September 7, 2022

Mr. Joe Rogers
Michigan Department of Environment, Great Lakes and Energy
Technical Support Unit
Hazardous Waste Section
Materials Management Division
Lansing District Office
Constitution Hall
525 West Allegan Street
Lansing, MI 48909

Subject: Revised RCRA Corrective Action Facility Investigation Work Plan Report –
Former Hayes Lemmerz; Ferndale Michigan
1600 West 8 Mile Road
Ferndale, Michigan
MID 041 803 123
Waste Data System Number 395519

Dear Mr. Rogers,

Please find enclosed this Revised RCRA Corrective Action Facility Investigation Work Plan – Former Hayes Lemmerz facility located at 1600 West Mile Road, Ferndale (Site) prepared by TRC Environmental Corporation (TRC) on behalf of Axle Holdings 1, LLC (Detroit Axle).

Pursuant to Title 40, Code of Federal Regulations, Part 270.11(b), I certify that I am authorized as a responsible corporate officer, president, director, secretary, superintendent, treasurer or vice president of the corporation in charge of the principal business function or any other person who performs similar policy or decision-making functions or operations for the corporation (Axle Holdings 1, LLC).

Axle Holdings 1, LLC

Mike Musheinesh
Printed Name

CEO
Title

Signature

TRC
1540 Eisenhower PL
Ann Arbor, MI 48108
T 734.971.7080
TRCcompanies.com

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Former Hayes Lemmerz; Ferndale Michigan.
MID 041 803 123
Waste Data System Number 395519
1600 West 8 Mile Road
Ferndale, Michigan

Dear Mr. Rogers,

TRC Environmental Corporation (TRC) is submitting this Response to Comments on the RCRA Corrective Action Facility Work Plan for the Former Hayes Lemmerz facility located at 1600 West Mile Road, Ferndale (Site) on behalf of Axle Holdings 1, LLC (Detroit Axle). As you are aware, TRC has since been retained by Detroit Axle to provide environmental consulting services for the subject Site moving forward.

The former consultant, Atlas Technical Consultants LLC (Atlas), submitted the RCRA Corrective Action facility Investigation Work Plan (Work Plan) for the Former Hayes Lemmerz Site to EGLE for approval on February 17, 2022. The EGLE replied to the submittal with comments in a letter dated July 7, 2022 (EGLE Comments). The following discussion documents the EGLE comments in bold followed by TRC's responses to those comments which reference the changes made in the enclosed Revised Work Plan.

1. *General Comments:*

a. **The RFI Work Plan must be revised to provide the name and number of each included Standard Operating Procedure (SOP) in the Table of Contents.**

The name and number of each TRC SOP has been added to the table of contents.

b. **The RFI Work Plan must be revised to include the project Health and Safety Plan as an Appendix so EGLE can review and become familiar with it.**

The Site HASP has been referenced in Section 5.4 and provided as Appendix B.

c. It should be noted that the MMD accepts the concept of implementing the investigation over time in the "margins", and "areas", with the following modifications:

i. The RFI Work Plan must be revised to provide a table summarizing the proposed schedule by area. The schedule must also be revised to provide for a one quarter (three month) staggered implementation between “margins” and/or “areas”, rather than the two quarters (six month) staggered implementation proposed.

A table with the proposed schedule has been added to Section 5.2. The schedule has been modified to have a three-month staggered implementation between margins or areas, rather than six months.

ii. It should be recognized that the proposed schedule may need to be adjusted based on the discovery of any release that poses an exposure risk to human health or the environment during the work. This includes the eastern area vapor intrusion work currently underway. Depending on the results of the investigation, implementation of interim remedial measures may be necessary.

A notation regarding the potential updates to the schedule based on the findings during the investigations or discovery of a new release has been added to Section 5.2.

iii. Implementation of the “Site-Wide Items for Investigation” is recommended to be implemented relatively early in the investigation so that results from this phase of the investigation can be considered in the investigation of the other “margins” and areas”.

The Site Wide Investigation has been proposed to be completed during the Southern Area Investigation, to begin in 3Q/4Q 2022.

d. The RFI Work Plan must be revised to specify that, as part of all investigations where borings are planned to be extended down to the base of the upper sand unit, contact with the underlying clay unit will be confirmed as part of the boring rather than drilling to a pre-specified depth thought to represent the base of the sand unit.

Updates have been made to the proposed monitoring well depths to require the installation of the monitoring wells to the base of the sand unit and the top of the clay unit.

e. The RFI Work Plan must be revised to provide for additional monitoring wells screened at the base of the sand unit in any waste management unit or area of concern (AOC) where chlorinated organics, or denser than water compounds have been previously detected in soil and/or groundwater.

Updates have been made to the proposed monitoring well depths to require the installation of the monitoring wells to the base of the sand unit and the top of the clay unit in areas with chlorinated organics. In AOCs 1, 2, 4 and 17, the planned assessment has been modified to include the installation of nested sets of monitoring wells (provided there is enough vertical space in the sand layer to accommodate both a shallow and a deep nested well) instead of a singular well, with a shallow and deep monitoring well at each set to address the full overburden column at the request of EGLE.

f. **The MMD requests that Atlas provide us with a minimum of two-weeks' notice prior to the implementation of any field work so that MMD can arrange to be on site to observe and/or collect split samples if desired.**

Updates have been made to the proposed schedule in Section 5.2 indicating a two weeks' notice shall be provided to the MMD by TRC prior to implementing any work.

g. **The Part 111 program is currently authorized by the United States Environmental Protection Agency to implement the September 28, 2012, Part 201, Environmental Remediation (Part 201), of the NREPA, criteria. The RFI investigation work should proceed utilizing these criteria. A copy of the 2012, Part 201 criteria is attached to this letter.**

The RFI will proceed using the Part 201 Criteria as referenced in Table 2.

2. ***Section 4.1; Site Investigation and Parameter List:***

a. **The RFI Work plan must be revised to provide for the full list of Part 201 analytical parameters, including per- and polyfluoroalkyl substances (PFAS) compounds, and polychlorinated biphenyls (PCB) as part of initial sampling events for a given unit or AOC where the use/characterization of the unit/AOC is not well defined. Based on initial sampling results, it may be possible to narrow the analytical parameter list down; however, due to the large amount of uncertainty related to former activities at the site, the MMD does not support preemptively limiting the investigation.**

In addition to the full list of Part 201 VOCs, SVOCs and Metals, each area will include initial sampling for PCBs and PFAS (currently 31 compound list) in soil and groundwater during this initial round of investigation.

b. **The RFI Work Plan must be revised to provide for data comparison to ALL cleanup criteria for all exposure pathways. Exposure risks may be eliminated based on use scenarios after this comparison, but locations where exceedances of Residential Criteria occur must be defined so that appropriate institutional controls or perimeter monitoring (in the case of groundwater) can be instituted.**

Section 4.1 of the RFI Work plan has been revised to indicate the results will be compared to all clean up criteria and for all exposure pathways. The Site RFI media will be compared to residential and nonresidential part 201 generic clean up criteria, and the eastern boundary samples will be compared to residential part 201 clean up criteria. After the initial round of sampling, we reserve the opportunity to narrow the analytical parameter list.

3. ***Section 4.3.1; AOC 2 – SWMU 2 – Former Burial Area:***

a. **The RFI Work Plan must be revised to clarify the initial sentence of the second paragraph (below the bullets) in the Groundwater Constituents of Concern Section that states: "Further delineation of SVOCS (e.g., PNAs and tetrahydrofuran) in soil, testing for COCs potentially associated with the reported buried laboratory wastes, and physical and chemical characterization and vertical and horizontal delineation of potential groundwater impacts in the form the objective for this AOC investigation". This sentence is unclear.**

This paragraph has been removed from section 4.3.1 as the additional investigation recommended and the rationale is thoroughly described in the Planned Assessment Section.

b. **The RFI Work Plan must be revised to clarify the first sentence of the second paragraph of the Planned Assessment Section that states: "Additional planned assessment work includes the installation of a nested pair of monitoring wells (one set within the shallow overburden and one set within the deeper section of the overburden) at the down-gradient edge of the AOC to vertically profile the groundwater within this area. Screened interval for each well is anticipated at approximately 8-13 feet bgs for shallow and 20 - 25 feet bgs for deep. Soil samples will also be collected from well borings." These sentences are unclear, are one or two pair of nested wells being proposed? The MMD recommends a minimum of two nested pair of wells in order to adequately characterize and define the horizontal and vertical nature and extent of contamination.**

The RFI work plan has been updated to include the installation of two nested sets of wells (two sets with both shallow and deep screened monitoring wells) in AOC 2, provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well.

c. **The RFI Work Plan must be revised to clarify the basis and decision logic for determining which "select" samples will be analyzed for tetraethyl lead.**

The RFI work plan has been updated to include the sampling for tetraethyl lead in groundwater samples collected from AOC 2 proposed in this work plan. The term select samples has been removed.

4. ***Section 4.3.3; AOC 17 – EMI Interference: The RFI Work Plan must be revised to clarify the first two sentences of the second paragraph of the Planned Assessment Section that state: "Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit (at a depth exceeding 10 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil borings PSB-132) will be installed in the central and southeastern portions of this area.". These sentences are unclear, what is the depth of the screened interval for the wells being proposed? The MMD recommends that due to the unknown nature of the contaminants potentially present, that nested wells with five-foot screens be installed in order to investigate the entire saturated thickness of the saturated unit.***

   The RFI work plan has been updated to include the installation of two nested sets of wells in AOC 17 (two sets with both shallow and deep screened monitoring wells), provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well)

5. ***Section 4.4.1; AOC 1 – SWMU 1 – Former Drum Storage Area: The RFI Work Plan must be modified to clarify the depth(s) of the screened interval for the planned monitoring wells. The MMD recommends that, due to the unknown nature of the contaminants potentially present, nested wells with five feet screens be installed in order to investigate the entire saturated thickness of the saturated unit.***

   The RFI work plan has been updated to include the installation of three nested sets of wells in AOC 1 (three sets with both shallow and deep screened monitoring wells), provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well.

6. ***Section 4.4.2; AOC 4 – SWMU 4: The RFI Work Plan must be modified to clarify the depth(s) of the screened interval for the planned monitoring wells. The MMD recommends that, due to the unknown nature of the contaminants potentially present, nested wells with five-foot screens be installed in order to investigate the entire saturated thickness of the saturated unit.***

   The RFI work plan has been updated to include the installation of two nested sets of wells in AOC 4 (three sets with both shallow and deep screened monitoring wells), provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well.

7. ***Section 4.5; Northeastern Area: The RFI Work Plan must be revised to clarify the third sentence of the second paragraph of this Section that states: "Atlas' work completed to address the eastern boundary concerns are further described in Sections 4.3". A description of work completed to address the eastern boundary concerns was not found in Section 4.3.***

The section has been modified to state the following: “The work completed to address the eastern boundary concerns are further described in the April 2022 RCRA Interim Work Plan Investigation Report – Eastern Site Boundary Report”.

8. ***Section 6.1; Test Pits: The RFI Work Plan must be revised to provide additional description regarding how any removed containers will handled, temporarily stored, and disposed of. The MMD recognize the Work Plan proposes that a plan be developed at the time of discovery and if needed; however, some thought to the process is appropriate to be developed now for inclusion in the RFI Work Plan.***

The following has been added to Section 6.1

The following procedure will be followed for found closed containers:

- For closed containers that appear in good condition, are not bulging or corroded, and can be safely sampled, TRC will arrange for a qualified contractor to open and sample the container contents. If the contents are suitable for nonhazardous disposal, the container and the contents will be disposed with the investigation derived waste (IDW) discussed in Section 8.6.
- For closed containers that do not appear in good condition, or are bulging, corroded or damaged, TRC will arrange for a qualified contractor to open and sample the container contents. If the contents are suitable for nonhazardous disposal, the containers and the contents will be disposed with the investigation derived waste (IDW) discussed in Section 8.6. Care will be taken to be sure no contents spill into uncontaminated areas during the removal.
- If any contents are determined to be hazardous waste after sampling is completed, TRC will arrange for the disposal of the waste by a qualified hazardous waste contractor.
- Any found containers will not be stored and handled at the Site after removal. Direct disposal upon removal will be facilitated by TRC. If containers cannot be directly disposed of in a reasonable timeframe due to subcontractor scheduling, they will remain in place in the excavated area (which will remain open and safely barricaded) until they can be directly disposed of.
- Records will be kept on the number of containers removed and disposed of and their contents.

9. ***Section 6.2; Soil Boring/Monitoring Well Installation: The RFI Work Plan must be revised to provide additional details regarding the purpose, design, and construction of the “small sump to allow for potential NAPL” to be built into the monitoring wells screened at the base of the sand/clay interface.***

The sentence “small sump to allow for potential NAPL” has been deleted from the RFI and the following has been added:

These wells will be screened with the bottom of the screened interval at the top of the clay layer interface to facilitate the accumulation of any dense non aqueous phase liquids (DNAPL) that may sink and accumulate at depth.

10. ***Section 7.2; Analysis and Testing: The RFI Work Plan must be revised to specify that MMD review and approval is required to utilize alternate analytical methods as described in this Section.***

The following has been added to Section 7.2:

MMD review and approval is required to utilize alternate analytical methods as described in this Section.

11. ***Section 7.4; Project Documentation: To the extent possible, copies of the forms to be utilized for documentation should be provided in an Appendix for MMD review.***

Example field forms have been included as Appendix C.

12. ***Section 8.1; Sample Management: The MMD supports the renaming of monitoring wells in order eliminate potential duplicate names and re-organize their nomenclature. Care needs to be taken to link new nomenclature with the historical nomenclature such that no data are lost.***

TRC has revised the nomenclature in Section 8.1 to a system that is appropriate for large sites with multiple AOCs. Future monitoring wells will be named with the AOC location, then year installed, followed by the monitoring well number (or similar). For example, monitoring well MW-01 installed in AOC 13 in 2022 would be named or AOC-13-22-MW-01. TRC may evaluate renaming the existing wells if appropriate using a similar naming convention.

13. ***Section 8.4; Reporting: The RFI Work Plan must be revised to provide additional details regarding the content of the RFI Reports. At a minimum, the RFI Reports must include: a narrative summary of the results, conclusions and recommended next steps, data tables, figures, lab reports, lab quality assurance / quality control, field sheets, etc. Reports must include both new data collected as well as available historical data for each "margin" and "area".***

The following has been added to Section 8.4:

Progress reports will include a narrative summary of the results, conclusions and recommended next steps. The reports shall include data summary tables, figures, lab reports, data quality assurance/quality control, field notes and any applicable manifests. Tables included shall be all encompassing and shall include historical results as well as current results for each area.

14. ***Section 8.6; Waste Disposal: The RFI Work Plan must be revised to specify that investigation derived waste must be characterized and stored on site per regulatory standards, and properly treated and/or disposed of within statutory timeframes. Reports of proper disposal (text and manifests) must be included in reports.***

The following has been added to Section 8.6:

Investigation derived waste will be characterized and stored at the Site per regulatory standards, and properly treated and/or disposed of within statutory timeframes. Reports of proper disposal (text and manifests) will be included in reports.

15. ***Section 9.0, Community Relations Plan:***

a. **The RFI Work Plan must be revised to eliminate the reference to Michigan PFAS Response Team (MPART) being part of EGLE and an EGLE Program. Although the MPART Executive Director Reports to the EGLE Director, it is a separate organization.**

The references to EGLE in the MPART discussion have been removed from Section 9.0

b. **The RFI Work Plan must be revised to provide procedures post-COVID, since it is anticipated that COVID restrictions will not be in place for the entire time of the project.**

The work plan has been revised for post-COVID conditions.

c. **The RFI Work Plan must be revised to provide for a public repository for all site related final documents. This will contain more than the fact sheet indicated. It is recommended that the City of Ferndale be involved in determining the best location for this repository.**

The work plan has been revised with the following:

- TRC will work with the City of Ferndale (City) to determine the best way to approach public involvement.
- If in person meetings with the public to discuss the Site are necessary or desirable, TRC will work with the City to arrange for and host such meetings.
- If deemed desirable by the City, TRC will prepare a public facing website to house reports and results for the Site to provide the public access to this information. The website will also house a Public Fact Sheet to present a summary of the following: historical operations at the Site and a generalized overview of proposed/ongoing activities being conducted at the Site by TRC to mitigate the threat of any potential contamination migration to off-site receptors.

16. ***Table 2; List of Analytical Compounds and Detection Limits:***

a. The RFI Work Plan must be revised to provide for the analysis and reporting of the full list of volatile (Method 8260) and semi volatile (Method 8270) organic compounds in both soil and groundwater.

Section 4.1 and Table 2 of the work plan has been revised to indicate analysis will be for the full list of volatile (Method 8260) and semi volatile (Method 8270) organic compounds in both soil and groundwater.

b. EGLE recommends that the RFI Work Plan be revised to provide for the analysis and reporting of the full list of 31 PFAS compounds. A copy of that list is attached for your reference.

The work plan has been revised to include the analysis of the full list of 31 PFAS compounds.

c. The RFI Work Plan must be revised to provide the list of compounds and method and reporting limits for soil gas analysis.

Table 2 of the work plan has been revised to include the analysis of the list of compound and method and reporting limits for soil gas analysis.

17. ***Appendix A; Standard Operating Procedures:***

a. In the Decontamination of Equipment SOP (SOP No. 7), there is a reference to an Investigative Derived Waste (IDW) SOP, and SOP No. 6; however, SOP No. 6 is not the IDW SOP. This issue should be clarified.

