 0.01g, record the tare weight, and write it on the label, and Low Level Extraction Log (Figure 2).

- o (1-5 ± 0.5)g of sample are weighed out and added to the vial in the field.
- o Upon arrival to the lab, samples are stored at (4 ±2)°C.

♦ Low concentration soil samples collected without a preservative.

- o When low concentration soil samples are collected without the use of a preservative, an EnCore sample container/sampler or an empty 40 ml vial is employed.
  - ▪ The EnCore sampler has not been thoroughly evaluated by the EPA as a sample storage device. Preliminary results indicate that storage in the EnCore device may be appropriate for up to 48 hours, and so samples collected this way must be preserved with sodium bisulfate within 48 hours of the sampling time. This preservation is documented in the Low Level Extraction Log (Figure 2).
- o Weigh out (1-5 ±0.5)g of soil sample into a 40-mL vial and add 5ml of reagent water and 0.2g of sodium bisulfate for every 1g of sample. Alternatively, weigh out (1-5 ±0.5)g of soil sample into a 40-mL vial and freeze (-7°C) for up to 14 days.
- o The preserved samples are stored at (4 ± 2)°C.
- o Bulk sample collection using USEPA Method 5030C can be used for approved sites/QAPPs.

7.0 PROCEDURE

1. The purge-and-trap technique for aqueous samples is found in Number 2 and method for analysis of solvent extracts from the High Concentration Method in Method 5035A is found in Number 3. The gas chromatographic determinative steps are found in SOP ORL-007. The method is also applicable to the analysis of gasoline, using SOP ORL-010.

2. This section provides guidance on the analysis of aqueous samples and samples that are water miscible, by purge-and-trap analysis.

   - ♦ Initial calibration. Calibrate system in accordance with Method 8260C.
   - ♦ If necessary or for project specific purposes, screen samples prior to purge-and-trap analysis to provide guidance on whether sample dilution is necessary and may prevent contamination of the purge-and-trap system. Screen the sample by GC/MS.

- Sample introduction and purging.
    - Assemble the purge-and-trap device. The operating conditions for the GC and GC/MS are given in method SOP ORL-007 and SOP ORL-010.
    - A daily check standard containing surrogates, internal standards and 20ug/l bromoform must be analyzed prior to the analysis of the daily check standard. If levels of chloromethane or bromomethane exceed 0.5ug/l, then the trap may be too contaminated with salts or tightly bound contamination for analysis to continue. The trap must be replaced and the system recalibrated. This can be achieved in the same run as the BFB.
    - GC or GC/MS calibration verification criteria must be met (SOP ORL-007 and SOP ORL-010) before analyzing samples.
    - Adjust the purge gas flow rate to provide the best response for chloromethane and bromoform, if these compounds are analytes. Excessive flow rate reduces chloromethane response, whereas insufficient flow reduces bromoform response.
    - Use autosampler to take a 5-mL aliquot of the sample. Care must be taken to remove any bubbles from the syringe. This process of taking an aliquot destroys the validity of the liquid sample for future analysis. Re-analysis must be done with duplicate VOA.
    - The autosampler adds 5.0 µL of surrogate and internal spiking solution as well as any matrix spike if applicable as described in SOP ORL-007 and SOP ORL-010.
    - Inject the aliquot into a purging vessel.
    - Purge for 11.0 minutes at room temperature in the sparge tube.
- Sample desorption.
    - Non-cryogenic interface - After the recommended purge (see above), place the purge-and-trap system in the desorb mode and preheat the trap to 190 °C without a flow of carrier gas passing through the trap. Start the flow of the carrier gas, begin the GC temperature program, and start GC data acquisition.
- Trap Reconditioning.
    - After desorbing the sample, recondition the trap by baking it at 210 °C for 7 minutes.

3. This section provides guidance on the analysis of solvent extracts from High Concentration Samples prepared by Method 5035A.

   - The GC or GC/MS system must be set up as in specific determinative method (SOP ORL-007 and SOP ORL-010).
   - Take 5mL's of organic-free reagent water and add 5.0 µL of surrogate and internal spiking solution as well as any matrix spike if applicable as described in SOP ORL-007 and SOP ORL-010.
   - Measure out a 100µL aliquot of the methanol phase of the sample.
   - The autosampler adds 5.0 µL of surrogate and internal spiking solution as well as any matrix spike if applicable as described in SOP ORL-007 and SOP ORL-010..
   - Purge for 11.0 minutes at room temperature in the 40ml vial.
   - Desorb the sample and recondition the trap.
   - If 1,4-Dioxane, heated purge is used.

4. This section provides guidance on the analysis of Low Concentration Samples prepared by Method 5035.

   - The GC or GC/MS system must be set up as in specific determinative method (SOP ORL-007 and SOP ORL-010).
   - Internal standards, surrogates and matrix spikes (if applicable) must be added automatically by the autosampler or manually by puncturing the septum using a small gauge needle.
   - Prior to purging the sample is preheated to 40°C for 1.5 minute while being agitated by the magnetic stir bar.
   - Purge for 11.0 minutes at 40°C while being agitated by the magnetic stir bar in the 40ml vial.
   - Desorb the sample and recondition the trap.

5. Tedlar Bag Air Analysis

   - The GC or GC/MS system must be set up as in specific determinative method (SOP ORL-007 and SOP ORL-010).

- To a 40 ml VOA bottle add 5 ml reagent water and add 5.0 µL of surrogate and internal spiking solution as well as any matrix spike if applicable as described in SOP ORL-007 and SOP ORL-010.

- Take a gas tight syringe with a needle fixed to the tip. Draw in a small volume of DI water into the syringe. This will provide a bubbling effect to show air is being drawn in from the bag.

- Insert the needle of the syringe through the septa of the Tedlar Bag and with draw 5 cc into the syringe.

- Bubble into 40 ml VOA bottle with 5 ml of DI water and surrogates and internal standards then cap promptly.

- Purge for 11.0 minutes at room temperature in the 40ml vial.
- Desorb the sample and recondition the trap.

6. Sample analysis. The samples prepared by this method will be analyzed according to SOP ORL-007 and SOP ORL-010.

8.0 QUALITY CONTROL

Refer to method SOP ORL-007 and SOP ORL-010 for specific quality control procedures. Quality control items employed and evaluated are provided in Table 1 and Table 2. In addition, the table indicates the frequency of each QC item along with appropriate courses of corrective action. The analyst will follow SOP # QA-007 and complete the appropriate review form upon completion of the analysis.

9.0 METHOD PERFORMANCE

Refer to the determinative methods for performance data.

10.0 EQUIPMENT MAINTENANCE AND TROUBLESHOOTING

Each instrument is assigned a maintenance logbook. All maintenance performed on the instrument must be recorded. Additionally, any modifications to the instrument settings shall be noted in the specific instrument logbook. Maintenance procedures provided in the equipment manual shall be followed. Maintenance may include, cleaning the MS source, clipping/replacing the column, or replacing the calibration standard.

Computer software and firmware can be found on Merit’s network at

F:\data\MERIT\EQUIPMENT\Instrument-Software Version List.200818.xls.

11.0 SAFETY

Eye protection and gloves must be worn while performing Volatile analyses. Every Laboratory area has eyewash, emergency shower, and fire extinguisher. The air system throughout the laboratory area is on a 100% fresh air exchange system, this system exchanges 100% the air in the laboratory area with air from outside 6 times per hour and 30 times per hour when the emergency purge button is hit. A reference file of material safety data sheets (MSDSs) is available to all personnel.

Specific attention be paid (but not limited) to:

- ♦ Hydrochloric acid is corrosive, extreme heat or contact with metals can release flammable hydrogen gas, stable under ordinary conditions of use and storage, and incompatible with many substances and highly reactive with strong bases, metals, metal oxides, hydroxides, amines, carbonates, cyanides, sulfides, sulfites, and formaldehyde.

- ♦ Methanol may react violently with acids, acid chlorides, acid anhydrides, oxidizing agents, reducing agents and alkali metals. Protect from moisture. Highly flammable.

12.0 WASTE DISPOSAL AND POLLUTION PREVENTION

All laboratory waste must be managed, stored, and disposed in accordance with all federal and state laws and regulations. Additional information can be found in the Sample Disposal SOP and Merit's Waste Management Plan and Handbook.

13.0 DEFINITIONS

An analytical batch is defined as a group of samples (not to exceed 20 samples) analyzed per sequential run. Depending on client or program requirements, an analytical batch may or may not include matrix spikes as part of the 20 samples.

Method Blank (MB): an analyte-free matrix to which all reagents are added in the same volumes or proportions as used in the sample processing. The method blank is carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.

Laboratory Control Sample (LCS) (also known as Laboratory Fortified Blank, Spiked Blank, or QC Check Sample): a sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. It is generally used to establish intra-laboratory or analyst-specific precision and bias or to assess the performance of all or a portion of the measurement system.

Matrix Spike (also known as Spiked Sample or Fortified Sample): a sample prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Matrix spikes are used, for example, to determine the effect of the matrix on a method's recovery efficiency.

Matrix Spike Duplicate (also known as Spiked Sample or Fortified Sample Duplicate): A second replicate matrix spike prepared in the laboratory and analyzed to obtain a measure of the precision of the recovery for each analyte.

14.0 REFERENCES

Bellar, T., "Measurement of Volatile Organic Compounds in Soils Using Modified Purge-and-Trap and Capillary Gas Chromatography/Mass Spectrometry", U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Cincinnati, OH, November, 1991.

Department of Defense, Quality Systems Manual for Environmental Laboratories (DoD QSM), DoD Environmental Data Quality Workgroup, Department of Navy, Lead Service, ISO/IEC 17025:2005, ISO/IEC 17025:2017 and The NELAC Institute (TNI) Standards, Volume 1, September 2009, Version 5.3, May 7, 2019

USEPA 40 CFR Part 136, "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule," October 26, 1984.

USEPA, SW-846, 1996, REVISION 0; METHOD 5000.

USEPA, SW-846, 1996, REVISION 2; METHOD 5030B.

USEPA, SW-846, 2003, REVISION 3; METHOD 5030C.

USEPA, SW-846, 2002, REVISION 1; METHOD 5035A.

USEPA, SW-846, 1996, REVISION 2; METHOD 8000B.

USEPA, SW-846, 1996, REVISION 2; METHOD 8260B.
USEPA, SW-846, 2006, REVISION 3; METHOD 8260C.

Table 1 Quality Control Items, Frequency, and Corrective Action

QC Item	Frequency	Acceptance Criteria	Corrective Action
Initial Calibration	Prior to all analytical runs	Method-based	Examine the entire analytical system; some or all of the following: clean MS source, re-tune, clip/replace column, replace calibration standards, re-calibrate.
BFB	12-hour	Method-based	Re-attempt injection; clean MS source, re-tune; failure requires the re-analysis of all associated analytical runs.
SPCC/CCC	12-hour	Method-based	Re-attempt injection; some or all of the following: clean MS source, re-tune, clip/replace column, replace calibration standards, re-calibrate; failure requires the re-analysis of all associated analytical runs.
LCS and MS	20 samples	Lab-based	A failed LCS must be re-extracted and re-analyzed. A failed MS requires no action provided that the LCS is acceptable. If additional sample exists, the samples associated with a failed LCS must be re-extracted and re-analyzed.
Duplicate or MSD	20 samples	n/a	Relative Percent Differences (RPDs) are computed and included in the QC report
Method Blank	20 samples	n/a	Method blank contamination is flagged on the analytical report for any identified target compound. Blanks indicative of contaminated analytical system (typically the purge-and-trap system) must result in a thorough cleansing of the affected system and sample/blank re-analysis.
Internal Standard	All samples	Method-based	Adverse matrix effects on areas/recoveries are demonstrated either by screening the extract of re-analyzing the sample within a 12-hour QC batch. The resulting analytical report is flagged appropriately. A negative bias unrelated to matrix effects indicates the need to: clean the MS source, re-tune, and re-calibrate
Surrogate Standard	All samples	Lab-based	Adverse matrix effects on areas/recoveries are demonstrated either by screening the extract of re-analyzing the sample within a 12-hour QC batch. The resulting analytical report is flagged appropriately. If additional sample exists, the sample must be re-extracted prior to re-analysis if a matrix effect cannot be demonstrated.
Target Compound	All samples	Method-based	Target compounds beyond the calibration range are diluted and re-analyzed and/or flagged as estimated on the analytical report.

Table 2: Quality Control Items, Frequency, and Corrective Action for DoD Projects

QC Check	**Minimum Frequency**	**Acceptance Criteria**	**Corrective Action**	**Flagging Criteria**	**Comments**
Tune Check	Prior to ICAL and prior To each 12-hour period of sample analysis	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify.	Flagging criteria is not appropriate.	No samples shall be analyzed without a valid tune.
Performance Check (Method 8270 only)	At the beginning of each 12-hour period, prior to analysis of samples.	Degradation ≤ 20% for DDT. Benzidine and pentachlorophenol shall be present at their normal responses and shall not exceed a tailing factor of 2.	Correct problem, then repeat performance checks.	Flagging is not appropriate.	No sample shall be analyzed until performance check is within criteria. The DDT breakdown and Benzidine/Pentachlorophenol tailing factors are considered overall system checks to evaluate injector port inertness and column performance and are required regardless of the reported analyte list.
Initial calibration (ICAL) for all analytes (including surrogates)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	Each analyte must meet one of the three options below: Option 1. RSD for each analyte ≤ 15%;. Option 2: linear least squares regression $r^2 \geq 0.99$; Option 3:non-linear least squares regression (quadratic) for each analyte: $r^2 \geq 0.99$.	Correct problem then repeat ICAL.	Flagging criteria is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. No samples shall be analyzed until ICAL has passed. If the specific version of a method requires additional evaluation (e.g., RFs or low calibration standard analysis and recovery criteria) these additional requirements must also be met.
Retention time window position establishment and surrogate	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Calculated for each analyte and surrogate.
Evaluation of relative retention times (RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	NA	After maintenance is performed which may affect retention times, RRTs may be updated based on the daily CCV. RRTs shall be compared with the most recently updated RRTs.

Table 2: Quality Control Items, Frequency, and Corrective Action for DoD Projects

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source prior to sample analysis	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing calibration verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last acceptable CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g, average RFs) these additional requirements must also be met.
Internal standards (IS)	Every field sample, standard, and QC sample.	Retention time ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the case narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging criteria is not appropriate for failed standards.	NA
Method blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater. Common contaminants, must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 2: Quality Control Items, Frequency, and Corrective Action for DoD Projects

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all surrogates and all analytes to be reported. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.
Matrix spike duplicate (MSD) or Matrix duplicate (MD)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	MSD: Must contain all surrogates and all analytes to be reported. The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.
Surrogate spike	All field and QC samples.	QC acceptance criteria specified by project, if available; otherwise use QSM Appendix C limits or in-house LCS limits if analyte(s) are not listed..	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present,	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.

Table 2: Quality Control Items, Frequency, and Corrective Action for DoD Projects

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
			reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the Case Narrative..		

DoD Appendix C LCS Limits
Method 8260 Solid Matrix

CAS ID	ANALYTE	LOWER CONTROL LIMIT (LCL)	UPPER CONTROL LIMIT (UCL)
630-20-6	1,1,1,2-Tetrachloroethane	78	125
71-55-6	1,1,1-Trichloroethane	73	130
79-34-5	1,1,2,2-Tetrachloroethane	70	124
79-00-5	1,1,2-Trichloroethane	78	121
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane [Freon-113]	66	136
75-34-3	1,1-Dichloroethane	76	125
75-35-4	1,1-Dichloroethene	70	131
563-58-6	1,1-Dichloropropene	76	125
87-61-6	1,2,3-Trichlorobenzene	66	130
96-18-4	1,2,3-Trichloropropane	73	125
526-73-8	1,2,3-Trimethlybenzene	82	118
120-82-1	1,2,4-Trichlorobenzene	67	129
95-63-6	1,2,4-Trimethylbenzene	75	123
96-12-8	1,2-Dibromo-3-chloropropane	61	132
106-93-4	1,2-Dibromoethane	78	122
95-50-1	1,2-Dichlorobenzene	78	121
107-06-2	1,2-Dichloroethane	73	128
17060-07-0	1,2-Dichloroethane-d4	71	136
540-59-0	1,2-Dichloroethene	78	122
78-87-5	1,2-Dichloropropane	76	123
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	64	132
108-70-3	1,3,5-Trichlorobenzene	71	128
108-67-8	1,3,5-Trimethylbenzene	73	124
541-73-1	1,3-Dichlorobenzene	77	121
142-28-9	1,3-Dichloropropane	77	121
542-75-6	1,3-Dichloropropene	77	126
106-46-7	1,4-Dichlorobenzene	75	120
105-05-5	1,4-Diethylbenzene	79	114
123-91-1	1,4-Dioxane	55	138
544-10-5	1-Chlorohexane	71	130
594-20-7	2,2-Dichloropropane	67	133
78-93-3	2-Butanone (MEK)	51	148

126-99-8	2-Chloro-1,3-butadiene	65	133
110-75-8	2-Chloroethyl vinyl ether	43	149
95-49-8	Chlorotoluene	75	122
591-78-6	2-Hexanone	53	145
79-46-9	2-Nitropropane	47	150
67-63-0	2-Propanol [Isopropyl alcohol]	60	140
460-00-4	4-Bromofluorobenzene	79	119
106-43-4	4-Chlorotoluene	72	124
108-10-1	4-Methyl-2-pentanone [MIBK]	65	135
67-64-1	Acetone	36	164
75-05-8	Acetonitrile	54	143
107-02-8	Acrolein [Propenal]	47	155
107-13-1	Acrylonitrile	65	134
107-05-1	Allyl chloride	68	135
71-43-2	Benzene	77	121
100-44-7	Benzyl chloride	64	120
108-86-1	Bromobenzene	78	121
74-97-5	Bromochloromethane	78	125
75-27-4	Bromodichloromethane	75	127
75-25-2	Bromoform	67	132
74-83-9	Bromomethane	53	143
75-15-0	Carbon disulfide	63	132
56-23-5	Carbon tetrachloride	70	135
108-90-7	Chlorobenzene	79	120
124-48-1	Chlorodibromomethane	74	126
75-00-3	Chloroethane	59	139
67-66-3	Chloroform	78	123
74-87-3	Chloromethane	50	136
156-59-2	cis-1,2-Dichloroethene	77	123
10061-01-5	cis-1,3-Dichloropropene	74	126
1476-11-5	cis-1,4-Dichloro-2-butene	69	143
110-82-7	Cyclohexane	67	131
108-94-1	Cyclohexanone	30	156
1868-53-7	Dibromofluoromethane	78	119
74-95-3	Dibromomethane	78	125
75-71-8	Dichlorodifluoromethane [Freon-12]	29	149

75-43-4	Dichlorofluoromethane	47	155
60-29-7	Diethyl ether	71	129
108-20-3	Diisopropyl ether	69	127
64-17-5	Ethanol	45	159
141-78-6	Ethyl acetate	52	139
97-63-2	Ethyl methacrylate	69	129
637-92-3	Ethyl tert-butyl ether	72	126
100-41-4	Ethylbenzene	76	122
462-06-6	Fluorobenzene	81	114
142-82-5	Heptane	49	138
87-68-3	Hexachlorobutadiene	61	135
67-72-1	Hexachloroethane	72	133
110-54-3	Hexane	45	142
74-88-4	Iodomethane	71	131
78-83-1	Isobutyl alcohol	60	135
108-21-4	Isopropyl acetate [Acetic acid]	58	131
98-82-8	Isopropylbenzene	68	134
179601-23-1	m/p-Xylene [3/4-Xylene]	77	124
126-98-7	Methacrylonitrile	66	132
79-20-9	Methyl acetate	53	144
80-62-6	Methyl methacrylate	63	134
1634-04-4	Methyl tert-butyl ether [MTBE]	73	125
108-87-2	Methylcyclohexane	66	133
75-09-2	Methylene chloride	70	128
123-86-4	n-Butyl acetate	62	128
71-36-3	n-Butyl alcohol	55	131
104-51-8	n-Butylbenzene	70	128
103-65-1	n-Propylbenzene	73	125
91-20-3	Naphthalene	62	129
95-47-6	o-Xylene	77	123
99-87-6	p-Isopropyltoluene [p-Cymene]	73	127
76-01-7	Pentachloroethane	69	135
107-12-0	Propionitrile [Ethyl cyanide]	68	134
135-98-8	sec-Butylbenzene	73	126
100-42-5	Styrene	76	124
994-05-8	tert-Amyl methyl ether [TAME]	73	126

75-65-0	tert-Butyl alcohol	68	133
98-06-6	tert-Butylbenzene	73	125
127-18-4	Tertachloroethene	73	128
109-99-9	Tetrahydrofuran	61	135
108-88-3	Toluene	77	121
2037-26-5	Toluene-d8	85	116
156-60-5	trans-1,2-Dichloroethene	74	125
10061-02-6	trans-1,3-Dichloropropene	71	130
110-57-6	trans-1,4-Dichloro-2-butene	62	136
79-01-6	Trichloroethene	77	123
75-69-4	Trichlorofluoromethane [Freon-11]	62	140
108-05-4	Vinyl acetate	50	151
75-01-4	Vinyl chloride	56	135
1330-20-7	Xylene [total]	78	124

DoD Appendix C LCS Limits
Method 8260 Water Matrix

CAS ID	Analyte	Lower Control Limit (LCL)	Upper Control Limit (UCL)
630-20-6	1,1,1,2-Tetrachloroethane	78	124
71-55-6	1,1,1-Trichloroethane	74	131
79-34-5	1,1,2,2-Tetrachloroethane	71	121
79-00-5	1,1,2-Trichloroethane	80	119
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane [Freon-113]	70	136
75-34-3	1,1-Dichloroethane	77	125
75-35-4	1,1-Dichloroethene	71	131
563-58-6	1,1-Dichloropropene	79	125
87-61-6	1,2,3-Trichlorobenzene	69	129
96-18-4	1,2,3-Trichloropropane	73	122
526-73-8	1,2,3-Trimethlybenzene	82	120
120-82-1	1,2,4-Trichlorobenzene	69	130
95-63-6	1,2,4-Trimethylbenzene	76	124
96-12-8	1,2-Dibromo-3-chloropropane	62	128
106-93-4	1,2-Dibromoethane	77	121
95-50-1	1,2-Dichlorobenzene	80	119
107-06-2	1,2-Dichloroethane	73	128

17060-07-0	1,2-Dichloroethane-d4	81	118
540-59-0	1,2-Dichloroethene	79	121
78-87-5	1,2-Dichloropropane	78	122
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	70	136
108-70-3	1,3,5-Trichlorobenzene	75	130
108-67-8	1,3,5-Trimethylbenzene	75	124
106-99-0	1,3-Butadiene	43	158
541-73-1	1,3-Dichlorobenzene	80	119
142-28-9	1,3-Dichloropropane	80	119
542-75-6	1,3-Dichloropropene	77	123
106-46-7	1,4-Dichlorobenzene	79	118
105-05-5	1,4-Diethylbenzene	79	118
123-91-1	1,4-Dioxane	59	139
544-10-5	1-Chlorohexane	76	124
540-84-1	2,2,4-Trimethylpentane [Isooctane]	58	132
594-20-7	2,2-Dichloropropane	60	139
75-85-4	2-Butanol	66	120
78-93-3	2-Butanone (MEK)	56	143
126-99-8	2-Chloro-1,3-butadiene	65	135
110-75-8	2-Chloroethyl vinyl ether	51	139
95-49-8	Chlorotoluene	79	122
591-78-6	2-Hexanone	57	139
91-57-6	2-Methylnaphthalene	17	142
79-46-9	2-Nitropropane	49	136
67-63-0	2-Propanol [Isopropyl alcohol]	56	142
624-95-3	3,3-Dimethyl-1-butanol	49	133
460-00-4	4-Bromofluorobenzene	85	114
106-43-4	4-Chlorotoluene	78	122
108-10-1	4-Methyl-2-pentanone [MIBK]	67	130
67-64-1	Acetone	39	160
75-05-8	Acetonitrile	50	142
107-02-8	Acrolein [Propenal]	39	155
107-13-1	Acrylonitrile	63	135
107-05-1	Allyl chloride	68	130
71-43-2	Benzene	79	120
100-44-7	Benzyl chloride	42	138

108-86-1	Bromobenzene	80	120
74-97-5	Bromochloromethane	78	123
75-27-4	Bromodichloromethane	79	125
75-25-2	Bromoform	66	130
74-83-9	Bromomethane	53	141
75-15-0	Carbon disulfide	64	133
56-23-5	Carbon tetrachloride	72	136
108-90-7	Chlorobenzene	82	118
124-48-1	Chlorodibromomethane	74	126
75-45-6	Chlorodifluoromethane	40	129
75-00-3	Chloroethane	60	138
67-66-3	Chloroform	79	124
74-87-3	Chloromethane	50	139
156-59-2	cis-1,2-Dichloroethene	78	123
10061-01-5	cis-1,3-Dichloropropene	75	124
1476-11-5	cis-1,4-Dichloro-2-butene	57	146
110-82-7	Cyclohexane	71	130
1868-53-7	Dibromofluoromethane	80	119
74-95-3	Dibromomethane	79	123
75-71-8	Dichlorodifluoromethane [Freon-12]	32	152
75-43-4	Dichlorofluoromethane	72	131
60-29-7	Diethyl ether	68	129
108-20-3	Diisopropyl ether	67	128
64-17-5	Ethanol	48	151
141-78-6	Ethyl acetate	55	138
97-63-2	Ethyl methacrylate	72	126
637-92-3	Ethyl tert-butyl ether	70	127
100-41-4	Ethylbenzene	79	121
462-06-6	Fluorobenzene	80	116
142-82-5	Heptane	49	140
87-68-3	Hexachlorobutadiene	66	134
67-72-1	Hexachloroethane	72	134
110-54-3	Hexane	48	143
74-88-4	Iodomethane	69	131
78-83-1	Isobutyl alcohol	63	133
108-21-4	Isopropyl acetate [Acetic acid]	63	133

98-82-8	Isopropylbenzene	72	131
179601-23-1	m/p-Xylene [3/4-Xylene]	80	121
126-98-7	Methacrylonitrile	63	133
79-20-9	Methyl acetate	56	136
80-62-6	Methyl methacrylate	67	128
1634-04-4	Methyl tert-butyl ether [MTBE]	71	124
108-87-2	Methylcyclohexane	72	132
75-09-2	Methylene chloride	74	124
123-86-4	n-Butyl acetate	69	125
71-36-3	n-Butyl alcohol	59	131
104-51-8	n-Butylbenzene	75	128
109-60-4	n-Propyl acetate	76	126
103-65-1	n-Propylbenzene	76	126
91-20-3	Naphthalene	61	128
95-47-6	o-Xylene	78	122
99-87-6	p-Isopropyltoluene [p-Cymene]	77	127
76-01-7	Pentachloroethane	69	133
109-66-0	Pentane	16	134
107-12-0	Propionitrile [Ethyl cyanide]	64	136
135-98-8	sec-Butylbenzene	77	126
100-42-5	Styrene	78	123
994-05-8	tert-Amyl methyl ether [TAME]	68	128
75-65-0	tert-Butyl alcohol	68	129
762-75-4	tert-Butyl formate	65	132
98-06-6	tert-Butylbenzene	78	124
127-18-4	Tertachloroethene	74	129
109-99-9	Tetrahydrofuran	57	133
108-88-3	Toluene	80	121
2037-26-5	Toluene-d8	89	112
156-60-5	trans-1,2-Dichloroethene	75	124
10061-02-6	trans-1,3-Dichloropropene	73	127
110-57-6	trans-1,4-Dichloro-2-butene	43	140
79-01-6	Trichloroethene	79	123
75-69-4	Trichlorofluoromethane [Freon-11]	65	141
108-05-4	Vinyl acetate	54	146
75-01-4	Vinyl chloride	58	137

1330-20-7	Xylene [total]	79	121

Figure 1: Volatiles Sample Preparation

VOLATILES
Sample Prep

Date: ___________
Analyst: ___________
Batch QC ID#: ___________

#	Merit #	Matrix	Surrogate ID	Vol. (ul)	Spike ID	Vol. (ul)	Time Start / End	PH	Notes
	BFB								
	SPCC								
	LCS								
	LCSD								
	BLK								
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

Reviewed by: ___________________

Date: ___________________

FIGURE 2. METHOD 5035A (LOW LEVEL) EXTRACTION SHEET

Method 5035A (Low Level)
Extraction Sheet

Analyst: ____________
Date: ____________
Batch QC ID #______

Merit Number	Tare wt (g)	Vial wt (g)	Sample wt.(g)	Time Start / End	Decontaminated	Decontamination Date	Notes

Reviewed By: ____________
Date: ____________

Figure 3. Method 5035A (High Level) Extraction Sheet

Method 5035A (High Level)
Extraction Sheet

Analyst: ____________
Date: ______________
Batch QC ID#________

Merit Number	Tare wt (g)	Vial wt (g)	Sample wt.(g)	Methanol (mL)	Sonicate (min)	Time Start / End	Notes

Reviewed By: ____________

Methanol Lot: ________________

Date: ____________

5035A High Level

Prepared by Merit Laboratories, Inc

STANDARD OPERATING PROCEDURE

VOLATILE ORGANIC COMPOUNDS BY GAS CHROMATOGRAPHY/MASS SPECTROMETRY
METHOD SW-846 8260C/ EPA 624.1

APPROVALS:

Barbara Ball
05/25/2022

QA Officer Date

Maya Murshedy
05/25/2022

Technical Director Date

Number	Description of Change	Date
001-011	Previous revisions not documented	
0012	Updated to comply with DoD QSM and ISO 17025 standards.	6/9/11
013	Updated to method 8260C	9/4/13
014	Updated to comply with DoD QSM 5.0 standards.	04/01/16
015	Updated to comply with DoD QSM 5.1 standards.	01/17/18
016	NY NELAC Audit Finding	03/13/19
017	DOD Audit Corrective Action	09/29/2020
018	2020 Internal Audit revisions	02/16/2021
019	NY NELAC Audit Finding	05/25/2022
020		
021		
022		

1.0 SCOPE AND APPLICATION

This SOP is used to determine volatile organic compounds (VOC) in a variety of matrices, regardless of water content, including various air sampling trapping media, ground and surface water, aqueous sludges, caustic liquors, acid liquors, waste solvents, oily wastes, mousses, tars, fibrous wastes, polymeric emulsions, filter cakes, spent carbons, spent catalysts, soils, and sediments. See Table 1 for a list of compounds (along with their characteristic ions) that have been evaluated.

There are various techniques by which these compounds may be introduced into the GC/MS system. Purge-and-trap, by SW-846 Methods 5030C (aqueous samples) and 5035A (solid, waste, and oil samples), are the most commonly used technique for volatile organic analytes. SW-846 Method 5000 provides general information on the selection of other introduction methods.

The practical quantitation limit (PQL) for an individual compound is instrument dependent and also dependent on the choice of the sample preparation/introduction method. Using standard quadrapole instrumentation and the purge-and-trap technique, limits should be approximately 50 μg/kg (wet weight) for solid samples and 1 μg/L for ground water. When lower reportable detection limits (RDLs) are required, the mass spectrometer (MS) can be set to selective ion monitoring (SIM) to achieve limits approximately 20 times lower then obtainable using the full scan method. Regardless of the sample matrix, PQLs will be proportionately higher for sample extracts and samples that require dilution or when a reduced sample size is used to avoid saturation of the detector.

Method Detection Limits (MDL) and Practical Quantitation Limits (PQL) are available in Merit's LIMs system.

This SOP is restricted to use by, or under the supervision of, analysts experienced in the use of gas chromatograph/mass spectrometers, and skilled in the interpretation of mass spectra and their use as a quantitative tool.

This SOP is not for use with samples that come into the lab for OHIO VAP work.

2.0 SUMMARY OF THE METHOD

VOC are introduced into the gas chromatograph by the purge-and-trap method or by other methods. The analytes are introduced directly to a wide-bore capillary column. The column is temperature-programmed to separate the analytes, which are then detected with a mass spectrometer interfaced to the gas chromatograph.

Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. Identification of target analytes is accomplished by comparing their mass spectra with the electron impact spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five point (or more) calibration curve.

The method includes specific calibration and quality control steps that supersede the general requirements provided in SW-846 Method 8000.

3.0 INTERFERENCES

Major contaminant sources are volatile materials in the laboratory and impurities in the inert purging gas and in the sorbent trap. The use of non-polytetrafluoroethylene (PTFE) thread sealants, plastic tubing, or flow controllers with rubber components should be avoided, since such materials out-gas organic compounds will be concentrated in the trap during the purge operation.

Cross-contamination may occur when any sample is analyzed immediately after a sample containing high concentrations of volatile organic compounds. After the analysis of a sample containing high concentrations of volatile organic compounds, one or more blanks should be analyzed to allow the system to be cleaned as well as to demonstrate the ultimate absence of cross-contamination. Alternatively, if the sample immediately following the high concentration sample does not contain the volatile organic compounds present in the high level sample, freedom from contamination has been established.

4.0 APPARATUS AND MATERIALS

Gas chromatograph/mass spectrometer system

- Gas chromatograph - An analytical system complete with a temperature programmable gas chromatograph suitable for splitless injection and all required accessories, including syringes, analytical columns, and gases. The capillary column should be directly coupled to the source.
- 20 m × 0.18 mm ID capillary column coated with DB-624 (J&W Scientific), Rt_x-502.2 (RESTEK), or VOCOL (Supelco), 1-µm film thickness, or equivalent.
- Mass spectrometer capable of scanning from 35 to 260 amu every 2 sec or less, using 70 volts (nominal) electron energy in the electron impact ionization mode. The mass spectrometer must be capable of producing a mass spectrum for 4-bromofluorobenzene (BFB) which meets the criteria in Table 4.
- GC/MS interface - The capillary column is interfaced through a direct connection to the GC/MS system.

- Data system - A computer system is interfaced to the mass spectrometer. Hewlett-Packard Chemstation software (with environmental data analysis) is used to acquire and process GC/MS data.

Purge-and-trap device.

Microsyringes - 2 to 500-µL.

Balance - Analytical, capable of weighing 0.001 g, and top-loading, capable of weighing 0.1 g.

Glass bottles - 40-mL, with PTFE-lined screw-caps.

pH paper.

5.0 REAGENTS

Reagent grade organic chemicals shall be used in all tests. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without introducing adverse interferences.

Organic-free reagent water - All references to water in this method refer to organic-free reagent water.

Stock standard solutions.

- Certified stock standard solutions are purchased when available for the bulk of desired analytes. They are typically available at concentrations of 1000 to 2000 mg/L.
- Supplemental compounds added to calibration mixes are generally prepared gravimetrically from neat standard references (in order to create a high-concentration stock solution).
- Stock standard solutions are stored in bottles with PTFE-lined screw-caps. They are refrigerated and protected from light, as recommended by the standard manufacturer.
- Stock standard solutions are replaced prior to expiration, or sooner if comparison with quality control check samples indicate a problem.

Internal standard solutions - The internal standards used are pentafluorobenzene, 1,4-difluorobenzene, chlorobenzene-d_5, and 1,4-dichlorobenzene-d_4 (see Table 2). Internal standards are used at a working concentration of 50 mg/L and are added to samples, spikes, blanks, and calibration standards at a uniform concentration of 50 µg/L (i.e. 10µL per 5000µL purge volume). For SIM (selective ion monitoring) analysis, internal standards are the same, but with concentrations at 0.4 ppb (µg/L).

Calibration standards - A minimum of five calibration standards are prepared at different concentrations. The lowest calibration standard corresponds to a sample concentration at or below the standard reporting limit. The remaining standards should represent the working range of the GC/MS system. Each standard should contain each analyte for quantitation by this method. For DoD projects, each standard shall contain all target compounds.

Surrogate standards - The surrogates used are toluene-d_8, 4-bromofluorobenzene, and 1,2-dichloroethane-d_4. Surrogate standards are used at a working concentration of 50 mg/L and are added to samples, spikes, blanks, and calibration standards at a uniform concentration of 50 μg/L, or less. For SIM (selective ion monitoring) analysis, surrogate standards are the same, but with concentrations at 0.4 ppb (μg/L).

Matrix spike (MS), matrix spike duplicate (MSD) and laboratory control standards (LCS) - Matrix spiking solutions are prepared using the same standards as those used for the calibration. For DoD projects, matrix spiking solutions shall contain all target compounds.

- Matrix spiking mixes for individual analytes are created at 100 mg/L and spiked into samples at 50 μg/L (*i.e.* 2.50μL per 5000μL purge volume).
- For SIM (selective ion monitoring) analysis, compounds of interest are spiked at concentrations of 0.4 ppb (μg/L).
- For 1-Dioxane, compounds of interest are spiked at concentrations of 50 ppb (μg/L).

Methanol, CH_3OH - Pesticide quality or equivalent, demonstrated to be free of analytes. Store apart from other solvents.

6.0 SAMPLE HANDLING AND PRESERVATION

Unanalyzed samples are refrigerated at 4 ± 2 degrees Celsius in sealed vials or containers.

Aqueous samples are preserved to a pH <2with HCl and/or $Na_2S_2O_3$ (unless unpreserved requested) and collected in a 40 ml. Preserved samples must be analyzed within 14 days from sample collection; unpreserved samples must be analyzed within 7 days from sample collection.

Soil samples collected Encore^{TM} Samplers must be preserved within 48 hours and analyzed within 14 days. Soil samples collected in glass jars shall be kept refrigerated and analyzed within 14 days from sample collection. For additional information on sample collection, handling and preservation for soil samples see SOP #ORL-005.

7.0 PROCEDURE

Sample introduction.

- Direct injection - This method of introduction is used only rarely, generally when the compounds of interest exhibit poor purging efficiency. Quantitation in this case, if required, is generally subject to external standard calibration procedures (*cf*. Method 8000).

- Purge-and-trap - This is generally used for sample introduction for both soil and water samples. All samples, standards, spikes, and blanks are introduced into the GC/MS system in an identical manner (see Merit SOP# ORL-005).

GC/MS operating conditions - see Table 3 for routine operating conditions for VOC analysis.

- For SIM, the MS is put into the SIM mode. Based on compounds of interest, the time windows are set within the run (i.e. for internal standards, surrogate standards, compounds). For each time window, corresponding to a compound, a minimum of 3 ions are chosen for qualitative analysis. One ion (primary ion), generally the most abundant ion is used for quantitative analysis.

Initial calibration.

- Each GC/MS system must be hardware-tuned to meet the criteria in Table 4 for 4-bromofluorobenzene. Analysis does not begin until these criteria are met.

    - In the absence of any other manipulations, evaluate the mass spectrum of the peak apex or the scan immediately preceding or following from the total ion chromatogram for the BFB peak. This is the default approach used.

    - If the above evaluation is adversely affected by ion peak asymmetry, average the three highest intensity scans of the peak or average the mass spectrum ranging from the 10% initial peak intensity to the tailing 10% peak intensity level from the total ion chromatogram for the BFB peak.

    - If the above evaluation is adversely affected by background contamination, perform a background subtraction with a spectrum within 20 scans of the BFB peak which does not represent a target compound. Use of this procedure may be indicative of failing MS performance. The MS source should be cleaned and re-tuned.

    - The BFB mass intensity criteria in Table 4 are used as tuning acceptance criteria.

    - All subsequent standards, samples, MS/MSDs, and blanks associated with a BFB analysis must use the identical mass spectrometer instrument conditions, Exception: for SIM, tune is run using full scan acquisition and subsequent samples are acquired using SIM.

- Purge and analyze each calibration standard (containing internal standards) and tabulate the area of the primary characteristic ion against concentration for each target analyte (as indicated in Table 1). A set of at least five calibration standards is necessary. The purge volume must be the same for all standards and sample extracts. Figure 1 shows a chromatogram of a midpoint calibration standard.

- Calculate response factors (*RF*s) for each target analyte relative to one of the internal standards as follows: $RF = A_s C_i / A_i C_s$. Here, A_s and A_i are the areas of the standard compound and corresponding internal standard, respectively. Likewise, C_s and C_i are the respective concentrations (in any consistent set of units) of the standard compound and corresponding internal standard.

- Response Factor Criteria
  - It is recommended that a minimum response factor for the most common target analytes as noted in Table 2b, be demonstrated for each individual calibration level as a means to ensure that these compounds are behaving as expected. In addition, meeting the minimum response factor criteria for the lowest calibration level is important in demonstrating the desired sensitivity. Due to the large number of compounds that may be analyzed, some compounds will fail to meet this criteria. In particular, poor performers such as ketones and 1,2-dibromo-3-chloropropane are likely to fail this criteria but have been demonstrated to perform adequately overall.
  - If the minimum response factors are not met, the system must be evaluated, and corrective action must be taken before sample analysis begins. Possible problems include standard mixture degradation, contamination in the purge-and-trap system, excessively high or low purge flow rates, and active sites in the column or chromatographic system. Replacing the calibration standards, clipping and/or replacing the column will likely solve this problem.

- Evaluation of retention times - The relative retention time (RRT) of each target analyte in each calibration standard should agree within 0.06 RRT units. This is accomplished by setting the retention time extraction windows in the Chemstation software.

- Linearity of target analytes - If the %RSD of any target analytes is 20% or less, then the relative response factor may be assumed to be constant over the calibration range, and the average relative response factor may be used for quantitation.

- Refer to SW-846 Method 8000 if a least-squares regression is used to determine a linear or quadratic fit to the calibration data. Quadratic polynomials are generally fit through the origin in order to prevent the symptomatic aphysical prediction of high concentrations at very low responses. The coefficient of determination for any regression fit should be ≥0.99. In addition, 6 calibration data points are required for a calibration fit with 3 free parameters, while 5 are required for a calibration fit with 1 or 2 free parameters.

- When the RSD exceeds 20%, the plotting and visual inspection of a calibration curve can be a useful diagnostic tool. The inspection may indicate analytical problems, including errors in standard preparation, the presence of active sites in the chromatographic system, analytes that exhibit poor chromatographic behavior, *etc*.