Given the TRC SOP for Equipment Decontamination is now included (SOP No. 6), this comment is no longer applicable. Any SOPs referenced are included with this work plan.

b. The RFI Work Plan must be revised to clarify the term “industrial amazons” in the fourth bullet of Section 5.1 of the Low-Flow Groundwater Sampling SOP (SOP No. 10).

Given the TRC SOP for Groundwater Sampling is now included (SOP No. 1), this comment is no longer applicable as the term industrial amazons is not included in the SOP.

c. Step 23 of Section 5.4 of the Low-Flow Groundwater Sampling SOP (SOP No. 10) of the RFI Work Plan must be revised to specify that the volatile organics analysis vials will be preserved with hydrochloric acid and will be filled completely without any headspace present.

This procedure is outlined in Section 2.3.2 of the TRC SOP for Groundwater Sampling (SOP No. 1).

d. **It was noted that the RFI Work Plan included SOPs for Slug Testing** (SOP No. 9), **and Three Volume Groundwater Sampling (SOP No. 11) even though the activities related to these SOPs were not proposed in the RFI Work Plan. The MMD is fine with retaining these SOPs in the RFI Work Plan in the event these activities are required to be implemented at some point in the future of the investigation.**

TRC has included the Slug Test Procedure SOP as SOP 10. TRC does not anticipate using the three volume groundwater sampling method for groundwater sampling at the Site, therefore no SOP for this is included within the revised work plan.

If you have any questions or concerns regarding this Report, please contact me at 734.585.7829 or kcratsenburg@trccompanies.com.

Sincerely,

TRC

Kelly C. Cratsenburg

Kelly C. Cratsenburg, CPG
Project Manager

Andrew D. Stuart
National Market Director

cc: Vincent Buening, CPG, TRC Client Service Manager

Attachments:

Attachment 1 Revised RCRA Corrective Action Facility Investigation Workplan

Attachment 1
Revised RCRA Corrective Action Facility Investigation Workplan

Revised RCRA Corrective Action Facility Investigation Workplan

Former Hayes Lemmerz Site Ferndale, Oakland County, Michigan

Site ID Number: MID 041 803 123

Waste Data System Number: 395519

September 2022

Prepared For:

Axle Holdings 1, LLC

Prepared By:

TRC
1540 Eisenhower Place
Ann Arbor, Michigan 48108

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TABLES

FIGURES

APPENDICES

1.0 Introduction

TRC Environmental Corporation (TRC), has been retained by Axle Holdings 1, LLC (Client) to prepare a revised Resources Conservation and Recovery Act (RCRA) Facility Investigation Workplan (RFI Workplan) in accordance with the RCRA Corrective Action Plan (May, 1994) for the former Hayes Lemmerz Site located on West Eight Mile Road, Ferndale, Oakland County, Michigan (Site). Corrective action will occur via a Corrective Action Consent Order that is being drafted by the Michigan Department of Environment, Great Lakes and Energy (EGLE) that will be negotiated between the two parties.

The original RFI Work Plan was previously developed and submitted to the EGLE by Atlas Technical Consultants LLC (Atlas), formerly known as ATC Group Services, LLC (ATC) in February 2022. The EGLE replied to the submittal with comments in a letter dated July 7, 2022 (EGLE Comments) and requested, in addition to addressing their comments in the July letter, that TRC re-submit a revised RFI Work Plan under TRC cover. Therefore, TRC is submitting this revised RFI Work Plan (previously developed by Atlas/ATC) to the EGLE as requested.

The Site is a former hazardous waste storage facility regulated under Part 111, Hazardous Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, and its administrative rules (Act 451). The Site is identified as Environmental Protection Agency (EPA) ID Number MID 041 803 123. Under Part 111, an owner or operator of such facilities is subject to corrective action to establish environmental protection standards based on zoning and intended land use.

2.0 Description Of Current Conditions

Current Site conditions were identified in ATC's (now known as Atlas) RCRA Corrective Actions, Description of Current Conditions and Interim Measures Report (CCR), prepared on behalf of Axle Holdings 1, LLC, a revised report was submitted on September 21, 2021 incorporating EGLE's comments of August 5, 2021.

2.1 Site Location Information

The Site is located on West Eight Mile Road in Ferndale, Oakland County, Michigan, on the north side of West Eight Mile Road between Mitchelldale Avenue and Pinecrest Drive. The Site consists of two parcels totaling approximately 34 acres, as shown on Site Details Map **(Figure 1)**.

2.2 Site and Vicinity General Characteristics

The Site is located in an area characterized by commercial business, light industrial, and residential use within the limits of the City of Ferndale, at the southern border of Oakland County. The Site is zoned light industrial (M-1) according to the City of Ferndale online Zoning Map Application. The adjacent parcels to the west, north and east are zoned light industrial, and predominately residential, with some commercial properties lining the major corridor to the south. Refer to the Site Details Map **(Figure 1).**

2.3 Current Use of Site

As described in detail in Section 3.0, the Site was formerly developed and used from the 1930s until 2012, when it was razed from 2012 to 2013. The current use is as partially graded, vacant land.

2.4 Intended Future Use of Site

The intended future use of the southern portion of the Site is for the construction of an additional industrial/warehouse/distribution building for the western adjacent Detroit Axle operation. There are no current plans for the remaining portions of the Site.

2.5 Topographic Setting

The Site is located in the west ½ of the southeast ¼ of Section 33, Township 1 North, Range 11 East, on the United States Geological Survey (USGS) 7.5 Minute Topographic Map, Detroit, Michigan Quadrangle, dated 1985. The Site is approximately 665 feet above mean sea level. The topography across the Site and surrounding area is relatively flat with a gentle slope to the east, as shown on Site Details Map, **Figure 1.**

2.6 Hydrogeologic Setting

The Site is located in the Clinton River drainage basin (HUC8: 0409003) of the River Rouge, which discharges to Lake St. Clair. The nearest surface-water body to the Site is a pond on the Woodlawn Cemetery located approximately 5,160 feet east/southeast of the Site. No wetlands were identified on the National Wetlands Inventory in the vicinity of the Site.

The USDA Soil Survey map of the area identifies surficial soils at the Site as primarily Fortress Family loamy sand with 0 to 6 percent slopes, which typically formed in sandy human-transported materials on the near-shore slopes of water-lain moraines and are characterized as moderately well drained with very low runoff potential. The EGLE GeoWebFace database identifies the Site as lying within a lacustrine sand and gravel plain overlying Upper Devonian-aged Antrim Shale. The brown to black pyritic organic-rich shale is identified as 60 to 200 feet thick in the area, with the bedrock surface approximately 100 to 150 feet below ground surface (bgs).

According to prior reports, Oakland County Health Department records indicate that a 560-foot deep well was installed at the Site by Corsault Well Drilling looking for a source of cooling water; however, the well was terminated in dry shale. Atlas has performed a search of the EGLE Wellogic database of historical scanned water well records to obtain a copy of this well log, however a well log was not found. Although the detailed description of bedrock lithology is not currently available for the Site, there are other wells in the general area that confirm the depth to bedrock and general lithology.

The nearest water-supply well identified in the EGLE Wellogic database for the area is a well installed by Consumers Energy approximately one mile northwest (upgradient) of the Site. The well log indicated a shale water bearing zone present at approximately 130 feet bgs, with approximately 129 feet of overburden consisting of a mix of gravel, gray clay and/or sandy clay. The water-bearing shale unit was approximately 140 feet in depth, and was underlain by dolomite at approximately 273 feet, extending to the boring terminus depth of 277 feet bgs.

Based on review of soil boring logs for the Site from current and previous Site investigations, the southern portion of the Site contains native sand of various grain size to approximately 20 feet bgs. The sand layer is followed by a clay layer approximately 115 feet thick that extends to bedrock. Up to five feet of discontinuous fill containing brick, concrete, and glass debris have been observed in various locations, overlying approximately 20 to 23 feet of loose native sand above the clay that then extends to bedrock.

On the northern portion of the property, the native sand is interbedded with clay, silty clay, and sandy clay. Boring logs for the Site can be found in Appendix C of the CCR. Cross sectional maps are presented in Appendix A of the CCR. These cross-sections help form the basis for the conceptual site model (CSM) that will be refined as additional RFI work is completed.

Groundwater generally is encountered between 8 to 11 feet bgs. Groundwater gradient maps completed for the April and June 2020 groundwater sampling events presented in the CCR indicate groundwater flow direction to be toward the east-southeast.

3.0 Facility Background

3.1 General Site Information and History of Ownership

The Site occupies the northwest corner of the intersection of West Eight Mile Road and Pinecrest Drive. The Site was developed as a multi-building research and development facility for chemical additives for gasoline products from the 1930s until the 1980s. Manufacturing operations took over the facility from the 1980s until 2012. Site buildings were demolished in 2012 and 2013.

Various Site historical building plans identified up to 38 buildings or building wings over time. Underground tunnels reportedly linked several of the southern buildings and several of the buildings reportedly were bunkered with earthen mounds as protection in the event of explosions. The locations of known tunnels can be found on **Figure 1**. However, the possibility remains that there are additional unmapped tunnels.

Additional investigation will be required to determine whether additional tunnels may exist on-site. As additional information is identified, the CSM and cross sections will be updated. Buildings were reportedly heated principally by central natural gas steam systems that also reportedly extended along the underground tunnels.

The Site was developed in stages from the 1930s until 2012 when demolition of the entire Site began. A summary of the former ownership at the Site is as follows:

- Ethyl Corporation (Ethyl) from 1936 to 1987;
- CMI purchased the site though a holding company (TC Realty) in 1987;
- TC Realty changed name to HLI Realty (operating as Hayes Lemmerz International) in 1999;
- HLI Realty transferred to Cedan Holdings VI, LLC 2012;
- Cedan Holdings VI transferred to Pinecrest Holdings, LLC purchased May 4, 2016;
- Pinecrest Holdings, LLC entered into a Land Contract with Axle Holdings 1, LLC (for a 6 acre portion of the Site) and a Land Contract with Axle Holdings 2, LLC (for a 28 acre portion of the Site).

3.2 Historical Facility Operations

Historical operations at the Site by Ethyl included blending of fuels, foundry, service, and maintenance operations, chemical storage, incineration, and laboratory testing. Subsequent manufacturing operations by CMI-Tech Center (after 1987), TC Realty, Inc. (in the early 1990s), and Hayes Lemmerz International (after 1999) included researching various casting and molding processes, integrity testing automotive parts, computer-aided product assembly and product testing, and other engineering and analysis testing. The Site has been vacant following demolition activities which ended in 2013. A summary of the former buildings and their uses on the Site includes:

Building ID	Description of Former Building Use
A	Executive Offices, Printing, Cafeteria, Library, and Machine Shop
B	Experimental Operations, Machine Shop, Vehicle Servicing, and Ref. Technology
C	Engine Research and Dynamometer, Fuel Testing, Control Testing
DA	Chemical Research, Executive Offices, and Patent Department
E	Office, Auto Application Department, and Large Engine Dynamometer Testing
F	Maintenance, Pipe Shop, Carpenter Shop, Glass Blower Shop, and Manufacturing
H	Fueling and Oil Blending
J	Fuel Storage
M	Chemical Development Lab, Heavy Equipment and Manufacturing
N	Chemical Storage
O	Maintenance Storage
Q	Guard Shack
AL	Vehicle Fueling
AN	Emissions Laboratory, Dynamometer Testing Area, Dipping Operations, and Manufacturing
AC	Active Metal Storage
AH	Chemical Engineering Products
L	Bulk Chemicals
U	Chemical Res. And Pilot Plant
AF	Drum Storage
AJ	Can Storage
AB	Can Storage
R	Fleet Building
K	Chemical Supplies Storage
P	Chemical Storage

3.2.1 Former Waste Generation

Ethyl submitted an application for a permit for the generation and storage of hazardous waste generated during the research and development activities at the facility. The Part A Hazardous waste permit application listed spent solvent waste codes for the container storage of 6,400 pounds of F002 waste; 5,600 pounds of F004 waste; and 21,000 pounds of F005 waste. These wastes were listed as ignitable (D001), corrosive (D002), reactive (D003), and toxic (D000). During RCRA facility inspections conducted by the Michigan Department of Natural Resources (MDNR) in the early 1980s, it was noted that Ethyl was generating organophosphate waste, 1,800 gallons of waste oil, and 4,500 gallons of waste gasoline.

TC Realty, Inc. (TCR) generated waste primarily from testing and analyzing automotive products. TCR generated mineral spirits wastes (D001) from cleaning machinery that tested automotive parts. TCR also generated hydraulic oil and motor oil wastes from automotive testing.

3.2.2 Former Waste Storage

According to a Preliminary Assessment/Visual Site Inspection Report, prepared by PRC Environmental in 1994, there were four former solid waste management units (SWMU) located at the Site. Ethyl submitted a notification of hazardous waste activity to EPA on August 6, 1980. The facility submitted a RCRA Part A Permit application on November 14, 1980. The application listed container storage (S01) of up to 5,000 gallons of hazardous waste with the following waste codes: F002 (6,400 pounds); F004 (5,600 pounds); and F005 (21,000 pounds).

Ethyl submitted a closure plan for its hazardous waste storage area SWMU-1 (former drum storage area) on June 3, 1983, which was approved by the EPA on October 11, 1983. The closure was reportedly completed and certified by the MDEQ on February 14, 1984 as a Clean Closure. A FOIA request was sent to EGLE on September 15, 2021 requesting the correspondence that certifies the Clean Closure. According to an EGLE response of September 24, 2021, “After a search, to the best of this public body’s knowledge, information, and belief, the public record(s) do not exist as described by you, or by another name or description reasonably known to the public body; therefore, your request to examine or receive a copy of the documents described above is denied.” Ethyl did not file any further permit applications for EPA hazardous waste activity after February 1984. TCR stored mineral spirits waste in a 500-gallon aboveground storage tank and waste oils were stored in 55- gallon drums at the SWMU-1 location.

3.2.3 Former Waste Disposal

Ethyl maintained no records for the generation, storage or disposal of waste onsite. However, according to correspondence from Ethyl to the Oakland County Health Department in 1985, laboratory wastes, residues, used glassware, foundry sands, and containers reportedly were buried in pits in the northern, central, and eastern portions of the Site from 1939 to the early 1980s. Oakland County Health Department records identified 11 pits in the vicinity of former Building AE in the northwestern portion of the Site. These locations have not been confirmed with geophysical or sampling investigations. The 11 pits are associated with AOC 2 (previously identified as SWMU 2).

Other disposal pits were reported north of former Building AI and in the vicinity of the eastern parking lot, where Ethyl reported that from about 1948 to 1962 metal pans containing residuals of the reaction of sodium compounds with water were disposed in shallow hand-dug holes. No information exists regarding disposal records or transportation for wastes generated by TCR. However, geophysical anomalies have been identified at several locations across the Site and will be investigated as part of the RFI to assess potential waste disposal pits. Refer to Sections 4.2 through 4.7 for further detail pertaining to proposed investigation activities.

3.2.4 Former Permits

Ethyl held a license from the U.S. Atomic Energy Commission (License #21-0064-01) from 1954 to 1957. According to the 2012 RJN Phase I ESA (RJN Environmental, 2012), the license was for the storage of a small amount of nuclear source material in the Soundproofing Room of Building C. A July 9, 1998 U.S. Nuclear Regulatory Commission (NRC) letter to CMI-Tech Center indicated that the license was terminated prior to 1985 and that there was insufficient information to justify closure. NRC requested access to perform an inspection of the Site. Inspection results and current permit status were not identified on available online databases.

Hayes-Lemmerz Technical Center, Inc. was identified as RCRA MID 041 803 123, with additional listings under alternative names as Hayes Lemmerz International Inc., Hayes Lemmerz Tech Svc Inc., Hayes Lemmerz Inc., and Hayes Lemmerz Technical Center Incorporated, Ethyl Corp. R&D Labs, and CMI Tech Center, Inc. The Conditionally Exempt Small Quantity Generator was first identified in 1980 and last reported in 2006 as a generator of ignitable hazardous waste (D001). Violations were identified in 1995, 2001, and 2005 for pre-transport and records/reporting concerns. In 2005, the EPA identified no records of generated waste shipped to off-site facilities, managed on- site, or received from another off-site facility.

The facility was added to the CERCLIS database by March 1986, with Preliminary Assessments performed in March 1986, February 1990, and March 1992 that determined the Site did not qualify for National Priority List (NPL) and deferred further response to RCRA Subtitle C. A CERCLIS NFAP determination was issued in December 1995. The treatment, storage and disposal facility (TSDF) was identified as potentially subject to Corrective Action in June 1992 and assigned a low corrective action priority. A RCRA corrective actions (CORRACTS) Stabilization Measures Evaluation performed in June 1992 determined that insufficient information was available relative to the facility to support implementation of stabilization measures or feasibility evaluation.