- The method of linear regression analysis has the potential for a significant bias to the lower portion of a calibration curve, while the relative percent difference and the quadratic methods of calibration do not have this potential bias. When calculating the calibration curves using the linear regression model, a minimum quantitation check on the viability of the lowest calibration point should be performed by re-fitting the response from the low concentration calibration standard back into the curve. The recalculated concentration of the low calibration point should be within 30% of the standard's true concentration. Other recovery criteria may be applicable depending on the project's data quality objectives. For analytes which do not meet the minimum quantitation calibration re-fitting criteria reporting those analytes as estimated when the concentration is at or near the lowest calibration point may be appropriate.

- The initial calibration curve should be verified immediately after performing the standard analyses using a second source standard at a concentration near the midpoint of the calibration range. The acceptance limits are 70-130% or project specific. Analytes that fail this criteria are considered estimated values.

- The quality of the calibration fit for any particular compound is communicated to the data user via the Quality Control report for a given batch of samples. The calibration summary report includes: the concentration and RF for each standard in the calibration curve, the type of calibration fit, the calibration fit parameters (*i.e*. average RF or regression coefficients), and the appropriate calibration quality metric (*i.e*. %RSD or COD).

♦ GC/MS calibration verification - Calibration verification consists of three steps that are performed at the beginning of each 12-hour analytical shift.

- Prior to the analysis of samples or calibration standards, purge the BFB standard into the GC/MS system. The resultant mass spectrum for BFB must meet the criteria given in Table 4 before sample analysis begins. These must be *injected* within 12 hours of the injection time for the BFB.
- The initial calibration for each compound of interest should be verified once every 12 hours prior to sample analysis, using the introduction technique and conditions used for samples. This is accomplished by analyzing a calibration standard at a concentration near the midpoint concentration for the calibration range of the GC/MS (50 μg/L; this represents 2.50 μL of the 100 mg/L calibration standard solution in a 5mL purge volume). A concentration of 0.1μg/L is analyzed for SIM procedures. The results from the calibration standard analysis must meet the verification acceptance criteria provided below. In addition the internal standards should be within 10s of those in the midpoint calibration standard and the responses should be 50-200% of those in the midpoint calibration standard.
- A method blank is run every 20 samples to ensure that the total system (preparation glassware, introduction device, transfer lines, and the GC/MS system itself) is free of contaminants. A method blank/wash sample is also run after calibration check/spike samples and prior to analytical samples in order to eliminate carryover contamination from the purge-and-trap system.
- Calibration Verification
    - A calibration verification must be made during every 12-hour analytical shift.
    - Each of the most common target analytes in the calibration verification standard should meet the minimum response factors as noted in Table 2b. This is the same check that is applied during the initial calibration and exceptions are noted above.
    - If the minimum response factors are not met, the system must be evaluated, and corrective action must be taken before sample analysis begins.
    - All target compounds of interest must be evaluated using a 20% variability criterion. If the percent drift for a compound is less than or equal to 20%, then the initial calibration for that compound is assumed to be valid. Due to the large numbers of compounds that may be analyzed by this method, some compounds will fail to meet the criteria. If the criterion is not met for more than 20% of the compounds included in the initial calibration, then corrective action must be taken prior to the analysis of samples. In cases where compounds fail, they may still be reported as non-detects if it can be demonstrated that there was adequate sensitivity to detect the compound at the applicable quantitation limit. For situations when a failed compound is present, the concentration is an estimated

value. Drift is defined as the normalized deviation of the measured from the spike value of a target component: $\%D = \left|C - C_{spike}\right| / C_{spike}$.

- Problems similar to those listed under initial calibration could affect the calibration verification. If the problem cannot be corrected by other measures, a new initial calibration must be generated. The calibration verification criteria must be met before sample analysis begins.

GC/MS analysis of samples.

- Samples are screened at a diluted state via GC/MS whenever possible prior to analysis within a 12-hour QC batch. This can identify potentially low surrogate recoveries, high target compound concentrations, non-target matrix interferences. This will minimize contamination of the GC/MS system from unexpectedly high concentrations of organic compounds.
- Use a 5 mL syringe to take a 5 mL aliquot from the sample vial. Be sure to eliminate any air bubbles from within the syringe.
- Add 5 µL of 50 mg/L internal/surrogate standard mixture are introduced to each sample through the autosampler. For SIM analysis, internal and surrogate standards are spiked at 0.1µg/L.
- If the concentration for any quantitation ion exceeds the initial calibration range of the GC/MS system, the sample extract should be diluted and reanalyzed. In any event, a result based on an extrapolation of calibration curve beyond the working range is flagged on the analytical report.
- The Extracted Ion Current Profile (EICP) area for all of the internal standards in all spikes, blanks, and samples is monitored relative to the most recent calibration verification standard. Changes by more than a factor of two (*i.e.* 50% to 200%) can indicate adverse matrix effects (in the case of an isolated sample) or degrading MS performance (in the case of a systematic low bias). A single-sample matrix effect is documented either via screening or re-analysis and is noted on the analytical report (see Table 5a and 5b). Similarly, the retention times for all of the internal standards in all spikes, blanks, and samples is monitored relative to the most recent calibration verification standard. The change in retention time for any internal standard by more than 30 seconds of the most recent calibration verification standard is indicative of the same potential problems listed above and should be flagged/corrected as appropriate.

Qualitative analysis.

- The qualitative identification of compounds determined by this method is based on retention time and on comparison of the sample mass spectrum, after background correction, with characteristic ions in a reference mass spectrum. The reference mass spectrum must be generated by the laboratory using the conditions of this method. The characteristic ions from the reference mass spectrum are given in Figures 1a and 1b. Compounds are identified when the following criteria are met.

- Initial selection of a target compound peak is performed by the Chemstation data system search routine. The search is based on the presence of a target chromatographic peak containing ions specific for the target compound at a compound specific retention time.
- The RRT of the sample component is within ± 0.06 RRT units of the RRT of the standard component. This is accomplished using retention time extraction windows within the Chemstation data system.
- The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum. (Example: For an ion with an abundance of 50% in the reference spectrum, the corresponding abundance in a sample spectrum can range between 20% and 80%.)
- Structural isomers that produce very similar mass spectra are identified as individual isomers if they have sufficiently different GC retention times. Sufficient GC resolution is achieved if the height of the valley between two isomer peaks is less than 25% of the sum of the two peak heights. Otherwise, structural isomers are identified as isomeric pairs.
- Identification is hampered when sample components are not resolved chromatographically and produce mass spectra containing ions contributed by more than one analyte. When gas chromatographic peaks obviously represent more than one sample component (*i.e.*, a broadened peak with shoulder(s) or a valley between two or more maxima), appropriate selection of analyte spectra and background spectra is important.
- Examination of extracted ion current profiles of appropriate ions can aid in the selection of spectra and in qualitative identification of compounds. When analytes coelute (*i.e.*, only one chromatographic peak is apparent), the identification criteria may be met, but each analyte spectrum will contain extraneous ions contributed by the coeluting compound.
- In the two previous cases, analyst expertise as well as knowledge of site history may be important in accepting/rejecting the identification of a compound. In the event of continued uncertainty, the analyst should preferentially make a conservative judgment and accept an identified hit, allowing the potential for a false positive.

- For samples containing components not associated with the calibration standards, a library search may be made for the purpose of tentative identification. The necessity to perform this type of identification will be determined by the purpose of the analyses being conducted. Only after visual comparison of sample spectra with the nearest library searches may the analyst assign a tentative identification. Guidelines for tentative identification are:
    - Relative intensities of major ions in the reference spectrum (ions > 10% of the most abundant ion) should be present in the sample spectrum.
    - The relative intensities of the major ions should agree within ± 20%.
    - Molecular ions present in the reference spectrum should be present in the sample spectrum.
    - Ions present in the sample spectrum but not in the reference spectrum should be reviewed for possible background contamination or presence of coeluting compounds.
    - Ions present in the reference spectrum but not in the sample spectrum should be reviewed for possible subtraction from the sample spectrum because of background contamination or coeluting peaks. Data system library reduction programs can sometimes create these discrepancies.

Quantitative analysis.

- Once a compound has been identified, the quantitation of that compound will be based on the integrated abundance of the primary characteristic ion from the EICP.
- The curve fit applied in the initial calibration is the same as that used to compute the concentration of a target analyte in a sample. All curve fits are evaluated by the data system and are of the form: $A_s / A_i = k_0 + k_1 [C_s / C_i] + k_2 [C_s / C_i]^2$. Here A_s and A_i are the areas of the target and internal standard, C_s and C_i are the concentrations of the target and internal standard, and k_i is the i^{th}-order regression coefficient. Note that for a mean RF fit to the calibration data, $k_1 \equiv \langle RF \rangle$, while $k_0, k_2 \equiv 0$.
- The concentration of any non-target analytes identified in the sample may be estimated by assuming a mean RF of 1 and by using the tentatively identified compound (TIC) areas for the nearest internal standard and target compound. The resulting concentration should be reported indicating: (1) that the value is an estimate, and (2) which internal standard was used to determine concentration. Use the nearest internal standard free of interferences.

- ♦ Structural isomers that produce very similar mass spectra should be quantitated as individual isomers if they have sufficiently different GC retention times. Otherwise, structural isomers are quantitated as isomeric pairs (such as p- and m-xylene).

8.0 QUALITY CONTROL

All of the quality control items employed and evaluated are provided in Table 5a and 5b. In addition, the table indicates the frequency of each QC item along with appropriate courses of corrective action. Control limits for surrogates and internal standards are listed in Table 6. The analyst will follow SOP # QA-007 and complete the appropriate review form upon completion of the analysis.

9.0 METHOD PERFORMANCE

The precision and accuracy of the method depends upon the overall performance of the sample preparation and analysis. Laboratory specific performance data is provided for Merit’s LIMs system. Each sample batch contains a method blank, laboratory control sample and matrix spike samples. Performance Evaluation samples are analyzed periodically in order to prove the performance of the method.

10.0 EQUIPMENT MAINTENANCE AND TROUBLESHOOTING

Each instrument is assigned a maintenance logbook. All maintenance performed on the instrument must be recorded. Additionally, any modifications to the instrument settings shall be noted in the specific instrument logbook. Maintenance procedures provided in the equipment manual shall be followed. Maintenance may include, cleaning the MS source, clipping/replacing the column, or replacing the calibration standard.

Computer software and firmware can be found on Merit’s network at F:\data\MERIT\EQUIPMENT\Instrument-Software Version List.200818.xls.

11.0 SAFETY

Eye protection and gloves must be worn while performing the analyses. Every laboratory area has eyewash, emergency shower, and fire extinguisher. The metals lab also has dust masks available for use with dust samples. The air system throughout the laboratory area is on a 100% fresh air exchange system, this system exchanges 100% the air in the laboratory area with air from outside 6 times per hour and 30 times per hour when the emergency purge button is hit.

A reference file of material safety data sheets (MSDSs) is available to all personnel. Specific attention shall be paid (but not limited) to:

a. Methanol may react violently with acids, acid chlorides, acid anhydrides, oxidizing agents, reducing agents and alkali metals. Protect from moisture. Highly flammable.

b. Hydrochloric acid is corrosive. Extreme heat or contact with metals can release flammable hydrogen gas, stable under ordinary conditions of use and storage, and incompatible with many substances and highly reactive with strong bases, metals, metal oxides, hydroxides, amines, carbonates, cyanides, sulfides, sulfites, and formaldehyde.

12.0 WASTE DISPOSAL AND POLLUTION PREVENTION

All laboratory waste must be managed, stored, and disposed in accordance with all federal and state laws and regulations. Additional information can be found in the Sample Disposal SOP and Merit's Waste Management Plan and Handbook.

13.0 DEFINITIONS

4-Bromofluorobenzene (BFB), is used to verify that the GC/MS is properly tuned and ready for calibration and sample analyses. BFB is directly injected at 25-50 ng and precedes all other analyses. A twelve hour analysis time window is used before another BFB injection is required.

An Initial Calibration Verification standard (ICV) is analyzed before the analysis of samples as a check on the calibration curve. The ICV shall be of a second source, meaning a separate vendor and/or lot # shall be used to prepare this standard. A second source is needed to validate the integrity and concentration of the standards used for calibration.

An Initial Calibration Blank (ICB) is also analyzed before samples to confirm that the deionized water (DI H_2O) used for standards, blanks, and dilutions are free from contamination. An ICB for soil samples also includes organic free sand and/or methanol used for standard and QC preparation, as well as sample dilutions and volume adjustments; the control sand and methanol must also be documented as free from contamination.

A Calibration Check Verification standard (CCV) is analyzed at the beginning of each sequence (following the BFB injection) shift and every 12 hour shift thereafter. A CCV is made up from the same standards used for calibration and is used to ensure that the calibration and retention times are stable.

An analytical batch is defined as a group of samples (not to exceed 20 samples) analyzed per sequential run. Depending on client or program requirements, an analytical batch may or may not include matrix spikes as part of the 20 samples.

Internal standards (ISTD) are added to each sample, blank, spike, and check standard. The ISTDs used are Fluorobenzene, Chlorobenzene-d_5, and 1,4-Dichlorobenzene-d_4. The ISTD is used for internal calibration as a reference peak and to check purging efficiency.

Surrogate standards (SSTD) are also added to each sample, blank, spike, and check standard. The SSTDs used are Toluene-d_4, 4-Bromofluorobenzene, 1,2-Dichloroethane-d_4, and Dibromofluoromethane. The SSTD is used as matrix interference and as a method control check.

Method Blank (MB): An analyte-free matrix to which all reagents are added in the same volumes or proportions as used in the sample processing. The method blank is carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.

A Continuing Calibration Blank (CCB) is analyzed every 12 hour shift after the MB has been analyzed and before sample reanalyzes to ensure the system is still free from contamination.

Instrument blanks are analyzed whenever instrument contamination is a suspected possibility. The purpose of an IB is to prevent carry over from a standard, spike, or contaminated sample into another sample or blank. The acceptance criteria for an IB is the same as for a MB or CCB (for example: if an IB contains detections above acceptance criteria and a MB and/or sample following the IB exhibit the same contamination above acceptance criteria, then the instrument shall be considered contaminated). The samples and/or MBs shall be reanalyzed after the instrument is confirmed free from contamination.

Laboratory Control Spike (LCS): Milli-Q water (for water) and Organic-Free Soil (for soil) is spiked with all target compounds and carried through the complete sample preparation and analytical procedure. The control spike is used to document the ability of an analyst to generate acceptable precision and bias to verify the analytical system performance, and to document method accuracy for each matrix.

Matrix Spike (MS): An aliquot of sample spiked with all target compounds. The spiking occurs prior to sample preparation and analysis. They are used to document the precision and bias of a method in a given sample matrix.

Matrix Spike Duplicate (MSD): Intra-laboratory split samples spiked with all target compounds. The spiking occurs prior to sample preparation and analysis. They are used to document the precision and bias of a method in a given sample matrix.

14.0 REFERENCES

Bellar, T., *Measurement of Volatile Organic Compounds in Soils Using Modified Purge-and-Trap and Capillary Gas Chromatography/Mass Spectrometry*, U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Cincinnati, OH, November, 1991.

Department of Defense, Quality Systems Manual for Environmental Laboratories (DoD QSM), DoD Environmental Data Quality Workgroup, Department of Navy, Lead Service, ISO/IEC 17025:2005, ISO/IEC 17025:2017 and The NELAC Institute (TNI) Standards, Volume 1, September 2009, Version 5.3, May 7, 2019

U.S. EPA 40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule*, October 26, 1984.

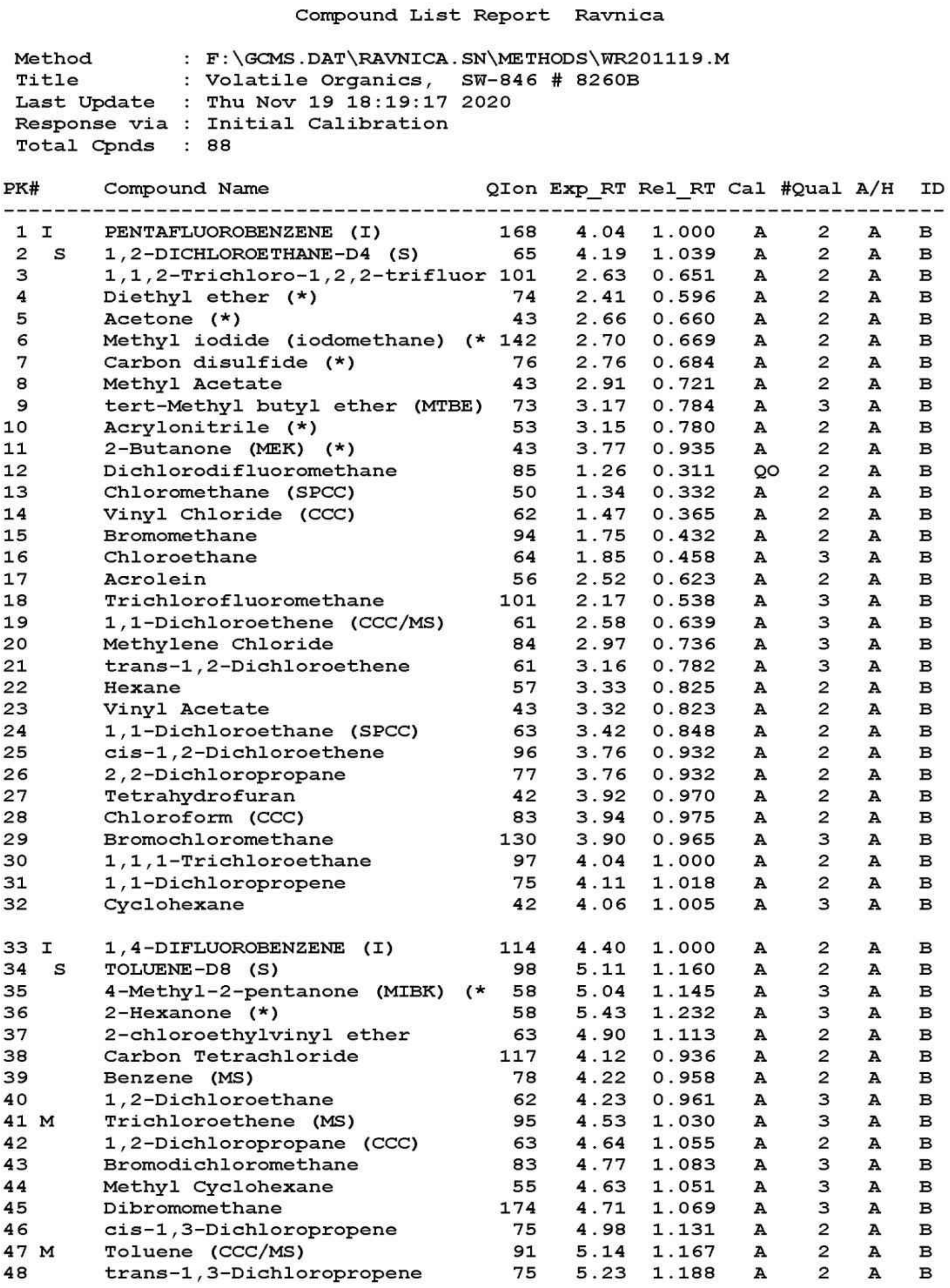
EPA SW-846, *Test Methods for Evaluation Solid Waste*, 3rd Edition, Update I dated 7/92, Update II dated 9/94, Update IIA dated 8/93, Update IIB dated 1/95, Update III dated 12/96, Update IV dated 1/08.

International Standards Organization (ISO), 2005. *General Requirements for the Competence of Testing and Calibration Laboratories.* ISO 17025.

National Environmental Laboratory Accreditation Conference (NELAC), 2003. *Standards, Chapters 1–6*, EPA/600/R-04/003.

EPA Method 624.1, December 2016

Table 1. Summary of Retention Times and Characteristic Ions for Volatile Organics



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                         Compound List Report  Ravnica

 Method       : F:\GCMS.DAT\RAVNICA.SN\METHODS\WR201119.M
 Title        : Volatile Organics,  SW-846 # 8260B
 Last Update  : Thu Nov 19 18:19:17 2020
 Response via : Initial Calibration
 Total Cpnds  : 88

PK#     Compound Name                  QIon Exp_RT Rel_RT Cal #Qual A/H  ID
---------------------------------------------------------------------------
 1 I    PENTAFLUOROBENZENE (I)          168   4.04  1.000  A     2   A   B
 2  S   1,2-DICHLOROETHANE-D4 (S)        65   4.19  1.039  A     2   A   B
 3      1,1,2-Trichloro-1,2,2-trifluor 101   2.63  0.651  A     2   A   B
 4      Diethyl ether (*)                74   2.41  0.596  A     2   A   B
 5      Acetone (*)                      43   2.66  0.660  A     2   A   B
 6      Methyl iodide (iodomethane) (* 142   2.70  0.669  A     2   A   B
 7      Carbon disulfide (*)             76   2.76  0.684  A     2   A   B
 8      Methyl Acetate                   43   2.91  0.721  A     2   A   B
 9      tert-Methyl butyl ether (MTBE)   73   3.17  0.784  A     3   A   B
10      Acrylonitrile (*)                53   3.15  0.780  A     2   A   B
11      2-Butanone (MEK) (*)             43   3.77  0.935  A     2   A   B
12      Dichlorodifluoromethane          85   1.26  0.311  QO    2   A   B
13      Chloromethane (SPCC)             50   1.34  0.332  A     2   A   B
14      Vinyl Chloride (CCC)             62   1.47  0.365  A     2   A   B
15      Bromomethane                     94   1.75  0.432  A     2   A   B
16      Chloroethane                     64   1.85  0.458  A     3   A   B
17      Acrolein                         56   2.52  0.623  A     2   A   B
18      Trichlorofluoromethane          101   2.17  0.538  A     3   A   B
19      1,1-Dichloroethene (CCC/MS)      61   2.58  0.639  A     3   A   B
20      Methylene Chloride               84   2.97  0.736  A     3   A   B
21      trans-1,2-Dichloroethene         61   3.16  0.782  A     3   A   B
22      Hexane                           57   3.33  0.825  A     2   A   B
23      Vinyl Acetate                    43   3.32  0.823  A     2   A   B
24      1,1-Dichloroethane (SPCC)        63   3.42  0.848  A     2   A   B
25      cis-1,2-Dichloroethene           96   3.76  0.932  A     2   A   B
26      2,2-Dichloropropane              77   3.76  0.932  A     2   A   B
27      Tetrahydrofuran                  42   3.92  0.970  A     2   A   B
28      Chloroform (CCC)                 83   3.94  0.975  A     2   A   B
29      Bromochloromethane              130   3.90  0.965  A     3   A   B
30      1,1,1-Trichloroethane            97   4.04  1.000  A     2   A   B
31      1,1-Dichloropropene              75   4.11  1.018  A     2   A   B
32      Cyclohexane                      42   4.06  1.005  A     3   A   B

33 I    1,4-DIFLUOROBENZENE (I)         114   4.40  1.000  A     2   A   B
34  S   TOLUENE-D8 (S)                   98   5.11  1.160  A     2   A   B
35      4-Methyl-2-pentanone (MIBK) (*   58   5.04  1.145  A     3   A   B
36      2-Hexanone (*)                   58   5.43  1.232  A     3   A   B
37      2-chloroethylvinyl ether         63   4.90  1.113  A     2   A   B
38      Carbon Tetrachloride            117   4.12  0.936  A     2   A   B
39      Benzene (MS)                     78   4.22  0.958  A     2   A   B
40      1,2-Dichloroethane               62   4.23  0.961  A     3   A   B
41 M    Trichloroethene (MS)             95   4.53  1.030  A     3   A   B
42      1,2-Dichloropropane (CCC)        63   4.64  1.055  A     2   A   B
43      Bromodichloromethane             83   4.77  1.083  A     3   A   B
44      Methyl Cyclohexane               55   4.63  1.051  A     3   A   B
45      Dibromomethane                  174   4.71  1.069  A     3   A   B
46      cis-1,3-Dichloropropene          75   4.98  1.131  A     2   A   B
47 M    Toluene (CCC/MS)                 91   5.14  1.167  A     2   A   B
48      trans-1,3-Dichloropropene        75   5.23  1.188  A     2   A   B
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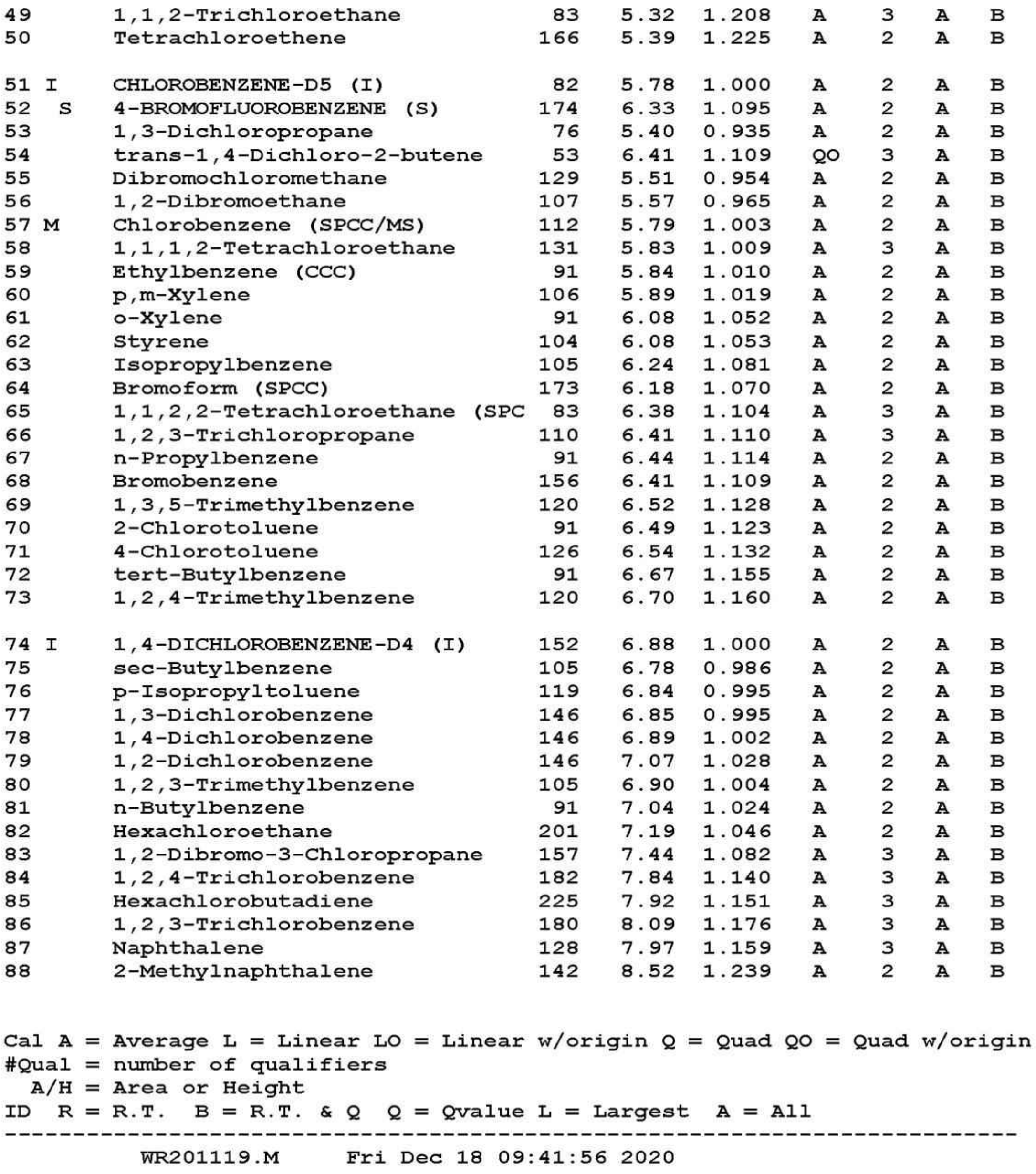

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49       1,1,2-Trichloroethane           83    5.32  1.208    A     3    A    B
50       Tetrachloroethene              166    5.39  1.225    A     2    A    B

51 I     CHLOROBENZENE-D5 (I)            82    5.78  1.000    A     2    A    B
52  S    4-BROMOFLUOROBENZENE (S)       174    6.33  1.095    A     2    A    B
53       1,3-Dichloropropane             76    5.40  0.935    A     2    A    B
54       trans-1,4-Dichloro-2-butene     53    6.41  1.109    QO    3    A    B
55       Dibromochloromethane           129    5.51  0.954    A     2    A    B
56       1,2-Dibromoethane              107    5.57  0.965    A     2    A    B
57 M     Chlorobenzene (SPCC/MS)        112    5.79  1.003    A     2    A    B
58       1,1,1,2-Tetrachloroethane      131    5.83  1.009    A     3    A    B
59       Ethylbenzene (CCC)              91    5.84  1.010    A     2    A    B
60       p,m-Xylene                     106    5.89  1.019    A     2    A    B
61       o-Xylene                        91    6.08  1.052    A     2    A    B
62       Styrene                        104    6.08  1.053    A     2    A    B
63       Isopropylbenzene               105    6.24  1.081    A     2    A    B
64       Bromoform (SPCC)               173    6.18  1.070    A     2    A    B
65       1,1,2,2-Tetrachloroethane (SPC  83    6.38  1.104    A     3    A    B
66       1,2,3-Trichloropropane         110    6.41  1.110    A     3    A    B
67       n-Propylbenzene                 91    6.44  1.114    A     2    A    B
68       Bromobenzene                   156    6.41  1.109    A     2    A    B
69       1,3,5-Trimethylbenzene         120    6.52  1.128    A     2    A    B
70       2-Chlorotoluene                 91    6.49  1.123    A     2    A    B
71       4-Chlorotoluene                126    6.54  1.132    A     2    A    B
72       tert-Butylbenzene               91    6.67  1.155    A     2    A    B
73       1,2,4-Trimethylbenzene         120    6.70  1.160    A     2    A    B

74 I     1,4-DICHLOROBENZENE-D4 (I)     152    6.88  1.000    A     2    A    B
75       sec-Butylbenzene               105    6.78  0.986    A     2    A    B
76       p-Isopropyltoluene             119    6.84  0.995    A     2    A    B
77       1,3-Dichlorobenzene            146    6.85  0.995    A     2    A    B
78       1,4-Dichlorobenzene            146    6.89  1.002    A     2    A    B
79       1,2-Dichlorobenzene            146    7.07  1.028    A     2    A    B
80       1,2,3-Trimethylbenzene         105    6.90  1.004    A     2    A    B
81       n-Butylbenzene                  91    7.04  1.024    A     2    A    B
82       Hexachloroethane               201    7.19  1.046    A     2    A    B
83       1,2-Dibromo-3-Chloropropane    157    7.44  1.082    A     3    A    B
84       1,2,4-Trichlorobenzene         182    7.84  1.140    A     3    A    B
85       Hexachlorobutadiene            225    7.92  1.151    A     3    A    B
86       1,2,3-Trichlorobenzene         180    8.09  1.176    A     3    A    B
87       Naphthalene                    128    7.97  1.159    A     3    A    B
88       2-Methylnaphthalene            142    8.52  1.239    A     2    A    B

Cal A = Average L = Linear LO = Linear w/origin Q = Quad QO = Quad w/origin
#Qual = number of qualifiers
  A/H = Area or Height
ID  R = R.T.  B = R.T. & Q  Q = Qvalue L = Largest  A = All
-----------------------------------------------------------------------
          WR201119.M     Fri Dec 18 09:41:56 2020
```

: For DoD projects, all target compounds will be included in the matrix spike and matrix spike duplicate

Table 2. Summary of Applicable Performance Compounds - Volatile Organics Analysis

COMPOUND	ISD	SSD
PENTAFLUOROBENZENE	✓	
1,2-DICHLOROETHANE-D4		✓
1,4-DIFLUOROBENZENE	✓	
TOLUENE-D8		✓
CHLOROBENZENE-D5	✓	
4-BROMOFLUOROBENZENE-		✓
1,4-DICHLOROBENZENE-D4	✓	

: For DoD projects, all target compounds will be included in the matrix spike and matrix spike duplicate

Key

ISD: Internal Standard Compound

SSD: Surrogate Standard Compound

Table 2b. Recommended Minimum Relative Response Factor Criteria For Initial And Continuing Calibration Verification.

Volatile Compounds	Minimum Response Factor (RF)[a]
Dichlorodifluoromethane	0.100
Chloromethane	0.100
Vinyl chloride	0.100
Bromomethane	0.100
Chloroethane	0.100
Trichlorofluoromethane	0.100
1,1-Dichloroethene	0.100
1,1,2-Trichloro-1,2,2-trifluoroethane	0.100
Acetone	0.100
Carbon disulfide	0.100
Methyl Acetate	0.100
Methylene chloride	0.100
trans-1,2-Dichloroethene	0.100
cis-1,2-Dichloroethene	0.100
Methyl tert-Butyl Ether	0.100
1,1-Dichloroethane	0.200
2-Butanone	0.100
Chloroform	0.200
1,1,1-Trichloroethane	0.100
Cyclohexane	0.100
Carbon tetrachloride	0.100
Benzene	0.500
1,2-Dichloroethane	0.100
Trichloroethene	0.200
Methylcyclohexane	0.100
1,2-Dichloropropane	0.100
Bromodichloromethane	0.200
cis-1,3-Dichloropropene	0.200
trans-1,3-Dichloropropene	0.100
4-Methyl-2-pentanone	0.100
Toluene	0.400
1,1,2-Trichloroethane	0.100
Tetrachloroethene	0.200
2-Hexanone	0.100
Dibromochloromethane	0.100
1,2-Dibromoethane	0.100
Chlorobenzene	0.500

Volatile Compounds	Minimum Response Factor (RF)[a]
Ethylbenzene	0.100
meta-/para-Xylene	0.100
ortho-Xylene	0.300
Styrene	0.300
Bromoform	0.100
Isopropylbenzene	0.100
1,1,2,2-Tetrachloroethane	0.300
1,3-Dichlorobenzene	0.600
1,4-Dichlorobenzene	0.500
1,2-Dichlorobenzene	0.400
1,2-Dibromo-3-chloropropane	0.050
1,2,4-Trichlorobenzene	0.200

[a] The Project-specific response factors obtained may be affected by the quantitation ion selected and when using possible alternate ions the actual response factors may be lower than those listed.

Table 3. GC/MS Operating Conditions - Volatile Organics Analysis

Operating Parameter	**Volatiles Analysis**
Chromatographic Column	DB 624, L = 20 *m*, ID = 0.18 *mm*
Carrier Gas	Helium (He)
Temperature Program	T_0 = 30°C, hold 2.0 *min* dT/dt_1 = 32°C/*min* T_1 = 195°C dT/dt_2 = 30°C/*min* T_2 = 235°C
Injector Temperature	150°C
Detector Temperature	300°C
Purge Volume	5 *mL*
Mass Scanning Range	35 *m/z* - 260 *m/z*
Mass Scanning Rate	2.0 *Hz*

Note: the above is subject to change based on GC and/or sample conditions.

Table 4. BFB Tune Evaluation Criteria

Target *m/z*	**Relative *m/z***	**LCL (%)**	**UCL (%)**
50	95	8	40
75	95	30	66
95	95	100	100
96	95	5.0	9.0
173	174	0	2.0
174	95	50	120
175	174	4.0	9.0
176	174	93	101
177	176	5.0	9.0

Abundance criteria are for a quadrupole mass spectrometer. Alternative tuning criteria from other published EPA reference methods may be used, provided method performance is not adversely affected. Alternative tuning criteria specified by an instrument manufacturer may also be used for another type of mass spectrometer, or for an alternative carrier gas, provided method performance is not adversely affected.

Table 5a. Quality Control Items, Frequency, and Corrective Action

QC Item	**Frequency**	**Acceptance Criteria**	**Corrective Action**
Initial Calibration	Prior to all analytical runs	Method-based	Examine the entire analytical system; some or all of the following: clean MS source, re-tune, clip/replace column, replace calibration standards, re-calibrate.
BFB	12-hour	Table 4	Re-attempt injection; clean MS source, re-tune; failure requires the re-analysis of all associated analytical runs.
Calibration Verification	12-hour	Table 2b	Re-attempt injection; some or all of the following: clean MS source, re-tune, clip/replace column, replace calibration standards, re-calibrate; failure requires the re-analysis of all associated analytical runs.
LCS and MS	20 samples	Laboratory in-house Control Limits with no more than 4 Marginal Exceedances	A failed LCS should be re-analyzed. A failed MS requires no action provided that the LCS is acceptable. If additional sample exists, the samples associated with a failed LCS should be re-analyzed or QC data qualified.
Duplicate or MSD	20 samples	n/a	Relative Percent Differences (RPDs) are computed and included in the QC report
Method Blank	20 samples	<RL	Method blank contamination is flagged on the analytical report for any identified target compound. Blanks indicative of contaminated analytical system (typically the purge-and-trap system) should result in a thorough cleansing of the affected system and sample/blank re-analysis.
Internal Standard	All samples	Section 7.5.5	Adverse matrix effects on areas/recoveries are demonstrated either by screening the extract of re-analyzing the sample within a 12-hour QC batch.

QC Item	**Frequency**	**Acceptance Criteria**	**Corrective Action**
			The resulting analytical report is flagged appropriately. A negative bias unrelated to matrix effects indicates the need to: clean the MS source, re-tune, and re-calibrate
Surrogate Standard	All samples	Table 6	Adverse matrix effects on areas/recoveries are demonstrated either by screening the extract of re-analyzing the sample within a 12-hour QC batch. The resulting analytical report is flagged appropriately. If additional sample exists, the sample should be re-extracted prior to re-analysis if a matrix effect cannot be demonstrated.
Target Compound	All samples	Method-based	Target compounds beyond the calibration range are diluted and re-analyzed and/or flagged as estimated on the analytical report.

Table 5b. Quality Control Items, Frequency, and Corrective Action for DoD Projects

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source prior to sample analysis	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing calibration verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last acceptable CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g, average RFs) these additional requirements must also be met.
Internal standards (IS)	Every field sample, standard, and QC sample.	Retention time ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed	If corrective action fails in field samples, data must be qualified and explained in the case	NA

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
		+100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	while system was malfunctioning is mandatory.	narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging criteria is not appropriate for failed standards.	
Method blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater. Common contaminants, must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
				associated preparatory batch.	
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all surrogates and all analytes to be reported. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.
Matrix spike duplicate (MSD) or Matrix duplicate (MD)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	MSD: Must contain all surrogates and all analytes to be reported. The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.
Surrogate spike	All field and QC samples.	QC acceptance criteria specified by project, if available; otherwise use QSM Appendix C limits or in-house LCS limits if analyte(s) are not listed..	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.

QC Check	**Minimum Frequency**	**Acceptance Criteria**	**Corrective Action**	**Flagging Criteria**	**Comments**
			available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the Case Narrative.		
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source prior to sample analysis	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing calibration verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last acceptable CCV. Alternately, recalibrate if	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g, average RFs) these additional requirements must also be met.

QC Check	**Minimum Frequency**	**Acceptance Criteria**	**Corrective Action**	**Flagging Criteria**	**Comments**
			necessary; then reanalyze all associated samples since the last acceptable CCV.		
Internal standards (IS)	Every field sample, standard, and QC sample.	Retention time ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the case narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging criteria is not appropriate for failed standards.	NA
Method blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater. Common contaminants, must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

QC Check	**Minimum Frequency**	**Acceptance Criteria**	**Corrective Action**	**Flagging Criteria**	**Comments**
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

DoD Appendix C LCS Limits
Method 8260 Solid Matrix

CAS ID	ANALYTE	LOWER CONTROL LIMIT (LCL)	UPPER CONTROL LIMIT (UCL)
630-20-6	1,1,1,2-Tetrachloroethane	78	125
71-55-6	1,1,1-Trichloroethane	73	130
79-34-5	1,1,2,2-Tetrachloroethane	70	124
79-00-5	1,1,2-Trichloroethane	78	121
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane [Freon-113]	66	136
75-34-3	1,1-Dichloroethane	76	125
75-35-4	1,1-Dichloroethene	70	131
563-58-6	1,1-Dichloropropene	76	125
87-61-6	1,2,3-Trichlorobenzene	66	130
96-18-4	1,2,3-Trichloropropane	73	125
526-73-8	1,2,3-Trimethlybenzene	82	118
120-82-1	1,2,4-Trichlorobenzene	67	129
95-63-6	1,2,4-Trimethylbenzene	75	123
96-12-8	1,2-Dibromo-3-chloropropane	61	132
106-93-4	1,2-Dibromoethane	78	122
95-50-1	1,2-Dichlorobenzene	78	121
107-06-2	1,2-Dichloroethane	73	128
17060-07-0	1,2-Dichloroethane-d4	71	136
540-59-0	1,2-Dichloroethene	78	122
78-87-5	1,2-Dichloropropane	76	123
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	64	132
108-70-3	1,3,5-Trichlorobenzene	71	128
108-67-8	1,3,5-Trimethylbenzene	73	124
541-73-1	1,3-Dichlorobenzene	77	121
142-28-9	1,3-Dichloropropane	77	121
542-75-6	1,3-Dichloropropene	77	126
106-46-7	1,4-Dichlorobenzene	75	120
105-05-5	1,4-Diethylbenzene	79	114

123-91-1	1,4-Dioxane	55	138
544-10-5	1-Chlorohexane	71	130
594-20-7	2,2-Dichloropropane	67	133
78-93-3	2-Butanone (MEK)	51	148
126-99-8	2-Chloro-1,3-butadiene	65	133
110-75-8	2-Chloroethyl vinyl ether	43	149
95-49-8	Chlorotoluene	75	122
591-78-6	2-Hexanone	53	145
79-46-9	2-Nitropropane	47	150
67-63-0	2-Propanol [Isopropyl alcohol]	60	140
460-00-4	4-Bromofluorobenzene	79	119
106-43-4	4-Chlorotoluene	72	124
108-10-1	4-Methyl-2-pentanone [MIBK]	65	135
67-64-1	Acetone	36	164
75-05-8	Acetonitrile	54	143
107-02-8	Acrolein [Propenal]	47	155
107-13-1	Acrylonitrile	65	134
107-05-1	Allyl chloride	68	135
71-43-2	Benzene	77	121
100-44-7	Benzyl chloride	64	120
108-86-1	Bromobenzene	78	121
74-97-5	Bromochloromethane	78	125
75-27-4	Bromodichloromethane	75	127
75-25-2	Bromoform	67	132
74-83-9	Bromomethane	53	143
75-15-0	Carbon disulfide	63	132
56-23-5	Carbon tetrachloride	70	135
108-90-7	Chlorobenzene	79	120
124-48-1	Chlorodibromomethane	74	126
75-00-3	Chloroethane	59	139
67-66-3	Chloroform	78	123
74-87-3	Chloromethane	50	136
156-59-2	cis-1,2-Dichloroethene	77	123

10061-01-5	cis-1,3-Dichloropropene	74	126
1476-11-5	cis-1,4-Dichloro-2-butene	69	143
110-82-7	Cyclohexane	67	131
108-94-1	Cyclohexanone	30	156
1868-53-7	Dibromofluoromethane	78	119
74-95-3	Dibromomethane	78	125
75-71-8	Dichlorodifluoromethane [Freon-12]	29	149
75-43-4	Dichlorofluoromethane	47	155
60-29-7	Diethyl ether	71	129
108-20-3	Diisopropyl ether	69	127
64-17-5	Ethanol	45	159
141-78-6	Ethyl acetate	52	139
97-63-2	Ethyl methacrylate	69	129
637-92-3	Ethyl tert-butyl ether	72	126
100-41-4	Ethylbenzene	76	122
462-06-6	Fluorobenzene	81	114
142-82-5	Heptane	49	138
87-68-3	Hexachlorobutadiene	61	135
67-72-1	Hexachloroethane	72	133
110-54-3	Hexane	45	142
74-88-4	Iodomethane	71	131
78-83-1	Isobutyl alcohol	60	135
108-21-4	Isopropyl acetate [Acetic acid]	58	131
98-82-8	Isopropylbenzene	68	134
179601-23-1	m/p-Xylene [3/4-Xylene]	77	124
126-98-7	Methacrylonitrile	66	132
79-20-9	Methyl acetate	53	144
80-62-6	Methyl methacrylate	63	134
1634-04-4	Methyl tert-butyl ether [MTBE]	73	125
108-87-2	Methylcyclohexane	66	133
75-09-2	Methylene chloride	70	128
123-86-4	n-Butyl acetate	62	128
71-36-3	n-Butyl alcohol	55	131

104-51-8	n-Butylbenzene	70	128
103-65-1	n-Propylbenzene	73	125
91-20-3	Naphthalene	62	129
95-47-6	o-Xylene	77	123
99-87-6	p-Isopropyltoluene [p-Cymene]	73	127
76-01-7	Pentachloroethane	69	135
107-12-0	Propionitrile [Ethyl cyanide]	68	134
135-98-8	sec-Butylbenzene	73	126
100-42-5	Styrene	76	124
994-05-8	tert-Amyl methyl ether [TAME]	73	126
75-65-0	tert-Butyl alcohol	68	133
98-06-6	tert-Butylbenzene	73	125
127-18-4	Tertachloroethene	73	128
109-99-9	Tetrahydrofuran	61	135
108-88-3	Toluene	77	121
2037-26-5	Toluene-d8	85	116
156-60-5	trans-1,2-Dichloroethene	74	125
10061-02-6	trans-1,3-Dichloropropene	71	130
110-57-6	trans-1,4-Dichloro-2-butene	62	136
79-01-6	Trichloroethene	77	123
75-69-4	Trichlorofluoromethane [Freon-11]	62	140
108-05-4	Vinyl acetate	50	151
75-01-4	Vinyl chloride	56	135
1330-20-7	Xylene [total]	78	124

DoD Appendix C LCS Limits
Method 8260 Water Matrix

CAS ID	ANALYTE	LOWER CONTROL LIMIT (LCL)	UPPER CONTROL LIMIT (UCL)
630-20-6	1,1,1,2-Tetrachloroethane	78	124
71-55-6	1,1,1-Trichloroethane	74	131
79-34-5	1,1,2,2-Tetrachloroethane	71	121
79-00-5	1,1,2-Trichloroethane	80	119
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane	70	136

	[Freon-113]		
75-34-3	1,1-Dichloroethane	77	125
75-35-4	1,1-Dichloroethene	71	131
563-58-6	1,1-Dichloropropene	79	125
87-61-6	1,2,3-Trichlorobenzene	69	129
96-18-4	1,2,3-Trichloropropane	73	122
526-73-8	1,2,3-Trimethlybenzene	82	120
120-82-1	1,2,4-Trichlorobenzene	69	130
95-63-6	1,2,4-Trimethylbenzene	76	124
96-12-8	1,2-Dibromo-3-chloropropane	62	128
106-93-4	1,2-Dibromoethane	77	121
95-50-1	1,2-Dichlorobenzene	80	119
107-06-2	1,2-Dichloroethane	73	128
17060-07-0	1,2-Dichloroethane-d4	81	118
540-59-0	1,2-Dichloroethene	79	121
78-87-5	1,2-Dichloropropane	78	122
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	70	136
108-70-3	1,3,5-Trichlorobenzene	75	130
108-67-8	1,3,5-Trimethylbenzene	75	124
106-99-0	1,3-Butadiene	43	158
541-73-1	1,3-Dichlorobenzene	80	119
142-28-9	1,3-Dichloropropane	80	119
542-75-6	1,3-Dichloropropene	77	123
106-46-7	1,4-Dichlorobenzene	79	118
105-05-5	1,4-Diethylbenzene	79	118
123-91-1	1,4-Dioxane	59	139
544-10-5	1-Chlorohexane	76	124
540-84-1	2,2,4-Trimethylpentane [Isooctane]	58	132
594-20-7	2,2-Dichloropropane	60	139
75-85-4	2-Butanol	66	120
78-93-3	2-Butanone (MEK)	56	143
126-99-8	2-Chloro-1,3-butadiene	65	135

110-75-8	2-Chloroethyl vinyl ether	51	139
95-49-8	Chlorotoluene	79	122
591-78-6	2-Hexanone	57	139
91-57-6	2-Methylnaphthalene	17	142
79-46-9	2-Nitropropane	49	136
67-63-0	2-Propanol [Isopropyl alcohol]	56	142
624-95-3	3,3-Dimethyl-1-butanol	49	133
460-00-4	4-Bromofluorobenzene	85	114
106-43-4	4-Chlorotoluene	78	122
108-10-1	4-Methyl-2-pentanone [MIBK]	67	130
67-64-1	Acetone	39	160
75-05-8	Acetonitrile	50	142
107-02-8	Acrolein [Propenal]	39	155
107-13-1	Acrylonitrile	63	135
107-05-1	Allyl chloride	68	130
71-43-2	Benzene	79	120
100-44-7	Benzyl chloride	42	138
108-86-1	Bromobenzene	80	120
74-97-5	Bromochloromethane	78	123
75-27-4	Bromodichloromethane	79	125
75-25-2	Bromoform	66	130
74-83-9	Bromomethane	53	141
75-15-0	Carbon disulfide	64	133
56-23-5	Carbon tetrachloride	72	136
108-90-7	Chlorobenzene	82	118
124-48-1	Chlorodibromomethane	74	126
75-45-6	Chlorodifluoromethane	40	129
75-00-3	Chloroethane	60	138
67-66-3	Chloroform	79	124
74-87-3	Chloromethane	50	139
156-59-2	cis-1,2-Dichloroethene	78	123
10061-01-5	cis-1,3-Dichloropropene	75	124
1476-11-5	cis-1,4-Dichloro-2-butene	57	146

110-82-7	Cyclohexane	71	130
1868-53-7	Dibromofluoromethane	80	119
74-95-3	Dibromomethane	79	123
75-71-8	Dichlorodifluoromethane [Freon-12]	32	152
75-43-4	Dichlorofluoromethane	72	131
60-29-7	Diethyl ether	68	129
108-20-3	Diisopropyl ether	67	128
64-17-5	Ethanol	48	151
141-78-6	Ethyl acetate	55	138
97-63-2	Ethyl methacrylate	72	126
637-92-3	Ethyl tert-butyl ether	70	127
100-41-4	Ethylbenzene	79	121
462-06-6	Fluorobenzene	80	116
142-82-5	Heptane	49	140
87-68-3	Hexachlorobutadiene	66	134
67-72-1	Hexachloroethane	72	134
110-54-3	Hexane	48	143
74-88-4	Iodomethane	69	131
78-83-1	Isobutyl alcohol	63	133
108-21-4	Isopropyl acetate [Acetic acid]	63	133
98-82-8	Isopropylbenzene	72	131
179601-23-1	m/p-Xylene [3/4-Xylene]	80	121
126-98-7	Methacrylonitrile	63	133
79-20-9	Methyl acetate	56	136
80-62-6	Methyl methacrylate	67	128
1634-04-4	Methyl tert-butyl ether [MTBE]	71	124
108-87-2	Methylcyclohexane	72	132
75-09-2	Methylene chloride	74	124
123-86-4	n-Butyl acetate	69	125
71-36-3	n-Butyl alcohol	59	131
104-51-8	n-Butylbenzene	75	128
109-60-4	n-Propyl acetate	76	126
103-65-1	n-Propylbenzene	76	126

91-20-3	Naphthalene	61	128
95-47-6	o-Xylene	78	122
99-87-6	p-Isopropyltoluene [p-Cymene]	77	127
76-01-7	Pentachloroethane	69	133
109-66-0	Pentane	16	134
107-12-0	Propionitrile [Ethyl cyanide]	64	136
135-98-8	sec-Butylbenzene	77	126
100-42-5	Styrene	78	123
994-05-8	tert-Amyl methyl ether [TAME]	68	128
75-65-0	tert-Butyl alcohol	68	129
762-75-4	tert-Butyl formate	65	132
98-06-6	tert-Butylbenzene	78	124
127-18-4	Tertachloroethene	74	129
109-99-9	Tetrahydrofuran	57	133
108-88-3	Toluene	80	121
2037-26-5	Toluene-d8	89	112
156-60-5	trans-1,2-Dichloroethene	75	124
10061-02-6	trans-1,3-Dichloropropene	73	127
110-57-6	trans-1,4-Dichloro-2-butene	43	140
79-01-6	Trichloroethene	79	123
75-69-4	Trichlorofluoromethane [Freon-11]	65	141
108-05-4	Vinyl acetate	54	146
75-01-4	Vinyl chloride	58	137
1330-20-7	Xylene [total]	79	121

LCS Limits
EPA 624.1 Water Matrix

CAS ID	ANALYTE	LOWER CONTROL LIMIT (LCL)	UPPER CONTROL LIMIT (UCL)
71-55-6	1,1,1-Trichloroethane	70	130
79-34-5	1,1,2,2-Tetrachloroethane	60	140
79-00-5	1,1,2-Trichloroethane	70	130
75-34-3	1,1-Dichloroethane	70	130
75-35-4	1,1-Dichloroethene	50	150
95-50-1	1,2-Dichlorobenzene	65	135
107-06-2	1,2-Dichloroethane	70	130
78-87-5	1,2-Dichloropropane	35	165
541-73-1	1,3-Dichlorobenzene	70	130
106-46-7	1,4-Dichlorobenzene	65	135
110-75-8	2-Chloroethyl vinyl ether	0	225
107-02-8	Acrolein [Propenal]	60	140
107-13-1	Acrylonitrile	60	140
71-43-2	Benzene	65	135
75-27-4	Bromodichloromethane	65	135
75-25-2	Bromoform	70	130
74-83-9	Bromomethane	15	185
56-23-5	Carbon tetrachloride	70	130
108-90-7	Chlorobenzene	65	135
124-48-1	Chlorodibromomethane	70	135
75-00-3	Chloroethane	40	160
67-66-3	Chloroform	70	135
74-87-3	Chloromethane	0	205
10061-01-5	cis-1,3-Dichloropropene	25	175
100-41-4	Ethylbenzene	60	140
75-09-2	Methylene chloride	60	140
127-18-4	Tetrachloroethene	70	130
108-88-3	Toluene	70	130
156-60-5	trans-1,2-Dichloroethene	70	130

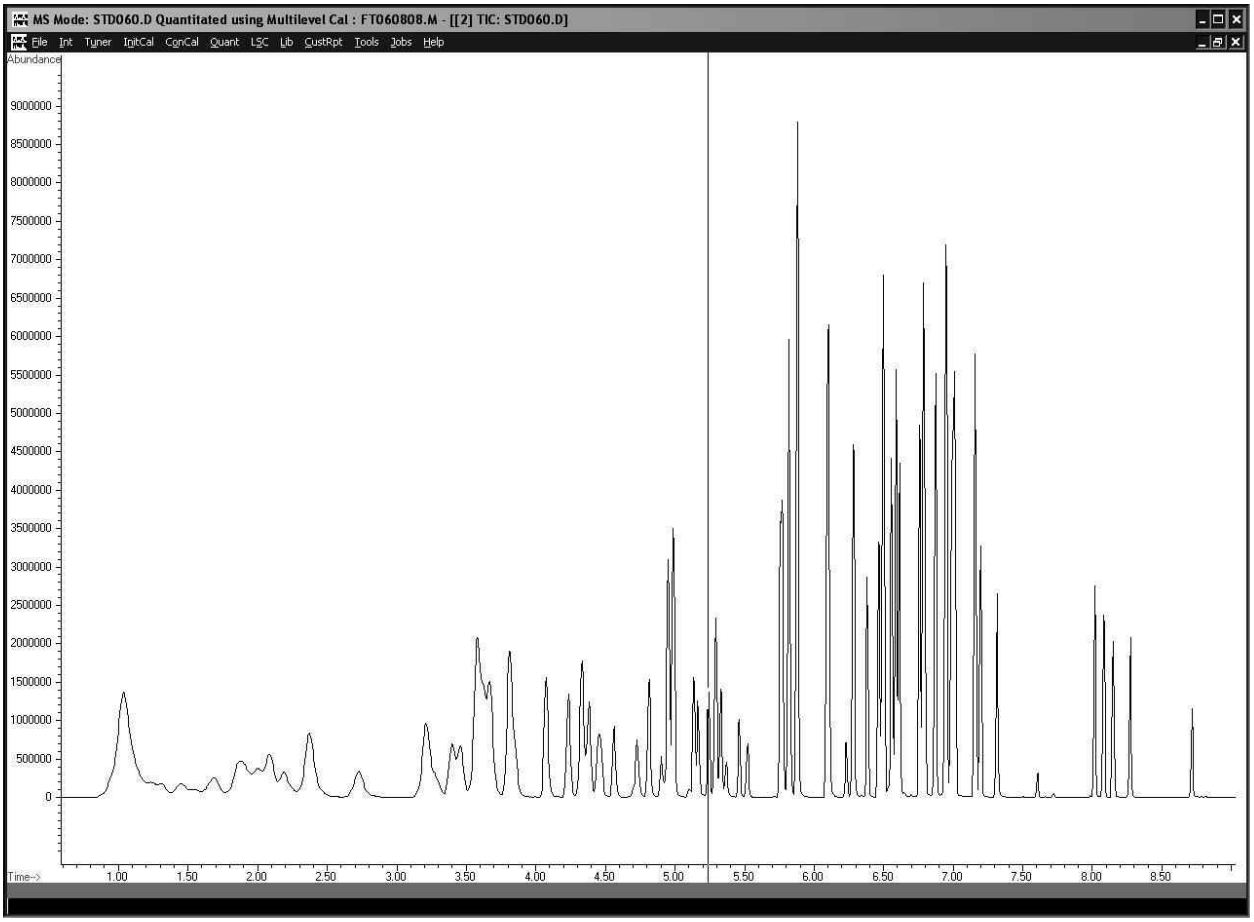
10061-02-6	trans-1,3-Dichloropropene	50	150
79-01-6	Trichloroethene	65	135
75-69-4	Trichlorofluoromethane [Freon-11]	50	150
75-01-4	Vinyl chloride	5	195

Table 6. Summary of Control Limits: Surrogate and Internal Standard Compounds Percent Recovery†

COMPOUND	Water Matrix		Solid Matrix	
	LCL (%)	UCL (%)	LCL (%)	UCL (%)
1.2-DICHLOROETHANE-D4	72.0	125.0	71.0	124.0
TOLUENE-D8	89.0	112.0	83.0	120.0
4-BROMOFLUOROBENZENE	80.0	124.0	81.0	124.0
Pentafluorobenzene	50.0	200.0	50.0	200.0
1,4-Difluorobenzene	50.0	200.0	50.0	200.0
Chlorobenzene-D5	50.0	200.0	50.0	200.0
1,4-Dichlorobenzene-D4	50.0	200.0	50.0	200.0

†: Results based on recovery data from 2020.

Figure 1. Example Total Ion Chromatogram for a Midpoint VOA Calibration Standard†



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†: Data file Std060.D (60 μg/L). GC/MS acquisition parameters are given by Table 4.

STANDARD OPERATING PROCEDURE

DETERMINATION OF THE METHOD DETECTION LIMIT (MDL), LIMIT OF DETECTION (LOD) AND LIMIT OF QUANTITATION (LOQ)

APPROVALS:

Barbara Ball

02/19/2021

QA Officer Date

02/19/2021

Technical Director Date

Number	**Description of Change**	**Date**
001-005	Previous updates not recorded.	
006	Updated to comply with DoD QSM and ISO 17025 standards.	6/15/11
007	Minor changes needs following SOP Review	10/26/13
008	Minor changes needs following SOP Review	01/15/16
009	2017 Method Update Rule MDL revisions	01/24/18
010	2020 Internal Audit revisions	02/19/2021
011		
012		
013		
014		
015		
014		

1.0 SCOPE AND APPLICATION

This SOP outlines the procedure for determining the Method Detection Limit (MDL), Limit of Detection (LOD) and Limit of Quantitation (LOQ) for an analysis. This procedure is applicable to any analytical method, unless stated otherwise in the specific method.

2.0 SUMMARY OF METHOD

This SOP is designed to have a uniform procedure for establishing MDL, LOD, and LOQ for each analyte unless method specified limits are established. All measures of sensitivity are specific to the analyte, sample matrix, test method, instrumentation, column, and analyst/laboratory performance. Therefore, analytical performance must be demonstrated for each variable (e.g., it is possible that two “identical” instruments from the same manufacturer may exhibit different sensitivities).

3.0 INTERFERENCES

Not applicable.

4.0 APPARATUS AND MATERIALS

Computer

Calculator

Method references

Analytical SOPs

5.0 REAGENTS

Deionized water

Clean sand

Matrix Spike solution

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

Not applicable.

7.0 PROCEDURE

1. Estimate the initial MDL using one or more of the following:

    - The mean determined concentration plus three times the standard deviation of a set of method blanks.

- The concentration value that corresponds to an instrument signal-to-noise ratio in the range of 3 to 5.

- The concentration equivalent to three times the standard deviation of replicate instrumental measurements of spiked blanks.

- That region of the calibration where there is a significant change in sensitivity, i.e., a break in the slope of the calibration.

- Instrumental limitations.

- Previously determined MDL.

2. Determine the initial MDL:

   - Select a spiking level, typically 2 – 10 times the estimated MDL. Spiking levels in excess of 10 times the estimated detection limit may be required for analytes with very poor recovery.

   - Process a minimum of seven spiked samples and seven method blank samples through all steps of the method. The samples used for the MDL must be prepared in at least three batches on three separate calendar dates and analyzed on three separate calendar dates. (Preparation and analysis may be on the same day.)

   - If there are multiple instruments that will be assigned the same MDL, then the sample analyses must be distributed across all of the instruments.

     - A minimum of two spiked samples and two method blank samples prepared and analyzed on different calendar dates is required for each instrument. Each analytical batch may contain one spiked sample and one method blank sample run together. A spiked sample and a method blank sample may be analyzed in the same batch, but are not required to be.

     - The same prepared extract may be analyzed on multiple instruments so long as the minimum requirement of seven preparations in at least three separate batches is maintained.

- Evaluate the spiking level: If any result for any individual analyte from the spiked samples does not meet the method qualitative identification criteria or does not provide a numerical result greater than zero, then repeat the spiked samples at a higher concentration.

3. For liquid MDL samples use DI water and for soil MDL samples use clean sand.

4. Analyze the sample aliquots exactly as normal samples, following procedures outlined in individual SOPs with results quantified and reported in proper units.

5. Compute the standard deviation (s) for each analyte as:

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \tilde{x}\right)^2$$

Where *n* is the number of measurement, x_i is the i^{th} result for measurement *i*, and $\tilde{x}$ is the mean of x_i.

6. Determine the MDL as the product of the standard deviation and the one-sided t-statistic at the 99% confidence interval:

$$MDL = st_{n,0.99}$$

7. Use Table 1 to calculate average, standard deviation, and MDL.

8. Compute the MDL_b (the MDL based on method blanks) as follows:

- If none of the method blanks give numerical results for an individual analyte, the MDL_b does not apply. A numerical result includes both positive and negative results, including results below the current MDL, but not results of “ND” (not detected) commonly observed when a peak is not present in chromatographic analysis.

- If some (but not all) of the method blanks for an individual analyte give numerical results, set the MDL_b equal to the highest method blank result. If more than 100 method blanks are available, set MDL_b to the level that is no less than the 99th percentile of the method blank results. For “n” method blanks where n ≥ 100, sort the method blanks in rank order. The (n * 0.99) ranked method blank result (round to the nearest whole number) is the MDL_b.

- If all of the method blanks for an individual analyte give numerical results, then calculate the MDL_b as:

  - $MDL_b = \bar{X} + t_{(n-1,1-\propto=0.99)} S_b$

    where:

    MDL_b = the MDL based on method blanks

    $\bar{X}$ = mean of the method blank results (use zero in place of mean if the mean is negative)

    $t_{(n-1,1-\propto=0.99)}$ = the Student's t-value appropriate for the single-tailed 99^{th} percentile t statistic and a standard deviation estimate with n-1 degrees of freedom.

    S_b = sample standard deviation of the replicate method blank sample analyses.

9. Select the greater of MDL_s or MDL_b as the initial MDL.

10. Ongoing Data Collection

- During any quarter in which samples are being analyzed, prepare and analyze a minimum of two spiked samples on each instrument, in separate batches, using the same spiking concentration.

- Ensure that at least seven spiked samples and seven method blanks are completed for the annual verification. If only one instrument is in use, a minimum of seven spikes are still required, but they may be drawn from the last two years of data collection.

- At least once per year, re-evaluate the spiking level.

  - If more than 5% of the spiked samples do not return positive numerical results that meet all method qualitative identification criteria, then the spiking level must be increased and the initial MDL re-determined following the procedure in Section 2.

- If the method is altered in a way that can be reasonably expected to change its sensitivity, then redetermine the initial MDL, and the restart the ongoing data collection.

- If a new instrument is added to a group of instruments whose data are being pooled to create a single MDL, analyze a minimum of two spiked replicates and two method blank replicates on the new instrument. If both method blank results are below the existing MDL, then the existing MDL_b is validated. Combine the new spiked sample results to the existing spiked sample results and recalculate the MDLs. If the recalculated MDLs does not vary by more than the factor specified in Section 13 of this procedure, then the existing MDLs is validated. If either of these two conditions is not met, then calculate a new MDL.

11. Ongoing Annual Verification

    - ♦ At least once every thirteen months, re-calculate MDL_s and MDL_b from the collected spiked samples and method blank results.
    - ♦ Include data generated within the last twenty four months, but only data with the same spiking level. Only documented instances of gross failures (e.g., instrument malfunctions, mislabeled samples, cracked vials) may be excluded from the calculations.
    - ♦ Include the initial MDL spiked samples, if the data were generated within twenty four months.
    - ♦ Only use data associated with acceptable calibrations and batch QC. Include all routine data, with the exception of batches that are rejected and the associated samples reanalyzed.
    - ♦ The verified MDL is the greater of the MDL_s or MDL_b . If the verified MDL is within 0.5 to 2.0 times the existing MDL, and fewer than 3% of the method blank results (for the individual analyte) have numerical results above the existing MDL, then the existing MDL may optionally be left unchanged. Otherwise, adjust the MDL to the new verification MDL. (The range of 0.5 to 2.0 approximates the 95th percentile confidence interval for the initial MDL determination with six degrees of freedom.)

12. Determine the LOD by spiking a quality system matrix (e.g. DI water or clean sand) at approximately two to three times the detection limit (for a single-analyte standard) or greater than one to four times the detection limit (for a multi-analyte standard). This spike concentration establishes the LOD when Section 8.0 Quality Control requirements are met.

13. Minimum of two samples must be extracted and analyzed the same as real environmental samples per quarter.

14. Document the LOD (spiked concentration) and complete the required information on the LOD spreadsheet (Table 2).

15. The LOQ is run by spiking a quality system matrix (e.g. DI water or clean sand) typically at the desired reporting limit for the analyte of interest. Minimum of two samples must be extracted and analyzed the same as real environmental samples per quarter. The LOQ is established at or above the lowest initial calibration point and must be above the LOD.

16. Complete the LOQ spreadsheet (Table 3).

17. Precision and bias at the LOQ is calculated using the LOQ Determination Spreadsheet (Table 4). If the method is modified, precision and bias at the new LOQ must be recalculated and reported.

18. Documentation must be maintained for all MDL determinations and LOD and LOQ verifications.

19. Frequency requirements:

    - MDL: initial, quarterly verification, and annual calculation
    - LOD: quarterly or when new MDL study is performed
    - LOQ: quarterly or when new MDL study is performed

8.0 QUALITY CONTROL

MDL must meet the following requirements:

- The MDL cannot be greater than the spike concentration.
- If the MDL does not comply with the stated rule, a new MDL study must be conducted.

LOD must meet the following requirements:

- The apparent signal to noise ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition.) For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentrations.
- If multiple instruments or columns are used for a given method the LOD must be verified on each.
- If the LOD verification fails, then the laboratory must repeat the detection limit determination and the LOD verification at a higher concentration or perform and pass two consecutive LOD verifications at a higher concentration and set the LOD at the higher concentration.

LOQ must meet the following requirements:

- The precision and bias at the LOQ must be evaluated and meet project specific requirements.

Only staff proficient in the appropriate analysis can generate the data used in MDL/LOD/LOQ determination.

Documentation is maintained by the analyst and QA Manager electronically. Reporting for LOD/LOQ in VLIMs under the QC / Prep Batches section, then click LOD / LOQ Sample Reporting, and load appropriate quarter.

9.0 METHOD PERFORMANCE

Not applicable.

10.0 EQUIPMENT MAINTENANCE AND TROUBLESHOOTING

Provide in the appropriate analytical SOP.

11.0 SAFETY

Eye protection and gloves must be worn while performing the analyses. Every laboratory area has eyewash, emergency shower, and fire extinguisher. The metals lab also has dust masks available for use with dust samples. The air system throughout the laboratory area is on a 100% fresh air exchange system, this system exchanges 100% the air in the laboratory area with air from outside 6 times per hour and 30 times per hour when the emergency purge button is hit. A reference file of material safety data sheets (MSDSs) is available to all personnel.

See analytical SOP for specific safety precautions.

12.0 WASTE DISPOSAL AND POLLUTION PREVENTION

All laboratory waste must be managed, stored, and disposed in accordance with all federal and state laws and regulations. Additional information can be found in the Sample Disposal SOP and Merit’s Waste Management Plan and Handbook.

See analytical SOP for specific waste disposal information.

13.0 DEFINITIONS

Method Detection Limit (MDL): the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.

Note that for reporting purposes, any result at or above the MDL must also meet qualitative identification criteria required by the test method. Although a result at or above the MDL indicates that the analyte is *present, the absence of a result at or above the MDL is inconclusive (i.e., one cannot confidently state whether the analyte is present or absent), because the false negative rate at the MDL is 50%.*

Limit of Detection (LOD): an estimate of the minimum amount of a substance that an analytical process can reliably detect and is analyte and matrix specific. LOD is the smallest amount or concentration of a substance that must be present in a sample in order to be detected at a 99% confidence level. If a sample has a true concentration at the LOD, there is a minimum probability of 99% of reporting a "detection" (a measured value ≥ MDL) and a 1% chance of reporting a non-detect (a false negative).

Limit of Quantitation (LOQ): the lowest concentration that produces a quantitative result within specified limits of precision and bias. The LOQ is at or above the concentration of the lowest initial calibration standard. Limit of Quantitation (LOQ) is the lowest concentration of a substance that produces a quantitative result within specified limits of precision and bias. The LOQ is typically larger than the LOD (but may be equal to the LOD, depending upon the acceptance limits for precision and bias); therefore, the following is true:

MDL < LOD ≤ LOQ (RL)

Quantitative results can only be achieved at or above the LOQ. Measurements between the DL and the LOQ assure the presence of the analyte with confidence, but their numeric values are estimates.

Estimated Quantitation Limit (EQL): the lowest non-zero standard in the calibration curve, adjusted by any sample preparation/extraction factors. Also known as Practical Quantitation Limit (PQL).

Reporting Limit (RL): A client-specified lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

14.0 REFERENCES

40 C.F.R. Appendix B Part 136, *Definition and Procedure for the Determination of the Method Detection Limit*, Revision 2.

Department of Defense, Quality Systems Manual for Environmental Laboratories (DoD QSM), DoD Environmental Data Quality Workgroup, Department of Navy, Lead Service, ISO/IEC 17025:2005, ISO/IEC 17025:2017 and The NELAC Institute (TNI) Standards, Volume 1, September 2009, Version 5.3, May 7, 2019

International Standards Organization (ISO), 2005. *General Requirements for the Competence of Testing and Calibration Laboratories.* ISO 17025.

National Environmental Laboratory Accreditation Conference (NELAC), 2003. *Standards, Chapters 1–6*, EPA/600/R-04/003.

Table 1: MDL Table

Analysis Date
Analytical Method
Preparation Date
Preparation Method
Spiked Value
Estimated Limit
Samples
Student T Value

Compound	**Spike**	**PQL$_w$**	**MDL$_w$**	**P/Mw**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**x**	**σ**	**x (%)**	**MDL**	**n**	**t-value**
	(ug/l)	(ug/l)	(ug/l)	(-)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)		(ug/l)		

S = sample
x = average
σ = standard deviation
x (%) = % recovery
n = number of samples

Table 2: LOD Table

Parameter/ Compound	Instrument ID	Method	Matrix	Units	Analyst	LOD	Detected

Table 3: LOQ Table

Parameter/ Compound	Instrument ID	Method	Matrix	Units	Analyst	LOQ	Bias (average % recovery)	Precision (%STD deviation)

Table 4: LOQ Determination Table

Analysis Date

Analytical Method

Spiked Value

Samples

		(ug/L)			(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	
Compound	**Date**	**Spike**	**x (%)**	**σ (%)**	**x**	**σ**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**n**

S = sample

σ (%) = precision

x (%) = bias

n = number of samples

TGI - MONITORING WELL INSTALLATION

Rev #: 0

Rev Date: April 24, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	4/24/2017	All	Re-written as a TGI	Marc Killingstad Peter C. Frederick

APPROVAL SIGNATURES

Prepared by:	Jay Erickson	4/20/17 Date:
Technical Expert Reviewed by:	Marc Killingstad	4/24/17 Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) describes methods used to install groundwater monitoring wells in granular aquifers. It is assumed that the monitoring well has been properly designed, including sizing of the filter pack and screen, the length of the screen, total depth of the well, material strength and compatibility and surface completion. Typical monitoring wells are constructed of manufactured screen and engineered filter pack and are generally suitable for formations with granular materials having a grain size distribution with up to 50% passing a #200 sieve and up to 20% clay-sized material. Monitoring wells installed in formations finer than this may not be able to produce turbidity free water.

The monitoring well installation procedures set forth herein are consistent with the approach and methods presented in the American Society of Testing and Materials (ASTM) D5092 – *Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D5092). As such, following this TGI in combination with proper well design (see appropriate TGI), well development (see appropriate TGI), groundwater sampling procedures (see appropriate TGI), and well maintenance and rehabilitation (see appropriate TGI), will result in a monitoring well suitable for: (1) collection of groundwater samples representative of the surrounding formation and free of artificial turbidity; (2) measurement of accurate groundwater levels; and (3) hydraulic conductivity testing of formation sediments immediately adjacent to the open interval of the well (e.g., slug testing).

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions or project objectives, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases within the overburden. Monitoring wells to be installed within consolidated materials such as fractured bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. For guidance when installing monitoring wells in consolidated materials, please refer to the appropriate document. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, project objectives, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring. No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the borehole will be obtained prior to mobilizing onsite; these materials generally include:

- Well casing (length, material, and diameter);
- Well screen (length, material, diameter, and slot size);
- Bentonite (type, as applicable, chips, non-coated and granular bentonite are acceptable);
- Filter pack (filter pack type and fine sand seal type, as applicable); and
- Grout (type, as applicable).

Well materials will be inspected and, if needed, cleaned or replaced prior to installation.

3 PERSONNEL QUALIFICATIONS

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil or bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate Standard Operating Procedures (SOPs) and/or TGIs for those activities.

4 EQUIPMENT LIST

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;

- Work Plan (or equivalent), Field Sampling Plan (FSP), and site-specific Health and Safety Plan (HASP);
- Personal protective equipment (PPE), as required by the HASP;
- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- Soil and/or bedrock logging equipment as specified in the appropriate project documents;
- Appropriate sample containers and labels;
- Drum labels as required for investigation derived waste handling;
- Chain-of-custody forms;
- Insulated coolers with ice, when collecting samples requiring preservation by chilling;
- Photoionization detector (PID) or flame ionization detector (FID);
- Ziplock style bags;
- Water level or oil/water interface meter;
- Locks and keys for securing the well after installation;
- Decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);
- Engineer’s tape/measuring wheel;
- Weighted tape;
- Disposable bailers;
- Digital camera (or phone with camera)
- Field notebook or Personal Digital Assistant (PDA); and
- Appropriate field forms, consider including a photo of the well head and a Google Earth map showing the well location.

Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller is necessary to ensure that the materials provided will meet the project objectives. Equipment/materials typically provided by the driller could include:

- Drilling equipment required by the ASTM standard guidance document D1586, when performing split-spoon sampling;
- Disposable plastic liners (when drilling with direct-push equipment);
- Drums for investigation derived waste;

- Drilling and sampling equipment decontamination materials;
- Decontamination pad materials, if required; and
- Well construction materials.

5 CAUTIONS

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See appropriate guidance for proper utility clearance protocol.

Prior to beginning field work, contact the project technical team to ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members.

Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the project specific documents for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquids (LNAPLs) are known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel or are corrosive to metal well materials. If questions arise, contact the CPM and/or project technical lead to discuss.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

As noted above, coated bentonite pellets will not be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Heat of hydration during neat cement grout curing must be considered to avoid damage to PVC well materials. The annular space for a typical monitoring well is small enough that heat of hydration should not create excessive temperature increases which may damage PVC well material. However, washouts in the borehole can lead to thick accumulations of grout which can produce enough heat during curing to weaken and potentially damage PVC casing. If heat of hydration is a concern, contact the project technical lead to address the issue.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

7 PROCEDURE

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Prior to monitoring well installation, determine the expected volumes of filter pack and seal materials including bentonite (if applicable) and grout (neat cement or cement-bentonite).
2. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
3. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan (or equivalent) and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan (or equivalent) and/or FSP. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in ASTM D1586 – *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D1586). Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology.
4. Describe each soil sample as outlined in the appropriate project records. Record descriptions in the field notebook and/or personal digital assistant (PDA). It is also beneficial to photo document the samples. It should be noted that PDA logs must be electronically backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used.

5. If it is necessary to install a monitor well into a permeable zone below a confining layer, particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel or stainless steel) is installed into the socket drilled into the top of the confining layer. The casing is then grouted in place. The preferred methods of grouting telescoping casings include: pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole. In all three cases, the casing is grouted to the ground surface, and the grout is allowed to set prior to drilling deeper through the casing. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.

6. Before installing a screened, it is important to confirm that the borehole has been advanced into the targeted saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

   To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and /or LNAPL, if applicable) in the borehole using an electronic water level probe, oil-water interface probe, or a new or decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, Rotasonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level. In low-permeability units like clay, fine-grained glacial tills, shale and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. Document depth to water in the borehole on the appropriate field forms and field notebook. If there are questions concerning the depth of the well/screen interval, consult with the project technical lead prior to finalizing well depth/screen interval. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. When in doubt, err on the side of slightly deeper well installation.

7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter (although sometimes 4-inch), flush-threaded PVC or stainless steel slotted or wire wrapped well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan (or equivalent) or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick

geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation and will (in most cases) be determined prior to the field mobilization.

The slot size and filter pack gradation should be predetermined in the Work Plan (or equivalent) or FSP and based on site-specific grain-size analysis (sieve analysis) or other geologic considerations or monitoring objectives. Typically, slot sizes for monitoring wells will range from 0.010 inches to 0.020 inches while the filter pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent filter pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent filter pack may be preferred. If the screen slot size and filter pack have not been based on site-specific grain-size analysis, consider collecting soil samples during well installation so future wells can be properly designed.

A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery/monitoring purposes. If so, the annular space around the sump may be backfilled with neat cement grout using a tremie to the bottom of the well screen prior to placing the filter pack around the screen. A blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centering the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica filter pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen (following specifications in the Work Plan) using a tremie. The filter pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. Verify that the expected volume of filter pack matches with the actual amount installed. There can be differences due to irregularities in the borehole. Washout of the borehole will result in the need for greater than calculated well materials. If a difference of more than 10% is noted, consult with the project technical team. The filter pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan (or equivalent) or FSP. The well should be gently surged to prevent filter pack material bridging and to settled the filter pack prior to well seal installation.

9. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack (alternatively, in some cases a fine sand seal may be installed instead of bentonite—follow the specifications in the Work Plan). If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. *No coated bentonite pellets will be used in monitoring well drilling or construction*. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure.

10. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 ft. below groundwater surface (bgs) or as specified in the Work Plan (or equivalent). As with the filter pack, it is recommended that seal material be placed with a tremie pipe. Ensure that seal materials are mixed at the proper ratios with water following manufacturer’s recommendations.

11. Install the monitoring well completion as specified Work Plan (or equivalent). Typical completions are a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well.
12. Monitoring wells should be labeled using indelible ink or paint with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.
13. When an above-grade completion is used, the riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the riser will be sealed using an unvented, expandable locking plug.
14. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook as well as appropriate field forms.
15. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 7 below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.
2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan (or equivalent). Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan (or equivalent) and/or FSP.
3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless steel slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Steps 9 through 11 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 12 above. During well installation, record construction details and tabulate materials used in field notebook as well as appropriate field forms.
5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 8 below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

8 WASTE MANAGEMENT

Investigation-derived wastes (IDW), including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan (or equivalent), FSP, and/or IDW management guidance document.

9 DATA RECORDING AND MANAGEMENT

Drilling activities should be documented on appropriate field/log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer’s tape will be used to determine approximate distances between important site features.

The well location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site Work Plan (or equivalent). Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 or 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

10 QUALITY ASSURANCE

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate SOP. Well materials will also be cleaned prior to well installation.

11 REFERENCES

American Society for Testing Materials (ASTM) D5092 - *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

American Society of Testing and Materials (ASTM) D1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

TGI – GROUNDWATER AND SOIL SAMPLING EQUIPMENT DECONTAMINATION

Rev: 0

Rev Date: February 23, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 23, 2017	ALL	Conversion from SOP to TGI	Cassandra McCloud / Pete Frederick

APPROVAL SIGNATURES

Prepared by: Derrick Maurer Date: 02/23/2017

Derrick Maurer

Technical Expert Reviewed by: Date: 02/23/2017

Cassandra McCloud (Technical Expert)

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

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In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project’s scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

Decontamination is performed on sampling equipment prior to sample collection to ensure that the sampling equipment that contacts a sample, or monitoring equipment that is brought into contact with environmental media to be sampled, is free from analytes of interest and/or constituents that could interfere with laboratory analysis for analytes of interest. Sampling equipment must be appropriately cleaned prior to use for sampling or coming into contact with environmental media to be sampled, and following completion of the sampling event prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The sampling equipment cleaning procedures described herein includes pre-field, in the field, and post-field cleaning of sampling equipment which may be conducted at an established equipment decontamination area (EDA) on site, as appropriate and necessary. Sampling equipment that may require decontamination at a given site includes: soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between each sample collected, and prior to placing sampling equipment in protective cases, or containers for transport. Cleaning procedures for sampling equipment should be monitored by collecting equipment blank samples as required in project work plans, field sampling plans, quality assurance project plans (QAPP), or other pertinent project documents. Dedicated and/or single-use (i.e., not to be re-used) sampling equipment will not require decontamination.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project health and safety plan (HASP) and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The equipment required for equipment decontamination is presented below:

- Health and safety equipment, including appropriate PPE, as required in the site Health and Safety Plan (HASP)
- Deionized water that meets that analytical criteria for deionized water with no detectable constituents above the reporting limits for the methods to be used and analytes being analyzed for. Deionized water is used for inorganics, and organic-free water for VOCs, SVOCs, pesticides, etc.
- Non-phosphate detergent such as Alconox or, if sampling for phosphorus or phosphorus-containing compounds, Liquinox (or equivalent).
- Tap water
- Rinsate collection plastic containers
- DOT-approved waste shipping container(s), as specified in the work plan, field sampling plan, or regulatory requirements if decontamination waste is to be shipped for disposal
- Brushes
- Large heavy-duty garbage bags
- Spray bottles
- (Optional) – Isopropyl alcohol (free of ketones) or methanol. These can be wipes or diluted with water (usually 1part isopropyl/methanol to 10 parts water) if a spray is needed.
- Airtight, sealable plastic baggies, such as Ziploc-type
- Plastic sheeting

5 CAUTIONS

Rinse equipment thoroughly and allow the equipment to dry before re-use or storage to prevent introducing solvent into sample medium. If manual drying of equipment is required, use clean lint-free material to wipe the equipment dry. Ensure all rinsate materials do not adversely affect sample collection efficiency or analytical results.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts. Properly containerize equipment to ensure cross-contamination doesn't happen from other uncontaminated surfaces or equipment.

If equipment is damaged to the extent that decontamination is uncertain due to cracks, gouges, crevices, or dents, the equipment should not be used and should be discarded or submitted for repair prior to use for sample collection.

A proper shipping determination regarding hazardous materials will be performed by a DOT-trained individual for cleaning materials shipped by Arcadis.

Caution should be exercised to avoid contact with the pump casing and water in the container while the pump is running (do not use metal drums or garbage cans) to avoid electric shock.

6 HEALTH AND SAFETY CONSIDERATIONS

Review the safety data sheets (SDS) for the cleaning agents and materials used in decontamination. If solvent is used during decontamination, use appropriate PPE and work in a well-ventilated area and stand upwind while applying solvent to equipment. Apply solvent in a manner that minimizes potential for exposure to workers and bystanders. Follow health and safety procedures outlined in the HASP.

7 PROCEDURE

A designated area will be established to clean sampling equipment in the field prior to and following sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location that expose equipment to contamination (i.e. exposed to combustion engine exhaust). Detergent solutions will be prepared in clean containers for use in equipment decontamination. Decontaminated equipment should be handled by workers wearing clean gloves, properly changed to prevent cross-contamination.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.
2. Wash with detergent solution (Alconox, Liquinox or equivalent) to remove all visible particulate matter and any residual oils or grease.
3. If equipment is very dirty, precleaning gross debris with a brush and tap water may be necessary.
4. If non-aqueous phase liquids are present, the use of isopropyl alcohol (free of ketones) or methanol is recommended. Cloth wipes or diluted solution can be used to remove the non-aqueous phase liquids that are hard to remove with detergent solution in step 2. Consult with project manager if

non-aqueous phase liquids are present onsite and design an appropriate decontamination procedure that includes step 4.

5. Rinse with deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps must be cleaned and flushed before and between uses. This cleaning process will consist of an external detergent solution wash and tap water rinse, a flush of detergent solution through the pump, followed by a flush of potable water through the pump. Flushing will be accomplished by using an appropriate container filled with detergent solution and another container filled with potable water. The pump should be flushed with deionized water as the last step prior to use. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Disconnect the pump from the power source before handling. The pump and hose should be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

8 WASTE MANAGEMENT

Equipment decontamination rinsate will be managed in conjunction with all other waste produced during the field sampling effort. Waste management procedures are outlined in the work plan or Waste Management Plan (WMP).

9 DATA RECORDING AND MANAGEMENT

Equipment cleaning and decontamination will be noted in the field notebook for project documentation. Information will include the type of equipment cleaned, the decontamination location, specific procedures utilized, solvents and/or cleaning agents used, source of water, and deviations or omissions from this TGI.

Unusual field conditions should be noted if there is potential to impact the efficacy of the decontamination or subsequent sample collection.

An inventory of the solvents brought on site and used and removed from the site will be maintained in the project documentation. Records will be maintained for solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

10 QUALITY ASSURANCE

Equipment blanks should be collected to verify that the decontamination procedures are effective in minimizing potential for cross contamination. The equipment blank is prepared by pouring deionized water (or organic-free water, for organic analyses) over the clean and dry tools and collecting the water into appropriate sample containers. Equipment blanks should be analyzed for the same set of parameters that are performed on the field samples collected with the equipment that was cleaned as specified in the sampling and analysis plan. Equipment blanks are collected per equipment set, which represents all of the tools needed to collect a specific sample.

11 REFERENCES

USEPA Region 9 - Field Sampling Guidance #1230, Sampling Equipment Decontamination.

USEPA Region 1 - Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

ARCADIS Design & Consultancy for natural and built assets

TGI - LOW-FLOW GROUNDWATER PURGING AND SAMPLING PROCEDURES FOR MONITORING WELLS

Rev: #0

Rev Date: October 12, 2018

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0	October 12, 2018	All	Updated and re-written as TGI with new branding and content	Marc Killingstad

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	Ryan McKinney	Date:
Technical Expert Reviewed by:		10/12/2018
	Marc Killingstad (Technical Expert)	Date:

1 INTRODUCTION

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2 SCOPE AND APPLICATION

Groundwater samples are collected from monitoring wells to evaluate groundwater quality. The protocol presented in this Technical Guidance Instruction (TGI) describes the procedures to purge monitoring wells and collect groundwater samples using the low flow purging/sampling methodology. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. Project teams will evaluate the last time the monitoring wells were developed and determine if additional development might be necessary. Water samples will not be taken immediately following well development. Sufficient time will be allowed for the groundwater flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, the groundwater sampling team will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP)/field sampling plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Additionally, the groundwater sampling team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

4 EQUIPMENT LIST

Specific to this activity, the following materials (or equivalent) will be used:

- Site-specific HASP and health and safety documents identified in the HASP
- Field Implementation Plan (FIP) that includes site map, well construction records, sampling plan (sample analyses, sample volume required, and sample holding time), and prior groundwater sampling records (if available)
- Field notebook and/or smart device (phone or tablet)
- Low-flow sampling field forms (**Attachment A**)
- Appropriate personal protective equipment (PPE) (e.g., latex or nitrile gloves, safety glasses, etc.) as specified in the HASP
- Well keys and other tools to remove manhole covers (manual torque wrench with 9/16” socket and flat head screwdriver typical)
- Photoionization detector (PID) or Flame ionization detector (FID) (as appropriate, depending on site-specific constituents of concern)
- Electronic water-level indicator (e.g., Solinist Model 101) or oil/water interface probe with 0.01-foot accuracy (oil/water as appropriate, note that sampling will not be performed when sheen or light non-aqueous phase liquid [LNAPL] is present)
- Down-hole multiparameter water-quality sonde (temperature/pH/specific conductivity/oxidation reduction [ORP]/turbidity/dissolved oxygen) meter and flow-through measurement cell; for example:

  - YSI 6-Series Multi-Parameter Instrument
  - Horiba U-22 Multi-Parameter Instrument.
  - Hydrolab Series 3 or Series 4a Multiprobe and Display.
- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment from contact with potential sources of contamination.
- Decontamination equipment
  - Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the present items are clean
  - Distilled or de-ionized water for equipment decontamination
- Indelible ink pen
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Sampling pump, which may consist of one or more of the following:
  - Submersible pump (e.g., Grundfos Redi-Flo 2)
  - Peristaltic pump (e.g., ISCO Model 150)
  - Bladder pump (e.g., Marschalk System 1, QED Micropurge, Geotech)
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery
  - Submersible pumps such as Grundfos require a pump controller to run the pump
  - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N2 or CO2 gas cylinders)
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used
  - For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will be used through the pump apparatus
  - Teflon® will not be used when sampling for per- and polyfluoroalkyl substances (PFAS)
- Graduated cylinder and stop watch or other device to measure time to determine pumping rate
- Appropriate water sample containers (supplied by the laboratory)
- Appropriate blanks (trip blank supplied by the laboratory)
- Sample labels and Chain-of-Custody forms (COC)
- 0.45-micron disposable filters (if field filtering is required)

- A supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020) may be required for specific projects and will be specified in the project FIP/ work plan and the kick-off notes.
  - If used, in-line 'T' and valve allows for collection of water for turbidity measurements before the pump discharge enters the flow-through cell

NOTE: *The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.*

5 CAUTIONS

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. It is the responsibility of the Project Team (Project Manager and Technical Lead) to be fully aware of the requirements from the applicable regulatory framework.

Weather

- If heavy precipitation occurs, and no cover over the sampling area and monitoring well can be erected, sampling may be discontinued until adequate cover is provided. Rain water could compromise groundwater samples.
- Avoid extreme weather situations. Be aware that thermal currents and vertical mixing of cold and warm water inside the well casing could create a convection cell within the well and compromise data collection (e.g., biological mechanisms).
  - Direct sunlight and hot ambient temperatures may cause the groundwater in the tubing or flow-through-cell to heat up and de-gas. This may result in the loss of volatile organic compounds (VOCs) and dissolved gases. Shade the equipment from direct sunlight, keep the tubing as short as possible, and avoid the hottest times of the day.
  - Sampling during freezing conditions may adversely impact the data quality objectives. USEPA recommends low-flow sampling be conducted at air temperatures above 32°F (0°C) or taking special precautions to prevent groundwater from freezing in the equipment.

Cross-Contamination

- To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, collect samples in order of up-gradient, then furthest down-gradient to source area locations.
- Note that permanent markers could introduce volatile constituents into the samples; *therefore, indelible ink is recommended* to be used for labels on sample containers or sample coolers.
- When using a gasoline generator, this power source will be set-up at least 30 feet downwind from the well to avoid exhaust fumes to contaminate samples.

Pumps

- Preferred methods of extracting groundwater are adjustable rate, submersible pumps - such as centrifugal pumps or bladder pumps – constructed of stainless steel or polytetrafluoroethylene (PTFE, i.e. Teflon®). However, *PTFE will not be used when sampling for per- and polyfluoroalkyl substances (PFAS). PTFE could contain PFAS*.
- When using a bladder pump for collecting VOCs and dissolved gases, "best practice" is to set-up the pump to deliver sufficient water to fill a 40 mL VOC vial.
- The use of peristaltic pumps will be based on the type of data to be collected. *Because the use a peristaltic pump can result in de-gassing of VOC and / or dissolved gases from groundwater, a different type of pump will be considered if these compounds are of concern.*
- *Manual or motor driven inertial pumping devices are not recommended because they cause greater disturbance during purging and pumping than regular pumps and are less easily controlled. This could cause a higher degree of data variability.*

Tubing

- When sampling for VOCs, SVOCs, pesticides, PCBs and inorganics, use of PTFE (Teflon®) or PTFE-lined tubing is preferred. However, PTFE tubing will not be used when sampling for PFAS.
- PVC, polypropylene or polyethelene tubing may be used when sampling for metals or other inorganics.
- Tubing with inside diameters of 1/4 or 3/8 inch is recommended because this will help ensure tubing remains water filled when operating at very low pumping rates.

General Precautions

- Store and/or stage empty and full sample containers and coolers out of direct sunlight.
- It may be necessary to field filter the groundwater for some parameters (e.g., metals) during collection, depending on preservation, analytical method, and project quality objectives. The task-kick-off notes and the FIP/work plan will list the samples that require field filtering.
- Be careful not to overtighten lids with Teflon® liners or septa (e.g., 40 mL vials). Over-tightening can cause the glass to shatter or impair the integrity of the Teflon® seal.

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel.

Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and the site-specific HASP.

Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work.

Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or non-aqueous phase liquid (NAPL) (e.g., oil). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife)—open well caps slowly and keep face and body away to allow to vent any built-up pressure; only use non-toxic peppermint oil spray for stinging insect nests; review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives, and use appropriate hand protection.

Generators and cord and plug equipment will employ an overcurrent protection device such as an integrated ground fault circuit interrupter (GFCI) cord. Grundfos pump controllers will not run properly with a GFCI, so the power source will be equipped with other overcurrent protection means.

Overtightening of lids with Teflon® liners can cause the glass to shatter and create a risk for hand injuries.

7 PROCEDURE

Field personnel will set up and perform low-flow sampling in accordance with the following procedures.

1. Review FIP and groundwater sampling records from previous sampling events (if available) prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for each well to perform sampling as efficiently as possible (i.e., reach a stabilized pumping condition)
2. Calibrate field instruments according to manufacturer procedures for calibration and record calibration procedure and results in field log
3. All equipment will either be new or decontaminated in accordance with appropriate guidance document (*TGI – Groundwater and Soil Sampling Equipment Decontamination)* prior to use
4. Visually inspect the well to ensure that it is undamaged, properly labeled and secured
    a) Damage or other conditions that may affect the integrity of the well will be recorded in the Field Activity Daily Log and brought to the attention of the designated Field Manager and/or Project Manager
    b) Record well construction and conditions on the Low-Flow Sampling Field Form (**Attachment A**)
5. Place clean plastic sheeting on the ground near the well to keep monitoring and sampling equipment off the surface unless the equipment is elevated above the ground (e.g. on a table).
6. Open the well cover while standing upwind of the well. Remove the well cap and place it on the plastic sheeting. If appropriate or required for site-specific conditions, insert the photoionization detector (PID) probe approximately 4 to 6 inches into the casing or the well headspace and cover it with a gloved hand. Record the PID reading in the field log. Perform air monitoring in the breathing zone according to the HASP and/or JSA.
7. Measure and record the initial depth to groundwater prior to placing the pumps
8. Prepare and install the pump in the well

NOTE: *Groundwater will be purged from the wells using an appropriate pump. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet below ground surface), a* *submersible or bladder pump will be used, provided that the well is constructed with a casing diameter of at least two (2) inches (the minimum well diameter capable of accommodating such pumps). For smaller diameter wells, where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) will be used to purge and sample the groundwater. Bladder pumps are preferred over peristaltic and submersible pumps to prevent volatilization if sampling of VOCs and/or dissolved gasses is required. Purge water will be collected and containerized according to the direction of the project team.*

a) For submersible and non-dedicated bladder pumps, decontaminate the pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new bladder and attachment of an air-line, sample discharge line, and safety cable prior to placement in the well. Attach the air-line tubing to the air-port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Take care not to reverse the air and discharge tubing lines during bladder pump setup, as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of pump (if present, depending on pump model used). Slowly lower the pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering the pump into the well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well, as this could lead to unintended contamination.

b) If using a bladder pump, connect the air-line to the pump controller output port. The pump controller will be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon® tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller power (if an on/off switch is present) and verify that all batteries are charged and fully functioning before starting the pump.

c) If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least two (2) feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

d) If using an in-line ‘T’ and valve, install between pump discharge water line and the bottom inlet port of the flow-through cell. Attach a short piece of tubing to the outlet. This set-up will be used to collect samples for turbidity readings.

9. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the water quality meter.

10. Before starting the pump, ensure that the water level inside the well has stabilized (i.e., measure the water level multiple times after deploying the pump in the well)

11. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified) and adjust the pumping rate to cause little or no water level drawdown in the well (less

than 0.3 feet below the initial static depth to water measurement): the water level should stabilize, however, this is not always possible.

12. If the well diameter is of sufficient size, measure the water level every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping
13. Maintain a steady flow rate to the extent practicable and do not break pump suction or cause entrainment of air in the sample
14. Record pumping rate adjustments and depths to water

    If necessary, reduce pumping rates to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters; if the recharge rate of the well is very low, use alternative purging techniques, which will vary based on the well construction and screen position:

    For wells screened across the water table, the well may be pumped dry and sampling can commence as soon as the volume in the well has recovered sufficiently to permit collection of samples

    For wells screened entirely below the water table, the well can be pumped until a stabilized level (which may be greater than the maximum displacement goal of 0.3 feet) is maintained and monitoring for stabilization of field indicator parameters can commence; if a lower stabilization level cannot be maintained, the well may be pumped until the drawdown is at a level slightly higher than top of the well screen

15. The sampling process may commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples
16. After water levels have stabilized and a sufficient volume has been purged, continue pumping and begin monitoring field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, ORP, and dissolved oxygen [DO]) every 3 to 5 minutes (or after each volume of the flow-through cell has been purged or other appropriate interval) using a flow-through analytical cell or a clean container such as a glass beaker and collect samples for turbidity readings using the T-valve
17. Record field indicator parameters on the groundwater sampling log
18. The well is considered stabilized and ready for sample collection when three consecutive readings are within the following limits:
    - **Turbidity** within ± 10% for values greater than 5 nephelometric turbidity unit [NTU] or if three turbidity values are less than 5 NTU, consider the values as stabilized;
    - **Dissolved Oxygen (DO)** within ± 10% for values greater than 0.5 mg/L or if three DO values are less than 0.5 mg/L, consider the values as stabilized;
    - **Specific Conductance** within ± 3%;
    - **Temperature** within ± 3%;
    - **pH** within ± 0.1 unit;
    - **Oxidation/Reduction Potential (ORP)** within ±10 millivolts (mV);

NOTE: *Alternate stabilization goals may exist in different geographic regions, consult the site-specific FIP/work plan for stabilization criteria).*

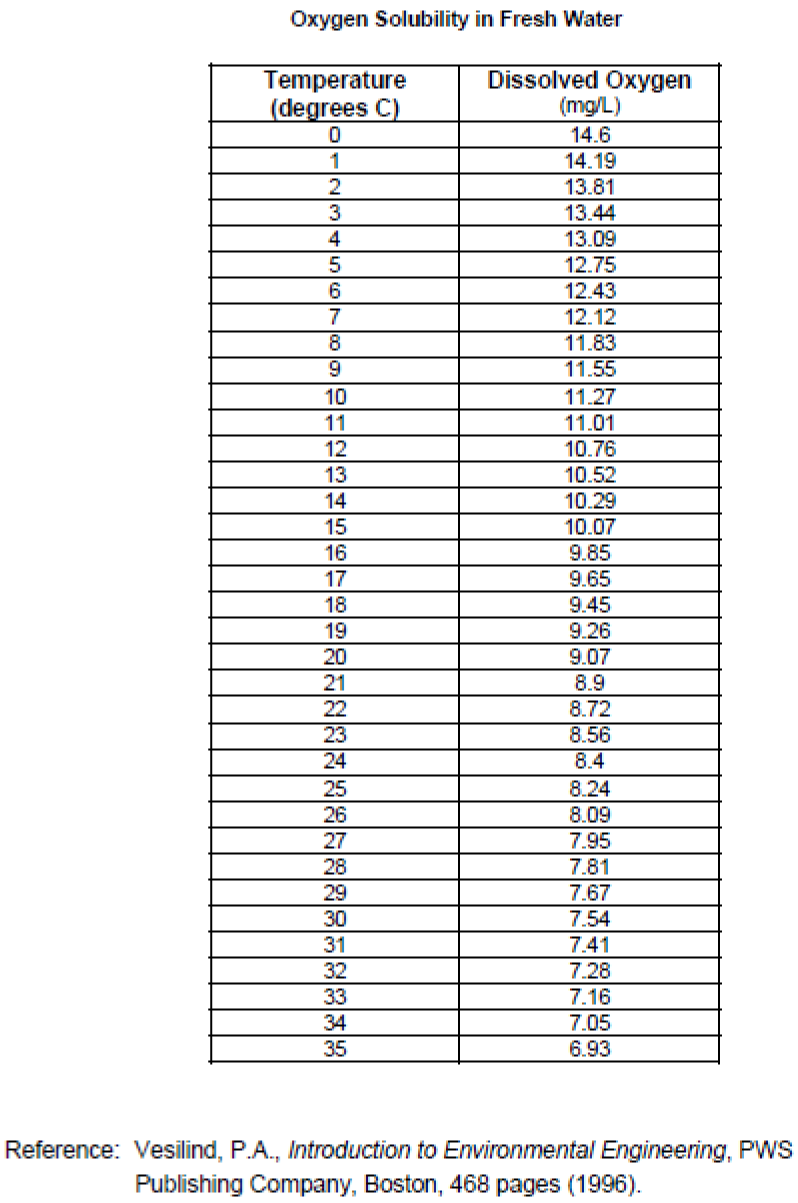
NOTE: *If the parameters have stabilized but turbidity remains relatively high (e.g., greater than 50 NTU), the pump flow rate may be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible.*

NOTE: *If field indicator parameters do not stabilize within one (1) hour of the start of purging, but the groundwater turbidity has been minimized (i.e., within ± 10%) and the values for all other parameters are within ± 10%, the well may be sampled; however, consult specifications in the FIP/work plan and/or the project technical lead.*

NOTE: *DO is extremely susceptible to various external influences (including temperature or the presence of bubbles on the DO meter); therefore, great care will be taken to minimize the agitation or other disturbance of water within the flow-through cell while collecting these measurements. If air bubbles are present on the DO probe or in the discharge tubing, remove them before taking a measurement. If DO values are not within acceptable range for the temperature of groundwater, again check for and remove air bubbles on the probe before re-measuring. The table below may be used as a general guide for DO values under various temperatures; however, understand that groundwater contaminants may affect oxygen solubility. If DO value is 0.00 or less, then the meter will be serviced and re-calibrated. If DO values are above possible results, then the meter will be serviced and re-calibrated.*

NOTE: *During extreme weather conditions, stabilization of field indicator parameters may be difficult to attain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field logbook/on the sampling form.*

NOTE: *If other field conditions are suspected of preventing stabilization of certain parameters, observations will be documented in the field logbook/on the sampling form.*



Oxygen Solubility in Fresh Water

Temperature (degrees C)	Dissolved Oxygen (mg/L)
0	14.6
1	14.19
2	13.81
3	13.44
4	13.09
5	12.75
6	12.43
7	12.12
8	11.83
9	11.55
10	11.27
11	11.01
12	10.76
13	10.52
14	10.29
15	10.07
16	9.85
17	9.65
18	9.45
19	9.26
20	9.07
21	8.9
22	8.72
23	8.56
24	8.4
25	8.24
26	8.09
27	7.95
28	7.81
29	7.67
30	7.54
31	7.41
32	7.28
33	7.16
34	7.05
35	6.93

Reference: Vesilind, P.A., *Introduction to Environmental Engineering*, PWS Publishing Company, Boston, 468 pages (1996).

19. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container

20. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container

    a) If a flow-through analytical cell is being used to measure field parameters, the flow-through cell will be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection

    b) Under no circumstances will analytical samples be collected from the discharge of the flow-through cell

   c) If an in-line ‘T’ and valve are used, the valve needs to be removed as well
   d) Samples will be collected in the following order: VOCs, total organic carbon (TOC), semi-volatile organic compounds (SVOCs), metals and cyanide, and others (or other order as defined in the site-specific FIP/work plan)
   e) When the container is full, tightly screw on the cap

21. If sampling for total and filtered metals and/or polychlorinated biphenyls (PCBs), a filtered and unfiltered sample will be collected
   a) Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected
   b) Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL)
   c) Collect the filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container
   d) When the container is full, tightly screw on the cap
22. Secure with packing material and store the samples on ice (targeting 4° Celsius) in an insulated transport container provided by the laboratory and include a temperature blank in each container to be shipped
23. Record on the Low-Flow Sampling Field Form (and bound field logbook) the time at which sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging (see **Attachment A**)
24. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump setup
25. Slowly remove the pump, tubing, lines, and safety cable from the well
   a) If using dedicated tubing, do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them
   b) If using dedicated tubing, it will be folded - without pinching it - to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events.
   c) Use a length of rope or string to tie the tubing to the well cap
   d) Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date, coil the tubing neatly and placed in a clean plastic bag that is clearly labeled with the well ID ensuring the bag is tightly sealed before placing it in storage
26. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment
27. Complete the procedures for packaging, shipping, and handling with the associated Chain-of-Custody

28. Complete decontamination for flow-through analytical cell and submersible or bladder pump, as appropriate (*TGI – Groundwater and Soil Sampling Equipment Decontamination*)
29. At the end of each day of the sampling event, perform calibration check of field instruments and record procedure and results in field log

8 WASTE MANAGEMENT

Materials generated during groundwater sampling activities, including disposable equipment and excess purge water, will be stored on site in appropriately labeled containers and disposed of properly. Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log book.

9 DATA RECORDING AND MANAGEMENT

Management of the original documents from the field will be completed in accordance with the site-specific QAPP.

In general, forms (e.g., Low-Flow Sampling Field Forms), logs/notes (including daily field and calibration logs), digital records, and Chain-of-Custody records will be maintained by the field team lead.

Field logs and Chain-of-Custody records will be transmitted to the Arcadis Project Manager and/or Task Manager, as appropriate, at the end of each day unless otherwise directed. Electronic data files will be sent to the project team and uploaded to the electronic project folder daily.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

10 QUALITY ASSURANCE

Quality assurance procedures will be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

Unless described otherwise in the project-specific FIP/work plan, QAPP, or Sampling and Analysis Plan, quality assurance/quality control samples will be collected as follows:

- One duplicate for every 10 samples
- One laboratory matrix/matrix spike sample for every 20 samples

In addition to the quality control samples to be collected in accordance with this TGI, the following quality control procedures will be observed in the field:

- Collect samples from monitoring wells, in order of increasing concentration, to the extent known based on review of historical site information if available
- Equipment blanks will include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well)

- Collect equipment blanks after wells with higher concentrations (if known) have been sampled
- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures—calibrate instruments at the beginning of each day, verify the calibration at the end of each day, and record all calibration activities in the field notebook
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well following the procedure for equipment decontamination

11 REFERENCES

USEPA. 1986. *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (September 1986).

USEPA. 1991. *Handbook Groundwater, Volume II Methodology*, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July 1991).

USEPA Region I. 2017. *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

U.S. Geological Survey (USGS). 1977. *National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination*. Reston, Virginia.

12 ATTACHMENTS

Attachment A - Low-Flow Sampling Field Form

ATTACHMENT

Attachment A - Low-Flow Sampling Field Form

LOW-FLOW GROUNDWATER SAMPLING FORM

ARCADIS

Page ____ of ____

Project No. ________________ Well ID ________________ Date ________________

Project Name/Location ________________________________ Weather ________________

Measuring Pt. Description ________________ Screen Setting (ft-bmp) ________________ Casing Diameter (in.) ________ Well Material ____ PVC ____ SS

Static Water Level (ft-bmp) ________________ Total Depth (ft-bmp) ________________ Water Column (ft) ________ Gallons in Well ________

MP Elevation ________________ Pump Intake (ft-bmp) ________________ Purge Method: ________________ Sample Method ________________

Centrifugal ________________

Submersible ________________

Other ________________

Pump On/Off ________________ Volumes Purged ________________

Sample Time: Label ________________ Gallons Purged ________________

Purge Start ________________ Replicate/ Code No. ________________ Sampled by ________________

Purge End ________________

Time	Minutes Elapsed	Rate (gpm)/(mL/min) 200mL/min +	Depth to Water (ft) -0.3	Gallons Purged	pH ± 0.1	Cond. (μMhos)/(mS/cm) ± 3%	Turbidity (NTU) ± 10%	DO (mg/L) ± 10%	Temp. (°C)/(°F) ± 3%	Redox (mV) ± 10mV	Appearance	
											Color	Odor
Stabilization Calculations (±)												
Stabilization Criteria					**± 0.1 s.u.**	**±3%**	**± 10% or within 1 NTU [1]**	**± 10%**	**±3%**	**±10 mV**		

(1) **Turbidity** < 50 NTU and ±10% or within 1 NTU of a previous reading when <10 NTU

Constituents Sampled	**Container**	**Number**	**Preservative**

Comments ________________________________

Well Casing Volumes

Gallons/Foot	*1" = 0.04*	*1.5" = 0.09*	*2.5" = 0.26*	*3.5" = 0.50*	*6" = 1.47*
	1.25" = 0.06	*2" = 0.16*	*3" = 0.37*	*4" = 0.65*	

Well Information

Well Location: ________________ Well Locked at Arrival: Yes / No