Hayes-Lemmerz Technical Center, Inc. was identified on the ICIS-AIR database as Facility MI00000000000A4646 and as State Registration Number A4646, having the following operating status listings:

Program Code	Program Description	Operating Status
CAACFC	Stratospheric Ozone Protection	Permanently Closed
CAAFESOP	Federally Enforceable State Operating Permit – Non-Title V	Permanently Closed
CAAMACT	MACT Standards (40 CFR Part 63, Subpart RRR)	Permanently Closed
CAASIP	State Implementation Plan for National Primary and Secondary Ambient Air Quality Standards	Permanently Closed
CAATVP	Title V Permits	Permanently Closed

3.2.5 *Former Storage Tanks*

The Site contained numerous unregistered Underground Storage Tanks (USTs) operated by Ethyl ranging in size from 500 to 10,000 gallons. The USTs were used to store gasoline for research and development. In the mid-1980s the Ferndale Fire Department oversaw the excavation of the USTs. Additionally, CMI operated one-15,000 gallon diesel UST and one-15,000 gallon gasoline UST. However, it is important to note that due to the lack of available documentation pertaining to regulated USTs (USTs which pre-date tank registration regulations) the exact amount of USTs previously located at the Site is currently unknown. A release (C-0185-96) of the CMI USTs was reported in 1996 and granted a Tier I Unrestricted LUST closure in 1998. A summary of the former storage tanks (65 USTs as provided to Atlas through historical documentation and/or previous reports) located on the Site is as follows:

Summary of Former Underground Storage Tanks

Number of USTs	Size (gallons)	Contents	Location	Date Installed	Date Removed
8	2,000	Gasoline and/or diesel	West of former Building B	Unknown	1985
15	500	Unknown	North of former Building H	1942	1985
11	1,000	Unknown	North of former Building H	1942	1985
4	5,000	Unknown	North of former Building H	1942	1985
4	10,000	Unknown	North of former Building H	1942	1985
14	1,000	Unknown	North of former Building H	1948	1985
4	10,000	Unknown	North of former Building H	1948	1985
3	1,000	Unknown	Likely in the vicinity of former Buildings O, M, J, E, and/or L	Unknown	1985
1	15,000	Diesel	West of former Building C	1988	2008
1	15,000	Gasoline	West of former Building C	1988	2008

3.2.6 *Summary of Releases*

The Site has previously been identified as a closed LUST site relative to one regulated gasoline UST. A release of gasoline was identified during the refueling of the 15,000-gallon gasoline UST and a secondary containment chamber boot failure occurred in 1996. The gasoline UST was located on the west side of Building C (inclusive to AOC 11). Following removal of 90 cubic yards of gasoline impacted soil, unrestricted Tier I LUST closure was granted by the MDEQ on February 4, 1998.

A release of heating oil from a former UST located near the north end of Building D was identified based on the 1995 presence of non-aqueous phase liquid (NAPL) in a nearby monitoring well. Because the heating oil UST was not registered, the release was not reported as a LUST.

As discussed above, there have been a number of known releases at the Site. It should be noted that presumptively there may have been other historical releases at the Site whose source is unknown. This is evidenced by the presence of contaminants in locations and types of contaminants other than where the known releases occurred. Historical petroleum and fuel additive releases are presumed to have occurred from multiple USTs formerly located in the south-central portion of the Site. This is evidenced by detected concentrations of multiple volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), including ethylbenzene, naphthalene, methylnaphthalene, xylenes and trimethylbenzenes (TMBs) in soil and/or groundwater, as well as detections of per fluorinated compounds (per- and polyfluoroalkyl substances identified as PFAS) in groundwater within this area.

3.3 General Site Lithology/Hydrogeology

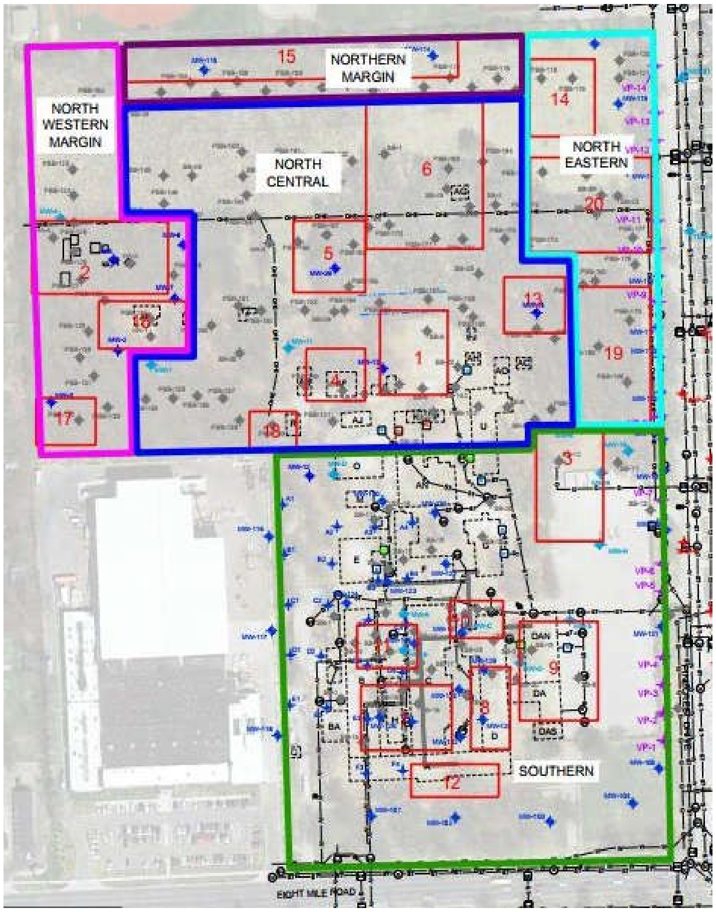
General site lithology derived from the historical and current subsurface investigations at the Site indicate up to five feet of discontinuous fill containing brick, concrete, and glass debris overlying approximately 20 to 23 feet of loose native sand above clay that extends more than 100 feet to bedrock. On the northern portion of the Site, the native sand is interbedded with clay, silty clay, and sandy clay. Groundwater generally is first encountered between 8 to 11 feet bgs and flows in an east-southeasterly direction.

Representative cross-sections are presented in the CCR. These cross sections provide a graphic depiction of general site lithology and form the physical basis of the CSM that will be refined as additional information is gathered as part of the ongoing RFI work. This will include evaluating where tunnels and utilities may be added onto the existing cross sections on a site-wide basis. Additionally, a cross section depicting the lithology/hydrogeology/utility corridors along the eastern boundary of the Site will be generated.

4.0 Areas Of Concern (AOCs) And Investigation Plans

The Site has been divided into twenty (20) areas of concern (AOC), based upon past use, identified solid waste management units (SWMUs), geophysical anomalies, electromagnetic induction (EMI) survey data and soil, groundwater and soil vapor concentrations within those specific AOCs. For investigation purposes and importance of potential receptor risk, each individual AOC has been placed into the groups listed below. Proposed AOCs by Area is presented as **Figure 2** (a copy of which is included below for easy reference). The summarized scope of work for all AOCs is presented by Area/Margin in **Table 1** and soil boring/monitoring well/test pit locations for each AOC are presented in **Figures 3** through **7**.

Note that Axle Holdings 1, LLC has agreed to undertake a request by EGLE to investigate potential exposure issues for residents living along the Site's eastern property boundary prior to work being completed under this RFI. A work plan detailing the planned investigative work was submitted as part of the September 2021 CCR. Starting in November 2021, Atlas began this work at EGLE's direction installing soil vapor points and sampling those and a number of existing monitoring wells placed in close proximity to the eastern property boundary. Results of the Eastern Property Boundary work along with a subsequent proposed work plan were presented in a separate report titled RCRA Interim Work Plan Investigation Report – Eastern Site Boundary (April 2022) and the findings will subsequently be combined with the findings of other Site- wide RFI work planned for delineation and assessment purposes.



Southern Area (area proposed for redevelopment for use by Axle Holdings 1 LLC):

The southern portion of the Site is the first area planned to be investigated as part of the RFI. The Southern Area includes AOCs 3, 7, 8, 9, 10, 11 and 12, which constitutes the majority of the former building and operational areas. The initial RFI work is planned to start upon EGLE approval of this work plan, likely starting in the Fourth Quarter 2022 and will continue into 2023 including the first round of groundwater sampling for all of the wells in the Southern area (new and intact existing wells). A second round of groundwater sampling will be completed with one calendar quarter between rounds to allow for seasonality.

Depending on findings of the initial RFI in the Southern Area, additional delineation may be necessary. The scope of any additional delineation in the Southern Area will be proposed to EGLE, with work proceeding following approvals through the remainder of 2023.

Once EGLE has accepted TRC's completed delineation of each phase, the next phase will be implemented. Timelines listed in this RFI Workplan are the best estimates at the time and are subject to change, as necessary. It is anticipated each consecutive RFI phase will begin within two quarters of the prior phase's completion. In the event of material deviations in scheduling or completion, TRC will notify EGLE.

Northern Half, which includes the following sub-groups:

Northwestern Margin:

Work in the Northwestern Margin will begin within two quarters of completed delineation and reporting in the Southern Area. The Northwestern Margin includes AOCs 2, 16 and 17. This second phase of the RFI will likely start in Second Quarter 2024 and with two rounds of segregated groundwater sampling, potential additional delineation, and reporting is estimated to run through the Second or Third Quarter of 2025.

Northcentral Area:

Work in the Northcentral Area will begin within two quarters of completed delineation and reporting in the Northwestern Margin. The Northcentral Area includes AOCs 1, 4, 5, 6, 13 and 18. This third phase of the RFI will likely start in First Quarter 2026 and with two rounds of segregated groundwater sampling, potential additional delineation, and reporting is estimated to run through the Second or Third quarter of 2027.

Northeastern Area:

Work in the Northeastern Area will begin within two quarters of completed delineation and reporting for the Northcentral Area. The Northeastern Area comprises the eastern property boundary adjacent to offsite residential areas. The Northeastern Area includes AOCs 14, 19 and 20. This fourth phase of the RFI will likely start in First Quarter 2028 and with two rounds of segregated groundwater sampling, potential additional delineation, and reporting is estimated to run through the Second or Third Quarter of 2029.

Northern Margin:

Work in the Northern Margin will begin within two quarters of completed delineation and reporting in the Northeastern Area. The Northern Margin includes AOC 15. This fifth phase of the RFI will likely start in First Quarter 2030 and with two rounds of segregated groundwater sampling, potential additional delineation, and reporting is estimated to be completed in the Second or Third Quarter of 2031.

Site-Wide Items for Investigation:

There is an additional need for a site-wide AOC, to create a holistic, site-wide approach to the investigation of the Site, when that makes logical sense to do so. The site-wide AOC will focus on vertical delineation of the geologic and hydrogeologic understanding of the overburden and the potential effects of areas and potentially preferential pathways may exist related to onsite features such as the former tunnels and utility corridors that are connected to, but not part of any individual AOC. This RFI work is expected to be completed in tandem with the Southern Half AOC Area work.

4.1 Site Investigation and Analytical Parameter List

Due to the nature and extent of various chemicals used, stored, managed, and disposed throughout the course of the history of the Site, a **Site-Specific Comprehensive Constituent List (SSCCL)** has been compiled, which will be utilized by TRC, at a minimum, during the analysis of all RFI soil and/or groundwater when indicated in the following sections below.

The **SSCCL** includes, but is not limited to:

- Full Part 201VOC list + tentatively identified compounds (TICs) (including MTBE, tetrahydrofuran, and 1,4-dioxane) plus 3 alcohols (methanol, ethanol, and n-butanol)
- Full Part 201 SVOC list + TICs
- Michigan List Part 201 Total Metals list
- Polychlorinated Biphenyls (PCBs) (by individual Aroclor)
- Michigan List 31 PFAS

The specific list of contaminants of concern (COCs) for each of the categories above are presented in **Table 2**. These COC lists are the same as was analyzed for Site investigative work completed by Atlas in 2020-2022 prior to the implementation of this RFI Workplan with the addition of the TICs. TICs have been added to identify other potential COCs that may be present on-site, but not on the Part 201 VOC or SVOC target lists. If during the course of this RFI, specific COCs identified as part of the TICs analyses are prevalent, consideration will be given to modify the SSCCL to add these COCs.

In addition to the SSCCL, where indicated in the sections below and on **Table 1**, additional parameters may be analyzed for, which will include the following, when indicated, based on AOC-specific knowledge as to the AOC’s known or suspected prior use:

- Hexavalent chromium
- tetraethyl lead

- dioxins/furans

The list of individual COCs for these additional parameters groups (i.e., PCBs, PFAS, and dioxin/furans) are also presented in **Table 2**. All site RFI media samples will be compared to Residential and Non Residential Michigan Part 201 Generic Cleanup Criteria and screening levels for all pathways. The soil gas and groundwater samples collected from the eastern boundary, will be compared to Residential Michigan Part 201 Generic Cleanup Criteria, based upon the potential for off-site residential receptors. Note that additional discussion relative to Atlas 2021 investigation of the Eastern Property Boundary is discussed in Section 4.3.

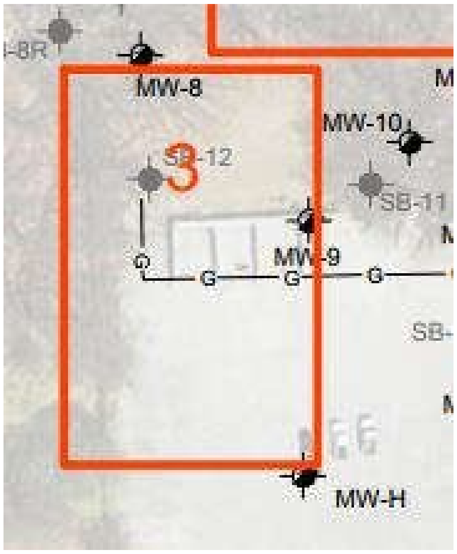
Each of the AOCs within a designated area or margin will be investigated simultaneously. Any additional assessment will be proposed and completed within six months of the reporting of the current RFI scope, as it is deemed necessary. Pending the results of the first round of assessment in each of the AOCs, the specific analysis may be focused to certain SSCCLs.

Groundwater sampling scoped in the AOCs includes two rounds of sampling spread approximately one quarter apart and will include all new and existing uncompromised wells. Well development will be completed prior to the first round of sampling. Some historic wells have not been encountered during recent sampling and any wells whose integrity is suspect prior to or at the time of sampling will not be sampled. Metals samples for groundwater will not be field filtered, and will be analyzed for totals, unless the water being sampled is visibly turbid, in which case a field filtered/dissolved aliquot sample will be collected in addition to the totals sample.

4.2 Southern Area

AOCs 3, 7, 8, 9, 10, 11 and 12 are all included in the Southern Area that will be the focus of the first phase of the RFI. Description of known uses, investigative work completed so far, and proposed additional sampling scope to address horizontal and vertical delineation of the area is presented below. As stated above, start of the first phase of RFI in the Southern Area is planned to begin in the Third or Fourth Quarter of 2022 and is expected to be completed by the end 2023. Refer to **Figure 3** for a depiction of planned assessment locations pertaining to each AOC in the Southern Area.

4.2.1 AOC 3 – SWMU 3 – Former Burial Area



The area designated as SWMU-3 (as originally defined in a Preliminary Assessment/Visual Site Inspection Report (PRC Environmental,1994) is located within the eastern portion of the Site, within the northwest corner of the paved parking lot area. This location was a former burial area for various wastes utilized by Ethyl from approximately 1939 until 1955.

Constituents of Concern/Objective:

Soil -

A total of six soil borings (with three being converted to temporary monitoring wells) and four permanent monitoring wells were evaluated within and surrounding this AOC. Of the six soil borings installed, five soil samples were analyzed between the years 2012 and 2015: SB/TMW-8 (1-2'), SB- 11 (10-12'), SB-12 (10-12'), SB-20 (10-12'), and PSB-144 (8-9'). Soil samples were not analyzed for borings SB/TMW-8R or monitoring wells MW-8, MW-9, MW-10 or MW-H.

The following COCs were detected:

- VOCs: 2-methylnaphthalene at SB-11 (10-12') and SB-12 (10-12') and trichloroethylene at SB-12 (10-12').
- Polynuclear aromatics (PNAs) (full scan SVOC analysis was not conducted): none detected at PSB-144 (8-9'). The remainder of the soil samples were not analyzed for PNAs.
- Metals: arsenic, barium, chromium, copper, lead, and zinc at SB/TMW-8 (1-2') and PSB-144 (8-9'). Mercury was also detected at SB/TMW-8 (1-2').
- PCBs: none detected at SB/TMW-8 (1-2'). The remainder of the soil samples were not analyzed for PCBs.

Groundwater -

Groundwater analytical data for monitoring well MW-8 has not been disclosed and/or the well was not sampled historically. Groundwater samples collected in 2012 from MW-9, MW-10 and

MW-H; as well as groundwater samples collected in 2015/2016 from temporary monitoring wells SB/TMW-8 and SB/TMW-8R, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **1,2-dichlorobenzene (SB/TMW-8 and SB/TMW-8R)**; **trichloroethylene (MW-9 and MW-10)**; chlorobenzene (MW-9) and 1,4-dichlorobenzene (SB/TMW-8 and SB/TMW-8R).
- PNAs/SVOCs (full scan SVOC analysis was not completed): none detected.
- Metals: barium, copper and/or zinc (MW-10 and SB/TMW-8). The remainder of the wells were not analyzed for metals.
- PCBs: wells were not analyzed for PCBs.

Further delineation of VOCs and metals detected (in particular, 2-methylnaphthalene, trichloroethylene and 1,2-dichlorobenzene) in soil and groundwater for COCs potentially associated with the reported buried laboratory wastes, and physical and chemical characterization and vertical and horizontal delineation of potential groundwater impacts form the objective for this AOC investigation. The unspecified laboratory wastes could be associated with virtually any chemicals used, stored, managed, or disposed onsite. COCs should target a broad spectrum of analysis to ensure current comprehensive analyses are completed.

Planned Assessment:

Provided the historical use of this area as a former burial pit for various unidentified wastes, planned assessment includes the completion of up to four test pits and will extend to the reach of the excavator, no less than 10 feet bgs. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval if any are identified.

Note that for all RFI work, the test pit depth selected is generally the depth to the water table and the reach of a standard excavator. We believe this should be sufficient to identify at least the tops of anything identified as anomalies during the EMI study. If any signs of anomalies or buried material is encountered that cannot be completely delineated, additional plans may be warranted to fully assess the visual limits of those items.

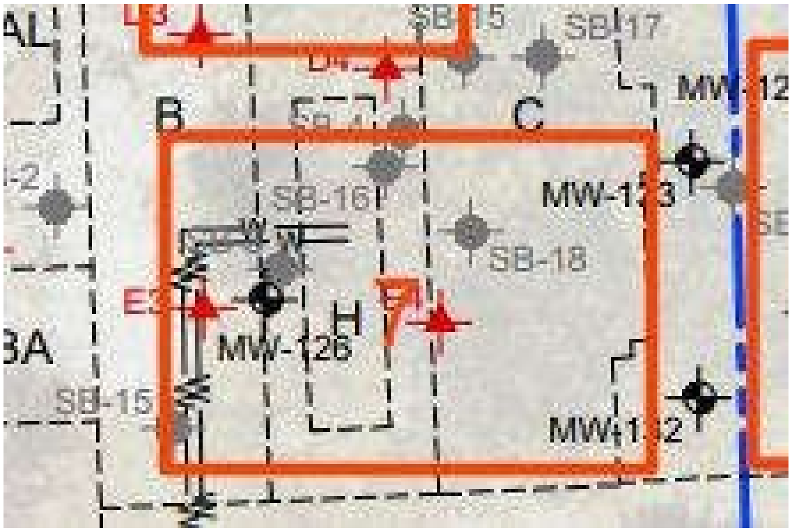
Additional planned assessment work includes the installation of two permanent monitoring wells within the northwestern and southeastern portions of SWMU-3 to evaluate soil and groundwater conditions in a cross-gradient direction. Wells will be screened to the base of the sand unit and in contact with the underlying clay unit, (at a depth greater than 16 feet bgs, according to historical boring logs for SB-11 and SB-12 completed in this area, which indicate sand extending to this depth with no underlying clay unit identified).

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

Groundwater sampling at newly installed monitoring wells (as well as existing monitoring wells MW-130 and MW-131) will be conducted via low-flow techniques. Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), plus at least one round of MI

PFAS 31 compounds. PFAS will be added to the AOC-specific COC list for this AOC if Non-Residential RBSL exceedances are observed.

4.2.2 AOC 7 – PCE/TCE



AOC 7 contained historical Building H, which was utilized for fuel and oil blending. This former building was situated in between former Building B, which was utilized for experimental operations, a machine shop, and vehicle servicing and former Building C, which was utilized for engine research and dynamometer, fuel testing and control testing.

Constituents of Concern/Objective:

Soil -

A total of six soil borings (with three being converted to temporary monitoring wells and one converted to a permanent monitoring well) were evaluated within and surrounding this AOC. Of the six soil borings installed, seven soil samples were analyzed between the years 2012 and 2020: SB-3 (10-12'), SB-4 (10-12'), SB/TMW-15 (1-2'), SB/TMW-16 (1-2'), SB/TMW-18 (7-8') and MW-126 (4-5') and (7.5-8.5'). Additionally two temporary soil vapor points, E-3 and E-4 were installed in 2019.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **naphthalene**, 2-methylnaphthalene and trichlorofluoromethane at **TMW/SB-18 (7-8').** VOCs were not detected in remaining samples analyzed.
- PNAs/SVOCs: Full scan SVOC analysis was only completed at the MW-126 location. **Up to 14 PNAs were detected at SB/TMW-18 (7-8') with multiple constituents exceeding the most restrictive criteria**. Select PNAs/SVOCs were also detected at SB-3 (10-12'), SB/TMW-16 (1-2'), SB/TMW-18 (7-8') and MW-126 (4-5'), however below respective screening levels.
- Metals: multiple metals (including arsenic, barium, cadmium, chromium etc.) were detected at all samples analyzed. **Mercury was detected at SB/TMW-16 (1-2') and SB/TMW-18 (7-**

8') above default background levels and at SB-3 (10-12'), however below default background levels.

- PCBs: not detected.

Groundwater –

Groundwater samples were not collected from temporary monitoring well SB/TMW-15. Groundwater samples collected in 2016 from temporary monitoring well SB/TMW-16 and SB/TMW-18, as well as groundwater samples collected in 2020 from monitoring well MW-126, detected the following COCs (only bolded COCs exceeded the most restrictive criteria:

- VOCs: **tetrachloroethylene** at **SB/TMW-16, SB/TMW-18 and MW-126**; **trichloroethylene at MW-126**; trichlorofluoromethane at SB/TMW-16 and SB/TMW-18; and 1,1-dichloroethylene at SB/TMW-18.
- SVOCs: none detected.
- Metals: up to 10 metals were detected in each sample collected, including **aluminum, boron, iron, manganese, and vanadium at MW-126.**
- PCBs: none detected at MW-126. SB/TMW-16 and SB/TMW-18 were not analyzed for PCBs.

Soil Gas –

Soil gas samples collected from temporary soil gas points E-4 and E-5, set at a depth of 5 feet bgs, detected multiple VOCs and/or SVOCs, however the concentrations were below their respective volatilization to indoor air pathway (VIAP) screening levels, with the exception of **trichloroethylene at E-4.**

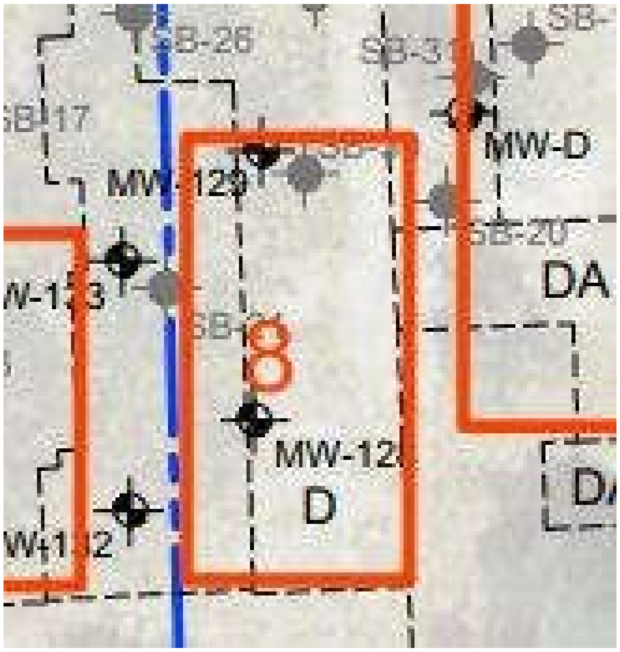
Planned Assessment:

Installation of two monitoring wells located within the central and northwestern portions of the AOC, which will be screened to the base of the sand unit and in contact with the underlying clay unit, (at a depth to exceed approximately 16 feet bgs, according to monitoring wells MW-126 and MW-132 installed within this area). Soil samples will be collected from both shallow (within the first 5 feet bgs) and deep intervals exhibiting the highest photoionization detector (PID) readings and/or which exhibit visual evidence of contamination to attempt to identify whether the source of soil gas vapors previously detected in soil gas samples collected is in this area.

Soil samples collected from each soil boring/monitoring well will be analyzed for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring well MW-126). Groundwater samples will be submitted for SSCCL parameter list (Table 1 and Table 2), plus MI 31 PFAS compounds and tetraethyl lead.

4.2.3 AOC 8 – PFOA/PFOS



AOC 8 contained historical Building D, of which the former operations occurring at this building are unknown. This former building was situated in between former Building DA, which was utilized for chemical research and former Building C, which was utilized for engine research and dynamometer, fuel testing and control testing.

<u>**Constituents of Concern/Objective:**</u>

<u>*Soil -*</u>

A total of seven soil borings (with two being converted to temporary monitoring wells and four converted to a permanent monitoring well) were evaluated within and surrounding this AOC. Of the seven soil borings installed, nine soil samples were analyzed between the years 2012 and 2020: SB/TMW-20 (1-2’), SB-21 (10-12’), SB/TMW-30 (8-9’), MW-128 (4-5’) and (8-9’), MW-129 (3-4’), MW-132 (5.5-6.5’) and MW-133 (3-4’) and (10-11’).

The following COCs were detected (only bolded COCs exceeded the most restrictive criteria):

- VOCs: none detected.
- PNAs/SVOCs: Full scan SVOC analysis was only completed at MW-128, MW-129, MW-132 and MW-133 locations. Multiple SVOCs were detected with **benzo(b)pyrene, carbazole, dibenzofuran, fluoranthene, naphthalene and/or phenanthrene exceeding the most restrictive criteria at each sample.** PNAs were not detected in remaining samples analyzed.
- Metals: multiple metals (including arsenic, barium, cadmium, chromium etc.) were detected at all samples analyzed, with the exception of SB-20 and SB/TMW-30, which were not analyzed for metals. **Mercury was detected at MW-129 (3-4’), MW-132 (5.5-6.5’), MW-133 (3-4’) and (10-11’) above default background levels and VIAP screening levels.**

- PCBs: not detected.

Groundwater –

Groundwater samples collected in 2016 from temporary monitoring wells SB/TMW-20 and SB/TMW- 30, as well as groundwater samples collected in 2020 from monitoring wells MW-128, MW-129, MW- 132 and MW-133, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: trichlorofluoromethane at SB/TMW-20 and SB/TMW-30; and 1,1-dichloroethylene at SB/TMW-20; **tetrachloroethylene at MW-128; trichloroethylene at MW-129;** acetone, chloromethane, 1,4-dioxane, **ethylbenzene, naphthalene,** toluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, xylene and **methanol at MW-132;** and chloromethane and **naphthalene at MW-133.**
- SVOCs: **carbazole,** fluoranthene, **naphthalene**, 2-nitrophenol, 4-nitrophenol, **phenanthrene** and phenol at **MW-132; carbazole,** fluoranthene**,** naphthalene and **phenanthrene at MW-133.**
- Metals: multiple metals (including arsenic, barium, cadmium, chromium etc.) were detected at all samples analyzed, with the exception of SB/TMW-30, which was not analyzed for metals. **Boron was detected in MW-128, MW-129 and MW-133.**
- PCBs: none detected.
- PFAS: A total of ten PFAS compounds were detected at MW-128, MW-129, MW-132 and MW-133 with **PFOA, PFNA and/or PFOS** exceeding the most restrictive criteria.

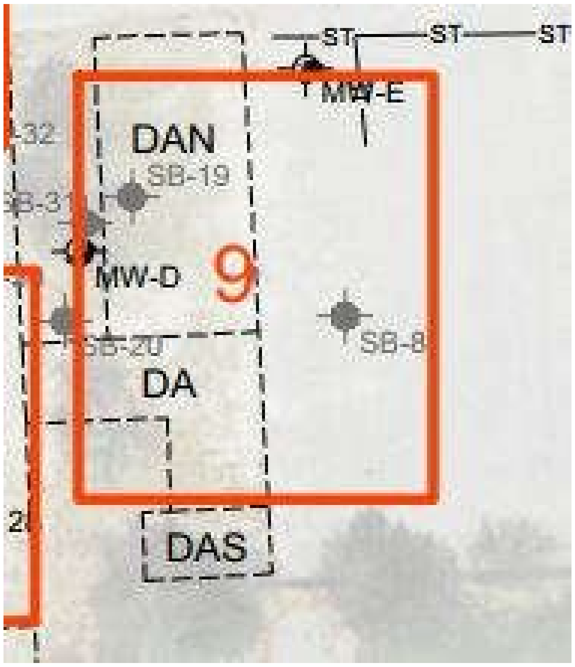
Planned Assessment:

Installation of two additional monitoring wells along the eastern/southeastern border of this area to determine if PFAS concentrations are migrating in a horizontal downgradient direction. The additional monitoring wells will be installed to the base of the sand unit, and in contact with the underlying clay unit due to the presence of chlorinated solvents in this area. Soil samples will be collected at up to three depth intervals in each of the well boings following the rational described above. Attempting to identify the source of PFAS concentrations will also be included in the assessment activities.

Soil samples collected from each soil boring/monitoring well will be analyzed for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring wells MW-128, MW-129, MW-132 and MW-133). Groundwater samples will be submitted for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

4.2.4 AOC 9 – Neutralization Basin/Former UST Area



The area of a former neutralization basin and former UST is located along the southeastern portion of the Southern Area.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of five soil borings (with three being converted to temporary monitoring wells and two permanent monitoring wells) were evaluated within and surrounding this AOC. Of the soil borings installed, four soil samples were analyzed between the years 2012 and 2016: SB-8 (10-12'), SB/TMW-19 (1-2'), SB/TMW-20 (1-2') and SB/TMW-31 (7-8'). Soil samples were not collected during the installation of monitoring wells MW-D and MW-E.

The following COCs were detected:

- VOCs: trichloroethylene at SB/TMW-19 (1-2'); 2-methylnaphthalene, naphthalene and 1,2,4-trimethylbenzene at SB-8 (10-12'). VOCs were not detected in the remaining samples analyzed.
- PNAs (full scan SVOC analysis was not conducted): none detected.
- Metals: arsenic, barium, chromium, copper, lead and zinc at SB/TMW-19 (1-2') and SB/TMW-20 (1-2'). Remaining soil samples were not analyzed for metals.
- PCBs: none detected.

<u>Groundwater –</u>

Groundwater samples collected in 2012 from monitoring wells MW-D and MW-E, as well as groundwater samples collected from temporary monitoring wells SB/TMW-19, SB/TMW-20 and SB/TMW-31 in 2015 and 2016, detected the following COCs:

- VOCs: chlorobenzene, 1,1-dichloroethylene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene and/or trichlorofluoromethane at SB/TMW-19, SB/TMW-20 and SB/TMW-31.
- Tetrachloroethylene at MW-E. No detections at MW-D.
- PNAs (full scan SVOC analysis was not completed): Diethyl phthalate at MW-E. None detected at remaining wells.
- Metals: arsenic, barium, copper and/or zinc at SB/TMW-19 and SB/TMW-20. SB/TWM-31, MW-D and MW-E were not analyzed for metals.
- PCBs: wells were not analyzed for PCBs.

Planned Assessment:

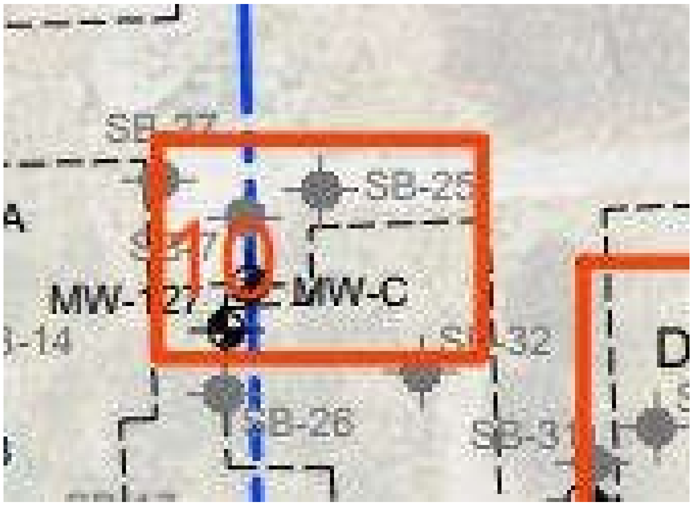
Completion of two soil borings, within the area of the identified electromagnetic anomalies present in the central-southern/southeastern portions of the area, which coincide with the location of the former USTs. The soil borings will extend to an approximate depth of 25 feet bgs to properly evaluate for the presence of buried orphaned tanks/sumps/vaults. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Additional planned assessment work includes the installation of three monitoring wells within the northern, eastern, southeastern and western portions of the AOC to evaluate soil and groundwater conditions in a cross-gradient direction. The monitoring wells will be screened to the base of the sand unit, and in contact with the underlying clay unit. Soil samples will also be collected from the well borings following the depth selection rationale described above.

Soil samples collected from each soil boring/monitoring well will be analyzed for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

Groundwater sampling will be conducted via low-flow techniques at newly installed monitoring wells. Groundwater samples will be submitted for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

4.2.5 AOC 10 – Former Heating Oil UST/EMI Interference – GPR Anomaly



Electromagnetic induction conducted indicated the presence of deep and shallow voids within the subsurface of this area, which is located within the southern-central portion of the Southern Area. Furthermore, a ground penetrating radar (GPR) survey conducted within this area indicated an anomaly within the subsurface. According to historical documentation, a former heating oil UST was located within this area.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of seven soil borings (with one being converted to a temporary monitoring well and two permanent monitoring wells) were evaluated within and surrounding this AOC. Of the seven soil borings installed, seven soil samples were analyzed between the years 2012 and 2020: SB-7 (10- 12'), SB-25 (10-12'), SB-26 (12-14'), SB-27 (10-12'), SB/TMW-32 (8-9') and MW-127 (6-7') and (10-11'). Soil samples were not collected during the installation of monitoring well MW-C.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: A total of 26 VOCs were detected from samples collected at SB-7 (10-12'), SB-25 (10-12'), SB-26 (12-14') and SB-27 (10-12'). Specifically, **benzene, chlorobenzene, ethylbenzene, 2-methylnaphthalene, naphthalene, toluene, 1,2,3-, 1,2,4- and 1,3,5-trimethylbenzene, xylenes, and/or 1,2-, 1,3- and 1,4-dicholobenzene were detected in excess of criteria at these sample locations.** Samples collected from SB/TMW-32 (8-9') and MW-127 (6-7') and (10-11') did not have VOCs detected.
- PNAs/SVOCs: Full scan SVOC analysis was only completed at the MW-127 location. Up to 10 PNAs were detected at the SB-7 (10-12'), SB-25 (10-12'), SB-27 (7-8') and MW-127 (10-11') with **acenaphthene, acenaphthylene, anthracene, chrysene, fluorene and/or phenanthrene exceeding the most restrictive criteria.** SB/TMW-32 (8-9') did not have any PNA detections. SB-26 (12-14') was not analyzed for PNAs.
- Metals: arsenic, barium, chromium, copper, lead, selenium and/or zinc at SB-7 (10-12'), SB-25 (10-12') and SB-27 (10-12'). Mercury was also detected at SB-27 (10-12') below default

background levels. Expanded metal analysis was completed at MW-127 (6-7') and (10-11') which indicated 16 metals including **aluminum, cobalt, iron and manganese above their most restrictive criteria.** SB-26 (12-14') was not analyzed for metals.