Condition of Well: ________________ Well Locked at Departure: Yes / No

Well Completion: Flush Mount / Stick Up Key Number To Well:

TGI - Manual Water-Level and NAPL Monitoring

Rev: 2

Rev Date: April 5, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
0	0	October 11, 2018	All	Updated and re-written as TGI	Marc Killingstad Everett H. Fortner III
1	1	May 8, 2020	All	Updated and added NAPL gauging	Marc Killingstad Everett H. Fortner III Andy Pennington
2	2	April 5, 2022	All	Formatting and Revisions	Martha Wulftange

Approval Signatures

Prepared by:		4/5/2022
	Everett H. Fortner III, PG (Preparer)	Date
Reviewed by:		4/5/2022
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

This TGI describes the equipment, field procedures, materials, and documentation procedures to measure and record water-levels using an electronic water-level probe or an oil-water level indicator. This TGI also describes procedures for measuring in-well thicknesses of non-aqueous phase liquid (NAPL), both light and/or dense (LNAPLs and DNAPLs, respectively).

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM’s responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project’s scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to measure and record water-levels (groundwater and surface-water) using manual water-level meters. Water levels may be measured using an electronic water-level probe or an oil-water level indicator from established reference points (e.g., top of casing). Reference points must be surveyed to evaluate fluid level elevations relative to a vertical datum (e.g., North America Vertical Datum of 1988 [NAVD88] relative to sea level). This TGI also describes procedures for measuring in well thickness of NAPL and DNAPLs.

Surface water-levels can be measured from stilling wells or fixed points (bridges, walls, etc.) and measuring from an established point of reference using a water-level meter. In some cases, surface water water-levels may be determined from a graduated stream gauge, attached to a pole located in open water with known elevation, without the use of a water-level meter.

The use of pressure transducers or other automated devices for the collection of groundwater elevation data will be subject of *TGI – Water-Level Monitoring using Pressure Transducers and TGI – Water-Level Measurements using Sonic Meters.*

4 Personnel Qualifications

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The following field equipment is suggested for water-level measurements:

- Site-specific Health and Safety Plan (HASP)
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Electronic water-level indicator graduated in 0.01 ft. increments
- Electronic oil-water (interface) level indicator graduated in 0.01 ft. increments, if necessary
- Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs.
- Distilled or de-ionized (required for some sites) water for equipment decontamination
- Photoionization detector (PID) and/or organic vapor analyzer (optional)
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement) – if required for total depth measurements of deeper wells
- Solvent (methanol/acetone/isopropyl alcohol) rinse – optional
- Spray bottle for solvent - optional
- Plastic drop cloth (e.g. Weatherall Visqueen) to place beneath the buckets or tubs to reduce potential for contamination of the tape or probe
- Tools and/or keys required for opening wells
- Well construction summary table and/or well construction logs
- Summary table of previous water-level measurements
- Field notebook and/or smart device (phone or tablet) or appropriate field forms (see Attachment 1).
- Indelible ink pen

6 Cautions

Electronic water-level indicators and oil-water interface probes may sometimes produce false-positive readings. For example, if the inside casing surface of the well or stilling tube has condensation above the water level, then an electronic water-level probe may produce a signal by contacting the sidewall of the well, rather than the true water-level surface. For accuracy, the electronic water-level probe and/or interface probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a fluid interface to verify consistent, repeatable results (three or more times). Additionally, some wells may be constructed with a sump. If local/regional groundwater levels have declined such that the water-level is below the base of the well screen, a sump may still contain water and provide an erroneous measurement. Therefore, possessing and comparing measurements with a well construction summary table or well construction log is recommended for proper reporting.

If the presence of a NAPL is known or suspected within specific wells, do not use an electronic water- level indicator. Use an oil-water interface probe instead. If NAPL presents ignition or explosion hazards, an intrinsically safe oil-water interface probe is required to be used with grounding and following the manufacturer’s instructions.

If the NAPL is known to be very viscous or problematic to gauge, the data quality will require additional consideration prior to measuring. Staff will consider the data quality objectives for the gauging activity – e.g., if quantifying NAPL thickness is necessary, or if assessing the presence/absence is sufficient.

Alternate NAPL measurement methods (such as using drop pipes or temporary coatings for down-well equipment) may be considered.

When measuring total well depths with an electronic water-level indicator, the measurement must have a correction factor applied for post processing or completed at the time of measurement that is equal to the length of the probe beneath the circuit closing electrodes (if applicable to the instrument). This is necessary because the tape distance markings are referenced to the electrode, rather than the end of the probe. Some newer instruments do not have an offset electrode and this correction factor is needed. In addition, total depth measurements are difficult with wells that have large water columns due to buoyancy issues. In addition, the total depth measurement will include notes that indicate a soft or hard bottom if recognized during the measurement.

Ensure that the type of electronic water-level indicator is compatible with the depth and diameter of the wells to be measured. Some smaller piezometers or larger diameter well stilling tubes will accommodate only smaller diameter probes.

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or oil. Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife). Appropriate personal protective equipment (PPE) will be worn during these activities. Only use non-toxic peppermint oil spray for stinging insect nests. Open well caps slowly and keep face and body away to allow to vent any built-up pressure. Field personnel will thoroughly review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives.

Obtaining measurements from active pumping wells requires knowledge of the construction and design, as the indicator probe and tape can become intertwined within down-well equipment (such as pump impellers) causing a serious health and safety hazard and equipment damage. Ensure that stilling wells have a perforated end and capped bottom to inhibit tape from extending into the downhole pump depth. If a stilling tube is not present or the still tube construction is not known, determine a conservative “not to exceed” measurement depth based on the top of pump depth with an added safety factor. If all information is not known, a water-level will not be taken from the pumping well until clarification on depths are available.

8 Procedure

Calibration procedures and groundwater level measurement procedures for electronic water-level indicators and oil-water indicators are described in the sections below. Calibration documentation can berequested from the rental or manufacturer.

Calibration Procedures

If the indicator requires length and markings verification is required by project data quality plan or other reasons, then the following steps may be used:

- Measure the lengths between each increment marker on the indicator with a measuring tape. The appropriate length of indicator measuring tape, suitable to cover the depth range for the wells of interest, will be checked for accuracy.
- If the indicator measuring tape is inaccurate, the probe will require to be sent back to the manufacturer or rental company. If a replacement can’t immediately be available, then an offset can be measured to correct the measurements.
- If multiple water-level indicators and/or oil-water interface probes are being used for an event, calibration of the multiple devices will be required by measuring a water-level at a single well contemporaneously with all indicators to be used and calculated correction factors provided for data processing (typical corrections are small and range from 0.01 to 0.03 foot).
- Equipment calibration will be recorded in the field logbook and/or smart device.

Water-Level Measurement Procedures

The general procedures to be followed for the collection of fluid level measurements and well depths from the monitoring wells are as follows:

- Check that the water-level/oil-water level indicator battery is functional, before mobilization and prior to each work day (e.g., turn power on and check that meter sounds when probe is lowered into a bucket of water – note that water-level meters will not work with low-electrical-conductivity liquids such as distilled water).
- Record instrument make, model, serial number, and (if present) Arcadis ID number in the field form or electronic field form.
- Don disposable nitrile gloves. Decontaminate the water-level/oil-water indicator, any attached tape and the spool with laboratory-grade soap and distilled water (see Initial Decontamination Procedures below). The spool requires caution with cleaning as it is not water-proof and can be damaged during cleaning.

- The top of the monitoring well will be cleaned with a clean rag to prevent loose particulate matter from falling into the well.
- Perform a well inspection (note that a well inspection form may be required to be filled out along with a photo to document the conditions).
- Place clean plastic sheeting on the ground next to the well.
- Unlock and/or open the monitoring well cover while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps – see Section 6).
- Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading (if applicable and requirement for the site).
- Allow the water-level in the well to equilibrate with atmospheric pressure for a few minutes (check previous field forms or field books for equilibration time, if noted).
- Locate the measuring reference point that correlates to the survey point on the well casing. If one is not found, make a reference point by notching the highest and/or north point on the inner casing (or outer if an inner casing is not present) or mark with a permanent mark. All downhole measurements will be taken from the reference point. Document any changes or new reference point addition.
- Measure to the nearest 0.01 foot and record the height of the inner well casing and outer protective casing to ground level (note that some well pads are raised and are not at true ground surface).
- Lower the indicator probe into the center of the well until contact with the water surface is indicated by either an audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. Use and install a tape guide (available from some manufacturers) to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does rub on the inner or outer casing which could fray and damage the tape.
- If an oil-water interface probe is being used to measure depth and thickness of NAPL, lower the interface probe into the center of the well until a contact with the NAPL surface is indicated by either audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. To gauge the water level in a well which contains LNAPL (LNAPL-water interface), advance the interface probe past the LNAPL-water interface until the probe produces a solid audible alarm indicating water. While slowly retrieving the probe upward, the equipment will produce a different tone when the LNAPL-water interface is reached (typically this is a multiple alarm sound or flashing light). This level should represent the depth to water. The depth indicating the bottom of the water column and top of DNAPL layer, if any, is indicated by the multiple alarm signal or flashing light emitted by the interface probe.
- Hold the tape at the measuring point and repeat the measurement two more times.
- Read and record measurement to the nearest 0.01 foot. Check the measurement with previous measurements, if available, and note any anomalies/discrepancies; if significant, contact the project staff.

- Measure and record total depth of well (see Total Depth Measurement Procedures below); note that measurement of total depth is not always performed at wells containing LNAPL or DNAPL, in order to reduce decontamination of the instrument and reduce potential exposure to NAPL.
- Record all measurements (with date and time collected to the nearest minute) and note any inconsistencies/anomalies and relevant observations in the field notebook and/or smart device or appropriate field forms.
- Follow decontamination procedure outlined below before measuring subsequent wells (see
- Decontamina*tion after Water Level and Total Depth Measurements* below).
- Replace cap and lock the well when all activities are completed.

Total Depth Measurement Procedures

- Weighted tape or electronic water-level indicator can be used to measure the total well depth.
- Follow initial procedures noted above in Water-Level Measurements above.
- Lower indicator probe (or tape) until weighted end is resting on the bottom of the well. Raise indicator slowly until there is no slack in the tape. Gently estimate the bottom of the well by slowly raising and lowering the indicator: great care should be taken to avoid damaging the sensor on the probe. The operator may find it easier to allow the weight to touch bottom and then detect the 'tug' on the tape while lifting the weight off the well bottom.
- Because of tape buoyancy and weight effects encountered in deep wells with long water columns, it may be difficult to determine when the probe is in contact the bottom of the well and sediment in the bottom of the well can also make it difficult to determine total depth. Care must be taken in these situations to ensure accurate measurements.
- If total depth measurements are to be collected during low-flow sampling events, the measurement will be made only after low-flow sampling has been completed or at least 12 hours prior to initiating sample collection from the well, in order to minimize: 1) mixing of the stagnant water at the top of the well column with potential formation water underneath; and/or 2) agitation and subsequent entrainment of possible sediment collected at the well bottom).
- Read and record measurement to the nearest 0.1 foot. Please refer to the note regarding total depth measurements described in Section 5 Cautions above.
- Follow decontamination procedure outlined below before gauging the next well (see Decontaminationafter *Water Level, NAPL Level, and Total Depth Measurements* below).

Initial Decontamination

- Note that there may be project specific decontamination procedure documents that will be followed in lieu of the below procedures.
- Set up a decontamination station consisting of three clean buckets (e.g., 5-gallon buckets). The buckets should not be used to containerize purge water; they will be used for decontamination purposes only.
- Fill the first bucket with one gallon of distilled water (use deionized water if metals are a contaminant at the site) and add non-phosphate laboratory-grade soap. Fill the second bucket

with distilled water (use deionized water if metals are a contaminant at the site) and leave the third bucket empty. Place the drop cloth underneath.

- Unwind the entire tape from the spool into a bucket with non-phosphate laboratory-grade soap and distilled water; Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Carefully brush all dirt of the spool and wipe down with a soapy cloth or paper towel.
- Transfer the tape into the second bucket containing rinse water. Carefully brush the tape using a second brush, dedicated to the rinse bucket. Lift the tape out of the bucket and allow rinse water to drip off the tape.
- Transfer the tape to the third bucket. Wind the tape onto the spool while wiping excess water off the tape using a paper towel.

Decontamination after Water Level, NAPL Level, and Total Depth Measurements

- Set up a decontamination station consisting of three clean buckets, fill according to the initial decon procedure.
- Unwind the only the length of tape used for gauging from the spool into a bucket with laboratory-grade soap and distilled water. Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Continue as described above.
- Extra care should be taken to clean the probe after a total depth measurement. All sediment or dirt needs to be removed during decontamination.
- If an oil-water interface probe is used to gauge NAPL, a solvent may be necessary to remove all NAPL residue. After decontaminations steps above, use a spray bottle filled with chosen solvent (ex. isopropyl alcohol) and spray across all surfaces of the tape. Use paper towels to wipe off solvent and/or residue. This step may be repeated if necessary.

Notes:

- Collect equipment blanks if required by the work plan (minimum 1 per 20 samples or 1 per sampling event).
- Prepare new wash solution and rinse water when necessary (e.g., every 10 to 20 wells). The spent wash and rinse solution should be discharged according to site practices.
- The decontamination station may be expanded by adding extra rinse and/or detergent stations (i.e., solvent wash station) to the set up. The addition of more stations depends on the requirements of the work plan or the site-specific Field Sampling and Quality Assurance Plan and outlined in the project field plan or kick-off meeting.
- Small crates or washtubs are a possible substitute for the buckets. In any case, it is recommended to use containers with a lid.

9 Waste Management

Decontamination fluids, PPE, and other disposable equipment will be properly stored on site in labeledcontainers and disposed of properly. Be certain that waste containers are properly labeled and documented in the field log book. Review *TGI – Investigation Derived Waste Handling and Storage*, foradditional information and state- or client-specific requirements.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If paper forms are used, fluid level measurements as well as all relevant observations should be documented in the field logbook, field forms and/or PDA as appropriate. The following information must be documented:

- Well or location identification;
- Measurement time;
- Total well depth or depth of the water body at the location;
- Depth to water and, where necessary, depth to NAPL.

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical Lead for notification. A summary of the work completed that day and any relevant observations noted (such as well inspections) during the daily activities as well as copies of the data mentioned above should be included with the email. The appropriate team member will review the datafor accuracy and provide feedback.

11 Quality Assurance

Suggested quality control measures are below; project teams may implement some or all of these at their discretion and based on project data quality needs.

- As described in the detailed procedure, the electronic water-level meter and/or oil-water interfaceprobe can be calibrated prior to use versus an engineer’s rule to ensure accurate length demarcations on the tape or cable. The results will be recorded.
- Measurements will be completed three times, with the final measurement recorded.
- Fluid interface measurements will be verified by gently raising and lowering the instrument through each interface to confirm repeatable results.

- Field notes will be reviewed by the project team once the field data has been delivered.

12 References

Cunningham, W.L., and Schalk, C.W., comps., 2011. *Groundwater technical procedures of the U.S.Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 pp*.

U.S. Environmental Protection Agency, 2013. *SESD Operating Procedure, Groundwater level and WellDepth Measurement.* January 29.

TGI – Sample Chain of Custody

Rev: 3

Rev Date: March 28, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	April 19, 2017	All	Re-write to COC only	Richard Murphy
	1	May 23, 2017	4,7,9	Add: Guidance on use of previous version of TGI. Add: Info on COCs for multiple shipping containers Modify: Move letter i. to letter m. and change to "when appropriate"	Peter Frederick
	2	April 29, 2020	4, 11	Remove obsolete link	Lyndi Mott
	3	December 28, 2022	All	Updated Arcadis format Added to 6c. Collection time between COC and container must match. Added to 6o. Add name of overnight courier when relinquishing samples. Updated reference documents and added internet links.	Lyndi Mott

Approval Signatures

Prepared by:		3/28/2022
	Lyndi Mott (Preparer)	Date
Reviewed by:	Dennis K. Capria	3/28/2022
	Dennis Capria (Chain of Custody Reviewer)	Date
Reviewed by:		12/22/2021
	Lyndi Mott (Subject Matter Expert)	Date

1 Introduction

This Technical Guidance Instruction (TGI) provides the procedure for Arcadis field personnel for required documentation during the collection of environmental field samples and transfer of custody to a laboratory. It provides direction for completion of the Chain of Custody form that must accompany collected field samples for analysis by a laboratory.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM’s responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project’s scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

This TGI describes the general Chain of Custody (COC) procedures and guidance instructions for samples collected from project sites that are relinquished from Arcadis’ possession.

COC is defined as the maintenance of an unbroken record of possession of an item from the time of its collection through some analytical or testing procedure. COC is typically documented by a written record of the collection, possession, and handling of samples collected from a project location. Each sample will be tracked by a documented record that efficiently documents the individuals who were responsible for the sample during each successive transfer of that sample to various recipients beyond Arcadis’ possession. This information can be used to legally establish the integrity of the samples and therefore the analytical results derived from the samples. This information can be used in addition to other records and documentation regarding the samples, such as field forms, field logs, and photographs.

A sample is considered under custody if:

- It is in your possession; or
- It is in your view, after being in your possession; or
- It was in your possession and then you then locked it up to prevent tampering; or
- It is in a designated secure area.

Continued use of previous version of TGI:

Although not recommended, Arcadis program-, project-, and client-teams may be able to use the previous version of this TGI provided that it meets all of the quality expectations of Arcadis and client and meets applicable regulatory requirements. It is up to the program, project, and/or client-team leader to determine whether it is appropriate to adopt the current TGI or to continue using the previous version.

However, all new work not associated with the previous version of this TGI must be performed with the current version of the TGI.

When adopting this new TGI, users of the previous versions must be aware that specific handling, packing, and shipping procedures and guidance has been removed and that those should be addressed within program or project plans (e.g., Quality Assurance Project Plans (QAPP), Work Plans, Sampling and Analysis Plans (SAPs), etc.) or in a more detailed TGI specific to that sampling activity, whether related to media, constituent/analyte, client, state, etc.

In addition, adopting this new TGI will require users to refer to the Arcadis Department of Transportation (DOT) Safety Program for procedures and guidance on the determination and handling, packing, and shipping of samples that are or may be considered hazardous materials.

4 Personnel Qualifications

Arcadis personnel performing work under the purview of this TGI will have received appropriate training and have field experience regarding the collection of samples from project locations. Arcadis personnel will have all other applicable and appropriate training relevant to the sampling work and project site.

5 Equipment List

The following list provides materials that may be required for each COC. Project reporting and documentation requirements must be reviewed with the CPM prior to execution of work. Additional materials, tools, equipment, etc. may be required, and project staff are required to verify with the CPM and/or Technical Expert what specific equipment is required to complete the COC.

- Indelible ink pen (preferably either black or blue ink);
- COC form **(Appendix A)** from either Arcadis, laboratory receiving and analyzing the samples, or other applicable and appropriate entity for the work performed;
- When appropriate, such as for litigation or expert testimony work, custody seals or tape.

6 Cautions

One way in which the law tries to ensure the integrity of evidence is by requiring proof of the chain of custody by the party who is seeking to introduce a particular piece of evidence.

A proper chain of custody requires three types of affirmations: (1) affirmation that a sample is what it purports to be (for example, soil collected from a specified location and depth); (2) affirmation of continuous possession by each individual who has had possession of the sample from the time it is collected until the time it is analyzed or held by a laboratory; and (3) affirmation by each person who has had possession that sample remained in substantially the same condition and not contaminated or affected by outside influences from the moment one person took possession until the moment that person released the evidence into the custody of another (for example, affirmation that the sample was stored in a secure location where no one but the person in custody had access to it).

Proving chain of custody is necessary to "lay a foundation" for the samples in question, by showing the absence of alteration, substitution, or change of condition.

Ensure that appropriate sample containers with applicable preservatives, coolers, and packing material are planned for and provided at the site at the time of sample collection.

Understand the offsite transfer requirements of the samples for the facility at which samples are collected.

If overnight courier service is required schedule pick-up or know where the drop-off service center is located and the hours of operation.

An Arcadis employee appropriately trained at the correct level of internal hazardous materials/DOT)shipping must complete an Arcadis shipping determination to address applicable DOT and International Air Transport Association (IATA) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging, and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.

The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

7 Health and Safety Considerations

Follow the health and safety procedures outlined in the project/site Health and Safety Plan (HASP) as well as other applicable H&S requirements, such as:

- Arcadis Hazardous Material/DOT handling, packaging, and shipping training
- Project site-specific H&S training
- Client-specific H&S training
- Constituent-specific H&S training
- Media-specific H&S training

8 Procedure

Collected samples must be uniquely identified, and properly documented, containerized, labeled with unique identifier, possessed in a secure manner during remainder of sampling event, packaged, and shipped to recipient laboratory.

Sample Identification

The method of sample identification depends on the type of measurement or analyses performed. In some cases, in-situ measurements of existing conditions and/or sample location must be made during sample collection.

These data will be recorded directly on field forms, logbooks, or other project record data sheets used to permanently retain this information for the project file. Examples of location identification information includes: latitude/longitudinal measurements, compass directions, well number, building number, floor number, room name, or proximity to a site feature unique to the site. Examples of in-situ measurements are pH, temperature, conductivity, flow measurement, or physical condition of the media being sampled. Physical samples collected are identified by a unique identifying number or code on a sample tag or label. These physical samples are removed from the sample location and transported to a laboratory for analyses.

In some cases, before samples are placed into individual containers and labeled as individual samples, samples may be separated into portions depending upon the analytical methods and required duplicate or triplicate analyses to be performed.

When completing a COC for samples, personnel must complete the following:

1. Written COCs must be completed with indelible ink (preferably either black or blue colored ink).
2. Written COCs must be completed using legible printed writing, and not cursive writing.
3. All entry fields on the COC form must be completed. If information is not applicable for a specific entry field, personnel will either put “N/A” or use a strike-out line or dash like “-----------“ to indicate no applicable information is needed for that field.
4. Use of quotation marks or lines/down arrows to represent repetitive/duplicative text in similar fields.
5. Regardless of the type or specific COC form, the following pertinent information must be provided on the COC form:
   a. Arcadis project number
   b. Arcadis project name
   c. Project location, including street address, city, state, building number, providing as much detail as appropriate
   d. Recipient laboratory contact and sample receiving shipping location information
   e. Entities’/persons’ contact information for who will be receiving analytical results
   f. Name of sampler, i.e., person collecting sample and relinquishing possession of samples to the next entity in the chain of custody
   g. Date of sample collection
   h. If appropriate for the sample media, contaminant/constituent of concern, or analytical method, document time of sample collection using standard military time
   i. Sample analytical method(s)

    j. Turnaround time required for analyses and/or reporting
    k. Instructions to laboratory regarding handling, timing, analyses, etc. as applicable and appropriate.
    l. Printed name and signature of the individual person who collected the samples and relinquishing possession of the samples
    m. If appropriate or when documentation of the specific sample collection method will influence how the laboratory handles, prepares, or analyzes the samples, document the sample collection methodology used for collecting the samples (e.g., ASTM D5755)

6. The following additional specific information will be entered on the COC form, regardless of what type of COC is being used:
    a. Unique Sample Identifier – The sample identifier (ID) must be unique to the individual sample it is applied to. The information in which the sample ID conveys is determined by the CPM, Technical Expert, and/or other project team members in advance of sample collection so that sample identification is consistently applied for the project. The sample nomenclature may be dictated by a specific client, program, or project database and require unique identification for each sample collected for the project. Consult with the CPM and/or Technical Expert for additional information regarding sample identification.

       The sample ID could convey specific information regarding the sample to aid personnel in recognizing what the sample represents, or they may be arbitrary so as to facilitate the anonymity of the sample location, media, constituent of concern, project site, etc.

       Examples of unique identifiers include:

        1. Well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30). When the depth interval is included, the complete sample ID would be “SB-30 (0.5-1.0) where the depth interval is in feet. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain of custody form. DO NOT use the apostrophe or quotes in the sample ID.
        2. Sample names may also use the abbreviations “FB,” “TB,” “FD” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively.
    b. List the date of sample collection. All indicated dates must be formatted using either mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g., 03/07/2009).
    c. List the local time that the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15. The time listed on the COC form must match the sample collection time on the sample container(s).
    d. Samples should be indicated to be either “Grab” or “Composite”. Grab samples are collected from only one unique location at one specific point in time.
    e. Composite samples are a group of individual samples that are combined for analysis in their totality. Composite samples need to be documented if they are either collected from a number of different locations over a broader area to be representative of the entire area being sampled, or if they are representative of a single location over an extended period of time.

f. If used, preservatives for the individual sample will be noted.

g. The requested analytical method(s) that the samples are being analyzed for must be indicated. As much detail, as necessary, should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering "EPA Method 8082 – PCBs" or "EPA PLM 600-R93-116." In cases where multiple analytical methods and/or analytical parameters are required for an individual sample, each method should be indicated for the sample (e.g., EPA 8082/8260/8270 or EPA PLM/400-point count).

h. If there are project-specific sample analytes to be reported, they should be specifically listed for each individual sample (e.g., 40 CFR 264 Appendix IX).

i. The total number of containers for each analytical method requested should be documented. This information may be included under the parameter or as a total for the sample.

j. When necessary, note which samples should be used for site specific matrix spikes in the Remarks or Comments field.

k. Indicate special project-specific requirements pertinent to the handling, shipping, or analyses. These requirements may be on a per sample basis such as "extract and hold sample until notified," or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG).

l. Indicate turnaround time (TAT) required for samples on COC. If individual samples have differing TATs, the different TATs for each sample or groups of samples must be clearly indicated.

m. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory. The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

n. If available, attach the Laboratory Task Order or Work Authorization forms.

o. The "Relinquished By" field must contain the signature of the Arcadis person who relinquished custody of the samples to the next entity in the chain of custody, which may be another person, the shipping courier, or the analytical laboratory. If a courier, enter the shipping courier in the "Received by" such as FedEx. The date/time relinquished should be when the person signs the COC and seals the cooler or shipping container for pick-up by the shipping courier.

p. Dates and times must be indicated using the following format:

   1) Date: either mm/dd/yy e.g., 01/01/17 OR mm/dd/yyyy e.g., 01/01/2017

   2) Time: use military format, e.g., 9:30 a.m. is 0930 and 9:30 p.m. is 2130

q. The "Received By" section is signed by sample courier or laboratory representative who received the samples from the sampler. The laboratory will sign upon laboratory receipt from the overnight courier service.

7. When more than one page of the COC form is required to complete the total number of samples, use as many sheets as necessary to accurately and clearly, document the samples and information. Some COCs may have a standard first page/cover page, and subsequent pages may not contain all the detailed fields as

the first page/cover page. Ensure that any subsequent pages convey all of the necessary and pertinent information for each individual sample as required in this procedure document.

8. Pages of the COC must retain a page count of the total number of pages; e.g., Page 1 of 3, Page 2 of 3, Page 3 of 3.
9. Upon completing the COC forms, forward the original signed COC with the sample package. Ensure that the original COC form is secured with the sample package so that it remains with the physical samples for the duration of transport and handling to its final destination and ensure that the COC form will not be become damaged or rendered unreadable due to sample breakage/leakage if stored inside the sample shipping container or outside influences if COC is stored in an outside plastic pouch to the container.
10. If you've collected enough samples that would require more than one container to ship them all to the same laboratory or location, then each separate/individual container that contains any number of samples must have a separate COC representing only those samples contained within that specific container. For example, if you have 3 total shipping containers for all of your samples, you must have a total of 3 separate, individual COCs for each of the 3 containers representing only those samples in their representative container. Thus, every container holding samples must have its own, individual COC.
11. If electronic chain of custody (eCOC) forms are utilized, ensure that the requirements of this procedure and guidance instructions are followed to the extent possible. Verify that proper signature and COC procedures are maintained with the CPM and/or Technical Expert when using eCOC.

9 Waste Management

Not Applicable.

10 Data Recording and Management

The original signed COC shall be submitted with the samples. Copies of COC records will be transmitted to the CPM or designee at the end of each day unless otherwise directed by the CPM. The sampling team leader retains copies of the chain of custody forms for filing in the project file. Record retention shall be in accordance with client- and project-specific requirements and Arcadis policies, the most stringent will apply.

The option to use the Electronic Chain of Custody (eCOC) form in conjunction with the appropriate sample application(s) may be available through the FieldNow® program but is currently limited to a select list of approved analytical laboratories. Use of the eCOC application is intended to reduce common transcription errors both by field staff and laboratory staff on a conventional handwritten paper COC. Once the eCOC form is completed and approved on the field tablet by field staff, a PDF version of the form is automatically emailed to each assigned team member. In addition, a dedicated or mobile printer is recommended for printing a hard copy of the completed eCOC to be included in each sample cooler to meet laboratory requirements.

11 Quality Assurance

COC forms will be legibly completed in accordance with this procedure and guidance instruction document, as well as other applicable and appropriate project documents such as SAP, Quality QAPP, Work Plan, or other project guidance documents.

COC records will be reviewed by the CPM or their appropriate designee for completeness and accuracy to the applicable requirements. Non-conformances will be noted and corrected in a timely manner on the copies retained by Arcadis as well as contacting the ultimate receiving entity for correction to the originally signed COC in their possession.

12 References

Arcadis Transportation Safety Program requirements, procedures, and guidance instructions.

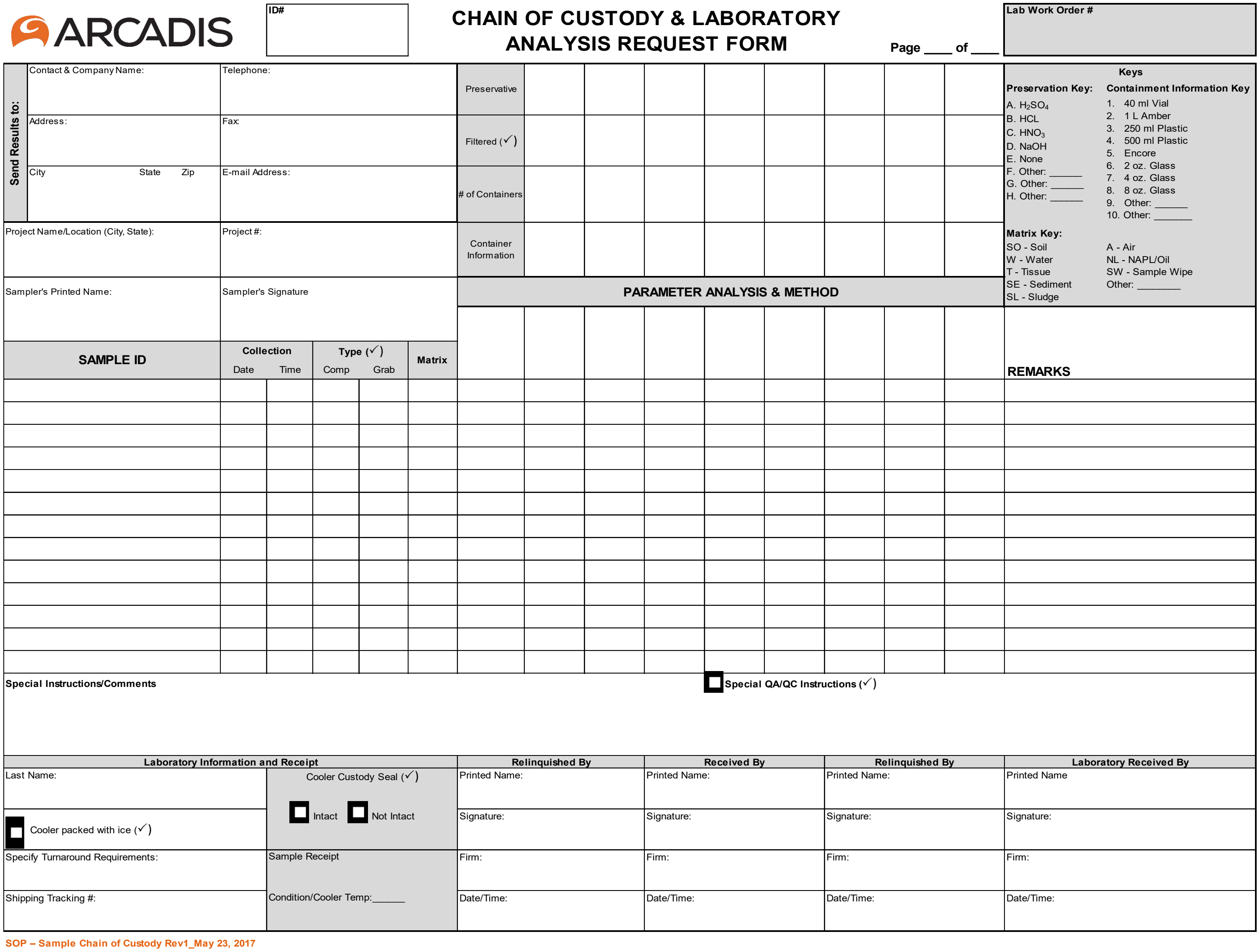
EPA Samplers' Guide – Contract Laboratory Program Guidance for Field Samplers, EPA document EPA-540-R014-013 October 2014 https://www.epa.gov/sites/default/files/2015-03/documents/samplers_guide.pdf.

EPA Region III – Sample Submission Procedures for the Office of Analytical Services and Quality Assurance (OASQA) Laboratory Branch revision 14.0 October 18, 2018, https://www.epa.gov/sites/default/files/2018-12/documents/sample-submission-procedures-rev14.pdf.

EPA Region IV Science and Ecosystem Support Division Operating Procedure for Sample and Evidence Management May 25, 2016, https://www.epa.gov/sites/default/files/2015-06/documents/Sample-and-Evidence-Management.pdf.

Attachment A

Chain of Custody and Laboratory Analysis Request Form



ID#

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ____ of ____

Lab Work Order #

Send Results to:

Contact & Company Name:	Telephone:
Address:	Fax:
City State Zip	E-mail Address:
Project Name/Location (City, State):	Project #:
Sampler's Printed Name:	Sampler's Signature

Preservative								
Filtered (✓)								
# of Containers								
Container Information								

PARAMETER ANALYSIS & METHOD

Keys

Preservation Key:
A. H_2SO_4
B. HCL
C. HNO_3
D. NaOH
E. None
F. Other: ______
G. Other: ______
H. Other: ______

Containment Information Key
1. 40 ml Vial
2. 1 L Amber
3. 250 ml Plastic
4. 500 ml Plastic
5. Encore
6. 2 oz. Glass
7. 4 oz. Glass
8. 8 oz. Glass
9. Other: ______
10. Other: _______

Matrix Key:

SO - Soil	A - Air
W - Water	NL - NAPL/Oil
T - Tissue	SW - Sample Wipe
SE - Sediment	Other: ________
SL - Sludge	

SAMPLE ID	**Collection**		**Type (✓)**		**Matrix**										**REMARKS**
	Date	Time	Comp	Grab											

Special Instructions/Comments

☐ **Special QA/QC Instructions (✓)**

Laboratory Information and Receipt		**Relinquished By**	**Received By**	**Relinquished By**	**Laboratory Received By**
Last Name:	Cooler Custody Seal (✓) ☐ Intact ☐ Not Intact	Printed Name:	Printed Name:	Printed Name:	Printed Name
☐ Cooler packed with ice (✓)		Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt	Firm:	Firm:	Firm:	Firm:
Shipping Tracking #:	Condition/Cooler Temp:______	Date/Time:	Date/Time:	Date/Time:	Date/Time:

SOP – Sample Chain of Custody Rev1_May 23, 2017

TGI – Soil Drilling and Sample Collection

Rev: #2

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Version Control