- PCBs: none detected.

Groundwater –

Groundwater samples collected in 2016 from temporary monitoring well SB/TMW-32, as well as groundwater samples collected in 2020 from monitoring well MW-127, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **chlorobenzene, 2-methylnaphthalene and naphthalene** at SB/TMW-32; chlorobenzene, 2-methylnaphthalene, **naphthalene,** trichlorofluoromethane, 1,2,4- and 1,3,5- trimethylbenzene, and xylenes at MW-127.
- PNAs/SVOCs (full scan SVOC analysis was only completed at MW-127): acenaphthylene, fluorene, **naphthalene, phenanthrene** and **2-methylnaphthalene** at SB/TMW-32; benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, **fluoranthene** and **phenanthrene** at MW-127.
- Metals: A total of 11 metals were detected at MW-127. Specifically, **aluminum, iron, manganese and vanadium** exceeded the most restrictive criteria at MW-127. SB/TMW-32 was not analyzed for metals.
- PCBs: none detected at MW-127. SB/TMW-32 was not analyzed for PCBs.
- PFAS: Seven PFAS compounds were detected at MW-127 with **PFOA and PFOS** exceeding the most restrictive criteria.

Planned Assessment:

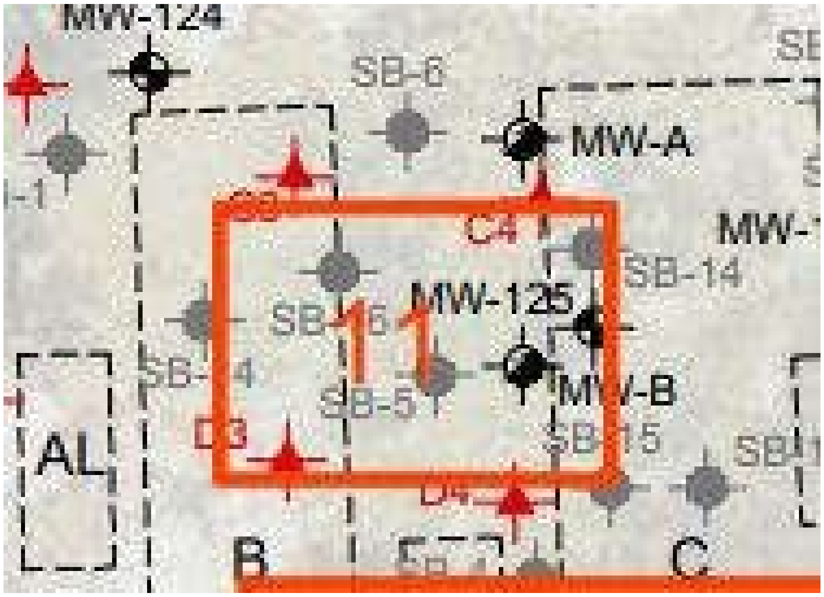
Provided the historical use of this area as a location for heating oil USTs, planned assessment includes the completion of two test pits, within the area of the identified electromagnetic anomalies present in the near monitoring well MW-127. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate for the presence of potential buried materials. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, if appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 15 feet bgs, which indicates sand extending to this depth with no clay interface encountered) will be installed in the northwestern and southeastern portions of this area.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list plus MI PFAS 31 compounds (Table 1 and Table 2).

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring wells MW-122, MW-123 and MW-127). Groundwater samples will be submitted for the SSCCL parameter list plus MI PFAS 31 compounds (Table 1 and Table 2).

4.2.6 AOC 11 – Former UST Area/EMI Interference



Electromagnetic induction conducted indicated the presence of deep and shallow voids within the subsurface of this area, which is located within the southern-central portion of the Southern AOC Area. According to historical documentation, USTs were formerly located within this area.

Constituents of Concern/Objective:

Soil -

A total of nine soil borings (with one being converted to a temporary monitoring well and five permanent monitoring wells) were evaluated within and surrounding this AOC. Of the nine soil borings installed, six soil samples were analyzed between the years 2012 and 2020: SB-5 (10-12'), SB-6 (10-12'), SB-14 (10-12), SB/TMW-14 (1-2'), MW-124 (4-5') and MW-125 (4-5'). Soil samples were not collected during the installation of monitoring wells MW-A or MW-B. Additionally four temporary soil vapor points, C-3, C-4, D-3 and D-4 were installed in 2019.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: 2-methylnaphthalene, naphthalene, n-propylbenzene, 1,2,3- 1,2,4- and 1,3,5-trimethylbenzene at SB-6 (10-12'); n-butylbenzene, sec-butylbenzene, chlorobenzene at SB-14 (10-12'); **n-butylbenzene, sec-butylbenzene**, **isopropylbenzene**, **ethylbenzene, 2-methylnaphthalene, naphthalene,** p-isopropyltoluene, **n-propylbenzene, 1,2,3- 1,2,4- and 1,3,5-trimethylbezene, xylenes at SB-5 (10-12').** None detected in remaining samples analyzed.
- PNAs/SVOCs: Full scan SVOC analysis was only completed at MW-124 and MW-125 locations. Up to nine PNAs were detected at the SB/TMW-14 (1-2') location with none exceeding the most restrictive criteria. Eleven SVOCs were detected at the MW-125 (4-5') sample with **phenanthrene exceeding the most restrictive criteria.** SVOCs were not

detected in MW-124 (4-5’). Samples collected from SB-5 (10-12’), SB-6 (10-12’) and SB-14 (10-12’) were not analyzed for PNAs.

- Metals: arsenic, barium, cadmium, chromium, copper, lead and zinc were detected at SB/TMW-14 (1-2’), along with **mercury which was detected in exceedance of its default background level**. Expanded metal analysis was completed at MW-124 (4-5’) and MW-125 (4-5’) which indicated 21 metals detected, of which **aluminum, cobalt, iron, manganese and/or silver above their most restrictive criteria.** Additionally, **mercury was detected exceeding VIAP screening levels at MW-125 (4-5’).** SB-5 (10-12’), SB-6 (10-12’) and SB-14 (10-12’) were not analyzed for metals.
- PCBs: none detected.

__Groundwater –__

Groundwater samples were not collected from MW-B. Groundwater samples collected in 2012 from monitoring well MW-A, groundwater samples collected in 2015 from temporary monitoring well SB/TMW-14, as well as groundwater samples collected in 2020 from monitoring wells MW-124 and MW-125, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: 1,2-dichlorobenzene at MW-A; and chloroethane, trichlorofluoromethane and **vinyl chloride at SB/TMW-14**. VOCs were not detected in MW-124 or MW-125.
- PNAs/SVOCs (full scan SVOC analysis was only completed at MW-124 and MW-125): none detected at SB/TMW-14, MW-124 and MW-125. MW-A was not analyzed for PNAs/SVOCs.
- Metals: arsenic and barium at SB/TMW-14. A total of nine metals, of which **aluminum, iron and manganese were detected at levels exceeding the most restrictive criteria at MW- 124 and MW-125.** MW-A was not analyzed for metals.
- PCBs: none detected at MW-125. SB/TMW-14, MW-A and MW-124 were not analyzed for PCBs.

__Soil Gas –__

Soil gas samples collected from temporary soil gas points C-3, C-4, D-3 and D-4, set at a depth of 5 feet bgs detected multiple VOCs and/or SVOCs. However, all concentrations were below respective VIAP screening levels, with the exception of **trichloroethylene at C-3.**

__Planned Assessment:__

Provided the historical use of this area as a former location of multiple USTs, planned assessment includes the completion of four test pits, within the area of the former UST locations. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate for the presence of orphaned and/or closed-in-place USTs, should they exist. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 15 feet bgs, which indicates sand extending to this depth with no clay interface encountered at monitoring well MW-125) will be installed in the northwestern and southeastern portions of this area. Soil samples will be collected from both shallow (within the first 5 feet bgs) and deep intervals exhibiting the highest PID readings and/or which exhibit visual evidence of contamination to determine the source of soil gas vapors previously detected in soil gas samples collected from this area. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

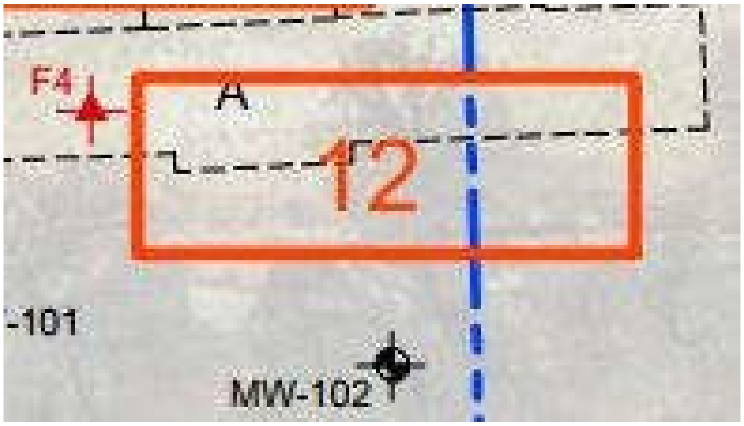
If the source of soil gas vapors is identified, three soil gas vapor points will be installed within the subsurface (one upgradient and two downgradient) targeting that location. If it is not identified, the same sequence will be placed around the perimeter of the former USTs.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring wells MW-124 and MW-125). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), plus MI 31 PFAS compounds and tetraethyl lead.

Soil gas samples will be analyzed for TO-15 analysis for VOCs.

4.2.7 AOC 12 – EMI Interference – GPR Anomaly



Electromagnetic induction conducted indicated the presence of a large deep void within the subsurface of this area, which is located within the southern portion of the Southern AOC Area. Furthermore, a GPR survey conducted within this area indicated an anomaly within the subsurface.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of three soil borings (all of which were converted to permanent monitoring wells) were evaluated surrounding this AOC. Of the three soil borings installed, three soil samples were analyzed in 2020: MW-101 (2-3'), MW-102 (2-3') and MW-132 (5.5-6.5'). Additionally two temporary soil vapor points, F-3 and F-4 were installed in 2019.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: none detected at MW-132 (5.5-6.5'). MW-101 (2-3') and MW-102 (2-3') were not analyzed for VOCs.
- PNAs/SVOCs: Multiple SVOCs were detected with **naphthalene and phenanthrene exceeding the most restrictive criteria at MW-132 (5.5-6.5').** MW-101 (2-3') and MW-102 (2-3') were not analyzed for SVOCs.
- Metals: arsenic, barium and/or chromium were detected at MW-101 (2-3') and MW-102 (2-3'). Multiple metals were detected at **MW-132 (5.5-6.5') with arsenic, boron, iron, magnesium, manganese and molybdenum exceeding the most restrictive criteria.** Additionally, **mercury was detected exceeding the VIAP screening level at MW- 102 (2-3') and MW-132 (5.5-6.5').**
- PCBs: none detected at MW-132 (5.5-6.5'). MW-101 (2-3') and MW-102 (2-3') were not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2020 from monitoring wells MW-101, MW-102 and MW-132, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: acetone, chloromethane, 1,4-dioxane, **ethylbenzene**, **naphthalene,** toluene, 1,2,4- and 1,3,5-trimethylbenzene, xylene and **methanol** were detected at **MW-132**. VOCs were not detected at MW-101 or MW-102.
- SVOCs: **carbazole,** fluoranthene, **naphthalene**, 2- and 4-nitrophenol, **phenanthrene** and phenol were detected at MW-132. SVOCs were not detected at MW-101 or MW-102.
- Metals: a total of ten metals, of which **aluminum and lead were detected at levels exceeding the most restrictive criteria at MW-132.** MW-101 and MW-102 had no detections for select metals analyzed.
- PCBs: none detected at MW-132. MW-101 and MW-102 were not analyzed for PCBs.
- PFAS: Nine PFAS compounds were detected between MW-101, MW-102 and MW-132, with **PFOA and PFOS** exceeding the most restrictive screening levels at **MW-132**.

Soil Gas –

Soil gas samples collected from temporary soil gas points F-3 and F-4, set at a depth of 5 feet bgs, detected multiple VOCs and/or SVOCs, however all detections were below the respective VIAP screening level.

Planned Assessment:

Provided the presence of a large deep void within the subsurface, planned assessment includes the completion of three test pits within the area of the void. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate the deep void and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 15 feet bgs, which indicates sand extending to this depth with no clay interface encountered at monitoring well MW-102) will be installed in the eastern and western portions of this area. Soil samples will be collected following the rationale for selecting depth intervals as described above to determine if this is a potential source area for contamination observed at this AOC.

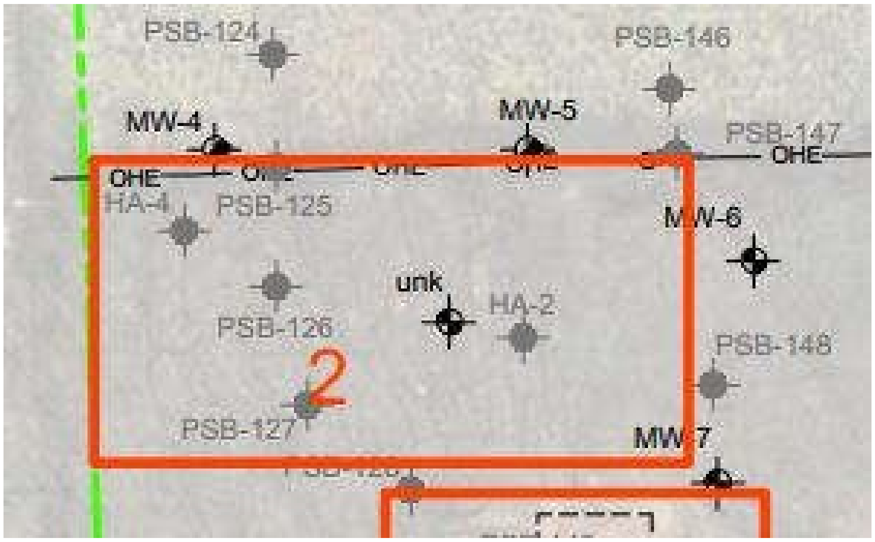
Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds to horizontally and vertically delineate previous detections.

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring wells MW-101, MW-102 and MW-103). Groundwater samples will be submitted for SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

4.3 Northwestern Margin

AOCs 2, 16 and 17 are all included in the Northwestern Margin that will be the focus of the third phase of the RFI. Description of known uses, investigative work completed so far, and proposed additional sampling scope to address horizontal and vertical delineation of the area is presented below. As stated above, start of the second phase of RFI in the Northwestern Margin is planned to begin in 2024 and be completed Second or Third Quarter 2025. Refer to **Figure 4** for a depiction of planned assessment locations pertaining to each AOC in the Northwestern Margin.

4.3.1 AOC 2 – SWMU 2 – Former Burial Area



The area designated as SWMU-2 (as originally defined in a Preliminary Assessment/Visual Site Inspection Report (PRC Environmental, 1994) is located within the northwestern portion of the Site, along the northwestern property boundary, in a vacant wooded area. This location was reportedly a former burial area for various laboratory wastes utilized by Ethyl from approximately 1962 until 1983.

Constituents of Concern/Objective:

Soil -

A total of twelve soil borings (and four permanent monitoring wells) were evaluated within and surrounding this AOC. Of the twelve soil borings installed, seven soil samples were analyzed between the years 2012 and 2016: HA-2 (8'), HA-4 (8'), PSB-127 (6.5-7.5'), PSB-146 (2-3'), PSB-147 (5-6'), PSB-148 (2-3'), and SB-28 (3-4'). Soil samples were not analyzed for soil borings PSB- 123, PSB-124, PSB-125, PSB-126, PSB-145 or monitoring wells MW-1, MW-5, MW-6 or MW-7.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: none detected.
- PNAs (full scan SVOC analysis was not conducted): anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene at HA-4 (8').
- Metals: arsenic, barium, cadmium, chromium, copper, lead, selenium and/or zinc. Mercury was detected at PSB-146 (2-3'), PSB-147 (5-6'), HA-4 (8'), HA-2 (8'), and SB-28 (3-4'). **Mercury was detected exceeding state default background levels at PSB-148 (2-3').**
- PCBs: none detected.

Groundwater -

Groundwater samples collected in 2012 from MW-7, as well as groundwater samples collected in 1985 from MW-4 and MW-5 (collected from the deeper water bearing unit of from approximately 20- 25 feet) detected the following COCs (only bolded COCs exceeded the most restrictive criteria):

- VOCs: tetrahydrofuran (MW-4 and MW-5).
- SVOCs: **1,2-dicholorethane (MW-7).**
- Metals: **lead (MW-7).**

Planned Assessment:

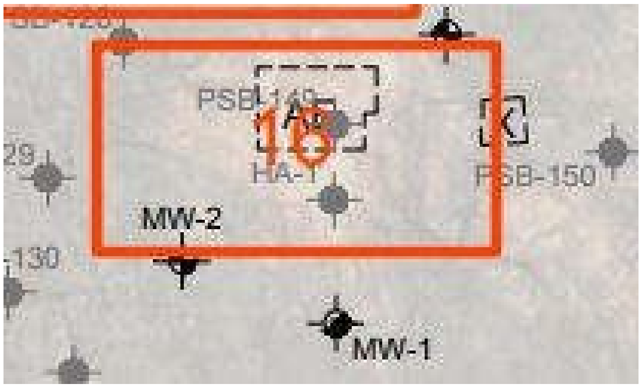
Provided the historical use of this area as a former burial pit for various unknown wastes, planned assessment includes the completion of up to four test pits to be conducted within each of the areas corresponding with previously identified magnetic anomalies detected within the SWMU. Soil samples will be collected from each sidewall and the bottom of each test pit, with sampling biased to the most contaminated interval based on PID and/or visual impacts.

Additional planned assessment work includes the installation of two nested sets of monitoring wells each with five foot screens, provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well. The two shallow wells shall be set within the shallow overburden straddling the water table and the two deeper nested wells will be set within the deeper section of the overburden at the base of the sand unit and the top of the clay unit. One nested set of wells will be installed at the down-gradient edge of the AOC to vertically profile the groundwater within this area, and the second nested set of wells will be installed in the center of the AOC. The screened interval for each nested well set is anticipated at approximately 8-13 feet bgs for shallow and up to 20 - 25 feet bgs for deep. Soil samples will also be collected from well borings.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring wells MW-6 and MW-7). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds and tetraethyl lead.

4.3.2 AOC 16 – Former Heating Oil UST



Historical documentation indicated the presence of a former heating oil UST within the southern portion of the northwestern corner of the Site, however EMI conducted did not indicate the presence of any voids within this area.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of eight soil borings (three of which were permanent monitoring wells) were evaluated within and surrounding this AOC. Of the eight soil borings installed, three soil samples were analyzed between 2012 and 2016: HA-1 (8'), PSB-149 (6-7') and PSB-150 (8.5-9.5').

The following COCs were detected:

- VOCs: none detected.

- PNAs/SVOCs (a full scan SVOC analysis was not completed): benzo(a)anthracene, chrysene and fluoranthene at HA-1 (8'). None detected in remaining samples analyzed.
- Metals: multiple metals (including arsenic, barium, cadmium, etc.) in all samples analyzed. Mercury was also detected at HA-1 (8') and PSB-149 (6-7'), however below default background levels.
- PCBs: samples were not analyzed for PCBs.

Groundwater –

Groundwater sampling data for MW-1 and MW-2 was not disclosed and/or sampling was not completed. Groundwater samples collected in 2012 from monitoring well MW-7 detected the following COCs (only bolded COCs exceeded their most restrictive screening criteria):

- VOCs: **1,2-dicholorethane** and 1,1,2-trichlorethane.
- PNAs/SVOCs: none detected.
- Metals: arsenic, barium, chromium, copper, **lead**, selenium and zinc.
- PCBs: well was not sampled for PCBs.

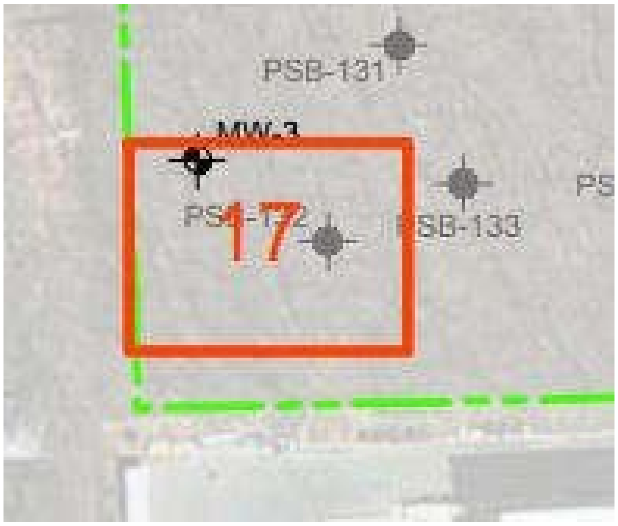
Planned Assessment:

Planned assessment includes the advancement of two soil borings, with conversion of at least one soil boring into a permanent monitoring well, within the location of the former heating oil UST and vertically screened to the base of the sand unit and the top of the clay unit (estimated at a depth exceeding 10 feet bgs, based on historical soil boring PSB-140 completed in this area, exhibiting sand to a maximum depth explored of 10 feet bgs, with no clay interface encountered). If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2).

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring well (as well as existing monitoring well MW-2). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2).

4.3.3 AOC 17 – EMI Interference



EMI conducted indicated the presence of one deep void within the subsurface of this area, which is located within the southern portion of the northwestern corner of the Site. The presence of a deep void indicates the potential for buried material, disturbed subsurface soils and/or orphaned underground tanks.

Constituents of Concern/Objective:

Soil -

A total of four soil borings (one of which was converted to a monitoring well) were evaluated within and surrounding this AOC. Of the four soil borings installed, no soil samples were collected and submitted for analysis. Therefore, the presence of soil COCs need to be determined for this area.

Groundwater –

Groundwater sampling data for MW-3 was not disclosed and/or was sampling was not completed. Therefore, the presence of groundwater COCs need to be determined for this area.

Planned Assessment:

Provided the presence of a deep void within the subsurface, planned assessment includes the completion of two test pits. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate the deep voids and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two nested sets of shallow and deep monitoring wells provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well. Each well will have a five-foot screen. The two shallow wells shall be set within the shallow overburden straddling the water table and the two deeper wells will be set within the deeper section of the overburden at the base of the sand unit and the top of the clay unit. The nested well sets will be installed in the central and southeastern portions of this area. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

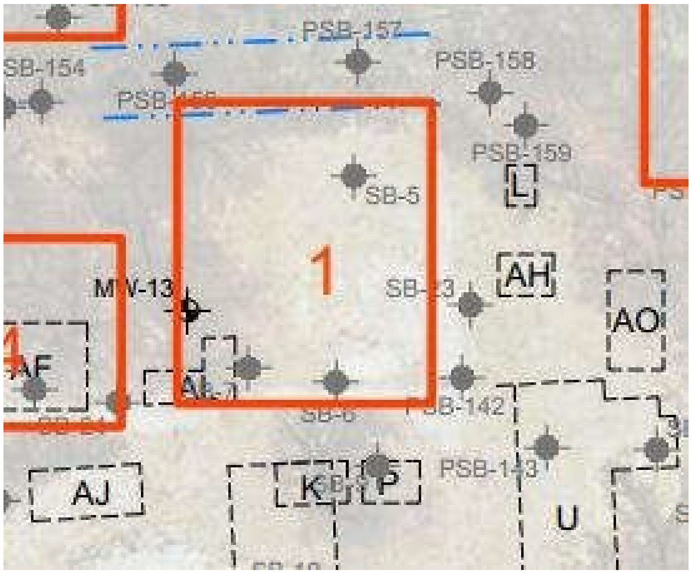
Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list compounds (Table 1 and Table 2) to determine if any site-related contamination exists.

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring well MW-3). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2).

4.4 Northcentral Area

AOCs 1, 4, 5, 6, 13 and 18 are included in the Northcentral Area that will be the focus of the third phase of the RFI. Description of known uses, investigative work completed so far, and proposed additional sampling scope to address horizontal and vertical delineation of the area is presented below. As stated above, start of the third phase of RFI in the Northcentral Area is planned to begin in the 2026 and be completed by the second or third quarter 2027. Refer to **Figure 5** for a depiction of planned assessment locations pertaining to each AOC in the Northcentral Area.

4.4.1 AOC 1 – SWMU 1 – Former Drum Storage Area



The area designated as SWMU-1 (as originally defined in a Preliminary Assessment/Visual Site Inspection Report (PRC Environmental, 1994) is a former drum storage area and is located within the north-central portion of the Site, in a sparsely wooded area. The area formerly consisted of an approximately 12,000 square foot exterior concrete pad.

Constituents of Concern/Objective:

Soil -

A total of eight soil borings (with three being converted to temporary monitoring wells) were evaluated within and surrounding this AOC. Of the eight soil borings installed, seven soil samples were analyzed between the years 2012 and 2015: SB/TMW-5 (1-2'), SB/TMW-7 (8-9'), SB/TMW-9 (1-2'), SB-23 (8-10'), PSB-142 (8-9'), PSB-156 (4-5') and PSB-157 (4-5'). Soil samples were not analyzed for soil boring SB-6 or monitoring well MW-13.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: sec-butylbenzene, p-isopropyltoluene, 1,2-dichlorobenzene, and **1,3-dichlorobenzene** at SB-33 (8-10').
- PNAs (full scan SVOC analysis was not conducted): none detected.
- Metals: arsenic, barium, chromium copper, lead, selenium and/or zinc at each soil sample. Mercury was also detected at SB-9 (1-2').
- PCBs: none detected.

Groundwater -

Groundwater sampling data for MW-13 was not disclosed and/or this well was historically never sampled. Groundwater samples collected in 2015 from temporary monitoring wells SB/TMW-5 and SB/TMW-6 detected the following COCs:

- VOCs: none detected.
- SVOCs: none detected.
- Metals: barium and zinc.

Based on limited previous sampling in this AOC, COCs cannot be refined, therefore a more comprehensive COC list will be analyzed. This AOC is still in a discovery phase of investigation. The objective of additional sampling will be to detect COCs and vertically and horizontally delineate any potential COCs in this AOC.

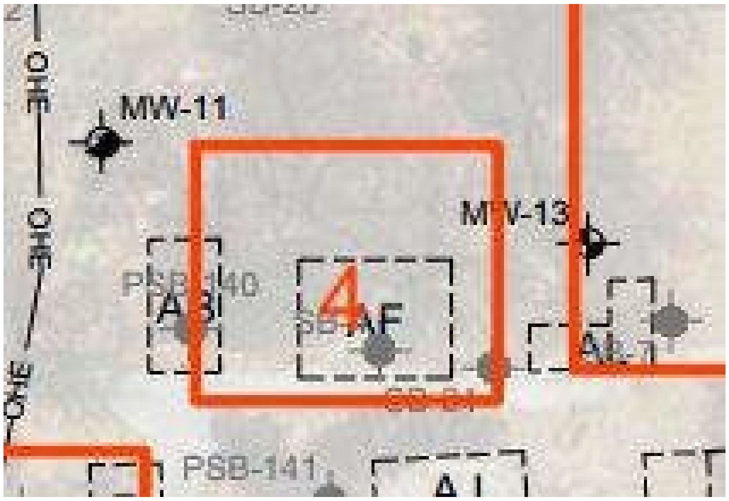
Planned Assessment:

Provided the historical use of this area as a former drum storage area for various unknown chemicals, planned assessment includes the installation of three nested sets of permanent monitoring wells, placed within the northwestern, central and southeastern portions of the former drum storage area to evaluate soil and groundwater conditions in a cross-gradient direction. The nested well sets will consist of one shallow and one deep monitoring well per set provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well. The shallow wells shall be set within the shallow overburden straddling the water table and the deeper wills will be set within the deeper section of the overburden at the base of the sand unit and the top of the clay unit. Each well will have a five-foot screen.

Soil samples collected from each soil boring/monitoring well will be analyzed for the SSCCL list parameters (Table 1 and Table 2) plus PCBs, tetraethyl lead and MI PFAS 31 compounds. A minimum of two and maximum of three soil sample depth intervals will be collected per boring. The surface depth immediately below ground cover (if present) and bottom of boring 0-6 inch interval should be collected. If elevated photoionization detector (PID) levels or visibly impacted intervals are observed, particularly at the depth immediately above the water table interface, then that depth interval will also be collected.

Groundwater samples will be collected via low-flow sampling techniques from newly installed monitoring wells (as well as existing monitoring well MW-13). Groundwater samples will be submitted for the SSCCL list parameters (Table 1 and Table 2) plus PCBs, tetraethyl lead and MI PFAS 31 compounds.

4.4.2 AOC 4 – SWMU 4



The area designated as solid waste management unit (SWMU) SWMU-4 (as originally defined in a Preliminary Assessment/Visual Site Inspection Report (PRC Environmental, 1994) is located in the north-central portion of the Site, within a heavily wooded area. This area was formerly utilized as a container and tank storage area that consisted of an approximately 1,500 square foot concrete pad with a curb, which was covered with a roof and secured with a chain linked fence. This area became active in 1987 for the staging of waste prior to disposal.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of four soil borings (with one being converted to a temporary monitoring well) and one permanent monitoring well were evaluated within and surrounding this AOC. Of the four soil borings installed, four soil samples were analyzed between the years 2012 and 2015: SB/TMW-4 (1-2'), SB- 24 (8-10'), PSB-140 (3-4') and PSB-141 (7-8'). Soil samples were not analyzed for monitoring well MW-11.

The following COCs were detected:

- VOCs: none detected.

- PNAs (full scan SVOC analysis was not conducted): none detected.
- Metals: arsenic, barium, cadmium, chromium, copper, lead, selenium and/or zinc at all soil sample locations. Mercury was also detected at SB/TMW-4 (1-2').
- PCBs: none detected at all of the sample locations. PSB-141 (7-8') was not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2012 from MW-11; as well as groundwater samples collected in 2015 from temporary monitoring well SB/TMW-4, detected the following COCs (only bolded COCs exceeded the most restrictive criteria):

- VOCs: 1,1 and 1,2-dicholorethane (MW-11).
- SVOCs: none detected.
- Metals: barium, selenium and/or zinc (MW-11 and SB/TMW-4).
- PCBs: wells were not analyzed for PCBs.

Further delineation of VOCS (e.g., 1,1 and 1,2-dicholorethane) in groundwater for COCs potentially associated with the historical chemical storage area, and physical and chemical characterization and vertical and horizontal delineation of potential groundwater impacts in the overburden form the objective for this AOC investigation. The unspecified laboratory wastes could be associated with virtually any chemicals used, stored, managed, or disposed onsite. COCs should target a broad spectrum of analysis to ensure current comprehensive analyses are completed.

Planned Assessment:

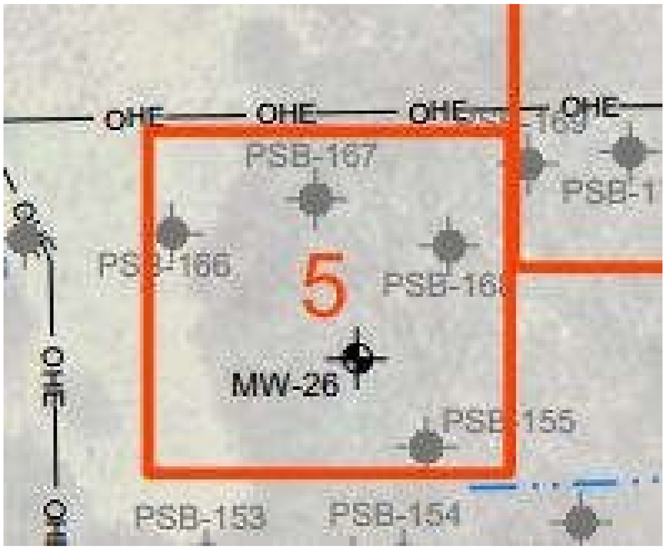
Provided the historical use of this area as a former container and tank storage area, planned assessment includes the completion of two soil borings, within the area of the identified electromagnetic anomaly present in the south/southwestern portion of the former SWMU. The soil borings will be conducted within the southern/southwestern portion of the former SWMU and extend to an approximate depth of 25 feet bgs to properly evaluate for the presence of buried orphaned tanks/sumps/vaults. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Additional planned assessment work includes the installation of two nested sets of permanent monitoring wells within the central and southeastern portions of the AOC to evaluate soil and groundwater conditions in a cross-gradient direction. The nested well sets will consist of one shallow and one deep monitoring well per set provided there is enough vertical space in the sand layer to accommodate a shallow and a deep nested well. The shallow wells shall be set within the shallow overburden straddling the water table and the deeper wills will be set within the deeper section of the overburden at the base of the sand unit and the top of the clay unit. Each well will have a five-foot screen.

Soil samples collected from each soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2) plus tetraethyl lead and MI PFAS 31 compounds.

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells. Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), with specific wells analyzed for tetraethyl lead, and MI PFAS 31 compounds.

4.4.3 AOC 5 – Former Disposal Pit Area



This location was a former burial area for various unknown wastes utilized by Ethyl from approximately 1948 until 1962. Specifically, reactive sodium compounds were reacted with water and the resultant residue was buried within this area.

Constituents of Concern/Objective:

Soil -

A total of nine soil borings (with one being converted to a temporary monitoring well) were evaluated within and surrounding this AOC. Of the nine soil borings installed, five soil samples were analyzed between the years 2012 and 2016: HA-3 (8'), SB/TMW-26 (2-3'), PSB-153 (7-8'), PSB-165 (6-7') and PSB-168 (2-3'). Soil samples were not collected from soil borings PSB-154, PSB-155, PSB-166 or PSB-167.

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **trichloroethylene at PSB-168 (2-3').** Not detected at remaining samples analyzed.
- PNAs (full scan SVOC analysis was not conducted): benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene at HA-3 (8'). Not detected at remaining samples analyzed.

- Metals: arsenic, barium, cadmium, chromium, copper, lead, selenium and/or zinc. **Mercury was also detected at PSB-168 (2-3') above default background levels** and also at HA-3 (8'), however below default background levels.
- PCBs: none detected at the sample locations analyzed. PSB-168 (2-3') and SB/TMW-26 (2- 3') were not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2016 from temporary monitoring well SB/TMW-26, detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **trichloroethylene, 1,1,2-trichloroethane,** 1,2-dichloroethane and 1,1,2,2-tetrachloroethane**.**
- SVOCs: none detected.
- Metals: none detected.
- PCBs: well was not analyzed for PCBs.