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Approval Signatures

Prepared by: 4/8/2022

Chris Shepherd (Preparer) Date

Reviewed by: 4/8/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM. All deviations or omissions should be documented.

2 Intended Use and Responsibilities

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3 Scope and Application

This Technical Guidance Instruction (TGI) describes general drilling procedures and the methods to be used to field screen and collect soil samples for laboratory analysis in unconsolidated or weakly consolidated sediments. For soil description procedures, please refer to the *TGI - Soil Description*. For monitoring well installation in granular aquifers, please refer to the *TGI - Monitoring Well Installation*. For per- and polyfluoroalkyl substances (PFASs) drilling and soil sampling procedures, please refer to: *TGI – PFAS-Specific Drilling and Monitoring Well Installation, TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*, and *TGI – Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

Overburden (unconsolidated sediments) drilling is commonly performed using the hollow-stem auger drilling method. Other drilling methods suitable for overburden drilling, which are sometimes necessary due to site-specific geologic conditions, include: direct-push, drive-and-wash, spun casing, rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and hand tools may also be used. Drilling within consolidated materials such as fractured rock is commonly performed using water-rotary (coring or tri-cone roller bit), air rotary or rotasonic methods. For guidance when drilling in consolidated materials (i.e., bedrock), please refer to *the TGI – Bedrock Core Collection and Description.*

The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling depths, targeted chemicals, site or regional geologic knowledge, types of sampling to be conducted, required sample quality and volume, and cost.

Field screening of soil samples is commonly performed using a photoionization detector (PID) and/or a flame ionization detector (FID). These instruments are used to measure relative concentrations of volatile organic compounds (VOCs) for the selection of samples for further laboratory or field analysis. Field screening for dense non-aqueous phase liquids (DNAPL) may be performed using hydrophobic dye (Oil Red O or Sudan IV), which is pertinent at chlorinated solvent sites.

Collection of soil samples for laboratory analysis may be performed using a variety of techniques including grab samples, undisturbed cores, and composite or homogenized samples. Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample. Samples for VOC analysis will not be homogenized or composited and are collected as discrete grab samples.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). Some lubricants (e.g., vegetable oil-based lubricants) may be acceptable, if the constituents won't interfere with the analyses.

4 Personnel Qualifications

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, Arcadis field personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP), Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Personnel responsible for overseeing drilling operations will have at least 16 hours of prior training overseeing drilling activities with an experienced geologist, environmental scientist, or engineer with at least 2 years of prior experience.

Arcadis personnel directing, supervising, or leading soil sampling activities will have a minimum of 1 year of previous environmental soil sampling experience. Field employees with less than 6 months of experience will be accompanied by a supervisor (as described above) to ensure that proper sample collection techniques are employed.

Additionally, the Arcadis field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

The following materials will be available, as required, during soil boring drilling, field screening, andsampling activities:

- Site-specific HASP and health and safety documents identified in the HASP
- FIP/work plan that includes site map with proposed boring locations, fieldsampling plan (with corresponding depths, sample analyses, sample volume required, and sample holding time), and previous boring logs (as available)
- Appropriate personal protective equipment (PPE), as specified in the HASP
- Including but not limited to disposable chemical resistant gloves and Level D PPE
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified in the Traffic Safety Plan (TSP)
- Photoionization detector (PID), flame ionization detector (FID) or other air/soil screening equipment, asneeded, in accordance with the HASP or workplan
- Sampling equipment:
- Drilling equipment required by *ASTM D1586*, when performing split-spoon sampling including clean sample sleeves
- Disposable plastic liners, when drilling with direct-push equipment
- Stainless steel hand auger and stainless-steel spade if using manual methods
- Appropriate soil sampling equipment (e.g., stainless steel spatulas/spoons/bowls, knife)
- Sealable plastic bags (e.g., Ziploc®)

- Air-tight sample containers and 8-oz. glass Mason jars or driller’s jars
- Aluminum foil
- Appropriate sample blanks (trip blank supplied by the laboratory), as specified in the FSP
- Soil sample containers and labels (supplied by the laboratory) appropriate for the analytical method(s) with preservative, as needed (parameter-specific)
- Sample labels
- Indelible ink pens
- Engineer’s ruler or survey rod
- Plastic sheeting (e.g., Weatherall Visqueen)
- Appropriate transport containers (coolers) with ice and appropriate labeling, packing, and shipping materials
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels) in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination*
- Forms/notes:
  - Tablet with digital forms, etc., if appropriate
  - Appropriate soil boring log (**Attachment 1**)
  - Chain-of-custody forms
  - Field notebook
  - Digital camera (or smart phone with camera)
- Drums or other containers appropriate for soil and decontamination water, as specified by the site investigation-derived waste (IDW) management plan, and appropriate drum labels

6 Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service in accordance with the work plan, client requirements, and Arcadis guidance. See appropriate guidance forproper utility clearance protocol. Work will be performed in accordance with the Arcadis *Utility Location and Clearance Health and Safety Standard* and the *Utilities and Structures Checklist* will be completed before beginning any intrusive work.

Prior to beginning field work, the project technical team will ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members. An internal call with the project technical team to review the FIP/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

Some regulatory agencies have specific requirements regarding borehole abandonment and grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling plan.

If DNAPL is known or expected to exist at the site, refer to the project specific documents (e.g., DNAPL Contingency Plan) for additional details regarding drilling to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquid (LNAPL) is known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions. Water used for drilling, decontamination of drilling/sampling equipment, or grouting boreholes uponcompletion will be of a quality acceptable for project objectives. Testing of water supply will be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPL is likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

Store and/or stage empty and full sample containers and coolers out of direct sunlight. Sample container threads should be wiped down with a clean, nonabrasive material (e.g., paper towels) to better ensure the sample container is properly sealed. Be careful not to over-tighten lids with Teflon® liners or septa. Over-tightening can impair the integrity of the seal and cancause the glass to shatter and create a risk for hand injuries.

NOTE: *Field logs and some forms are considered to be legal documents. All field logs and forms will therefore be filled out in indelible ink. Do not use permanent marker or felt-tipped pens for labels on sample container or sample coolers. Permanent markers could introduce volatile constituents into the samples.*

NOTE: *An Arcadis employee that is appropriately trained at the correct level of internal hazardous materials/DOT (Department of Transportation) shipping must complete an Arcadis shipping determination to address applicable DOT and IATA (International Air Transport Association) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.*

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 5). Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and thesite-specific HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., oil). Other potential hazards include biological hazards (e.g., stinging insects, ticks in long grass/weeds, etc.), and potentially the use of sharp cutting tools (scissors, knife). Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the useof fixed/folding-blade knives and use appropriate hand protection.

If thunder or lightning is present, discontinue drilling and sampling until 30 minutes have passed after the last occurrence of thunder or lightning.

8 Procedure

The procedures for drilling and the methods to be used to field screen and collect soil samples for laboratory analysis are presented below:

8.1 Drilling Procedures

8.1.1 Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area.
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance boring to target depth:
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using the appropriate tooling (e.g., split-barrel sampler) and sample containers
        i. Split-barrel or drive-ahead samples are obtained during drilling
        ii. A common sampling method that produces high-quality soil samples with relatively littlesoil disturbance is described in *ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* (ASTM D1586).
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
    e. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. The core is retrieved by vibrating the soil/rock into a separate core bag, typically in 5-foot or 10-foot increments. The soil cores may consolidate or expand during retrieval, depending on soils, etc.
    f. Dual-rotary removes cuttings by compressed air or water/mud and allow only a

 generalassessment of geology unless separate coring tools and techniques are used

  g. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)

3. Describe each soil sample as outlined in the appropriate project records (refer to the description procedures outlined in the *TGI - Soil Description*)
   a. Record descriptions on the soil boring log (**Attachment 1**) and/or field notebook
   b. When possible, photo document the samples (e.g., soil cores, split-barrels)
   c. During soil boring advancement, document all drilling events in field notebook, including blow counts (i.e., the number of blows from a soil sampling drive weight [140 pounds] required to drive the split-barrel sampler in 6-inch increments) and work stoppages
   d. Blow counts will not be available if rotasonic, dual-rotary, or direct-push methods are used; however, if standard penetration testing is required during rotasonic drilling, an automatic drop hammer may be used in conjunction with the method to switch from core barrel advancement to standard penetration testing
   e. If soils are screened with a PID/FID or another instrument, document the measurement in accordance with the work plan
4. The drilling contractor will be responsible for obtaining accurate and representative samples, informing the supervising Arcadis geologist of changes in drilling pressure, drilling penetration rates, and keeping a separategeneral log of soils encountered, including blow counts
   a. The term “samples” means soil materials from particular depth intervals, whether or not portions of these materials are submitted for laboratory analyses
   b. Records will also be kept of occurrences of premature refusal due to boulders, construction materials that may have been used as fill, etc.
   c. Where a boring cannot be advanced to the desired depth, the boring will be abandoned, and an additional boring will be advanced at an adjacent location to obtain the required sample in accordance with the work plan
   d. Where it is desirable to avoid leaving vertical connections between depth intervals (e.g., if DNAPL or perched LNAPL are known or expected to exist at the site), the borehole will be sealed using cement and/or bentonite (see **Section 5** above)
   e. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location

8.1.2 Direct-Push Method

The direct-push drilling method may also be used to complete soil borings. Examples of this technique include Geoprobe®, Diedrich Environmental Soil Probe (ESP) System, or AMS PowerProbe.

Environmental probe systems typically use a hydraulically operated percussion hammer.

Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual tube liner for samplingsoil (dual tube sampling system).

The outside diameter (OD) of the outer casing ranges from 2.25 to 6 inches and the OD of the inner sampling tube diameter ranges from 1.4 to 4.5 inches. The outer casing isolates overlying soil and permits the unit to continue to probe at depth. The dual tube sampling system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, a single rod system may be used that does notprovide a cased boring and which limits tremie-grouting from the bottom up.

Direct-push drilling can generally achieve target depths 100 feet or less depending on the site geology. The known or expected site conditions (e.g., presence of NAPL) will be evaluated when selecting the typeof direct-push sampling system to be employed.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance soil boring to target depth.
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using clean/disposable sampling equipment (plastic liners)
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in theFIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
3. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)
4. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.1.3 Manual Methods

Manual methods may also be used to complete shallow soil borings. Examples of this technique include using a spade, spoon, scoop, hand auger, or slide hammer. Manual methods are typically used to collect surface soil samples (0 to 6 inches) or to complete soil borings/collect soil samples from a depth of 5 feet or less.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
2. Clear the ground surface of brush, root mat, grass, leaves, or other debris
3. Use a spade, spoon, scoop, hand auger, or slide hammer to collect a sample of the required depth interval
4. Use an engineer’s ruler or survey rod to verify that the sample is collected to the correct depth and

record the top and bottom depths from the ground surface

5. To collect samples below the surface interval, remove the surface interval first; then collect the deeper interval
    a. To prevent the hole from collapsing, it may be necessary to remove a wider section from the surface or use cut polyvinyl chloride (PVC) pipe to maintain the opening
    b. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) and transfer to the appropriate, laboratory-supplied container
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
6. Decontaminate equipment between samples in accordance with the FIP/work plan (orequivalent)
7. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.2 Field Screening Procedures

8.2.1 PID and FID Screening

Soils are typically field screened with a PID or FID for a relative measure of the total VOCs at sites where VOCs are known or suspected to exist. PIDs and FIDs require calibration in accordance with the work plan(s) and manufacturer’s specifications and PIDs should be calibrated based on the target chemicals. The PID employs an ultraviolet lamp to measure VOCs and the ionizationenergy (IE) of the site constituents need to be considered when selecting the type of lamp (e.g., 10.6 eV, 11.7 eV) that will be used. In general, any compound with an IE lower than that of the lamp photons canbe measured. The FID has a wide linear range and responds to almost all VOCs.

Field screening is performed using one (or both) of the following two methods:

1. Upon opening the sampler, the soil is split open and the PID or FID probe is placed in the opening and covered with a clean, gloved hand. Such readings will be obtained at several locations along the lengthof the sample.
2. A portion of the collected soil is placed in a jar, which is covered with aluminum foil, sealed, and allowed to warm to room temperature (see below). After warming, the cover is removed, the foil is pierced withthe PID or FID probe, and a reading is obtained.

Prior to usage, the PID or FID must be calibrated according to the manufacturer's specifications at a minimum frequencyof once per day prior to collecting PID or FID readings. The PID will be calibrated to a benzene-related compound (isobutylene) or other appropriate gas, while the FID will be calibrated to methane. The time, date, and calibration procedure must be clearly documented in the field notebook and/or the calibration form.

If at any time the PID or FID results appear erratic or inconsistent with field observations, then the instrument will be recalibrated.

If calibration is difficult to achieve, then the PID's lamp will be checked for dirt or moisture and cleaned, or technical assistance will be required. Maintenance and calibration records will be kept as part of the field quality assurance program.

Initial PID readings will be recorded on the soil boring log (**Attachment 1**) and/or in the field notes. The soil sample will be separated from the slough material (if any) by using disposable gloves and a pre-cleaned stainless-steel spoon or tool.

For the second method, a representative portion of the sample will be placed in a pre-cleaned air-tight container (as quickly as possible to avoid loss of VOCs), filling the container half full to allow for the accumulation of vapors above the soil. An aluminum foil seal will be placed between the glass and cap and the cap will be screwed on tightly. Unless the screening will be performed immediately after the sample is placed in the container, the sample containers will be stored in a cooler chilled to approximately4ºC until screening can be performed.

The headspace of the container will be measured using a PID or FID as follows:

1. Samples will be taken to a warm workspace and allowed to equilibrate to room temperature for atleast one hour.
2. Prior to measuring the soil vapor headspace concentration, the container will be shaken.
3. The headspace of the sample will then be measured directly from the container by piercingthe aluminum foil seal with the probe of the PID or FID and measuring the relative concentration of VOCs in the headspace of the soil sample. The initial (peak) reading must be recorded.

8.2.2 NAPL Screening

To screen for the potential presence of non-aqueous phase liquid (NAPL) in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-barrel samplers or direct-push samplers will be collected continuously ahead of the auger, drill casing/rods, or probe rods. Upon opening each split-barrel sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible NAPL and odors. If suspected NAPL is immediately visible in the sample, its depth will benoted.

Additionally, the soil will be screened for the presence of organic vapors using a PID or FID, in accordance with the work plan, if applicable. During screening, the soil will be split open using a clean spatula or knife and the PID or FID probe will be placedin the opening and covered with a clean, gloved hand (**Method 1** above). Such readings will be obtained along the entire length of the sample. Alternatively, **Method 2** for PID/FID screening (outlined above) may also be performed. If the PID or FID examination reveals the presence of organic vapors above 100 parts permillion (ppm), the sample will undergo further detailed evaluation for visible NAPL.

The assessment for NAPL will include the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler
  - NAPL sheen will be a colorful iridescent appearance on the soil sample
  - NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL
  - Creosote DNAPL (associated with wood-treating sites) and coal tar DNAPL (associated with manufactured gas plant [MGP] sites) are typically black and have a characteristic, pungent odor
  - Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed

with oils may appear brown

  - Particular care will be taken to fully describe any sheens observed, staining, discoloration, droplets (blebs), or NAPL saturation

- Soil-Water Pan Test
  - A portion of the selected soil interval with the highest PID or FID reading above 100 ppm will be placed in a disposable polyethylene dish along with a small volume of potable or distilled water
  - The dish will be gently tilted back and forth to mix the soil and water, and the surface of the water will be viewed in natural light to observe the development of a sheen, if any
  - A small quantity of Oil Red O or Sudan IV hydrophobic dye powder should be added in accordance with the work plan, and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish tocreate a paste-like consistency
  - A positive test result will be indicated by a sheen on the surface of the water and/or a bright red color imparted to the soil following mixing with dye
- Soil-Water Shake Test
  - A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, jar containing an equal volume of potable or distilled water (40-mL vials are well suited to this purpose, but not required)
  - After the soil settles into the water, the surface of the water will be evaluated for a visible sheen under natural light
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam
  - A small quantity (approximately 0.5 to 1 cc) of Oil Red O or Sudan IV powder will be placed in the jar in accordance with the work plan
  - The sheen layer, if present, will be evaluated for a reaction to the dye (change to bright red color)
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - The contents in the closed jar will be examined under natural light for visible bright red dyed liquid inside the jar

- A positive test result will be indicated by the presence of a visible sheen or foam on the surface ofwater, a reaction between the dye and the sheen layer upon first addition of the dye powder, a bright red coating on the inside of the vial (particularly above the water line), or red-dyed droplets within the soil

NOTE: *If NAPL is obviously present upon opening the soil sampler or evaluating the soil sample within the split-spoon sampler or direct-push liner sleeve, it is not necessary to perform a soil-water pan test or soil-water shake test. In addition, it is not necessary to perform both a soil-water pan test and a soil-water shake test; either test method is acceptable. The pan test may be preferred in some circumstances because the presence of a sheen may be easier to see on a wider surface. Further, these tests will only be performed if specified in the work plan(s).*

NOTE: *When using hydrophobic dye in the tests above, color will be assessed outdoors under natural light during the period between sunrise and sunset, regardless of the degree of cloud cover. The hydrophobic dye Safety Data Sheets (SDS) will be incorporated into the HASP and reviewed prior to use and the dyes will be carefully handled and disposed in accordance with regulations, if applicable*.

8.3 Soil Sample Collection for Laboratory Procedures

If not specifically identified in the FIP/work plan, soil samples will be selected for laboratory analysis based on:

1. Their position in relation to identified source areas
2. The visual presence of source residues (e.g., NAPL or staining)
3. The relative levels of total VOCs based on field screening measurements
4. The judgment of the field coordinator
5. Moisture content or relative position with regard to apparent groundwater table/saturation

Samples designated for laboratory analysis will be placed in the appropriate containers.

Sample containers for VOC analysis will be filled first immediately following soil core retrieval to reduce loss of VOCs.

If samples will be collected for other analyses, a sufficient amount of the remaining soil willthen be homogenized as described below and sample containers will be filled for other parameters.

VOC samples will be collected as discrete samples using a small diameter core sampler (e.g., En Core® Sampler, Terra Core™ Sampler).

The En Core® Sampler is a disposable volumetric sampling device that collects, stores and delivers soil samples without in-field chemical preservation. The En Core® Sampler requires the use of a reusable T-handle.

The Terra Core™ Sampler is a one-time use transfer tool, designed to collect soil samples and transfer them to the appropriate containers for in-field chemical preservation (e.g., methanol).

The small diameter core samplers will be used according to the manufacturer's instructions (e.g., En Novative Technologies). Some regulatory agencies have specific requirements regarding VOC sample collection. Determine whether the oversight agency has specific requirements prior to commencing sampling and collect samples at appropriate interval as specified in the FIP/work plan (or equivalent). Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample.

NOTE: *Samples for VOC and PFAS analysis will NOT be homogenized or composited and will be collected asdiscrete samples as described above*.

The procedure for mixing samples is provided below.

1. Mix the materials in a stainless steel (or appropriate non-reactive material) bowl using a stainless-steel spoon (or disposable equivalents)

a. When dealing with large sample quantities, use disposable plastic sheeting and a shovelor trowel

b. NOTE: *When preparing samples for metals analyses, do not use disposable aluminum(or metal tools or trays other than stainless steel), as it may influence the analytical results*

2. Flatten the pile by pressing the top without further mixing
3. Divide the circular pile by into four equal quarters by dividing out two diameters at right angles
4. Mix each quarter individually using appropriate non-reactive bowls, spoons and/or sheeting
5. Mix two quarters (as described above) to form halves, then mix the two halves to form a composite orhomogenized sample
6. Place composite or homogenized sample into specified containers
7. Remaining material will be disposed of in accordance with project requirements and applicableregulations
8. Sample containers will be labeled with sample identification number, date, and time of collection andplaced on ice in a cooler (target 4° Celsius)
9. Samples selected for laboratory analysis will be documented (chain-of-custody forms), handled, packed, and shipped in accordance with the procedures outlined in the FIP/work plan (or equivalent).

8.4 Soil Boring Abandonment

All soil borings need to be abandoned in accordance with ***TGI for Monitoring Well and Soil Boring Decommissioning***. See Attachment E of the TGI for specifics.

9 Waste Management

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP/work plan or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Management of the original documents from the field will be completed in accordance with the site- specific QAPP.

In general, drilling activities will be documented on appropriate field/log forms as well as in a proper field notebook. All field data will be recorded digitally or with indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead. Any deviations or omissions from this TGI should be documented.

Initial field logs and chain-of-custody records will be transmitted to the Arcadis CPM and Technical Lead at the end of each day unless otherwise directed by the CPM. The field teamleader retains copies of the field documentation.

Additionally, all documents (and photographs) will be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of drilling activities, soil descriptions, soil boring information, and quantities of materials used.

In addition, the locations of soil borings will be documented photographically and in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

11 Quality Assurance

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate TGI.

Field-derived quality assurance blanks will be collected as specified in the FIP/work plan and/or site- specific QAPP, depending on the project quality objectives. Typically, field rinse blanks (equipment blanks) will be collected when non-dedicated equipment (e.g., split-spoon sampler, stainless steel spoon) is used during soil sampling. Field rinse blanks will be used to confirm that decontamination procedures are sufficient and samples are representative of site conditions. Trip blanks for VOCs, which aid in the detection of contaminants from other media, sources, or the container itself, will be kept with the coolers and the sample containers throughout the sampling activities and during transport to the laboratory.

Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.

12 References

ASTM D1586 - *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*. ASTM International. West Conshohocken, Pennsylvania.

13 Attachments

Attachment 1. Soil Boring Log Form

Attachment 1

Soil Boring Log Form

BORING LOG

ARCADIS

Boring ID:		**Project Name:**		**Page:**	
Permit ID:		**Date Started:**		**Ground Elevation:**	
Site Address:		**Date Completed:**		**Vertical Datum:**	
City, State:		**Total Depth:**		**Northing:**	
Drilling Co:		**Depth to Water:**		**Easting:**	
Driller:		**Hole Diameter:**		**Horizontal Datum:**	
Drilling Method:		**Core Device:**		**Prepared by:**	
Boring Status:		**Drilling Fluid:**		**Reviewed by:**	

Drilling Information				**Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**PID Reading (ppm)**	**Fines**		**Sand**					**Gravel**				Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

BORING LOG

ARCADIS

Boring ID: ____________ **Project Name:** ____________ **Page:** /

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

ARCADIS

Boring ID: ____________________ **Project Name:** ______________________________ **Page:** ______ / ______

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	Fines		Sand					Gravel				Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

ARCADIS

TGI – Vertical Aquifer Profile (VAP) Sampling

Rev: 2.0

Rev Date: June 15, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	June 22, 2018	All	Original SOP	Joe Quinnan
	1	May 11, 2020	Multiple	Added content to Personnel Qualifications, references to Geoprobe SP-16 and SP-22, Attachment 3, and updated references /formatting	Marc Killingstad
	2	June 15, 2022	Multiple	Combined with PFAS-specific VAP TGI and dye/tracer procedures.	Patrick Curry

Approval Signatures

Prepared by: 6/15/2022

Patrick Curry (Preparer) Date

Reviewed by: 6/15/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This Arcadis Technical Guidance Instruction (TGI) describes proper vertical aquifer profile (VAP) sampling procedures using a variety of methods and approaches. This document has been developed to emphasize drilling and sampling procedures used to collect groundwater samples from boreholes installed via direct push technology (DPT), hollow stem auger (HSA), and rotary-sonic (sonic) methods and includes the use of visible tracer in drilling fluid to obtain representative samples during vertical profiling.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

Vertical aquifer profile (VAP) borings are typically advanced via DPT, HSA, or sonic drilling techniques to collect single or multiple depth-discrete groundwater samples using low-flow or grab sampling methodologies. This can be combined with retrieval of continuous soil cores and lithologic logging, as well as collection of single or multiple depth-discrete dry and saturated soil samples.

When possible, co-locate or bias VAP groundwater sampling intervals towards potential discrete transport zones (and target slow advection zones when feasible) as indicated by soil logging observations or permeability measurements (e.g., point slug tests, Geoprobe® hydraulic profiling tool [HPT] [preferred], Waterloo APS™ [alternate]). Permeability measurements coupled with contaminant concentration allows estimationof relative flux and mass discharge to evaluate potential risk to downgradient receptors. In the absence ofpermeability measurements, field soil lithological logging observations may be used to interpret hydrostratigraphy and select sampling intervals.

The intent of this TGI is to provide VAP instructions including specific considerations for per- and polyfluoroalkyl substances (PFAS) due to their unique chemical and physical properties, low detection limits, and regulatory standards. It also covers field procedures for using nontoxic fluorescent tracer (e.g., fluorescein dye) in drilling fluid during drilling to assist in determining when sufficient purging has been performed prior to collecting screening-level groundwater samples during the drilling process. Screening level groundwater samples may be obtained by evacuating water from the drill casing or from intervals of geologic formations isolated by inflatable packers. This procedure improves the quality of screening-level groundwater samples by providing a technical basis to determine when purging has sufficiently removed drill water prior to collecting screening-level groundwater samples.

Multiple VAP samples can be collected through temporary wells, drilling rod tooling (e.g., Geoprobe® Screen Point 16 [SP-16]/Screen Point 22 [SP-22] Groundwater Samplers or SP-60 Sonic Groundwater Sampler or Cascade's Sonic Push-Ahead or Packer Isolation Groundwater Profilers) or via combined hydraulic profiling and sampling tools (e.g., Geoprobe® HPT-Groundwater Sampling System [HPT-GWS] or Waterloo APS™). They can be analyzed quickly via on-site mobile lab or expedited off-site fixed lab analysis to provide adaptive high-resolution quantitative groundwater concentration data. The vertical frequency of groundwater sampling within a formation will be determined relative to the scale of variability demonstrated in site hydrostratigraphy and outlined in the FIP/Work Plan. Thin aquifers with transport zones only tens of feet thick (or less) can be sampled at intervals as close as 3 to 5 feet. In aquifers with transport zones substantially thicker (e.g., more than 50 feet), sample spacing of 5 to 20 feet may be adequate. It is important to note that field data be evaluated to verify that sampling intervals provide sufficient resolution to meet data quality objectives (DQOs) (See **Section 7**).

4 Personnel Qualifications

In general, VAP activities will be performed by persons who have been trained in proper drilling and sampling procedures under the guidance of an experienced field geologist, engineer, or technician. Arcadis personnel overseeing, directing, or supervising VAP activities shall have previous related experience (minimum of 2 years) in drilling and groundwater sampling. Drilling subcontractors will need current applicable drilling licenses.

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilization, the field team will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP)/field sampling plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Additionally, the field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

The following equipment and materials must be available for VAP sampling

- Site plan with proposed sampling locations
- Relevant work plan (or equivalent)
- Health and Safety Plan (HASP)
- Field Tablet with appropriate Fulcrum app for logging groundwater sampling.
- NOTE: *As of June 2022, several digital logging applications are available through the FieldNow™ program and the Fulcrum app. A future revision of this TGI, likely in early 2023, will emphasize digital logging methods and groundwater sampling. FieldNow™ is discussed further in Section 10.*
- Appropriate health and safety equipment, as specified in the site HASP
    - Drilling Equipment
    - Drill rig (to be provided by drilling subcontractor). Type (e.g., roto-sonic, direct push) to be determined based on site-specific details
    - Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area,if not provided by the drillers

      NOTE: *Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling equipment will be provided in quantities capable of achieving estimated target depths. Typical equipment/materials providedby the driller could include*

        - Acetate or plastic liners
        - Appropriate length of drilling rods and tooling
        - Drilling and sampling equipment decontamination materials,
        - Decontamination pad materials, if required. See **Section 6.3** below for more information
- Sampling Equipment
    - Appropriate groundwater sampling equipment (e.g., disposable bailers for volumetric sampling,peristaltic pump for shallow groundwater sampling, submersible bladder pump for deeper sampling). Refer to *the TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells* (Arcadis 2020a) for necessary equipment
    - Direct push groundwater samplers (e.g., Geoprobe® SP-22) or roto-sonic sampling devices (e.g.,Cascade Push Ahead/Packer Isolation Groundwater Profiler or Geoprobe® SP-60 Sonic Groundwater Sampler) (to be provided by drilling subcontractor)
    - Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife, metal trowel)

- Dedicated plastic sheeting (preferably high-density polyethylene [HDPE]) or other clean surface toprevent sample contact with the ground
- Multi-parameter water quality probe (e.g., conductivity, temperature, pH, dissolved oxygen,oxidation reduction potential, and turbidity meter)
- Water level meter
- Appropriate sample containers and labels
  - Labeled sample bottles: see the *TGI – Poly- and Perfluorinated Alkyl Substances (PFAS)Field Sampling Guidance* (Arcadis 2017a) for PFAS-specific considerations
  - Ziplock-style bags to hold ice and samples
  - Appropriate blanks (field reagent blanks supplied by the laboratory)
  - Packing and shipping materials
  - Chain-of-Custody (COC) Forms; see the *Sample Chain of Custody* for reference (Arcadis2017b)
  - Appropriate transport bottles (coolers) with ice and appropriate labeling, no blue ice

- Decontamination Equipment
  - Equipment cleaning materials: see the *TGI – Poly- and Perfluorinated Alkyl Substances (PFAS)Field Sampling Guidance* (Arcadis 2017a) or the *TGI – Groundwater and Soil Sampling Equipment Decontamination* (Arcadis 2020b) as applicable
  - Drum labels as required for investigation derived waste handling: see the *TGI – Investigation-Derived Waste Handling and Storage* for details (Arcadis 2017c)
- Documentation/Field Notes
  - Electronic data collection device (smart phone or tablet) as applicable
  - Pens, pencils, and/or Sharpie® brand pens for writing
  - Digital camera
  - Any other appropriate field forms
- Tracer Equipment (as needed)
  - Sodium fluorescein (also known as fluorescein or uranine dye) tracer (to be added to drilling water to produce a vibrant yellow-green color); 38 grams of dye will be added to each 500 gallons of drilling water (potable water) to achieve target applied tracer concentration of 20 milligrams per liter (mg/L)
  - Bottles for retaining dyed drilling water samples and preparing visual dye standards (clear, colorless, 40 mL unpreserved VOA bottles or equivalent)
  - Graduated cylinders (50 mL and 1 L)
  - Scale for measuring mass of dye to the nearest 1 gram
  - Bottles for groundwater samples to be analyzed for tracer dye (if necessary) and chemicals of concern (COCs)

  - Poly storage tank (typically 550-to-1,000-gallon capacity)
  - Potable water source
  - Generator
  - Utility pump for mixing dye
  - Pump for groundwater purging and sampling
  - Flashlight or other portable lighting device
  - Blue ice (for tracer dye samples)

6 Cautions

Field activities associated with borehole advancement and VAP groundwater sampling will be performed in accordance with the HASP, a copy of which will be present on site during such activities. Field staff (including subcontractors) will be aware of and understand the associated physical and health hazards.

6.1 Utility Clearance

The appropriate drilling authorities will be contacted and a site visit for public utility line clearance at the proposed boring locations will be conducted at least 72 hours prior to work commencing. As applicable, utility maps will be reviewed during field reconnaissance of the proposed investigation locations to determine if any are co-located with public utility lines. Arcadis will also contract an independent geophysical survey company to verify that proposed boring locations are not co-located with existing underground utility/substructure features, as necessary. Arcadis will clear locations with soft dig methods to assess the presence of underground utilities as necessary.

See the *Utility Location and Clearance Arcadis Health and Safety Standard* (Arcadis 2020c) for reference.

6.2 PFAS-Specific General Sampling Considerations

This section provides a summary of methods and procedures applicable to the collection of environmental samples for field screening or laboratory analysis during PFAS site characterization activities. In general, sampling techniques used for PFAS site characterization are consistent with conventional sampling techniques used in the environmental industry, but special consideration is made regarding PFAS-containing materials and cross-contamination potential. For example, Teflon™ and other fluoropolymer containing materials are found in pumps, tubing, and sample storage containers and, therefore, will be avoided if possible (Department of Environment Regulation [DER], Western Australia 2016; New Hampshire Department of Environmental Services [NHDES] 2016). Certain field documentation materials such as waterproof paper or field books, adhesive paper products, and some writing utensils (grouped as non-Sharpie® markers) are also prohibited items during PFAS sampling (DER 2016; NHDES 2016).

Attachment 1 (Tables 1 and 2) provides recommendations for PFAS Site Investigation equipment. Table 1 provides a summary of materials that have been approved for site investigation; this list is expected to grow longer as industry experience increases. Table 2 provides a summary of field equipment and materials that have available testing information and/or industry knowledge regarding PFAS cross-contamination potential, and it is recommended that these materials be prohibited for samplecollection. For materials that are suspected of containing and/or retaining PFAS, these recommendations are considered preliminary and subject to change.

Given the extremely low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, field personnel are typically advised to err on the side of caution by strictly following field wear guidelines and decontamination procedures as specified in the *TGI - Poly- and Perfluorinated Alkyl Substances (PFAS) Field Sampling Guidance* (Arcadis 2022).The most important consideration during PFAS related VAP sampling is to prevent contact between sample media and suspect PFAS sources.

6.3 PFAS-Specific Groundwater Sampling

The potential presence of material containing PFAS in equipment that may come into contact with the target water sample must be evaluated as part of the sample planning process to maintain sample integrity. For example, low-flow sampling with a peristaltic pump will be conducted using silicone or HDPE tubing; Teflon™ tubing is prohibited (DER 2016). If a bladder pump is used to collect samples, the bladder and other internal parts (e.g., check balls, O-rings, compression fittings) will not contain Teflon™, and bladder and O-rings will be changed between samples (DER 2016).

Note that if high concentrations of PFAS related to Class B firefighting foams are expected in a groundwater sample, it has been recommended to collect and shake a small portion of the sample at the time of sample collection (USACE 2016; Arcadis 2017a). If foaming is noted within the sample, it indicates elevated concentrations of PFAS may be present and the sample will be proactively diluted at the laboratory prior to analysis, and the foaming will be noted on the sample COC form. It is recommended to collect sampling equipment blanks following foam observation to confirm the effectiveness of decontamination procedures.

6.4 Use of Tracer in Drilling Fluid

Field staff (including subcontractors) will be aware of tracer hazards and understand the associated health hazards. Please be sure to read the SDS (included as Attachment 2) for fluorescein dye. Note that some individuals can experience a mild allergic reaction to skin contact with fluorescein. Protective gloves will be worn during dye handling and mixing activities, and rinse bottles will be readily available for washing affected areas in case of accidental contact.

7 Health and Safety Considerations

To ensure the safety of the field personnel, field activities associated with VAP will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Review all site-specific and procedural hazards as they are provided in the HASP and review relevant Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Appropriate personal protective equipment (PPE) will be always worn in line with the task and the site-specific HASP. Verify staff has required health and safety training and personal protection equipment in accordance with the HASP and JSAs. At a minimum, all staff will have level D PPE with chemical resistant gloves.

8 Procedure

The specific procedure for advancing VAP borings will be developed after careful review and consideration of project DQOs and clearly detailed in the FIP/Work Plan. Typically, VAP borings are conducted in boreholes adjacent to soil borings previously completed to develop stratigraphic and relative permeability profiles of the aquifer to determine sampling depth intervals that target transport zones. Prior boreholes typically consist of soil borings with detailed soil descriptions or Geoprobe® HPT borings. The primary advantage of completing stratigraphic/permeability profiles in advance of VAP sampling is to gain an understanding of hydrofacies trends to ensure that the most appropriate intervals and sampling methods are used. For sonic or HSA drilling, VAP samples are typically collected from the same borehole as soil samples. In the absence of a co-located boring, sample depth intervals can be determined based upon lithologic logging of soil cores, either from a separate adjacent borehole or from the same borehole. HPT drilling will be completed consistent with the *TGI – Geoprobe Hydraulic Profiling Tool (HPT)* (Arcadis 2022a), and soil lithologic logging will be performed in accordance with *TGI – Soil Description* (Arcadis 2022b).

NOTE: *Waterloo APS™ can be utilized as an alternative to HPT to provide permeability profiles, but it is more time consuming than HPT; therefore, it is not considered the preferred tool for permeability profiling.*

8.1 Direct Push Vertical Aquifer Profile Sampling

Direct push tooling is ideal for shallow unconsolidated aquifers and requires minimal water for drilling, reducing the potential for sample dilution/cross-contamination. For sites with shallow groundwater in unconsolidated formations (e.g., at less than 100 feet bgs), the typical approach is to collect VAP groundwater samples nominally every 5 to 10 feet with a bias to the more permeable transport zones.

When a zone of interest is identified, either by using permeability measurements (preferred) or logging soil, a screen point sampling device such as Geoprobe® SP-16 or SP-22 (see **Attachment 3**) can be driven to the target interval and the screen opened to collect a groundwater sample. In poorly sorted aquifers with appreciable amounts of silt, VAP sampling from an adjacent borehole after completing initial permeability profiling (e.g., Geoprobe® HPT or point slug tests) is typically more efficient and cost effective. In the absence of permeability profiling tools (e.g., HPT), VAP sampling can be performed based on soil lithological observations alone, either from a separate borehole or in the same borehole. However, VAP sample collection can be more efficient when conducted from an adjacent borehole, particularly if a bottom-up sampling approach is used. See Section 8.1.1.

Combined permeability profiling and sampling tools such as the Geoprobe® HPT-GWS (or Waterloo APS™ as an alternate) can be used to collect groundwater samples based on permeability measurements from the same borehole at deeper depths where the process is more cost-effective; otherwise at shallower depths, separate permeability profiling prior to VAP sampling is preferred. This is most effective in well-sorted sand and gravel when small volumes are required for analysis, since these tools provide limited volumes for purging and sample collection. Use of these combined tools (HPT-GWS or Waterloo APS™) for PFAS sites is not recommended because low detection and regulatory thresholds for PFASs require more extensive purging to decontaminate the sampling equipment (i.e., insufficient data are available to confirm the volume of purging required to eliminate cross-contamination with PFAS).

It is recommended that DPT drilling for VAP sampling be completed using a dual-tube drilling approach. An outer casing is advanced with the screen point sampling device to limit the potential for cross-contamination between sampling intervals. Pre-calculated volume purging and monitoring for water quality parameter stabilization can be performed consistent with low-flow sampling to help determine when purge water is representative of the groundwater formation.

There are two general methods for completing VAP sampling: bottom-up and top-down. With bottom-up sampling, a greater purge volume is required to ensure a representative groundwater sample; however, the overall time savings is significant relative to top-down sampling, where more time is required per borehole to lower the tooling, retract it, and decontaminate it between subsequent sampling intervals. However, the top-down method minimizes any potential for cross-contamination and is the preferred approach for PFAS projects due to the low detection limits and regulatory levels associated with PFASs.

8.1.1 Bottom-Up VAP Sampling

Bottom-up VAP sampling involves advancing dual-tube direct push casing to the deepest target depth with either a solid drive tip (without collecting soil cores) or acetate liners for collection of continuous soil cores to provide a lithological log for the entire boring. This is followed by lowering the groundwater sampling screen through the outer casing to the bottom of the borehole and collecting multiple VAP groundwater samples at different depths as the casing and screen is retracted up the borehole.

Using this approach, the external casing is retracted to allow borehole collapse around the sampling screen while isolating it from the section above that is still covered by the external casing.

NOTE: *Bottom-up VAP sampling is not recommended when there is a potential for dense non-aqueous phase liquid (DNAPL), the highest concentrations are expected to be at the bottom of the formation, or the borehole goes through multiple confining units. Bottom-up is not recommended for PFAS sampling due to potential cross-contamination concerns associated with lack of decontamination between sample intervals.*

The advantages of this approach are: (1) when combined with soil core collection, groundwater sampling depth intervals can be pre-selected based on lithologic observations to target the transport zones, especially in the absence of any co-located permeability measurements, and (2) the entire process is much more time-efficient per borehole as the sampling equipment is not pulled, decontaminated, and then drilled to the next interval. However, additional purging (i.e., 3to 5 casing volumes) is required to assure a representative groundwater sample. Bottom-up sampling also does not allow for post-grouting of the borehole since when the groundwater sampling device is pulled up to the next VAP sampling interval, the sidewalls of the open borehole below collapse.

8.1.2 Top-Down VAP Sampling

Top-down VAP sampling involves advancing dual-tube direct push casing with either a solid drive tip (without collecting soil cores) or a plastic liner for soil core retrieval from target depth interval followed by lowering the screen point sampling screen to target depth and pulling up the outer casing to expose the screen. After purging and sample collection, the screen point device is pulled back up and decontaminated. A solid drive tip or plastic liner is lowered back into the borehole and the entire assembly is then advanced to the next depth interval. Thus, top-down sampling requires pulling the tooling after each sample interval, decontaminating the tooling, re-setting the groundwater sampler, and advancing the tooling to the next planned interval.

The advantages of this approach are that it allows grouting of the borehole from the bottom of the borehole and reduces the potential for cross-contamination from adjacent sampling intervals.

The primary disadvantage is that the entire process is much less time-efficient per borehole since the tooling must be retracted and re-advanced every time.

NOTE: *Top-down is the preferred method for PFAS VAP sampling.*

8.2 Sonic Drilling VAP Sampling

For sites with deep unconsolidated aquifers, bedrock/weathered bedrock, or otherwise challenging drilling conditions (e.g., presence of dense tills, caliche, cobbles), sonic drilling will be necessary to complete VAP. Like direct push, groundwater profilers can be used with sonic rigs to collect multiple depth-discrete groundwater samples biased towards transport zones based on soil lithological cores. The configuration of individual samplers varies based on their manufacturer by different drilling contractors (e.g., Cascade Push Ahead/Packer Isolation Groundwater Profiler or Geoprobe® SP-60).

The overall strategy of sonic drilling VAP sampling is consistent with direct push VAP sampling; however, drilling with sonic or some rotary methods can require the introduction of drilling fluid/water that can potentially affect the integrity of the groundwater sample. If possible, sonic drilling for VAP borings will be conducted without the use of drilling water. If, for example, the geology is known for flowing sands or VAP is required deep below the water table, drilling water will be used to keep the core barrel free inside the outer drill casing. In this case it is recommended that a visible dye be used to spike the drilling water to assist with purging of the VAP interval. The VAP interval is then purged until the visible dye is no longer visible, or less the 10% of the starting concentration. For more on drilling with visible dye, see Section 8.2.3. Sonic VAP sampling is typically performed in a top-down manner using either a push ahead sampling device or a packer system.

8.2.1 Push-Ahead Groundwater Profiler

Push-ahead groundwater sampling devices are available through Cascade Drilling and other sonic drillers and consists of a stainless-steel sheathed “screen” threaded to the base of the sonic drill rod. The device is driven ahead of the sonic casing into the undisturbed formation to the prescribed sample depth interval. Once the point is at the specified interval, the threaded portion between the profiler and rod is partially unthreaded to expose the water ports to allow native formation water to enter the profiler. A groundwater sample is then obtained using either a stainless-steel bailer or pump with tubing depending on the DQOs. The interval is typically purged until relatively free of fine-grained material.

The disadvantage of using this device is that groundwater samples are obtained from undisturbed native formation with unknown soil lithology, so sampling is conducted “blind”. Therefore, it is recommended that a pre-existing lithological log from an adjacent borehole is used to determine sampling depth intervals.

8.2.2 Packer Isolation Groundwater Profiler

Packer Isolation groundwater profilers (e.g., Packer Isolation groundwater profiler from Cascade, Geoprobe ® SP-60 Sonic Groundwater Profiler) work by driving the casing over the soil core, retrieving the soil core barrel, and then lowering a stainless screen and packer assembly to the base of the sonic casing. The sonic outer casing is then extracted to expose the screen to the formation, and the packer is inflated within the casing above the screen to isolate the screened interval from any water that might be above the packer in the sonic casing. A groundwater sample can then be collected from the screen.

The biggest advantage of this device is that groundwater sampling depth intervals can be determined based on lithological logs obtained from the same borehole.

A disadvantage is that a large volume of purge water may need to be removed to clear the borehole of water introduced from above.

8.2.3 Drilling with Visible Dye

Potable water is commonly used as a drilling fluid during drilling to remove cuttings of geologic materials from the borehole (e.g., coring or roller-bit rotary drilling), cool the drill bit (e.g., sonic drilling), and/or maintain sufficient hydraulic pressure within the drilling tools to prevent heaving of aquifer solids into the drill casing(s).

Typically, if groundwater sampling is performed during drilling, the purge volume to be removed is at least as much as was lost during drilling. However, accurately determining the volume of water lost to the formation, or to specific intervals of the borehole, is not always feasible or possible.

To ensure that groundwater samples accurately represent groundwater quality of the surrounding formation and are not significantly influenced by unrecovered drilling fluid, fluorescein dye can be added to the drilling water to visually confirm when unimpacted native groundwater enters the borehole and can be sampled.

The target concentration of dye is approximately 20 mg/L, which is greater than two (2) orders of magnitude above its visual threshold (approximately 0.1 mg/L) and over five (5) orders of magnitude above its typical laboratory detection limit (less than 0.001 mg/L). Once the drilling tool has been advanced to the prescribed depth for groundwater sampling, water will be pumped from the borehole until the discharge water is relatively clear of fluorescein. The goal of purging is to reach the clarity of a prepared visual standard, indicating that the discharge water is comprised of at least 95 percent formation water and less than 5 percent drilling water. Groundwater samples will then be collected for COC analysis.

If the visual standard is still not reached after a reasonable period and volume of purging, then COC sampling can still be performed, provided that samples of the dyed drilling water and groundwater are also sent for fluorescein analysis. The fluorescein data can then be used to calculate a correction factor to be applied to COC analytical results.

[redacted] Set-Up Procedures

a. <u>Dye Batch Preparation</u>

- Prior to initiating drilling activities, measure the proper mass of powdered dye for mixing with drilling water - 38 grams of fluorescein (provided by Ozark Underground Laboratory) will be added to every 500 gallons of water to yield an average tracer concentration of approximately 20 mg/L.
- If the drilling water "batch" is larger or smaller than 500 gallons, the same ratio of dye to drilling water will be used.
- Measure the mass of dye using a scale with an accuracy of +/- 1 gram.
- Add the dye to the drilling water batch tank while also adding the potable water to provide agitation to assist in mixing the dye.
- A utility pump is also recommended to mix the tracer with the drilling water by recirculating water in the tank for at least 15 minutes.

- Place 40 mL of the dyed drilling water into a 50 mL graduated cylinder for use in preparing the visual standard discussed below.
- Collect four (4) additional 40 ml unpreserved VOA vials of drilling water from each batch of drilling water – label all four of these vials “DW1” for the first batch of drilling water, “DW2” for the second batch, etc. These samples will be archived for potential use in preparing other standards with other dilutions (optional) or for submittal for laboratory analysis, if necessary.

b. Preparation of Visual Standard: A visual standard will be prepared for each batch of dyed drilling water, as follows.

- Pour the 40 mL volume of dyed drilling water from the 50 mL graduated cylinder into a 1 L graduated cylinder.
- Add 760 mL of un-dyed potable water (from the same potable water source used to prepare the dyed drilling water) to the 1 L graduated cylinder to produce 800 mL of “visual standard”.
- Fill one 40-mL unpreserved VOA vial with visual standard solution and label this “VS1” for the visual standard from the first batch of drilling water, “VS2” for the visual standard from the second batch of drilling water, etc.
- These visual standards represent a 95% dilution of the drill water and will provide a visual standard to verify that sufficient purging has been performed to remove at least 95% of the drilling water from a given interval, indicating that the purge water consists of at least 95% formation water.
- Discard the remaining fluid within the graduated cylinder using an appropriate container.
- Photograph the “DW” samples and the “VS” sample from each batch of drilling water with adequate, consistent light, against a white background.
- Keep all the dyed drilling water (“DW”) samples and visual standard (“VS”) samples in a cooler to keep them dark as the dye will degrade with exposure to light.

[redacted] Drilling Procedures

- Fresh drilling water from the dyed drilling water batch tank will be used during drilling operations. In general, a positive head will be maintained during drilling, which should prevent dilution of the drilling water by formation water. However, any water upwelling from the casing during drilling will be contained in a tub positioned over the borehole. As needed, recovered water in the tub will be pumped to a frac tank.
- The drilling water source will be sampled for chlorine and pH at the start of the project. Chlorine, if present in detectable quantities, will consume fluorescein; therefore, wait a period of at least four (4) hours between dye addition and sampling (and use) of the drilling fluid. Below pH values of about 5, fluorescein will have reduced fluorescence. Depending on the source of the drilling fluid and project objectives, the source water may also be sampled for COCs and fluorescein.
- In open sunlight, fluorescein photodegrades rapidly. If the tracer batch tank is translucent, use 1-millimeter (mm) thick black plastic to cover the tank during the day to minimize photodegradation of the tracer batch water.
- After tracer addition, each batch of drilling fluid will be sampled at least once for fluorescein.
- At the end of the day, any excess tracer batch water can be stored for use on the following day, or it may be disposed of as investigation derived waste. Alternatively, fluorescein concentrations can be reduced to below

visible concentrations with granular activated carbon, UV-oxidation, chemical oxidants, or direct exposure to sunlight for several days.

- The field geologist will record the amount of drilling water lost to the formation during drilling of each sampling depth interval.
- At the end of the project, any excess tracer batch water can be disposed of as investigation derived waste. Alternatively, fluorescein concentrations can be reduced to below visible concentrations with granular activated carbon, UV-oxidation, chemical oxidants, or direct exposure to sunlight for several days. Depending on project and regulatory requirements, excess batch water with fluorescein concentrations below the visible limit could be discharged to a sanitary sewer or other discharge location.

[redacted] Purging and Sampling Procedures

- After a groundwater sampling interval is reached, purging and screening-level groundwater sampling will be performed.
- The target sample interval will be purged using a pump, and during purging, purge water will be periodically collected in a 40-mL unpreserved VOA vial and compared to the visual standard (“VS” sample) prepared from the drilling water used to drill that depth interval.
- If the purge water contains significant suspended particulates/turbidity, it may be necessary to allow particulates to settle before comparing the purge water sample to the visual standard.
- Purging will continue until *one* of the following two conditions is met:
    1) Purge water clarity (in terms of remaining dye content) matches or exceeds the clarity of the visual standard, indicating that the purge water consists of at least 95% formation water.
        a. In this case, the purge water sample and the associated visual standard will be photographed against a white background to document that the purging goal has been reached.

OR

    2) A different practical purging limit has been reached, based on purge volume or time
        a. In this case, the purge water sample and the associated visual standard will be photographed against a white background to document the degree of purge water visual clarity that was attained
        b. Also, a sample of the purge water will be collected in a 40 mL unpreserved VOA; this sample and one of the vials of dyed drilling water will be submitted to Ozark Underground Laboratories for quantitative analysis of fluorescein. These samples will be shipped in a cooler with reusable “Blue Ice” rather than wet ice. The analytical results for fluorescein will be used to calculate a COC correction factor, as discussed below (see Section 8.2.3.4).

- After purging has been completed, screening-level groundwater samples will be collected from the discharge end of the pump tubing for COC analysis in accordance with the approved work plan.

[redacted] Calculation of Correction Factor

- If the purge water does not reach the goal indicated by the visual standard (“VS” sample), a sample of the drilling water and a sample of the purge water (obtained immediately prior to sampling for COC analysis) will be sent for laboratory analysis of fluorescein.
- Representative COC concentrations in groundwater (C_{gw}) can then be calculated as:

$$C_{gw} = C_m \, [F_d / (F_d - F_s)]$$

where: C_m = measured COC concentration, as reported by the lab

F_d = fluorescein concentration in drilling water

F_s = fluorescein concentration in groundwater sample

- The term $[F_d / (F_d - F_s)]$ is the COC correction factor.

8.3 Boring Abandonment

Upon completion, each top-down borehole is backfilled with bentonite grout from the terminal end of the boring upward. The top portion of each boring is sealed with asphalt or concrete to match the existing grade. Each bottom-up borehole is typically abandoned by the collapse as the rods are retraced.

Borehole abandonment requirements in some geographies dictate top-down sampling; this should be verified in advance of work and outlined in the FIP/Work Plan. See also *TGI for Monitoring Well and Borehole Decommissioning.*

9 Waste Management

Investigation derived waste (IDW) (e.g., soil cuttings and decontamination water generated during cleaning procedures) will be collected and contained on site in appropriate containers: see the *TGI – Investigation- Derived Waste Handling and Storage* for details (Arcadis 2020d). All IDW generated during field activities will be placed in Department of Transportation approved containers, sealed, and labeled. Containerized IDW will be stored on site until it is profiled and subsequently transported to an approved facility for disposal or recycling.

Personal protective equipment (e.g., gloves, disposable clothing, disposable equipment) resulting from personnel cleaning procedures and soil sampling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled containers for appropriate disposal.

Waste manifests for all IDW suspected to have come into contact with PFAS will clearly note the potential presence of PFAS.

Additional IDW sampling and management details will be provided in the site-specific FIP/Work Plan/QAPP addendum and will be consistent with applicable client and state requirements.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

The supervising field lead will be responsible for documenting drilling events and for recording all relevant information in a clear and concise format. The record of drilling events will include (at a minimum):

- Start and finish drilling dates
- Project name and location
- Project number, client, and site location
- VAP boring number and depths
- Depth to water
- Type of VAP performed and associated tools
- Core barrel size
- Names of contractor’s drillers, inspectors, or other people onsite
- Weather conditions

Field staff will ensure COC Forms are properly completed and will verify which analytes (including PFAS analytes) are required for analysis and note on the COC.

Waterproof field books must not be used for field notes. Instead, it's recommended that field notes be on loose paper on Masonite, plastic, or aluminum clip boards and/or electronic data collection tablets (as required). Other requirements for field notes include:

- Keep field notes, writing implements, and electronic data collection tablets away from samples and sampling materials; and,
- Do not write on sampling bottles unless they are closed.

11 Quality Assurance

In general, the following quality assurance and quality control (QA/QC) samples will be collected:

- Equipment blanks
- Field duplicates
- Field (i.e., reagent) blanks

- Matrix spike/matrix spike duplicate

Details on QC sampling requirements (e.g., frequency of collection, types of QA/QC samples) are provided in the QAPP and/or FIP/Work Plan. Additionally, detailed procedures related to equipment and field (i.e., reagent) blank sample collection are outlined in the *TGI for Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

In general, equipment blanks should be collected from every piece of downhole equipment that could come into contact with soil or groundwater during sample collection. This includes the profiling tools (e.g., Geoprobe® SP-16, Geoprobe® SP-22, Geoprobe® SP-60, Cascade Packer Isolation Groundwater Profiler).

To avoid cross-contamination during drilling and sampling, reusable equipment such as hand tools will be cleaned using a non-phosphate soap free of VOCs, double-rinsed in potable water, and allowed to air dry prior to re-use. Drive casings and other drilling equipment will be steam cleaned or replaced with new equipment between boreholes. The drilling equipment will be cleaned in an area designated by the supervising engineer or geologist that is located outside of the work zone.

Prior to initiating field activities, water sources to be used during drilling activities will be sampled to verify those sources are PFAS-free to the extent possible.

Refer to quality control requirements for the project to ensure that appropriate quality assurance and quality control (QA/QC) samples are collected. When collecting QA/QC samples, the same guidelines apply as when collecting regular samples – specifically that:

- Samples will be collected in laboratory-supplied HDPE bottles
- Bottle caps must remain in the hand of the sampler until replaced on the bottle
- Labels must be completed after the caps have been placed back on each bottle
- Samples must be stored in appropriate transport bottles (coolers) with ice (Ziplock-type bags for use as ice containers) with appropriate labeling
- Do not use blue ice except for shipping fluorescein samples
- Store PFAS samples in a separate cooler from other types of samples

11.1 Equipment Blanks (if relevant)

QA/QC sampling typically includes daily collection of equipment blanks using the laboratory-supplied water, or in the case of PFAS sampling, “PFAS-free” water. For peristaltic pump tubing, laboratory supplied water will be poured into a clean HDPE sample bottle and then pumped through new HDPE tubing using the peristaltic pump (with new silicone tubing). Equipment blanks will also be collected from the water used by drillers, as well as any downhole tooling to ensure absence of any cross-contamination. Drilling water sources must be submitted for analysis of all COCs before work commences for VAP as discussed above. See *also TGI for Poly- and Perfluorinated Alkyl Substances (PFAS) Potable Water Sampling Guidance*.

11.2 Field Duplicates

QA/QC sampling typically includes the collection of one field duplicate for every 10 or 20 samples collected. Each duplicate sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-provided sample bottle. Do not indicate to the laboratory which sample the duplicate replicates (i.e., it will be given a blind reference on the COC and sample name such as “Dup 1”).

11.3 Field Blanks

QA/QC sampling for typically includes the submission of one laboratory supplied field blank per day. The reagent field blank sample is brought to the site in a laboratory-supplied sample bottle. Field staff transfer the laboratory-supplied reagent blank to an empty sample bottle. This reagent fieldblank will be placed in the same cooler as the other PFAS samples.

11.4 Matrix Spikes (optional in some cases)

QA/QC sampling includes submitting a sample to be used as a matrix spike if the project requires it. If a separate sample bottle is required, an additional sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-supplied sample bottle.

11.5 Laboratory Analytical QA/QC

- Internal laboratory QA/QC will consist of one laboratory blank and one laboratory control sample (or blank spike) per batch of samples, and additional QA/QCs as indicated by the laboratory QA/QC procedures. Isotope dilution will be used for quantification with isotope-labeled surrogate standards, as available.
- For groundwater and surface water samples, extract the entire groundwater and surface water sample and at least two sampling bottle solvent rinsates for analysis to increase sample accuracy. Avoid sub-sampling an aliquot of the sample bottle.
- Soil samples will be analyzed in their entirety or thoroughly homogenized before extraction and analysis.
- As part of the internal QA/QC, relative percent difference will be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates will be reviewed to verify that all calculations/recoveries were within acceptable limits as established by the laboratory method.
- In January 2017, the U.S. Department of Defense and U.S. Department of Energy Quality Systems Manual (QSM) 5.1 (U.S. Department of Defense 2017) was finalized and introduced laboratory guidance for the measurement of PFAS in matrices other than drinking water. This guidance is not a detailed procedural method such as an U.S. Environmental Protection Agency method, but it does recommend best practices around the analysis of PFAS. Laboratories are not required to comply with QSM 5.1 until 2019, although the recommendations around PFAS analysis are similar to what most laboratories are already implementing. Arcadis recommends that any request for PFAS analysis in

groundwater or soil should specifically reference the need to comply with Table B-15 in the QSM 5.1 (i.e., Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water); however, this list can be modified to support project specific deliverables.

12 References

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ATTACHMENT 1

Table 1 and Table 2: PFAS Investigation Material Recommendations

Table 1: Summary of Acceptable Sampling Equipment and Materials for PFAS Site Investigations

Sampling Materials	Additional Considerations	References
Water Sampling Materials		
High density polyethylene (HDPE) or silicone tubing materials	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
HDPE HydraSleeves™	Low density polyethylene (LDPE) HydraSleeves™ are not recommended	USACE 2016; MassDEP 2017
Drilling and Soil Sampling Materials		
PFAS-free drilling fluids	--	DER 2016
PFAS-free makeup water	Confirm PFAS-free water source via laboratory analysis prior to investigation	--
Acetate liners	For use in soil sampling	USACE 2016
Sample Containers and Storage		
HDPE sample containers with HDPE lined lids for soil and water samples	Laboratory should provide; whole bottle analysis of aqueous samples combined with a solvent rinse of bottle is recommended	DER 2016, MassDEP 2017
Ice contained in plastic (polyethylene) bags (double bagged)	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Field Documentation		
Sharpie®	--	NHDES 2016; USACE 2016; MassDEP 2017
Ball point pens	--	MassDEP 2017
Standard paper and paper labels	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Decontamination		
Water-only decontamination	Confirm PFAS-free water source via laboratory analysis prior to investigation	DER 2016
Alconox®, Liquinox® or Citranox® followed by deionized water or PFAS-free water rinse	Alconox® known to contain trace levels of 1,4-dioxane	NHDES 2016; USACE 2016; MassDEP 2017
Methanol, isopropanol, or acetone	Special health and safety precautions are necessary	UNEP 2015; USACE 2016

Note: This list is considered preliminary and additional materials may be added as additional information becomes available. Project teams are expected to follow a methodical evaluation process of materials to be used and confirm acceptance prior to implementation of field activities.

Table 2: Summary of Equipment and Materials Not Recommended for PFAS Site Investigations.

Sampling Materials	Known PFAS-Containing Materials	Suspected PFAS-Containing Materials	Materials with Potential to Retain PFASs	References
Water Sampling Materials				
Teflon® or polytetrafluoroethylene (PTFE)-containing or coated field equipment (e.g., tubing, bailers, tape, plumbing paste)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Passive diffusion bags			x	MassDEP 2017
LDPE HydraSleeves ™			x	USACE 2016; MassDEP 2017
Water particle filters			x	MassDEP 2017
Drilling and Soil Sampling Materials				
Aluminum foil			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Drilling fluid containing PFASs	x	x		DER 2016
Sample Containers and Storage				
Glass sample containers with lined lids			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
LDPE containers and lined lids			x	USACE 2016
Teflon® or PTFE- lined lids on containers (e.g., sample containers, rinsate water storage containers)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Reusable chemical or gel ice packs (e.g., BlueIce®)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Field Documentation				
Self-sticking notes and similar office products (e.g., 3M Post-it-notes)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Waterproof paper, notebooks, and labels	x			DER 2016, MassDEP 2017
Non-Sharpie® markers		x		NHDES 2016
Decontamination				
Some detergents and decontamination solutions (e.g., Decon 90® Decontamination Solution)	x	x		DER 2016; NHDES 2016; MassDEP 2017

Note: For materials that are suspected of containing PFASs, or have the potential to retain PFASs, project specific considerations may provide adequate justification for use during the field event. For example, further evaluation may be conducted in the form of pre-field equipment blank sample analysis.

ATTACHMENT 2

Safety Data Sheet (SDS) Fluorescein

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION
Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ………………….…… **HUE URANINE CONC** (Also known as Fluorescein)
PRODUCT NUMBER ….................… 1-C8-073PC
COLOR INDEX NAME ….................. ACID YELLOW 073
COLOR INDEX NO …..…..……….…… 45350
C. A. S. # …………….………….…… 518-47-8
CHEMICAL FAMILY……………….…… XANTHENE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US):	NO SYMBOL
SIGNAL WORD	WARNING
HAZARD STATEMENT(S)	H333 - MAY BE HARMFUL IF INHALED H320 - CAUSES EYE IRRITATION H316 - CAUSES MILD SKIN IRRITATION
PRECAUTIONARY STATEMENTS	P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS:
GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL

OTHER HAZARDS	NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY	NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION:	REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.
SKIN:	WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.
EYES:	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.
INGESTION:	INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL.
IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY	STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID	OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS	OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS	- CO, CO_2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL	GREATER THAN 7,000 MG/KG - RAT
DERMAL (ANIMAL)	NA
EFFECTS TO EYES (ANIMAL)	EYES - RABBIT, NOT IRRITATING
SKIN IRRITATION (ANIMAL)	SKIN - RABBIT, SLIGHT IRRITANT

SKIN CORROSION/IRRITATION	NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION	CAUSES EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION	NOT CLASSIFIED
GERM CELL MUTAGENICITY	NOT CLASSIFIED
CARCINOGENICITY	NOT CLASSIFIED
REPRODUCTIVE TOXICITY	NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE)	MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD	NOT CLASSIFIED
INHALATION	MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT	CAUSES SERIOUS EYE IRRITATION.
INGESTION	INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY	NA
PERSISTENCE AND DEGRADABILITY	NA
BIOACCUMULATIVE POTENTIAL	NA
MOBILITY IN SOIL	LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL CATFISH - 2,267,000 UG/LITER RAINBOW TROUT - 1,372,000 UG/LITER BLUEGILL - 3,433,000 UG/LITER
OTHER ADVERSE EFFECTS	NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL.
PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING.
OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER	NONE
UN PROPER SHIPPING NAME	NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT)	NA
DOT SPECIAL PROVISIONS	NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT	NONE
TRANSPORT BY SEA	NONE
AIR TRANSPORT	NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT	NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT	NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

518-47-8	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

ALL INFORMATION AND DATA APPEARING ON THIS SDS ARE BELIEVED TO BE RELIABLE AND ACCURATE. HOWEVER, IT IS THE USER' S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY, AND SUITABILITY FOR USE OF THE PRODUCT DESCRIBED. SINCE THE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO GUARANTEE, EXPRESSED OR IMPLIED, IS MADE BY HUE CORPORATION.
USER ASSUMES ALL RISK AND RESPONSIBILITY.

ATTACHMENT 3

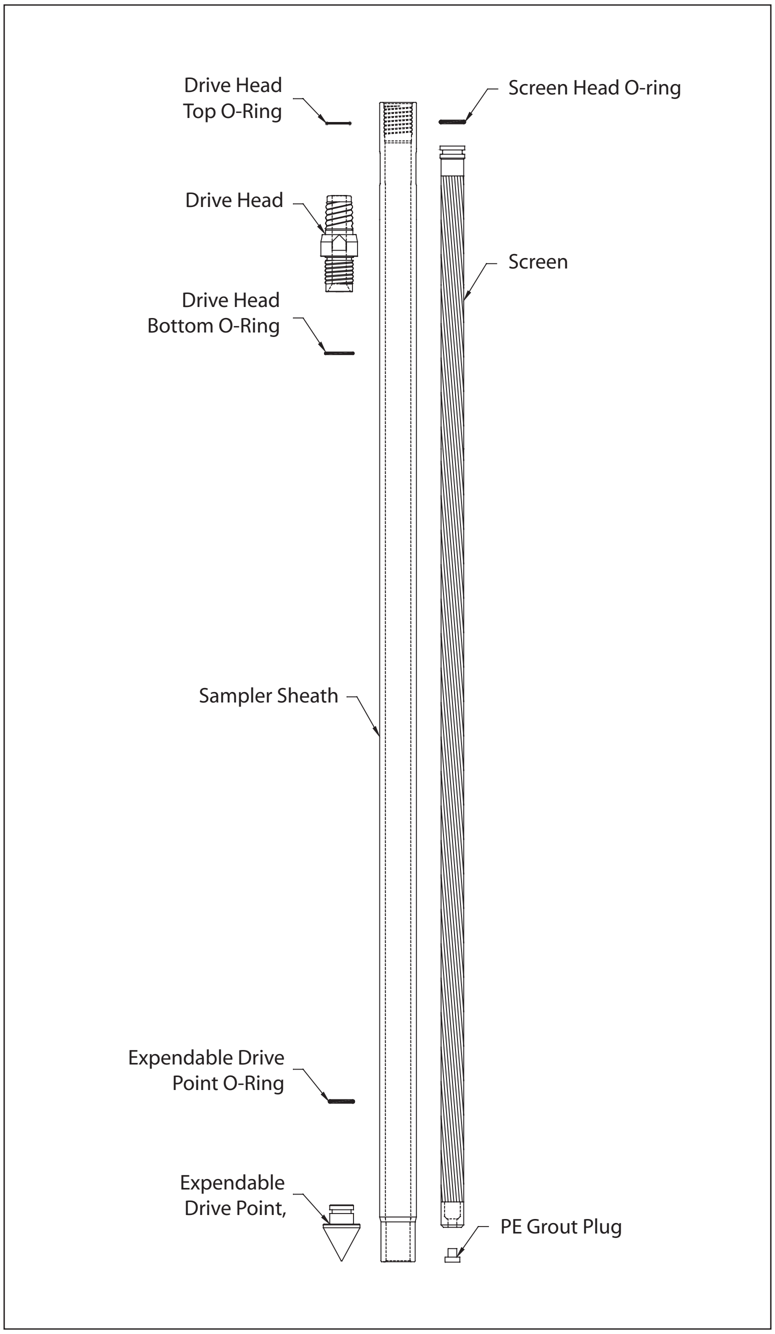
SOPs Geoprobe® Screen Point 16 and Screen Point 22 Groundwater Samplers

GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3142

PREPARED: November, 2006



GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER PARTS

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

Screen Point 16 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to drive a sealed stainless steel or PVC screen to depth, deploy the screen, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 16 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 16 (SP16) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is driven to depth within a sealed, steel sheath and then deployed for the collection of representative groundwater samples. The assembled SP16 Sampler is approximately 51.5 inches (1308 mm) long with an OD of 1.625 inches (41 mm). Upon deployment, up to 41 inches (1041 mm) of screen can be exposed to the formation. The Screen Point 16 Groundwater Sampler is designed for use with 1.5-inch probe rods and machines equipped with the more powerful GH60 Hydraulic Hammer. Operators with GH40 Series hammers may chose to use this sampler in soils where driving is difficult.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with extension rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion

In this procedure, the assembled Screen Point 16 Groundwater Sampler (Fig. 2.1A) is threaded onto the leading end of a Geoprobe® probe rod and advanced into the subsurface with a Geoprobe® direct push machine. Additional probe rods are added incrementally and advanced until the desired sampling interval is reached. While the sampler is advanced to depth, O-ring seals at each rod joint, the drive head, and the expendable drive point provide a watertight system. This system eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once at the desired sampling interval, extension rods are sent downhole until the leading rod contacts the bottom of the sampler screen. The tool string is then retracted approximately 44 inches (1118 mm) while the screen is held in place with the extension rods (Fig. 2.1B). As the tool string is retracted, the expendable point is released from the sampler sheath. The tool string and sheath may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