Planned Assessment:

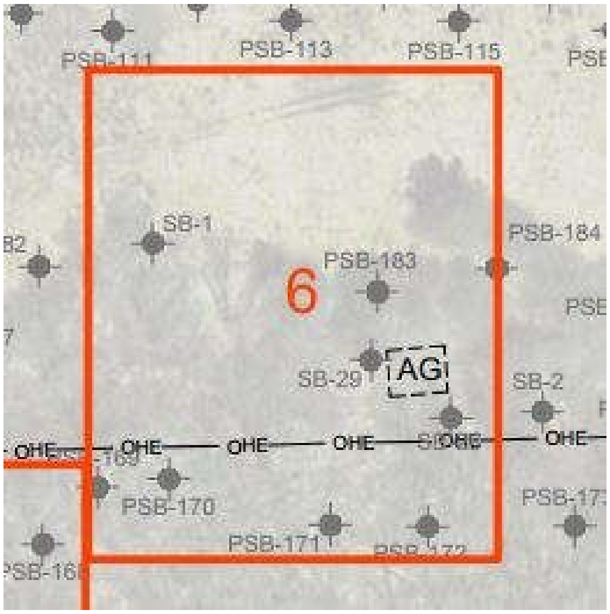
Provided the historical use of this area as a former disposal pit, planned assessment includes the completion of four test pits, within the area of the identified electromagnetic anomalies. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate for the presence of buried materials. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of three monitoring wells within the former disposal pit area. Specifically, monitoring wells will be installed that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth greater than 15 feet bgs, according to historical boring logs completed for this area) and located within the southwestern, northern and eastern/southeastern portions of the former disposal pit area. One shallow surface sample (1–2 feet bgs) and one sample at depth (to be determined based on visual/PID readings) will be collected from each of the soil borings/monitoring wells during installation, with the collection of soil sample intervals not to exceed six inches.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), tetraethyl lead and MI PFAS 31 compounds.

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring well MW-26). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), tetraethyl lead and MI PFAS 31 compounds.

4.4.4 AOC 6 – EMI Interference – GPR Anomaly Area/Concrete Pad Burn Pit



EMI conducted across the Site indicated the presence of deep and shallow voids within the subsurface of this area, which is located within the northern-central portion of the Site. The presence of deep and shallow voids indicate the potential for buried material, disturbed subsurface soils and/or orphaned underground tanks. Furthermore, GPR surveys conducted within this area indicated anomalies within the subsurface, which may also indicate the presence of orphaned underground tanks. According to historical documents, a burn pit, consisting of a concrete pad, was historically located within this area as well as a depression pond and notable ground disturbance/soil stockpiles.

Constituents of Concern/Objective:

Soil -

A total of twelve soil borings (with three being converted to temporary monitoring wells) were evaluated within and surrounding this AOC. Of the twelve soil borings installed, twelve soil samples were analyzed between the years 2012 and 2016: SB/TMW-1 (5-6'), SB/TMW-2 (3-4'), SB/TMW-27 (4-5'), SB-28 (10-12'), SB-29 (10-12'), PSB-169 (2-3'), PSB-170 (2-3'), PSB-171 (2-3'), PSB-172 (1-2'), PSB-182 (4-5'), PSB-183 (3-4') and PSB-184 (4-5').

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria)

- VOCs: trichloroethylene at PSB-170 (2-3') and PSB-171 (2-3'); tetrachloroethylene at PSB-171 (2-3'); toluene at PSB-170 (2-3'); and naphthalene at SB/TMW-27 (4-5'). Not detected at remaining samples analyzed.
- PNAs (full scan SVOC analysis was not conducted): **up to 18 PNAs were detected at SB/TMW-27 (4-5') and PSB-170 (2-3') with multiple constituents exceeding the most restrictive criteria.** Multiple PNAs were also detected at and PSB-182 (4-5'), however concentrations were below respective criteria. Fluoranthene was detected at SB-29 (10-12').

- Metals: arsenic, barium, cadmium, chromium, copper, lead, selenium, silver and/or zinc. **Mercury was also detected at SB/TMW-27 (4-5') and PSB-170 (2-3') above default background levels** and at SB/TMW-2 (3-4'), SB-29 (10-12'), PSB-169 (2-3'), PSB-171 (2-3') and PSB-172 (1-2'), however below default background levels.
- PCBs: detected at PSB-171 (2-3'). Not detected at remaining samples analyzed.

Groundwater –

Groundwater samples were not collected from temporary monitoring wells SB/TMW-1 or SB/TMW-2. Groundwater samples collected in 2016 from temporary monitoring well SB/TMW-27, detected the following COCs:

- VOCs: none detected.
- SVOCs: none detected.
- Metals: arsenic.
- PCBs: not analyzed for PCBs.

Planned Assessment:

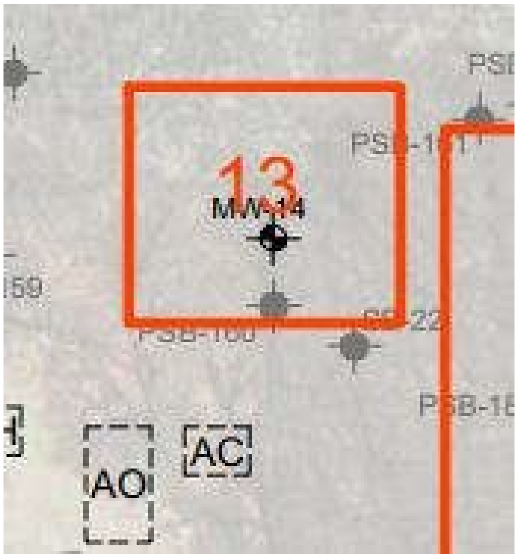
Provided the historical use of this area as a former burn pit, planned assessment includes the completion of four test pits, within the area of the identified electromagnetic anomalies. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate for the presence of buried materials. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of four monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth of approximately 23 feet bgs, according to historical boring log SB-1 completed within the central-western portion of this AOC) will be installed in the northwestern, central, eastern and southeastern portions of this area. However, depth of sand layer was also encountered at historical boring PSB-183 (located within the central-eastern portion of the AOC) at a depth of approximately 7 feet bgs. Therefore, wells will be screened based upon field observations of encountered sand/clay interface depth, which may result in differential depth intervals to properly characterize the sand unit. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), PCBs, dioxins/furans and MI PFAS 31 compounds.

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells. Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), PCBs, dioxins/furans and MI PFAS 31 compounds.

4.4.5 AOC 13 – EMI Interference



Electromagnetic induction conducted indicated the presence of approximately four deep voids within the subsurface of this area, which is located within the northeastern portion of the Site.

<u>**Constituents of Concern/Objective:**</u>

<u>Soil -</u>

A total of seven soil borings (one of which was converted to a monitoring well) were evaluated within and surrounding this AOC. Of the seven soil borings installed, six soil samples were analyzed between 2012 and 2016: SB-22 (8-10'), PSB-158 (4-5'), PSB-159 (6-7'), PSB-160 (2-3'), PSB-161 (4-5') and PSB-178 (3-4'). No soil samples were collected during the installation of MW-14 (also known as MW-C).

The following COCs were detected:

- VOCs: none detected.
- PNAs/SVOCs (a full scan SVOC analysis was not completed): none detected.
- Metals: arsenic, barium chromium, copper, lead, selenium and/or zinc at all samples collected. Mercury was also detected at SB-22 (8-10'), however below default background levels.
- PCBs: none detected at SB-22 (8-10'), PSB-159 (6-7'), PSB-160 (2-3'). PSB-158 (4-5'), PSB-161 (4-5') and PSB-178 (3-4') were not analyzed for PCBs.

<u>Groundwater –</u>

Groundwater samples collected in 2015 from monitoring well MW-14 (also referred to as MW-C) detected the following COCs:

- VOCs: trichloroethylene, however below the most restrictive criteria.
- SVOCs: not sampled for PNAs/SVOCs.

- Metals: not sampled for metals.
- PCBs: not sampled for PCBs.

Planned Assessment:

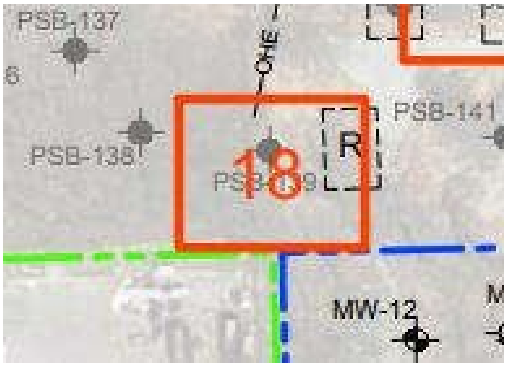
Provided the presence of a large deep void within the subsurface, planned assessment includes the completion of two test pits, within the area of the void. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate the deep void and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 12 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil boring SB-22) will be installed in the northeastern and southwestern portions of this area. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2).

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring well MW-14). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2).

4.4.6 AOC 18 – EMI Interference – GPR Anomaly



EMI conducted indicated the presence of one large deep void within the subsurface of this area, which is located within the central northwestern portion of the Site. Historical documentation indicates the presence of a former UST within this AOC as well.

Constituents of Concern/Objective:

Soil -

A total of five soil borings (one of which was converted to a monitoring well) were evaluated within and surrounding this AOC. Of the five soil borings installed, two soil samples were analyzed in 2016: PSB-139 (6.5-7.5’) and PSB-141 (7-8’).

The following COCs were detected:

- VOCs: none detected.
- PNAs/SVOCs (full scan SVOC analysis was not completed): none detected.
- Metals: arsenic, barium, chromium, copper, lead and zinc.
- PCBs: samples were not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2012 from monitoring well MW-12 detected the following COCs:

- VOCs: none detected.
- PNAs/SVOCs: none detected.
- Metals: barium.
- PCBs: well was not sampled for PCBs.

Planned Assessment:

Provided the presence of a deep void within the subsurface as well as the former UST pit, planned assessment includes the completion of three test pits to assess the deep void and one within the southeastern corner to assess the former UST pit. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate the deep void and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 15 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil borings PSB-139) will be installed in the central and southeastern portions of this area. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), PCBs and tetraethyl lead.

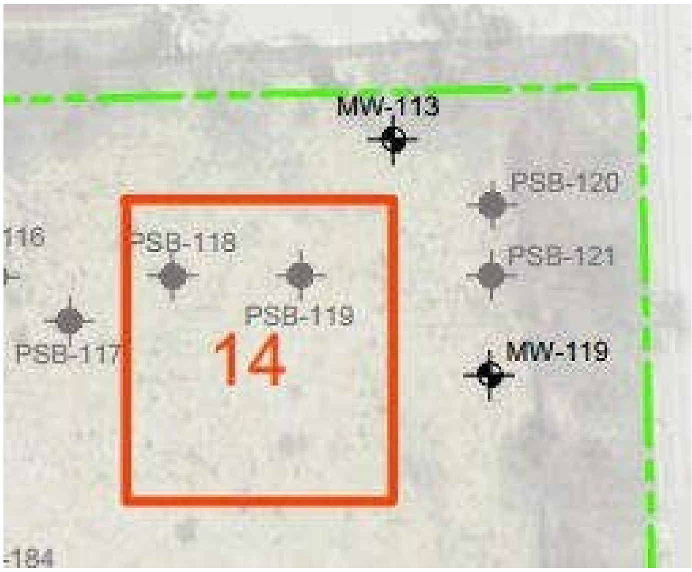
Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells. Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), PCBs and tetraethyl lead.

4.5 Northeastern Area

AOCs 14, 19 and 20 are all included in the Northeastern Area that will be the focus of the fourth phase of the RFI. Description of known uses, investigative work completed so far, and proposed additional sampling scope to address horizontal and vertical delineation of the area is presented below.

As stated above, start of the fourth phase of RFI in the Northeastern Area is planned to begin in 2028 and be completed by the Second or Third Quarter 2029. However, as this Area lies within the eastern boundary of the Site, groundwater and soil gas investigations are currently proceeding to determine if off-site migration of VOCs is occurring. The work completed to address the eastern boundary concerns are further described in the April 2022 RCRA Interim Work Plan Investigation Report – Eastern Site Boundary Report. Refer to **Figure 6** for a depiction of planned assessment locations pertaining to each AOC in the Northeastern Area.

4.5.1 AOC 14 – EMI Interference



EMI conducted indicated the presence of a large area of deep and shallow voids within the subsurface of this area, which is located within the northeastern-most portion of the Site. This large subsurface void area may be attributed to disturbed soil/non-native material fill and/or the presence of buried material.

<u>Constituents of Concern/Objective:</u>

<u>Soil -</u>

A total of eight soil borings (two of which were converted to permanent monitoring wells) were evaluated within and surrounding this AOC. Of the eight soil borings installed, six soil samples were analyzed between 2016 and 2020: PSB-116 (3-4'), PSB-117 (2-3'), MW-113 (2-3') and (7-8') and MW-119 (2-3') and (6-7').

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria):

- VOCs: 2-methynaphthalene at PSB-116 (3-4') and **methanol at MW-113 (2-3')** and (7-8') and MW-119 (6-7').
- PNAs/SVOCs (full scan SVOC analysis was not completed): multiple PNAs detected at SB-116 (3- 4') and SB-117 (2-3') with **benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and naphthalene detected at SB-117 (2-3').** PNAs were not detected at other sample locations.
- Metals: multiple metals were detected in all samples collected. **Specifically, mercury was detected above default background levels and VIAP screening levels at PSB-117 (2-3') and arsenic and selenium in excess of lowest screening levels at MW-119 (2-3').**
- PCBs: no samples were analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2020 from monitoring wells MW-113 and MW-119 detected the following COCs:

- VOCs: methanol at MW-119.
- SVOCs: none detected.
- Metals: none detected.
- PCBs: no samples were analyzed for PCBs.
- PFAS: none detected.

Planned Assessment:

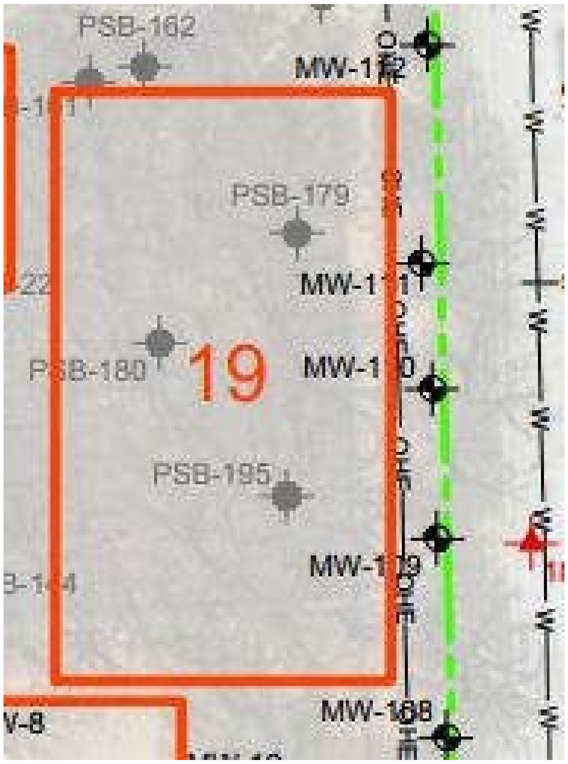
Provided the presence of shallow and deep voids within the subsurface and previous exceedances in soil, planned assessment includes the completion of four test pits. The test pits will extend to the reach of the excavator, no less than 10 feet bgs, to properly evaluate the deep voids and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 15 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil borings PSB- 118 and PSB-119) will be installed in the central-northern and southeastern portions of this area. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2).

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring wells MW-113 and MW-119). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2).

4.5.2 AOC 19 – TCE



Constituents of Concern/Objective:

Soil -

A total of eleven soil borings (five of which were converted to permanent monitoring wells) were evaluated within and surrounding this AOC. Of the eleven soil borings installed, five soil samples were analyzed between 2016 and 2020: PSB-144 (8-9'), PSB-161 (4-5'), MW-108 (4-5'), MW-109 (4-5') and MW-110 (4-5').

The following COCs were detected:

- VOCs: methanol at MW-108 (4-5'), MW-109 (4-5') and MW-110 (4-5').
- PNAs/SVOCs (full scan SVOC analysis was not completed): none detected.
- Metals: barium and chromium at MW-108 (4-5'), MW-109 (4-5') and MW-110 (4-5').
- PCBs: samples were not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2020 from monitoring wells MW-109, MW-110, MW-111 and MW- 112 detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **trichloroethylene at MW-111** exceeding VIAP screening levels and trichlorofluoromethane at MW-108.
- SVOCs (full scan SVOC analysis was not completed): none detected.
- Metals: **arsenic at MW-114**.
- PCBs: no samples were analyzed for PCBs.
- PFAS: a total of seven PFAS compounds were detected between samples collected from MW-109, MW-110, MW-111 and MW-112, with **PFOA exceeding the most restrictive criteria at MW-109 and MW-112**.