There are three types of screens that can be used in the Screen Point 16 Groundwater Sampler. Two of the these, a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm), are recovered with the tool string after sampling. The third screen is also manufactured from PVC with a standard slot size of 0.010 inches (0.25 mm), but is designed to be left downhole when sampling is complete. This disposable screen has an exposed screen length of approximately 43 inches (1092 mm). The two screens that are recovered with the sampler both have an exposed screen length of approximately 41 inches (1041 mm).

(continued on following page)

An O-ring on the head of the stainless steel screens maintains a seal at the top of the screen. As a result, any liquid entering the sampler during screen deployment must first pass through the screen. PVC screens do not require an O-ring because the tolerance between the screen head and sampler sheath is near that of the screen slot size.

The screens are constructed such that flexible tubing, a mini-bailer, or a small-diameter bladder pump can be inserted into the screen cavity. This makes direct sampling possible from anywhere within the saturated zone. A removable plug in the lower end of the screens allows the user to grout as the sampler is extracted for further use.

Groundwater samples can be obtained in a number of ways. A common method utilizes polyethylene (TB25L) or Teflon® (TB25T) tubing and a Check Valve Assembly (GW4210). The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to the tubing. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP16 sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

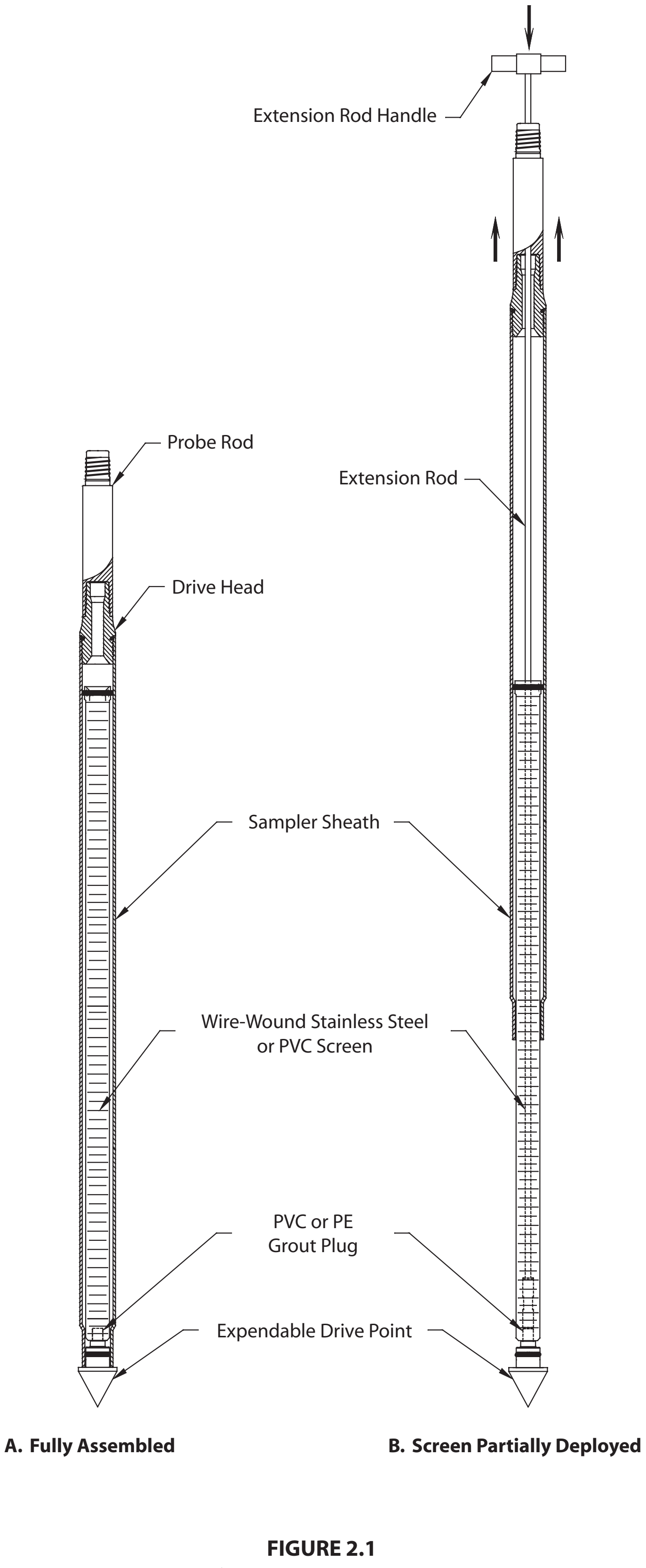


FIGURE 2.1
Screen Point 16 Groundwater Sampler

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 16 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP16 / 1.5-inch probe rod configurations. Additional parts for optional rod sizes and accessories are listed in Appendix A.

SP16 Sampler Parts	**Part Number**
SP16 Sampler Sheath	15187
SP16 Drive Head, 0.5-inch bore, 1.5-inch rods*	18307
SP16 O-ring Service Kit, 1.5-inch rods *(includes 4 each of the O-ring packets below)*	15844
O-rings for Top of SP16 Drive Head, 1.5-inch rods only (Pkt. of 25)	*15389*
O-rings for Bottom of SP16 Drive Head (Pkt. of 25)	*13196*
O-rings for GW1520 Screen Head (Pkt. of 25)	*GW1520R*
O-rings for SP16 Expendable Drive Point (Pkt. of 25)	*GW1555R*
Screen, Wire-Wound Stainless Steel, 4-Slot*	GW1520
Grout Plugs, PE (Pkg. of 25)	GW1552K
Expendable Drive Points, steel, 1.625-inch OD (Pkg. of 25)*	GW1555K
Screen Point 16 Groundwater Sampler Kit, 1.5-inch Probe Rods *(includes 1 each of: 15187, 18307, 15844, GW1520, GW1535, GW1540, GW1555K, and GW1552K)*	15770

Probe Rods and Probe Rod Accessories	**Part Number**
Drive Cap, 1.5-inch probe rods, threadless, (for GH60 Hammer)	12787
Pull Cap, 1.5-inch probe rods	15090
Probe Rod, 1.5-inch x 60-inch*	11121

Extension Rods and Extension Rod Accessories	**Part Number**
Screen Push Adapter	GW1535
Grout Plug Push Adapter	GW1540
Extension Rod, 60-inch*	10073
Extension Rod Coupler	AT68
Extension Rod Handle	AT69
Extension Rod Jig	AT690
Extension Rod Quick Link Coupler, pin	AT695
Extension Rod Quick Link Coupler, box	AT696

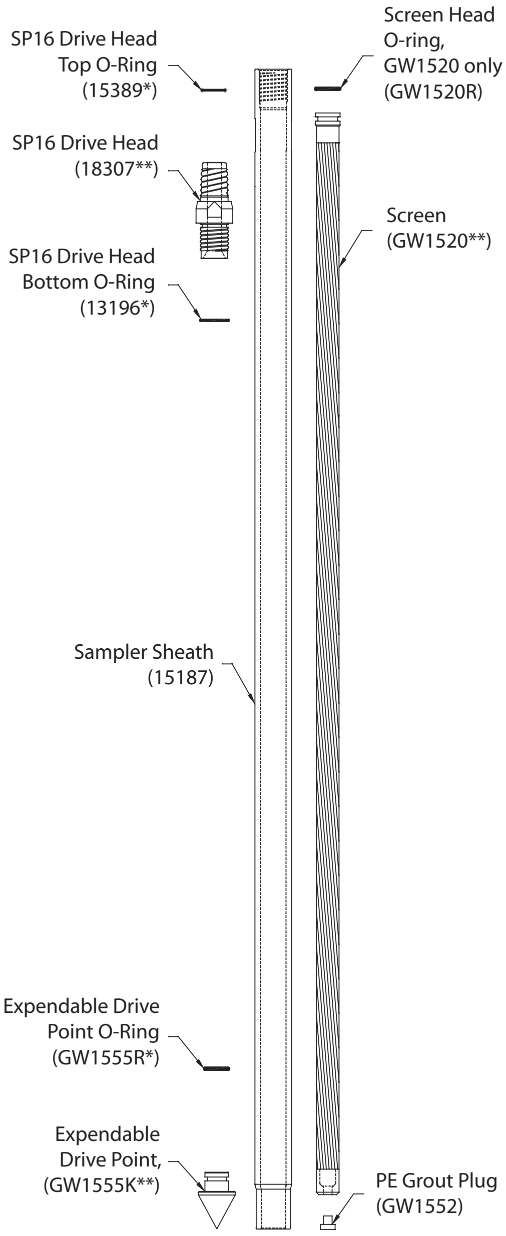
Grout Accessories	**Part Number**
Grout Nozzle, for 0.375-inch OD tubing	GW1545
High-Pressure Nylon Tubing, 0.375-inch OD / 0.25-inch ID, 100-ft. (30 m)	11633
Grout Machine, self-contained*	GS1000
Grout System Accessories Package, 1.5-inch rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-inch OD, 500 ft.*	TB25L
Check Valve Assembly, 0.375-inch OD Tubing*	GW4210
Water Level Meter, 0.438-inch OD Probe, 100 ft. cable*	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, stainless steel	GW41

Additional Tools	**Part Number**
Adjustable Wrench, 6.0-inch	FA200
Adjustable Wrench, 10.0-inch	FA201
Pipe Wrenches	NA

* See Appendix A for additional tooling options.

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration. See Appendix A for alternative parts.

FIGURE 3.1
SP16 Sampler Parts

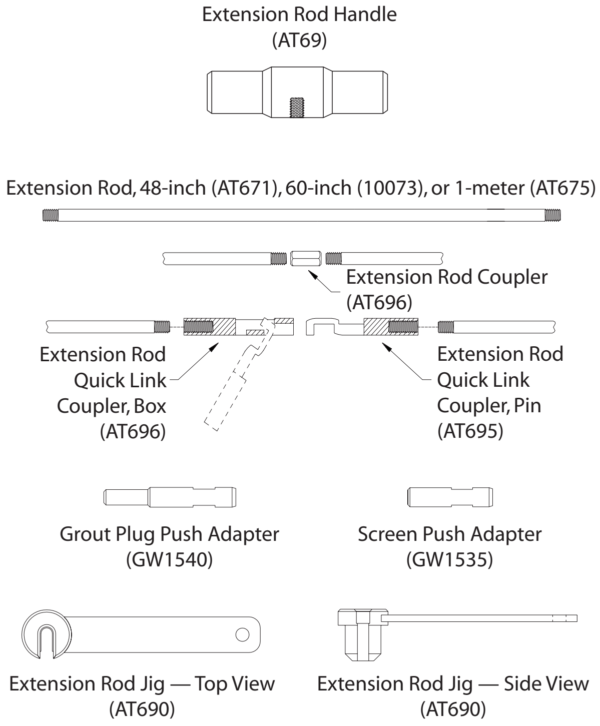


FIGURE 3.2
Geoprobe® Extension Rods and Accessories

4.0 OPERATION

4.1 Basic Operation

The SP16 sampler utilize a stainless steel or PVC screen which is encased in an alloy steel sampler sheath. An expendable drive point is placed in the lower end of the sheath while a drive head is attached to the top. O-rings on the drive head and expendable point provide a watertight sheath which keeps contaminants out of the system as the sampler is driven to depth.

Once the sampling interval is reached, extension rods equipped with a screen push adapter are inserted down the ID of the probe rods. The tool string is then retracted up to 44 inches (1118 mm) while the screen is held in place with the extension rods. The system is now ready for groundwater sampling. When sampling is complete, a removable plug in the bottom of the screen allows for grouting below the sampler as the tool string is retrieved.

4.2 Sampler Options

The Screen Point 15 and Screen Point 16 Groundwater Samplers are nearly identical. Subtle differences in the design of the SP16 sampler make it more durable than the earlier SP15 system. Operators of GH60-equipped machines should always utilize SP16 tooling. Operators of machines equipped with GH40 Series hammers may also choose SP16 tooling when sampling in difficult probing conditions.

A 1.75-inch OD Expendable Drive Point (17066K) and Disposable PVC Screen (16089) provide two useful options for the SP16 sampler. The 1.75-inch drive point may be used when soil conditions make it difficult to remove the sampler after driving to depth. The disposable PVC screen may be left downhole after sampling (when regulations permit) to eliminate the time required for screen decontamination.

4.3 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.4 SP16 Sampler Assembly (Figure 4.1)

Part numbers are listed for a standard SP16 sampler using 1.5-inch probe rods. Refer to Page 6 for screen and drive head alternatives.

1. Place an O-ring on a steel expendable drive point (GW1555K). Firmly seat the expendable point in the necked end of a sampler sheath (15187).

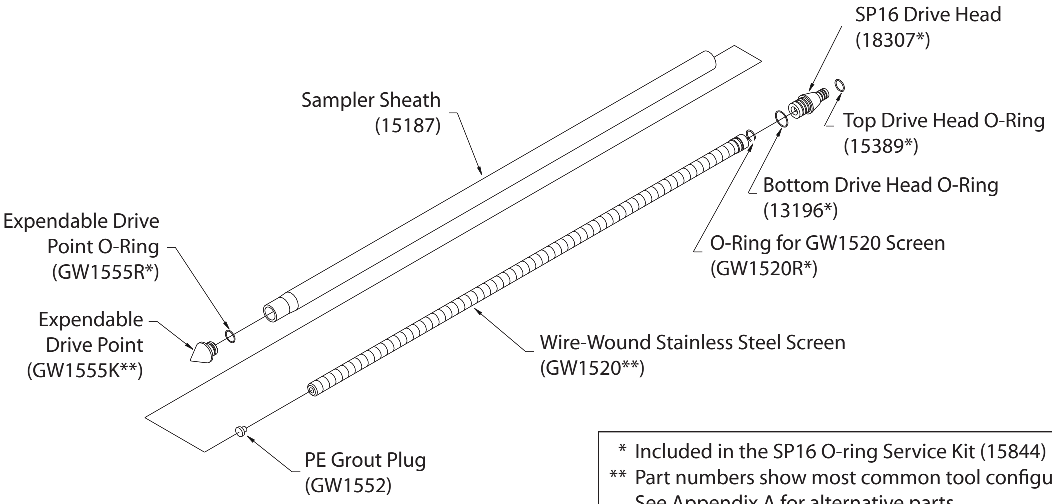
2. Install a PE Grout Plug (GW1552) in the bottom end of a Wire-wound Stainless Steel Screen (GW1520). Place a GW1520R O-ring in the groove on the top end of the screen.

3. Slide the screen inside of the sampler sheath with the grout plug toward the bottom of the sampler. Ensure that the expendable point was not displaced by the screen.

4. Install a bottom O-ring (13196) on a Drive Head (18307 or 15188). Thread the drive head into the sampler sheath using an adjustable wrench if necessary to ensure complete engagement of the threads. Attach a Drive Cap (12787 or 15590) to the top of the drive head.

   NOTE: The 18307 drive head should be used whenever possible as the smaller 0.5-inch ID provides a greater material cross-section for increased durability.

Sampler assembly is complete.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration.
See Appendix A for alternative parts.

FIGURE 4.1
Screen Point 16 Groundwater Sampler Assembly

4.5 Advancing the SP16 Sampler

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Begin by placing the assembled sampler (Fig. 2.1.A) in the driving position beneath the hydraulic hammer of the direct push machine as shown in Figure 4.2.

2. Advance the sampler with the throttle control at slow speed for the first few feet to ensure that the sampler is aligned properly. Switch to fast speed for the remainder of the probe stroke.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the drive head. Distilled water may be used to lubricate the O-ring if needed.

   Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the sampler the entire length of the new rod with the throttle control at fast speed.

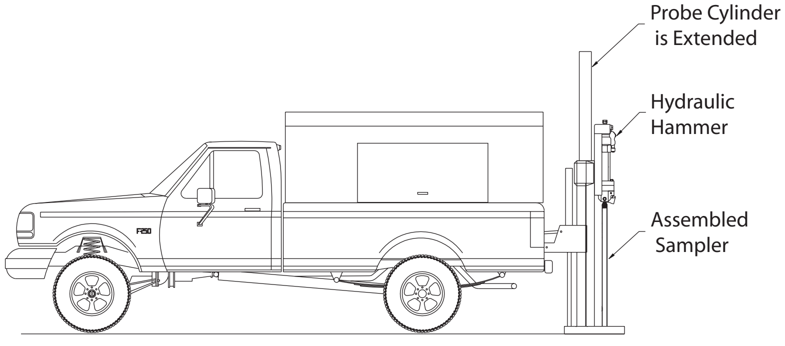


FIGURE 4.2
Screen Point 16 Groundwater Sampler in Driving Position

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

4.6 Screen Deployment

1. Thread a screen push adapter (GW1535) on an extension rod of suitable length (AT671, 10073, or AT675). Attach a threaded coupler (AT68) to the other end of the extension rod. Lower the extension rod inside of the probe rod taking care not to drop it down the tool string. An extension rod jig (AT690) may be used to hold the rods.

2. Add extension rods until the adapter contacts the bottom of the screen. To speed up this step, it is recommended that Extension Rod Quick Links (AT695 and AT696) are used at every other rod joint.

3. Ensure that at least 48 inches (1219 mm) of extension rod protrudes from the probe rod. Thread an extension rod handle (AT69) on the top extension rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the tool string while physically holding the screen in place with the extension rods (Fig. 4.3.B). A slight knock with the extension rod string will help to dislodge the expendable point and start the screen moving inside the sheath.

   Raise the hammer and tool string about 44 inches (1118 cm) if using a GW1520 or GW1530 screen. At this point the screen head will contact the necked portion of the sampler sheath (Fig. 4.3.C.) and the extension rods will rise with the probe rods. Use care when deploying a PVC screen so as not to break the screen when it contacts the bottom of the sampler sheath.

   The Disposable Screen (16089) will extend completely out of the sheath if the tool string is raised more than 45 inches (1143 mm). Measure and mark this distance on the top extension rod to avoid losing the screen during deployment.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top extension rod (with handle) and top probe rod. Finally, extract all extension rods.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

4.7 Abandonment Grouting for GW1520 and GW1530 Screens

The SP16 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of GW1520 and GW1530 screens. A GS500 or GS1000 Grout Machine is then used to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling. Attach the rod grip puller to the top probe rod. Raise the tool string approximately 4 to 6 inches (102 to 152 cm) to allow removal of the grout plug.

2. Thread the Grout Plug Push Adapter (GW1540) onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the grout plug at the bottom of the screen. Attach the handle to the top extension rod. When the extension rods are slightly raised and lowered, a relatively soft rebound should be felt as the adapter contacts the grout plug. This is especially true when using a PVC screen.

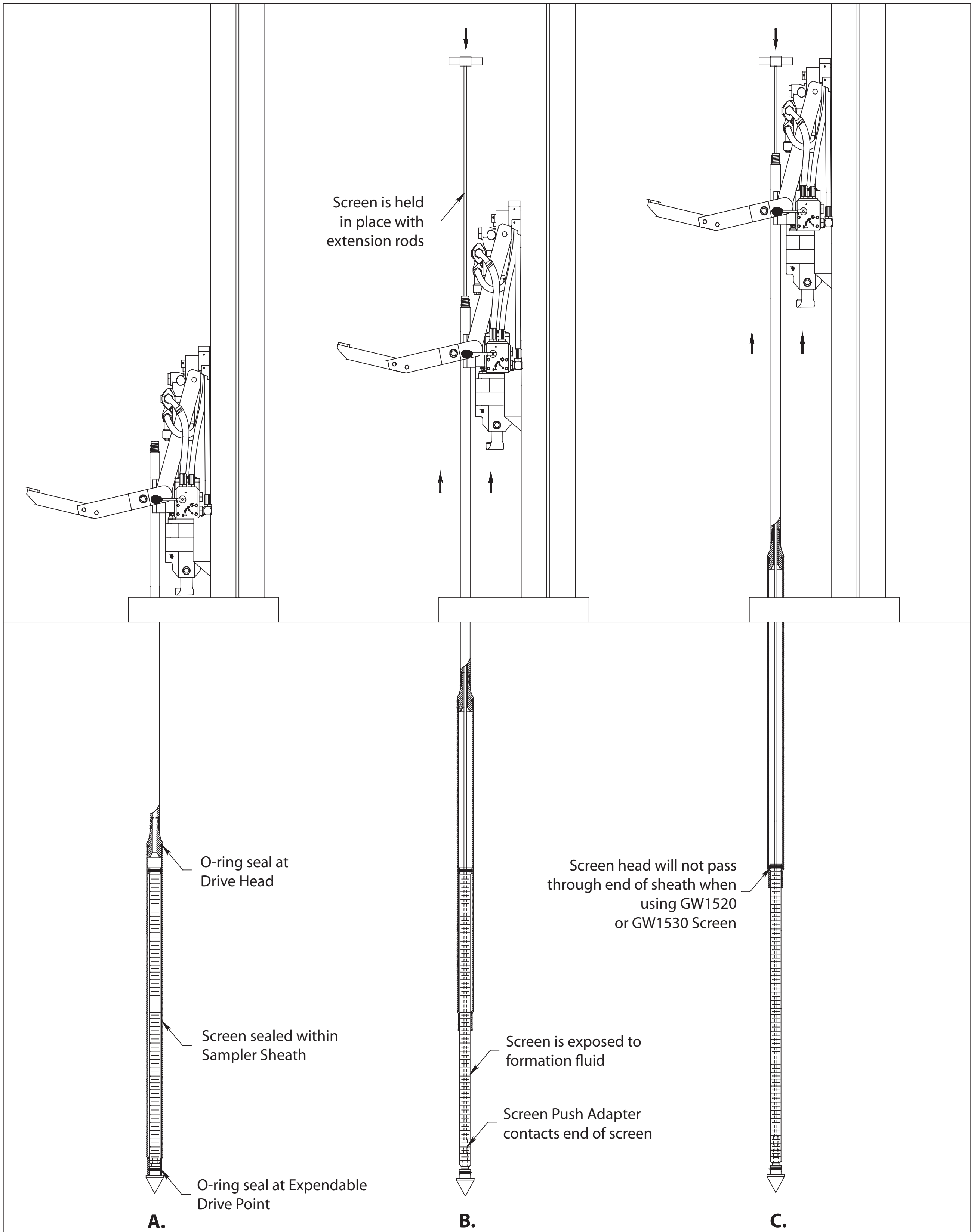


FIGURE 4.3

Screen Deployment for SP16 Sampler

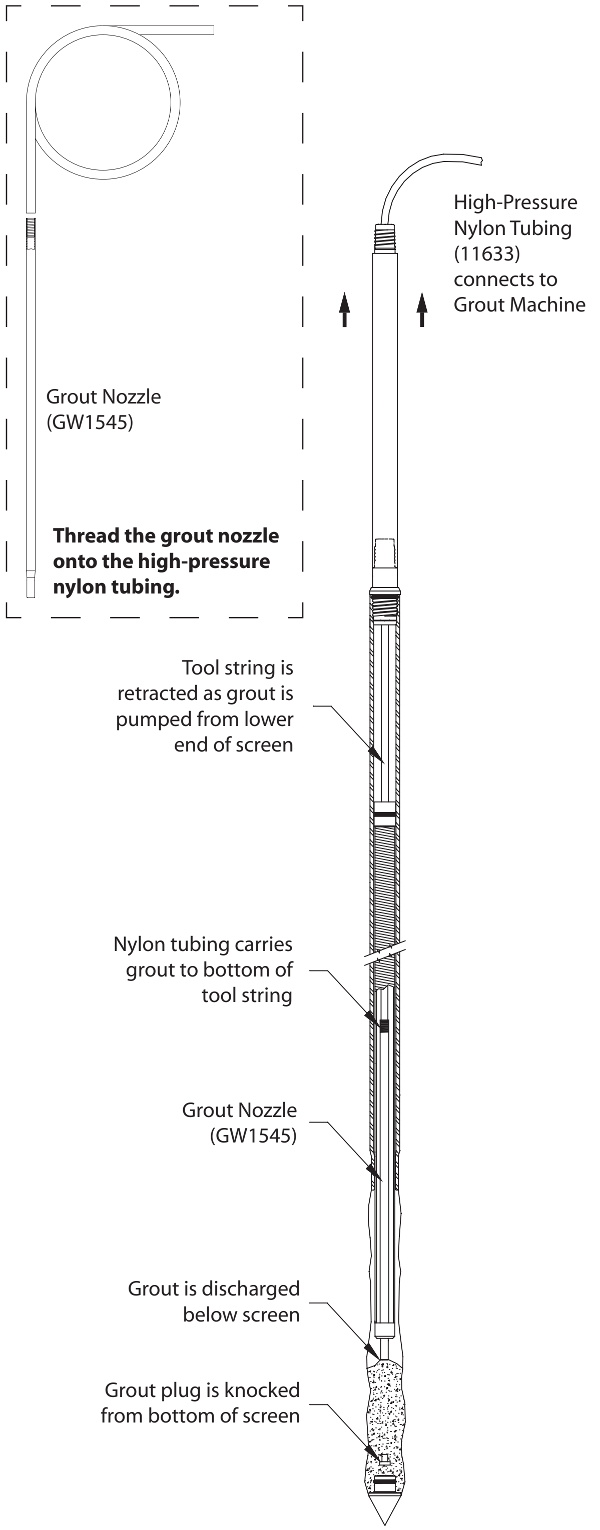


FIGURE 4.4
Grouting the SP16 Sampler With a GW1520 or GW1530 Screen

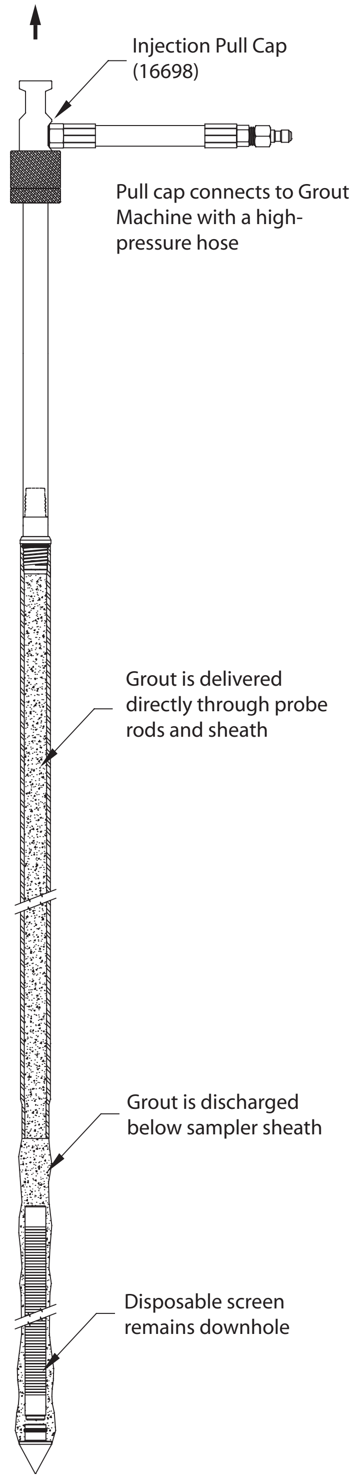


FIGURE 4.5
Grouting the SP16 Sampler With a 16089 Disposable Screen

3. Place a mark on the extension rod even with the top of the probe rod. Apply downward pressure on the extension rods and push the grout plug out of the screen. The mark placed on the extension rod should now be below the top of the probe rod. Remove all extension rods.

   Note: When working with a stainless steel screen, it may be necessary to raise and quickly lower the extension rods to jar the grout plug free. When the plug is successfully removed, a metal-on-metal sensation may be noted as the extension rods are gently "bounced" within the probe rods.

4. A Grout Nozzle (GW1545) is now connected to High-Pressure Nylon Tubing (11633) and inserted down through the probe rods to the bottom of the screen (Fig. 4.4). It may be necessary to pump a small amount of clean water through the tubing during deployment to jet out sediments that settled in the bottom of the screen. Resistance will sometimes be felt as the grout nozzle passes through the drive head. Rotate the tubing while moving it up-and-down to ensure that the nozzle has reached the bottom of the screen and is not hung up on the drive head.

   ***Note:** All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

5. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

6. Repeat Step 5 until the sampler is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

7. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.8 Abandonment Grouting for the 16089 Disposable Screen

ASTM D 5299 requirements can also be met for the SP16 samplers when using the 16089 disposable screen. Because the screen remains downhole after sampling, the operator may choose either to deliver grout to the bottom of the tool string with nylon tubing or pump grout directly through the probe rods using an Injection Pull Cap (16698). A GS500 or GS1000 Grout Machine is needed to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling with the rod grip puller.

2. Thread the screen push adapter onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the bottom of the screen. Attach the handle to the top extension rod.

3. The disposable screen must be extended at least 46 inches (1168 mm) to clear the bottom of the sampler sheath. Considering the length of screen deployed in Section 4.7, determine the remaining distance required to fully extend the screen from the sheath. Mark this distance on the top extension rod.

4. Pull the tool string up to the mark on the top extension rod while holding the disposable screen in place.

   The screen is now fully deployed and the sampler is ready for abandonment grouting. Apply grout to the bottom of the tool string during retrieval using either flexible tubing (as described in Section 4.7) or an injection pull cap (Fig. 4.5). This section continues with a description of grouting with a pull cap.

5. Remove the rod grip handle and maneuver the probe assembly directly over the tool string. Thread an Injection Pull Cap (16698) onto the top probe rod and close the hammer pull latch over the top of the pull cap.

6. Connect the pull cap to a Geoprobe® grout machine using a high-pressure grout hose.

7. Operate the pump to fill the entire tool string with grout. When a sufficient volume has been pumped to fill the tool string, begin pulling the rods and sampler while continuing to operate the grout pump. Considering the known pump volume and sampler cross-section, time tooling withdrawal to slightly "overpump" grout into the subsurface. This will ensure that all voids are filled during sampler retrieval.

   The grouting process can lubricate the probe hole sufficiently to cause the tool string to slide back downhole when disconnected from the pull cap. Prevent this by withdrawing the tool string with the rod grip puller while maintaining a connection to the grout machine with the pull cap.

4.9 Retrieving the Screen Point 16 Sampler

If grouting is not required, the Screen Point 16 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (15164) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

5.0 REFERENCES

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Appendix A
ALTERNATIVE PARTS

The following parts are available to meet unique soil conditions. See section 3.0 for a complete listing of the common tool configurations for the Geoprobe® Screen Point 16 Groundwater Sampler.

SP16 Sampler Parts and Accessories	**Part Number**
SP16 Drive Head, 0.625-inch bore, 1.5-inch rods	15188
Expendable Drive Points, aluminum, 1.625-inch OD (Pkg. of 25)	GW1555ALK
Expendable Drive Points, steel, 1.75-inch OD (Pkg. of 25)	17066K
Screen, PVC, 10-Slot	GW1530
Screen, Disposable, PVC, 10-Slot	16089

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.25-inch OD, 500 ft.	TB17L
Polyethylene Tubing, 0.5-inch OD, 500 ft.	TB37L
Polyethylene Tubing, 0.625-inch OD, 50 ft.	TB50L
Check Valve Assembly, 0.25-inch OD Tubing	GW4240
Check Valve Assembly, 0.5-inch OD Tubing	GW4220
Check Valve Assembly, 0.625-inch OD Tubing	GW4230
Water Level Meter, 0.375-inch OD Probe, 100-ft. cable	GW2001
Water Level Meter, 0.438-inch OD Probe, 200-ft. cable	GW2002
Water Level Meter, 0.375-inch OD Probe, 200-ft. cable	GW2003
Water Level Meter, 0.438-inch OD Probe, 30-m cable	GW2005
Water Level Meter, 0.438-inch OD Probe, 60-m cable	GW2007
Water Level Meter, 0.375-inch OD Probe, 60-m cable	GE2008

Grouting Accessories	**Part Number**
Grout Machine, auxiliary-powered	GS500

Probe Rods, Extension Rods, and Accessories	**Part Number**
Probe Rod, 1.5-inch x 1-meter	17899
Probe Rod, 1.5-inch x 48-inch	13359
Drive Cap, 1.5-inch rods (for GH40 Series Hammer)	15590
Rod Grip Pull Handle, 1.5-inch Probe Rods (for GH40 Series Hammer)	GH1555
Extension Rod, 48-inch	AT671
Extension Rod, 1-meter	AT675

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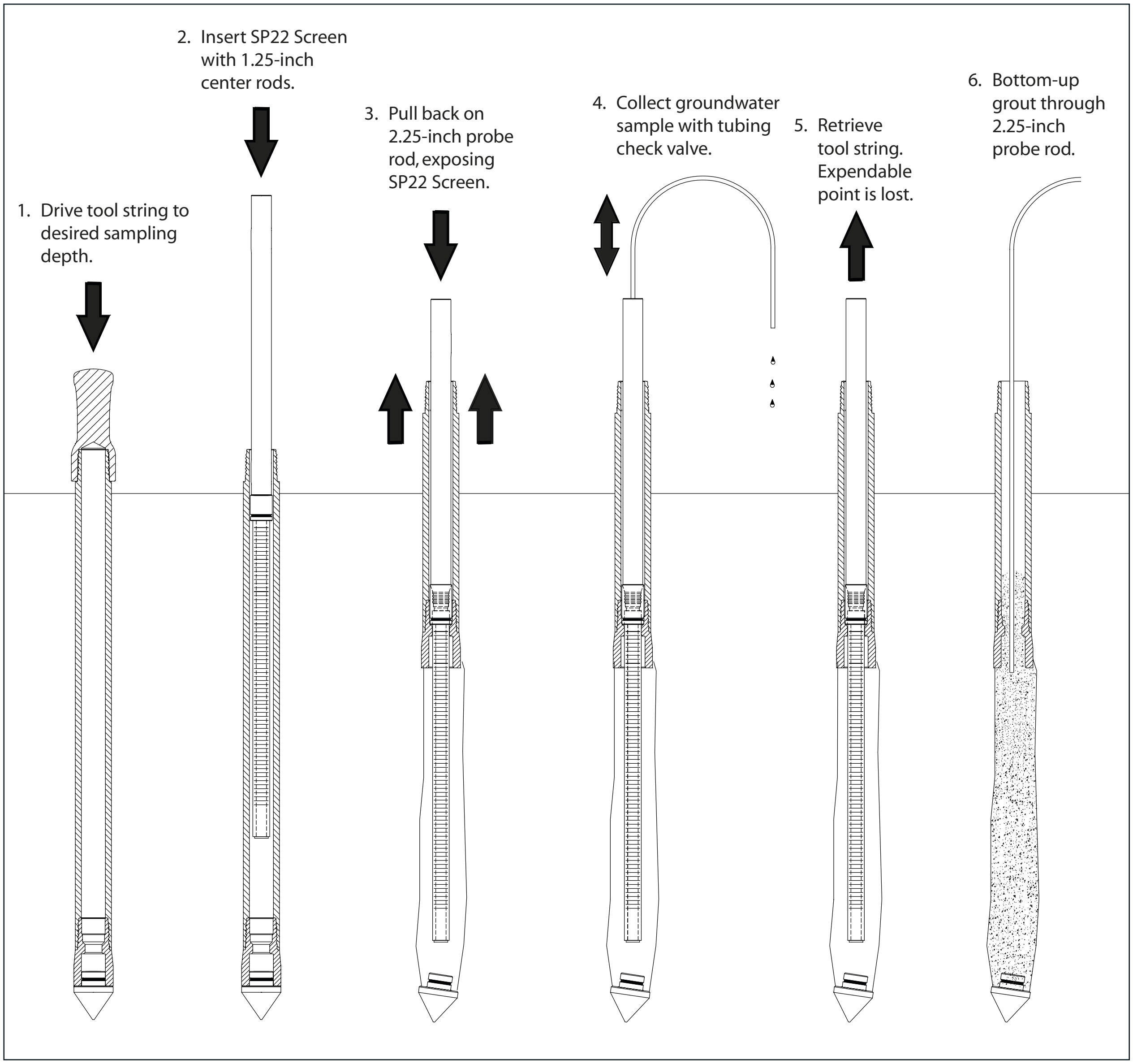
Geoprobe® Screen Point 22 Groundwater Sampler

Standard Operating Procedure

Technical Bulletin No. MK3173

PREPARED: April 2010



1. Drive tool string to desired sampling depth.
2. Insert SP22 Screen with 1.25-inch center rods.
3. Pull back on 2.25-inch probe rod, exposing SP22 Screen.
4. Collect groundwater sample with tubing check valve.
5. Retrieve tool string. Expendable point is lost.
6. Bottom-up grout through 2.25-inch probe rod.

OPERATION OF THE GEOPROBE® SCREEN POINT 22 GROUNDWATER SAMPLER

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

Screen Point 22 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to deploy a stainless steel or PVC screen at depth, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 22 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize static force and percussion or rotation to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform activities such as soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 22 (SP22) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is lowered (post-run) to depth within a sealed string of steel probe rods and then deployed for the collection of representative groundwater samples. Upon deployment, up to 48 inches (1219 mm) of screen can be exposed to the formation. There is also an optional 12-inch screen that can be used. The Screen Point 22 Groundwater Sampler is designed for use with 2.25-inch probe rods and machines equipped with the more powerful GH60 and GH80 series hydraulic hammers. Operators with GH40 series hammers may choose to use this sampler in soils where driving is easier.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with probe rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion (Fig. 2.1)

In this procedure, 2.25-inch probe rods are advanced into the subsurface with a Geoprobe® subsurface machine (Fig. 2.1, Step 1). While the tool string is advanced to depth, O-ring seals at each rod joint, the expendable point holder, and the expendable drive point provide a watertight system. This eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once the leading end of the 2.25-inch probe rods reaches the desired sampling interval, an SP22 screen is lowered to the bottom of the rods using a string of either 1.25-inch outside diameter (OD) light-weight center rods, 1.25-inch probe rods, or 0.75-inch schedule 40 flush-thread PVC riser (Fig. 2.1, Step 2). The 2.25-inch rods are then retracted while the SP22 screen is held in place with the 1.25-inch rods or PVC riser (Fig 2.1, Step 3). As the 2.25-inch tool string is retracted, the expendable point is released from the expendable point holder. The tool string and expendable point holder may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

The SP22 Sampler can also be used with the Geoprobe® DT22 system. (Fig. 2.2)

(continued on following page)

Expendable Drive Points

The SP22 system utilizes an SP22 Expendable Point Holder (33764) and standard 2.45-inch (62-mm) OD steel Expendable Drive Points for 2.25-inch probe rods (AT2015K). Extended Shank Expendable Drive Points (19442) are available for soft soil conditions where standard points may be advanced out of the point holder during percussion. A third option is to use a part number 43128 SP22 Expendable Point Holder along with 1.625-inch (41-mm) steel Expendable Drive Points (GW1555K). These smaller drive points are more economical to purchase and ship, but must not be used with GH80 Series Hydraulic Hammers as they may not stay seated during percussion.

Screens

Two types of screens have been developed for use in the Screen Point 22 Groundwater Sampler - a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm). These screens are available in nominal 48- and 12-inch lengths. Effective screen lengths for the 48- and 12-inch PVC screens are 48 inches (1219 mm) and 12 inches (305 mm), while 48- and 12-inch stainless steel screens have effective screen lengths of 43 inches (1092 mm) and 14 inches (356 mm) respectively. Both types of screens are recovered with the tool string after sampling.

The SP22 PVC Screen Head Adapter (37871) provides yet another screen option for the SP22 sampler. Using this adapter, a section of slotted 0.75-inch Schedule 40 PVC pipe may be lowered through the 2.25-inch probe rods using a string of flush-threaded 0.75-inch Schedule 40 PVC Riser. An SP22 PVC Screen Plug (38968) is installed in the leading end of the slotted pipe prior to use. The slotted pipe may be cut and the screen plug installed to provide custom screen lengths .

An O-ring is located at the top of each stainless screen and on the screen adapters. When a screen is deployed, this O-ring maintains a seal between the top of the screen and the inner wall of the probe rods or expendable point holder as indicated in Figure 2.1. As a result, any liquid entering the tool string must first pass through the screen.

Screens are constructed such that equipment can be inserted into the screen cavity for sample collection as noted in the following section and illustrated in Figure 2.1, Step 4. This makes direct sampling possible from anywhere within the saturated zone.

The inner rod string and screen are generally removed prior to grouting through the 2.25-inch rod string as shown in Figure 2.1, Steps 5-6. However, a removable plug in the lower end of the screens allows for grouting through flexible tubing extending out the bottom of the screen as with the Geoprobe® SP15/16 Groundwater Samplers if desired.

Sample Collection

Groundwater samples can be obtained from the SP22 screen in a number of ways. A common method utilizes 0.375-inch OD polyethylene (TB25L) or Teflon® (TB25T) tubing and a check valve assembly. The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is then pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An SP22 Check Valve Assembly (37893) is recommended if sampling through 1.25-inch light-weight center rods. The SP22 Check Valve Assembly is approximately 20 inches long to enable it to pass through the stepped diameters at each rod joint that may cause problems for other, shorter check valves.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to tubing that is inserted through the inner rods to within the SP22 screen. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP22 Sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

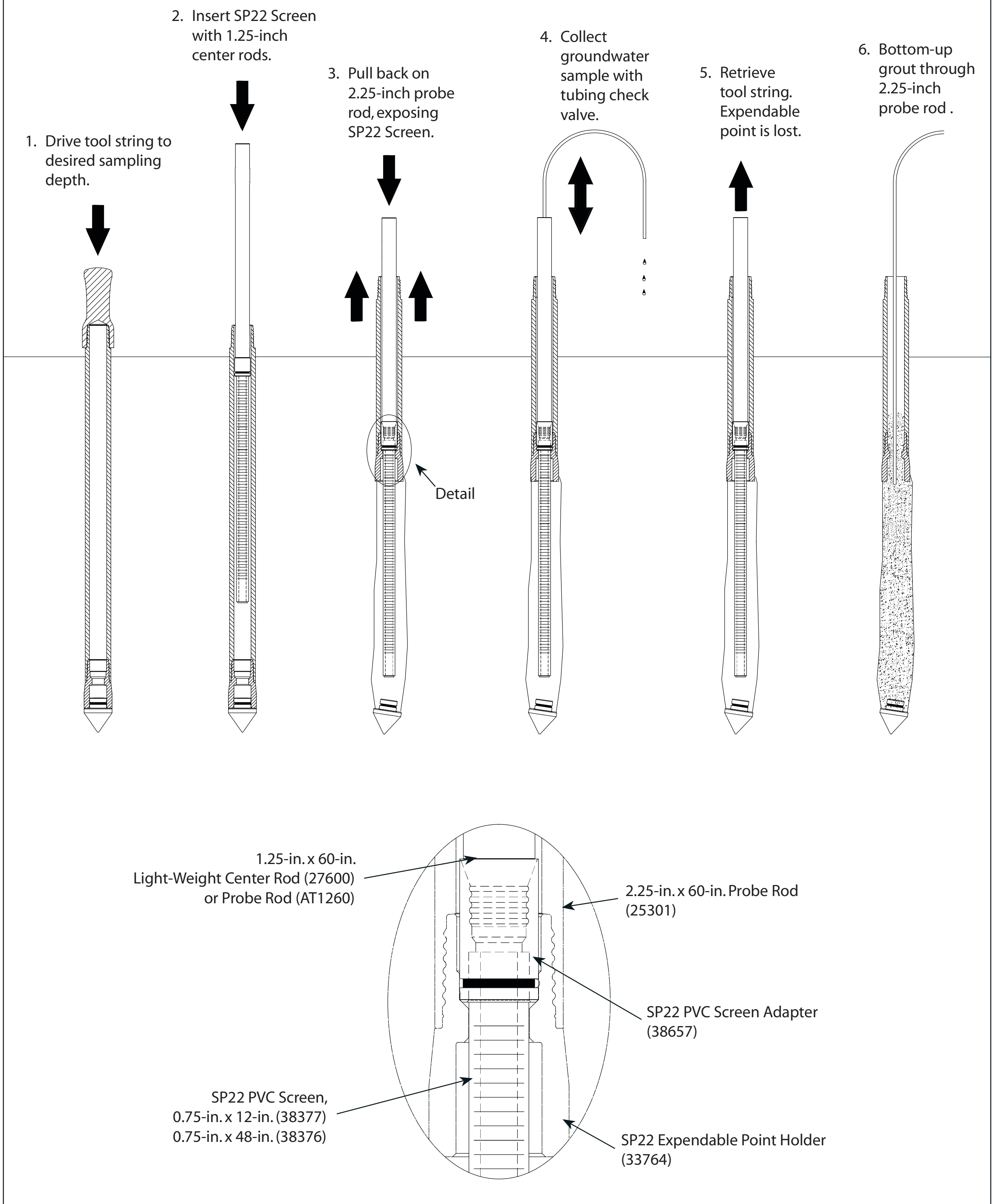


FIGURE 2.1

Screen Point 22 Groundwater Sampler - 0.75-inch PVC Screen Option

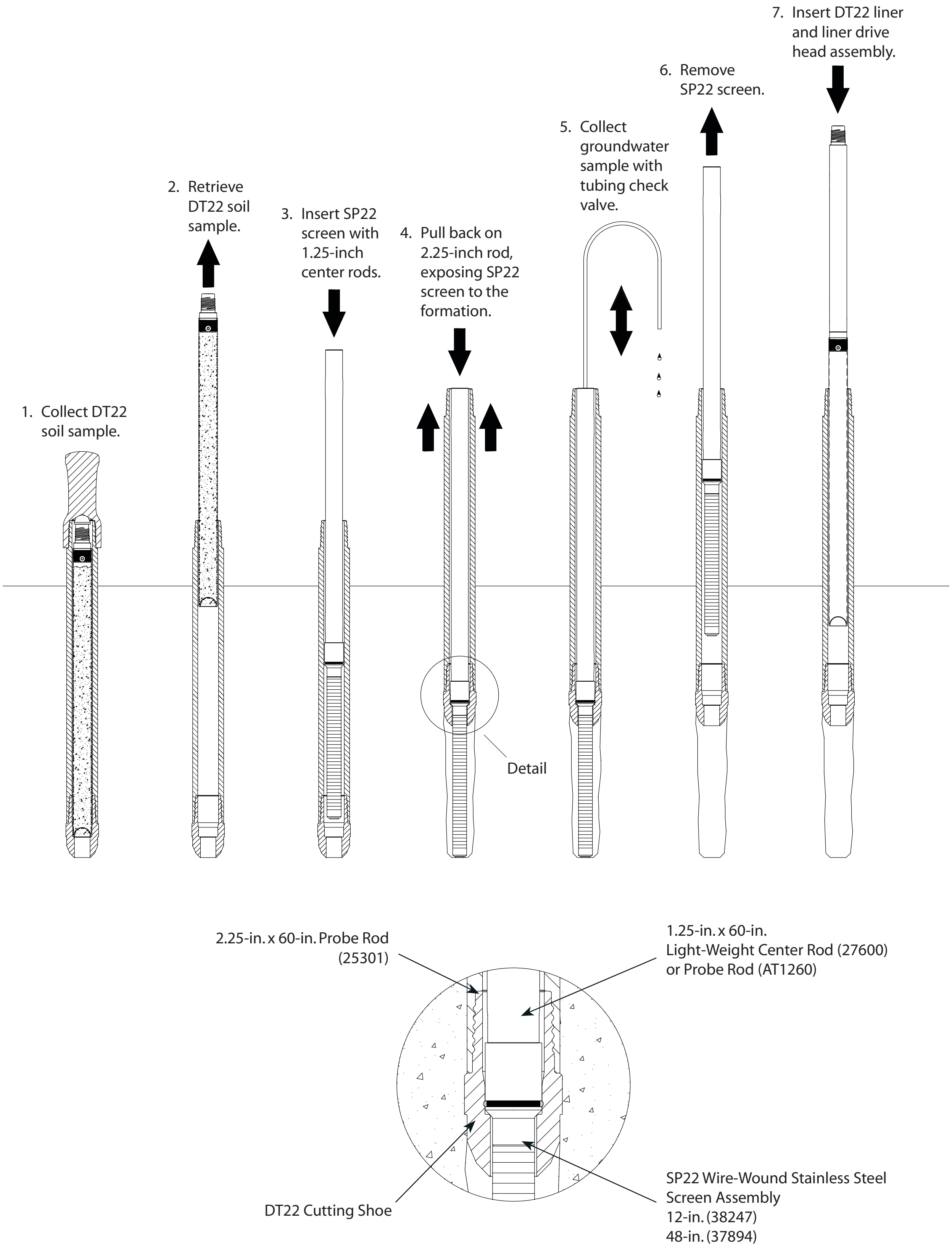


FIGURE 2.2

Screen Point 22 Groundwater Sampler Operation with DT22 Sampling System

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 22 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP22 / 2.25-inch probe rod configurations. Additional rod sizes and accessories are available. Contact Geoprobe Systems® for information regarding tools and equipment options.

SP22 Sampler Parts	**Part Number**
SP22 Screen, Wire-Wound Stainless Steel, 4-Slot (48-in.)	37894
SP22 Screen, Wire-Wound Stainless Steel, 4-Slot (12-in.)	38247
Grout Plugs, PE (Pkg. of 25)	GW1552K
SP22 Screen, PVC, 10-Slot, 0.75-in. x 48-in.	38376
SP22 Screen, PVC, 10-Slot, 0.75-in. x 48-inch, Kit (includes 2 each of 38376 and 38429)	*38664*
SP22 Screen, PVC, 10-Slot, 0.75-in. x 12-in.	38377
SP22 Screen, PVC, 10-Slot 0.75-in. x 12-in., Kit (includes 2 each of 38377 and 38429)	*38667*
SP22 PVC Screen Plug	38968
SP22 PVC Screen Plug Kit (includes 10 of 38968)	*38530*
SP22 PVC Screen Adapter, 0.75-in. PVC x 1.25-in. Probe Rod Box	38657
SP22 PVC Screen Head Adapter, 0.75-in. (for flush-threaded 0.75-in. Schedule 40 PVC)	37871
SP22 O-ring Kit (Pkg. of 10 O-rings for SP22 PVC screen adapters and stainless steel screens)	37853
O-rings, 0.75-in. PVC Riser (Pkg. of 25)	GW4401R
SP22 Expendable Point Holder, 2.25-in. Probe Rods, AT2045K and 19442 Points	33764
SP22 Expendable Point Holder, 2.25-in. Probe Rods, GW1555 Points*	43128

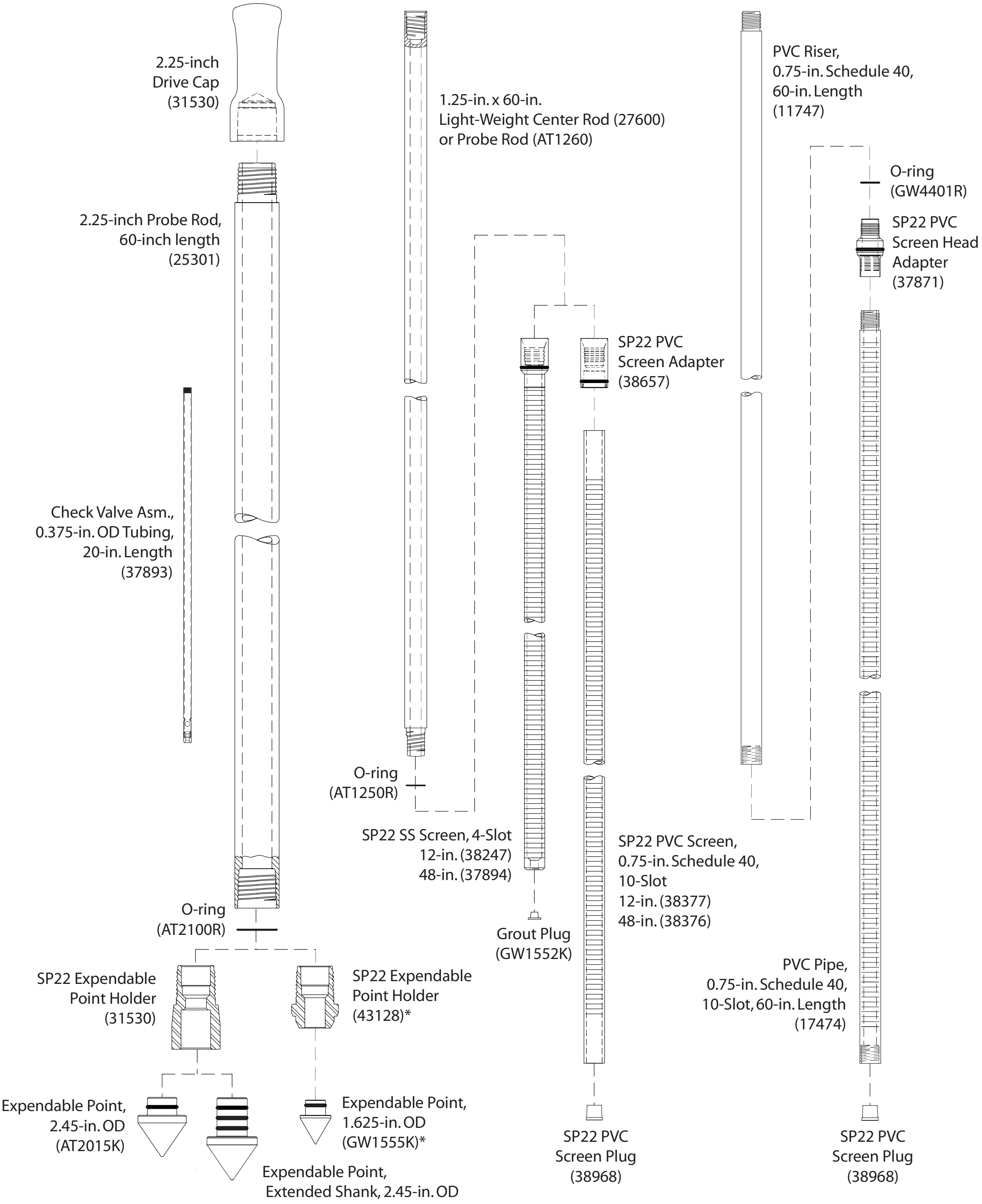
Outer Casing (2.125-inch Probe Rods) and Inner Rod String	**Part Number**
Probe Rod, 2.25-in. x 60-in.	25301
Expendable Drive Points, Steel, 2.45-in. OD (Pkg. of 25)	AT2015K
Expendable Drive Points, Steel, 2.45-in. OD, extended shank	19442
Expendable Points, steel, 1.625-in. OD (Pkg. of 25)*	GW1555K
Drive Cap, 2.25-in. Probe Rods, Threadless, (for GH60 and GH80 Series Hammers)	31530
O-Rings, 2.25-in. Probe Rods (Pkg. of 25)	AT2100R
Rod Grip Handle, 2.25-in. Probe Rods, (for GH60 and GH80 Series Hammers)	29385
Light-Weight Center Rod, 1.25-in. x 60-in.	27600
Probe Rod, 1.25-in. x 60-in.	AT1260
O-ring, 1.25-in. rods (Pkg. of 25)	AT1250R
Rod Grip Handle, 1.25/1.5-in. Rods, (for GH60 and GH80 Series Hammers)	15554
PVC Riser, 0.75-in. Schedule 40 x 60-inch	11747
PVC Pipe, 0.75-in. Schedule 40 x 60-inch, 10-Slot	17474

Grout Accessories	**Part Number**
High-Pressure Nylon Tubing, 0.375-in. OD / 0.25-in. ID, 100-ft. (30 m)	11633
Grout Machine, Auxiliary-Powered	GS2200
Grout System Accessories Package, 2.25-in. rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-in. OD, 500 ft.	TB25L
Check Valve Assembly, 0.375-in. OD Tubing x 20 in. Long	37893
Water Level Meter, 0.438-in. OD Probe, 100 ft. cable	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, Stainless Steel	GW41

* Not for use with GH80 Series Hydraulic Hammers

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.



* Do not use 43128 or
GW1555K with GH80
series hammers

FIGURE 3.1
SP22 Sampler Parts

4.0 OPERATION

4.1 Basic Operation

The SP22 Sampler utilizes a stainless steel or PVC screen which is lowered (post-run) through an alloy steel 2.25-inch OD probe rod tool string. An expendable drive point is placed in an expendable point holder on the leading 2.25-inch probe rod prior to advancement (Fig. 4.1). This expendable point is removed and stays in the subsurface as the rods are pulled back to exposes the SP22 screen. O-rings on the probe rods , the expendable point holder, and the expendable drive point provide a watertight tool string which keeps contaminants out of the system as the 2.25-inch rods are driven to depth in preparation for installation of the SP22 screen.

Once the sampling interval is reached with the 2.25-inch probe rods, the stainless steel or PVC screen is lowered through the rods using 1.25-inch probe rods, 1.25-inch light-weight center rods, or 0.75-inch PVC riser pipe. The 2.25-inch tool string is then retracted while the screen is held in place with the inner rods or riser. The system is now ready for groundwater sampling. When sampling is complete, the inner rods and screen are removed for grouting during retrieval or the 2.25-inch rods. Alternatively, a removable plug is located in the bottom of the screens to allow grouting directly through the inner tool string with high-pressure tubing during retrieval.

4.2 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.3 Lead Rod Assembly (Fig. 4.1)

1. Place an O-ring on the expendable point holder.
2. Thread expendable point holder into the 2.25-inch probe rod.
3. Place an O-ring on a steel expendable drive point.
4. Firmly seat the expendable point in the expendable point holder.
5. Place 2.25-inch Drive Cap (31530) on the top of the 2.25-inch probe rod. The lead rod assembly is now ready to be driven to depth.

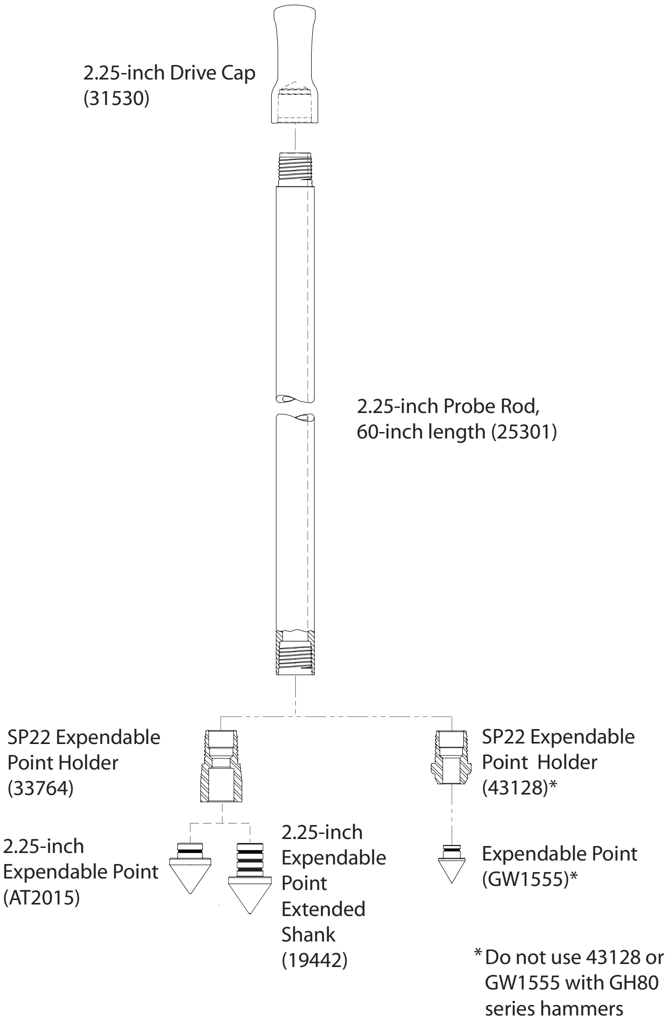


FIGURE 4.1
Lead Rod Assembly for the SP22 Groundwater Sampler

4.4 Advancing the Tool String (Fig. 4.2, step 1)

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Drive first 2.25-inch probe rod (as assembled in section 4.3).

2. Advance the tool string at a slow speed for the first few feet to ensure that the string is aligned properly.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the driven probe rod. Distilled water may be used to lubricate the O-ring if needed.

   Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the tool string the entire length of the new rod.

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

4.5 Screen Deployment (Fig 4.2, step 2 - 4)

1. Attach an SP22 stainless steel or PVC screen to a 1.25-inch probe rod, 1.25-inch light-weight center rod, or 0.75-inch fiush-thread PVC riser using an SP22 PVC Screen Adapter (38657) or SP22 PVC Screen Head Adapter (37871) as shown in Figure 3.1. Note that the 38657 screen adapter is connected to the SP22 PVC screen using the setscrews provided with the adapter.

and lower it into the driven casing.

2. Lower the screen into the 2.25-inch probe rod casing and add rods or riser until the screen head contacts the bottom of the tool string.

3. Ensure that at least 48 inches (1219 mm) of rods or riser protrudes from the top 2.25-inch probe rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the outer 2.25-inch tool string while physically holding the screen in place with the inner 1.25-inch rods or 0.75-inch riser. A slight knock with the inner tool string will help to dislodge the expendable point and start the screen moving inside the probe rod.

   Raise the hammer and outer tool string to expose the desired length of screen. The inner rods will begin raising with the outer rods when the screen adapter contacts the necked portion of the expendable point holder or DT22 Cutting Shoe. Use care when deploying a PVC screen so as not to break the screen when it contacts the expendable point.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top 2.25-inch probe rod.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

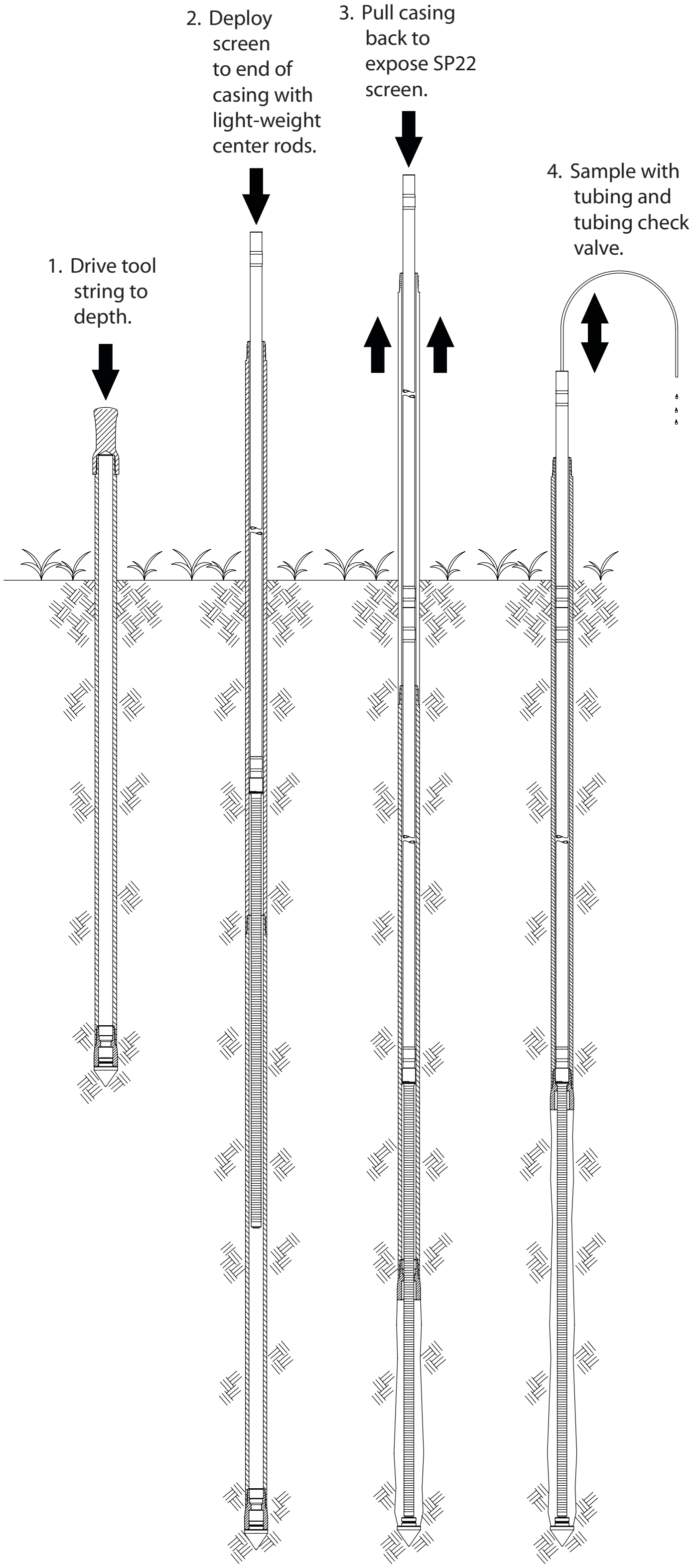


FIGURE 4.2
Screen Deployment for SP22 Sampler

4.6 Abandonment Grouting for SP22 Screens

The SP22 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of the SP22 screens, but the easiest method is to remove the inner string of rods; including the SP22 screen. A Grout Machine is then used to pump grout into the open probe hole as the outer casing is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations. (Figure 4.3)

1. Maneuver the probe assembly into position for pulling.

2. High-Pressure Nylon Tubing (11633) is inserted down through the probe rods through the bottom of the expendable point holder (Fig. 4.3).

   Note: *All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

3. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

4. Repeat Step 5 until the tool string is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

5. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.7 Retrieving the Screen Point 22 Sampler

If grouting is not required, the Screen Point 22 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (33622) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

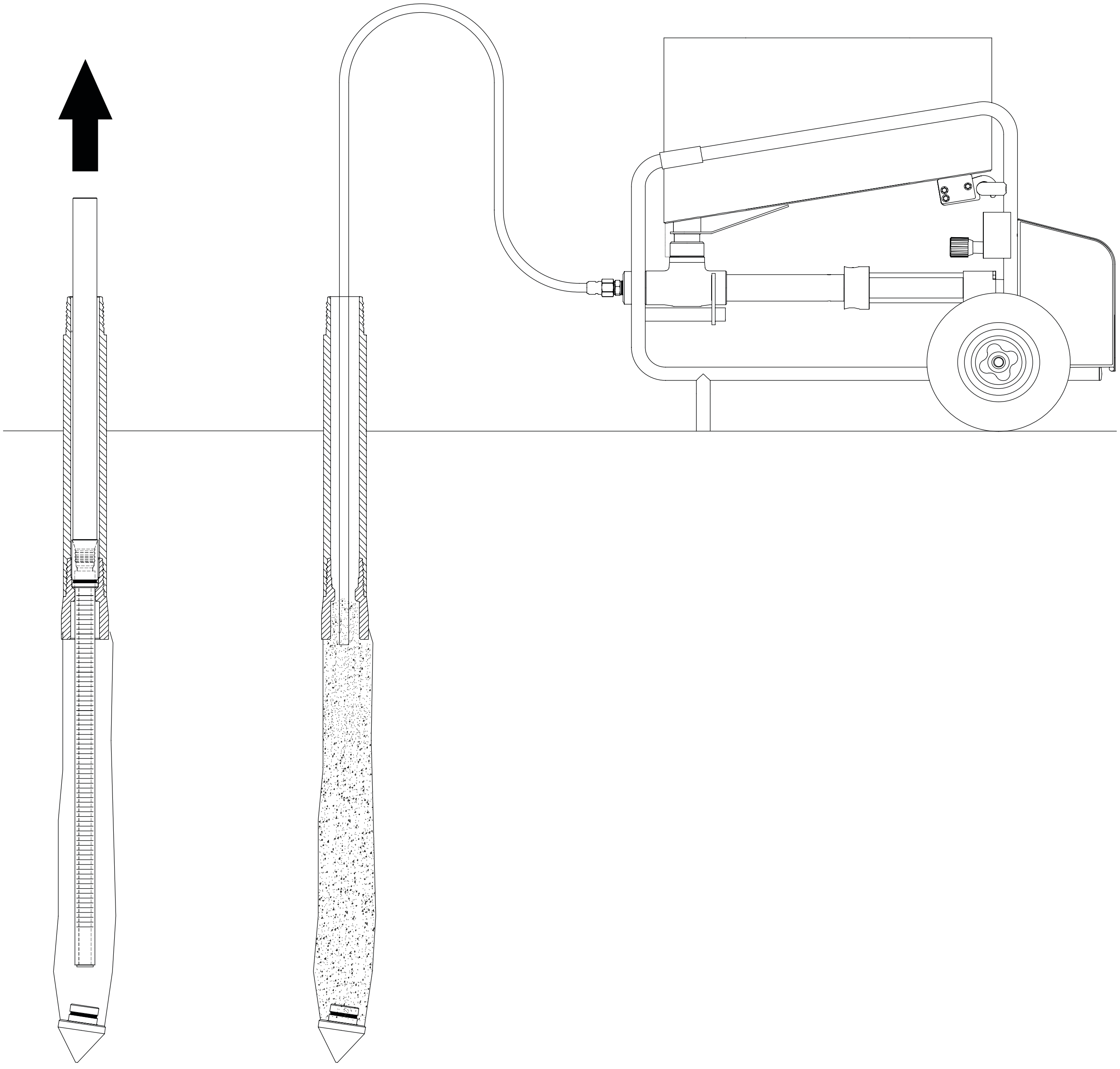


FIGURE 4.3
Abandonment Grouting for the SP22 Sampler

5.0 REFERENCES

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Puls, Robert W., and Michael J. Barcelona, 1996. Ground Water Issue: Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures. EPA/540/S-95/504. April.

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Appendix C

Safety Data Sheets

Material Safety Data Sheet

Guar gum

ACC# 89758

Section 1 - Chemical Product and Company Identification

MSDS Name: Guar gum
Catalog Numbers: S76773, S76774
Synonyms: Guaran; Indalca AG; Jaguar.
Company Identification:
Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410
For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
9000-30-0	Guar gum	100.0	232-536-8

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: yellowish-white powder.
Caution! Repeated inhalation of dust can cause sensitization to susceptible individuals. May cause allergic skin reaction. May cause eye, skin, and respiratory tract irritation. The toxicological properties of this material have not been fully investigated.
Target Organs: Respiratory system, skin.

Potential Health Effects

Eye: Dust may cause mechanical irritation.
Skin: May cause skin irritation. May cause sensitization by skin contact.
Ingestion: May cause irritation of the digestive tract. The toxicological properties of this substance have not been fully investigated.
Inhalation: The toxicological properties of this substance have not been fully investigated. Inhalation of dust may cause respiratory tract irritation. May cause respiratory sensitization.
Chronic: Some individuals may develop a respiratory allergenic response to guar dust. Persons with a history of respiratory allergies may have those conditions aggravated by exposure to guar dust.

Section 4 - First Aid Measures

Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion: Never give anything by mouth to an unconscious person. Get medical aid. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.
Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Runoff from fire control or dilution water may cause pollution.
Extinguishing Media: Use agent most appropriate to extinguish fire.
Flash Point: Not available.
Autoignition Temperature: Not available.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Clean up spills immediately, observing precautions in the Protective Equipment section. Sweep up or absorb material, then place into a suitable clean, dry, closed container for disposal. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid ingestion and inhalation.
Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Guar gum	none listed	none listed	none listed

OSHA Vacated PELs: Guar gum: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin: Wear appropriate protective gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN

149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Powder
Appearance: yellowish-white
Odor: Not available.
pH: 5.5-6.2 (1% solution
Vapor Pressure: Not available.
Vapor Density: Not available.
Evaporation Rate: Not available.
Viscosity: Not available.
Boiling Point: Not available.
Freezing/Melting Point: Not available.
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density: Not available.
Molecular Formula: Not available.
Molecular Weight: Not available.

Section 10 - Stability and Reactivity

Chemical Stability: Stable.
Conditions to Avoid: Incompatible materials, dust generation, excess heat.
Incompatibilities with Other Materials: None reported.
Hazardous Decomposition Products: Irritating and toxic fumes and gases, acrid smoke and fumes.
Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:
CAS# 9000-30-0: MG0185000
LD50/LC50:
CAS# 9000-30-0:
Oral, mouse: LD50 = 8100 mg/kg;
Oral, rabbit: LD50 = 7 gm/kg;
Oral, rat: LD50 = 6770 mg/kg;
.

Carcinogenicity:
CAS# 9000-30-0: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No information found
Teratogenicity: No information found
Reproductive Effects: No information found
Mutagenicity: No information found
Neurotoxicity: No information found
Other Studies:

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	**Canada TDG**
Shipping Name:	Not regulated as a hazardous material	No information available.
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 9000-30-0 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
Section 313 No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
CAS# 9000-30-0 is not present on state lists from CA, PA, MN, MA, FL, or NJ.

California Prop 65

California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

Not available.

Risk Phrases:

Safety Phrases:

WGK (Water Danger/Protection)

CAS# 9000-30-0: 0

Canada - DSL/NDSL

CAS# 9000-30-0 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of D2B.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 1/19/1998
Revision #6 Date: 2/18/2008

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name	:	Ferox Flow zero valent iron powder
Brand	:	Hepure
CAS-No.	:	7439-89-6

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Environmental remediation, water treatment, various

1.3 Details of the supplier of the safety data sheet

Company	:	Hepure Technologies, Inc. 63 Main Street, Suite 203B Flemington, NJ 08822
Telephone	:	877-727-4776

1.4 Emergency telephone number

Emergency Phone # : Chemtrec 800-424-9300 CCN234339

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Not classified as hazardous

2.2 GHS Label elements, including precautionary statements

Signal Word: not applicable
Hazard Statements: not applicable
Precautionary Statements: not applicable

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS – none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Formula: Fe
Molecular Weight: 55.85 g/mol
CAS-No.: 7439-89-6
EC-No.: 231-096-4

Carbon:	2 to 2.5%
Sulfur:	0.050%
Silicon :	1.5 to 2%
Iron:	Balance

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Move out of dangerous area. Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

No data available

4.3 Indication of any immediate medical attention and special treatment needed

No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use Class D or other metal extinguishing agent.

5.2 Special hazards arising from the substance or mixture

These materials, as coarse particles, are non-flammable and do not react with water or other materials used for extinguishing fire. Fine metal dust may pose a risk of fire or explosion if accumulated, mixed and confined with an ignition source. When handling fine particles generated from this material, avoid creating dust clouds and ignition sources. May release iron oxide fume if involved in a fire.

5.3 Advice for firefighters

Wear self-contained breathing apparatus for fire fighting if necessary.

5.4 Further information

Use water spray to cool unopened containers.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Avoid dust formation. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas.
For personal protection see section 8.

6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up

Sweep up and shovel. Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13). Keep in suitable, closed containers for disposal. Contain spillage, pick up with an electrically protected vacuum cleaner or by wet-brushing and transfer to a container for disposal according to local regulations (see section 13).

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed. Keep away from sources of ignition - No smoking. Take measures to prevent the build up of electrostatic charge.

7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

Store under inert gas. Moisture sensitive. Keep in a dry place.

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Impermeable gloves, protective work clothing as necessary.

Respiratory Protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a) Appearance	Form: powder
b) Odor	no data available
c) Odor Threshold	no data available
d) pH	no data available
e) Melting point/freezing point	Melting point/range: 1,535 °C (2,795 °F) - lit.
f) Initial boiling point and boiling range	2,750 °C (4,982 °F) - lit.
g) Flash point	no data available

h)	Evaporation rate	no data available
i)	Flammability (solid, gas)	not flammable as a course particle; Fine metal dust may pose a risk of fire or explosion if accumulated, mixed and confined with an ignition source
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapor pressure	no data available
l)	Vapor density	no data available
m)	Relative density	7.86 g/cm3 at 25 °C (77 °F)
n)	Water solubility	insoluble
o)	Partition coefficient: n-octanol/water	no data
p)	Auto-ignition temperature	available no
q)	Decomposition temperature	data available
		no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information

Bulk density	2,500.0 - 3,500.0 kg/m3

10. STABILITY AND REACTIVITY

10.1 Reactivity

No data available

10.2 Chemical stability

Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions

No data available

10.4 Conditions to avoid

Heat, flames and sparks. Extremes of temperature and direct sunlight.

10.5 Incompatible materials

Acids, Oxygen, Strong oxidizing agents, Halogens, Phosphorus

10.6 Hazardous decomposition products

Other decomposition products - no data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - rat - 30,000 mg/kg
Remarks: Nutritional and Gross Metabolic: Weight loss or decreased weight

gain. Inhalation: no data available

Dermal: no data available

No data available

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitization
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data

available No

data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: NO4565500

Overdose of iron compounds may have a corrosive effect on the gastrointestinal mucosa and be followed by necrosis, perforation, and stricture formation. Several hours may elapse before symptoms that can include epigastric pain, diarrhea, vomiting, nausea, and hematemesis occur. After apparent recovery a person may experience metabolic acidosis, convulsions, and coma hours or days later. Further complications may develop leading to acute liver necrosis that can result in death due to hepatic coma. Long term inhalation exposure to iron (oxide fume or dust) can cause siderosis. Siderosis is considered to be a benign pneumoconiosis and does not normally cause significant physiologic impairment. Siderosis can be observed on x-rays with the lungs having a mottled appearance.

12. ECOLOGICAL INFORMATION

Non-hazardous

13. DISPOSAL CONSIDERATIONS

Waste Disposal Method:

Product: Dispose of in accordance with Federal, State and Local regulations.
Packaging: Dispose of in accordance with Federal, State and Local regulations.

14. TRANSPORT INFORMATION

Shipping Regulations:	Not regulated
UN Number:	N/A
UN Proper Shipping Name:	N/A
Transport Hazard Class:	N/A
Packing Group:	N/A
Marine Pollutant:	No

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components	CAS-No.	Revision Date
Iron, Powder	7439-89-6	

New Jersey Right To Know Components	CAS-No.	Revision Date
Iron, Powder	7439-89-6	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Further information
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Version: 2.3   Revision Date: 6/23/2016