Soil Gas –

Temporary soil vapor points 18VP-1, 18VP-2 and 18VP-3 (each set at 5 feet bgs) installed by EGLE in August 2018, to the east of AOC 19 across Pinecrest Drive, exhibited trichloroethylene and tetrachloroethylene concentrations in 18VP-1 and 18VP-2. **Trichloroethylene exceeded VIAP screening levels at 18VP-1 and 18VP-2.**

Planned Assessment:

As part of Atlas' RCRA CCR September 2021 submittal, the installation of 14 soil vapor points traversing north-south along the eastern boundary of the Site was proposed to monitor trichloroethylene concentrations along this boundary. Atlas completed the installation of the soil vapor points (named VP-1 through VP-14) in November 2021. Additionally, collection of groundwater samples via low-flow methodology was conducted at thirteen existing monitoring wells (MW-104 through MW-113 and MW-119 through MW-121) along the eastern boundary of the Site to assess for the potential of off-site COC migration through the groundwater media. Data obtained from the soil vapor sampling and groundwater sample collection was submitted to the EGLE in the RCRA Interim Work Plan Investigation Report – Eastern Site Boundary Report (April 2022).

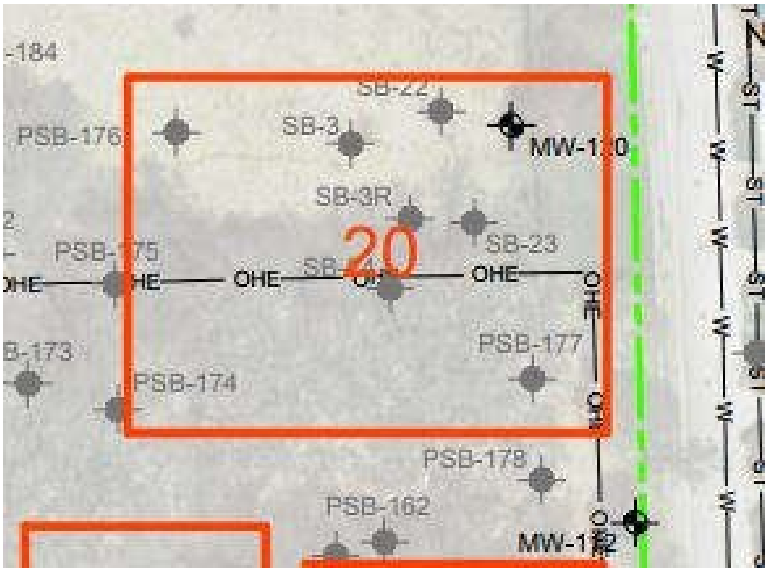
The planned assessment of this AOC will incorporate the data obtained from the soil vapor sampling and groundwater sampling conducted along the eastern boundary. To accomplish this RFI goal, the installation of three monitoring wells will be conducted. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 10 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil borings PSB-179, PSB-180 and PSB-195) will be installed in the northwestern, central and southeastern portions of this area. Soil samples will be biased toward any visual evidence of contamination and/or photoionization (PID) readings present following sample depth selection rationale described above.

Soil samples collected from each soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring wells MW-109, MW-110, MW-111 and MW-112). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2) plus MI PFAS 31 compounds.

Soil gas samples will be analyzed for TO-15 analysis.

4.5.3 AOC 20 – TCE/SVOC/VOCs



Constituents of Concern/Objective:

Soil -

A total of eleven soil borings (five of which were converted to temporary monitoring wells and one completed as a permanent monitoring well) were evaluated within and surrounding this AOC. Of the eleven soil borings installed, ten soil samples were analyzed between 2015 and 2020: SB/TMW-3R (3-4'), SB/TMW-22 (3-4'), SB/TMW-23 (4-5'), SB/TMW-24 (3-4'), PSB-174 (5-6'), PSB-175 (2-3'), PSB-177 (5.5-6.5'), PSB-178 (3-4') and MW-120 (2-3') and (4-5').

The following COCs were detected:

- VOCs: **methanol** at MW-120 (4-5').
- PNAs/SVOCs (full scan SVOC analysis was not completed): multiple SVOCs were detected at SB/TMW-3R (3-4'), SB/TMW-22 (3-4'), SB/TMW-23 (4-5') and SB/TMW-24 (3-4'), however only fluoranthene and phenanthrene at SB/TMW-3R (3-4') exceeded lowest respective screening levels.
- Metals: multiple metals detected at each sampling location with arsenic at PSB-178 (3-4'). Additionally, mercury was detected at SB/TMW-22 (3-4') and at PSB-175 (2-3'), however below default background levels.
- PCBs: none detected at SB/TMW-3R (3-4'), SB/TMW-22 (3-4'), SB/TMW-23 (4-5'), SB/TMW-24 (3-4') and PSB-175 (2-3'). Remaining samples were not analyzed for PCBs.

Groundwater –

Groundwater samples collected in 2015 and/or 2016 from temporary monitoring wells SB/TMW-3, SB/TMW-3R, SB/TMW-22, SB/TMW-23 and SB/TMW-24 and in 2020 from monitoring well MW-120 detected the following COCs (only bolded COCs exceeded their lowest respective screening criteria):

- VOCs: benzene**, chlorobenzene (exceedance only at SB/TMW-3),** trichloroethylene (SB/TMW-22 only) and methanol (MW-120 only).
- SVOCs (full scan SVOC analysis was not completed): none detected.
- Metals: **arsenic**, barium and/or zinc at SB/TMW-3 and SB/TMW-24.
- PCBs: no samples were analyzed for PCBs.
- PFAs: a total of three PFAS compounds were detected at MW-120, however all were below the most restrictive criteria.

Planned Assessment:

As part of Atlas' RCRA CCR September 2021 submittal, the installation of 14 soil vapor points traversing north-south along the eastern boundary of the Site was proposed to monitor trichloroethylene concentrations along this boundary. Atlas completed the installation of the soil vapor points (named VP-1 through VP-14) in November 2021. Additionally, collection of groundwater samples via low-flow methodology was conducted at thirteen existing monitoring wells (MW-104 through MW-113 and MW-119 through MW-121) along the eastern boundary of the Site to assess for the potential of off-site COC migration through the groundwater media. Data obtained from the soil vapor sampling and groundwater sample collection was provided to the EGLE in the RCRA Interim Work Plan Investigation report – Eastern Site Boundary Report (April 2022).

The planned assessment of this AOC will incorporate the data obtained from the soil vapor sampling and groundwater sampling conducted along the eastern boundary. To accomplish this RFI goal, and provided the presence of a large shallow void identified within the subsurface along the central portion of the area, planned assessment includes the completion of three test pits to assess the shallow void. The test pits will extend the reach of the excavator, no less than 10 feet bgs, to properly evaluate the shallow void and assess for potential orphaned USTs/buried material. Soil samples will be collected from each sidewall (at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of two monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth exceeding 12 feet bgs, which indicates sand extending to this depth with no clay interface encountered at soil borings SB- 22, SB-23 and PSB-177) will be installed in the northwestern and central-southern portions of this area. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), plus MI 31 PFAS compounds.

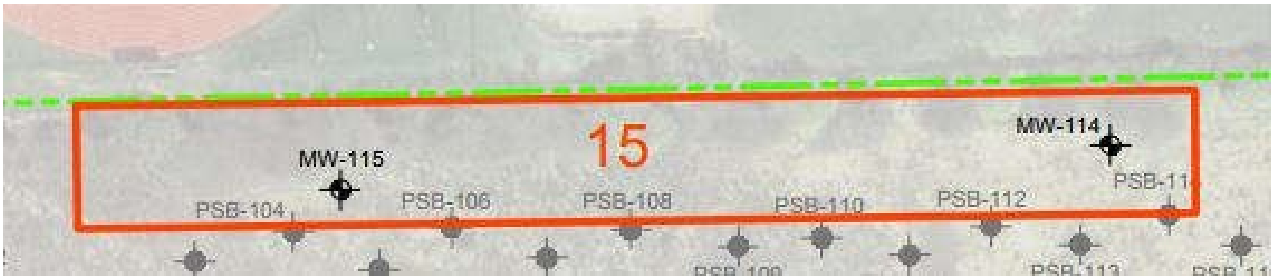
Groundwater samples will be collected via low-flow techniques from newly installed monitoring wells (as well as existing monitoring well MW-120). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), plus MI PFAS 31 compounds.

Soil gas samples will be submitted for TO-15 analysis.

4.6 Northern Margin

AOC 15 is included in the Northern Margin that will be the focus of the final phase of the RFI. Description of known uses, investigative work completed so far, and proposed additional sampling scope to address horizontal and vertical delineation of the area is presented below. As stated above, start of the fifth phase of RFI in the Northern Margin is planned to begin in 2030 and be completed by the second or third quarter 2031. Refer to **Figure 7** for a depiction of planned assessment locations pertaining to each AOC.

4.6.1 AOC 15 – Historical Ground Disturbances



Historical aerial photographs (particularly from the 1930s to the 1960s) identified areas of disturbance on the sparsely developed northern portion of the property. Indications of disturbed soil including a depression pond and soil stockpiles have been documented within this area.

<u>**Constituents of Concern/Objective:**</u>

<u>*Soil -*</u>

A total of sixteen soil borings (two of which were converted to permanent monitoring wells) were evaluated within and surrounding this AOC. Of the sixteen soil borings installed, fifteen soil samples were analyzed between 2016 and 2020: PSB-102 (2.5-3.5'), PSB-103 (12-13'), PSB-104 (9-10'), PSB-106 (8-9'), PSB-109 (12-13'), PSB-110 (3-4'), PSB-111 (7-8'), PSB-112 (8-9'), PSB-113 (8-9'), PSB-114 (3-4'), PSB-115 (3.5-4.5), MW-114 (3-4') and (8-9') and MW-115 (2-3') and (7-8').

The following COCs were detected (only bolded COCs exceeded their most restrictive criteria)

- **VOCs: multiple VOCs including** benzene, n-butylbenzene, sec-butylbenzene, 2-methylnaphthalene, naphthalene, n-propylbenzene, toluene, 1,2,3- 1,2,4- and 1,3,5 **TMBs and/or xylenes** at PSB-103 (12-13'), PSB-104 (9-10'), PSB-110 (3-4'), PSB-111 (7-

8'), PSB-112 (8-9'), PSB-113 (8-9'), PSB-114 (3-4') and PSB-115 (3.5-4.5'). Methanol at MW-114 (3-4') and (8-9') and MW-115 (7-8').

- PNAs/SVOCs (full scan SVOC analysis was not completed): multiple PNAs detected including **benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene and/or phenanthrene** at PSB-111 (7-8'), PSB-113 (8-9'), PSB-114 (3-4'), PSB-115 (3.5-4.5') and MW-114 (3-4').
- Metals: multiple metals were detected in all samples collected. **Specifically, mercury in excess of default background levels and/or VIAP screening level was detected** at PSB-103 (12- 13'), PSB-104 (9-10'), PSB-109 (12-13'), PSB-112 (8-9'), PSB-113 (8-9'), PSB-115 (3.5-4.5'), MW-114 (3-4') and MW-115 (7-8'). Mercury was also detected at PSB-106 (8-9'), however below default background levels.
- PCBs: detected at PSB-103 (12-13'), however below the most restrictive criteria.

Groundwater –

Groundwater samples collected in 2020 from monitoring wells MW-114 and MW-115 detected the following COCs (only bolded COCs exceeded their most restrictive criteria):

- VOCs: **benzene, 1,2-dicholorethane** (including cis- and trans-), **naphthalene, trichloroethylene (MW-114 only), vinyl chloride (MW-114 only) and xylenes**.
- SVOCs: naphthalene and **phenanthrene** at MW-115.
- Metals: **arsenic** at MW-114.
- PCBs: no samples were analyzed for PCBs.
- PFAS: a total of six PFAS compounds were detected in MW-114 and MW-115, however none exceed the most restrictive criteria.

Planned Assessment:

Provided the nature of the AOC (land disturbance), planned assessment is focused on determining the extent of material contributing to groundwater impact, with the goal of designing a potential source removal or ground coverage effort. Investigation includes the completion of six test pits. The test pits will extend to the extent of the excavator, to at least 10 feet bgs, to properly assess for buried material, which may include buried containers. Soil samples will be collected from each sidewall (default at approximately 5 feet bgs) and the bottom of each test pit, with sampling biased to the most contaminated interval, as appropriate.

Additional planned assessment includes installation of four monitoring wells. Specifically, monitoring wells that are vertically screened to the base of the sand unit and in contact with the underlying clay unit (at a depth of approximately 13 feet bgs, which indicates sand/sandy clay extending to this depth with a clay interface encountered beneath at soil borings/monitoring wells advanced in this area) will be installed in the northern, eastern, southern and western margins/areas. If subsurface structures are identified, soil samples will be collected from a depth immediately below the base of the structure, with samples biased toward any visual evidence of contamination and/or PID readings present. Additionally, other soil depth intervals will be collected following the rationale described above for a maximum of three per boring. Specifically for this AOC, all of the soil depth intervals with detections and exceedances were collected at depth. The future land use of this space is expected to remain wooded and be used for green space/walking trails, so surface depth intervals will be critical for risk-based evaluations of this AOC Area.

Soil samples collected from each test pit and soil boring/monitoring well will be analyzed for the SSCCL parameter list (Table 1 and Table 2), plus PCBs (since PCBs have been historically detected in soil).

Groundwater samples will be collected via low-flow techniques from the newly installed monitoring wells (as well as existing monitoring wells MW-114 and MW-115). Groundwater samples will be submitted for the SSCCL parameter list (Table 1 and Table 2), plus PCBs (since PCBs in groundwater has not been evaluated to date).

4.7 Site Wide Investigation

As stated in Section 4.0, the purpose of the Site Wide Investigation is to create a holistic, site-wide approach to the investigation of the Site. Activities to be performed during the Site Wide Investigation include 1) the vertical delineation of overburden to provide a better understanding of the overall deep lithology (greater than the current maximum explored depth of 30 feet bgs); and 2) assess potential preferential pathways created by utility corridors and/or known underground tunnels on the Site.

The Site Wide Investigation will run in tandem with the proposed assessment of the Southern Area, as all known tunnels and the majority of the known utilities are located within the Southern Area as well as the planned deep well. Locations of the proposed sampling Site Wide is shown primarily on **Figure 3**.

Planned Assessment:

Vertical delineation of overburden -

Based on the data collected to date, there is reasonable knowledge of site-related COCs present in the overburden, particularly at the water table interface. The scope of proposed RFI work in various individual AOCs will supplement knowledge base regarding the presence of the presumed continuous shallow clay surface across the Site and how that affects migration potential in this water- bearing zone. Additional RFI work scopes will supplement knowledge of the continuity of the presumed clay by tagging the sand/clay interface at a number of locations within individual AOCs allowing horizontal delineation to be better assessed and understanding more complete. However, without penetrating deeper through the shallow clay surface, interpretation on vertical delineation of COCs below the clay cannot be determined.

One deep well (likely to be set at approximately 130-150 feet bgs) will be installed within the Southern Area of the Site. Based upon Wellogic records obtained from EGLE's online database, a well installed by Consumers Energy approximately one mile northwest (upgradient) of the Site indicated a water bearing zone within the shale present at approximately 130 feet bgs. The purpose of the deep, water bearing well on-site will be to vertically profile the underlying lithologic and hydrogeologic conditions beneath the Site.

A deep, double-cased monitoring well will be installed for vertical delineation purposes targeting the next water-bearing zone below the overburden. The proposed total depth of the well is approximately 130 feet bgs, just above the interface of the gray clay and the black and gray shale, as identified in the Consumers Energy well installed approximately one mile northwest of the Site. A drill rig will be used to advance an outer casing to a depth of approximately 20-30 feet or a proper depth to set the outer casing at least three feet into the underlying clay unit to isolate the upper sand rich unit from the water bearing shale. The inner borehole will be drilled to a depth of 150 feet bgs. Two-inch inner diameter Schedule 40 PVC surface casing will be installed and the annular space will be sealed using a neat cement grout placed using a tremie pipe. The annular seal will be allowed to cure overnight. The drilling method will be used to advance the borehole to the target total depth.

A monitoring well will be constructed using Schedule 40 PVC threaded riser and 10 to 20 feet of factory machine-slotted threaded, 2-inch diameter screen (0.010 slot size). Centralizers will be installed on the riser at maximum intervals of 30 feet. A clean silica sand pack will be placed opposite the screen and to a height of at least 5.0 feet above the top of the screen. Above the screen, a 5.0 foot seal will be constructed with hydrated sodium bentonite. A locking, flush mounted steel, traffic rated manway and cement apron will be installed. The monitoring well will be developed approximately 24 hours after completion using a pump and surge method until suspended solids are significantly reduced. All development water will be collected and contained for proper disposal. All other associated procedures for well installation, decontamination, and screening will follow Standard Operating Procedures as presented in Section 6.0.

Underground Tunnels and Subsurface Utility Corridors -

Multiple utility corridors and historical underground pedestrian tunnels on-site connecting former buildings will be investigated. The initial focus of the site wide assessment of these former and current features is to identify and map their locations for delineation purposes. Secondarily, risks associated with the presence of utility corridors (which are typically shallow, set at an average of 3- 5 feet bgs) can exacerbate impacts to soil, groundwater and/or soil gas through migration of COCs along preferential pathways provided by the surrounding fill material of the utility line or through residual void space of the crushed tunnels.

Although it has been demonstrated that overburden within the Site is typically sand, fill material surrounding utility lines may present a preferential pathway concern. Therefore, the termination of on-site utility corridors into off-site mains within both Pinecrest Drive and 8 Mile Road will be evaluated within the right-of-way of each respective roadway and along the locations of the tunnels and the paths of the underground utility corridors.

Historical underground pedestrian tunnels, will be evaluated during assessment of the Southern Area. These tunnels were reported to have been crushed and compacted with fill during demolition activities in 2012/2013. Specifically, during test pit evaluation and soil boring/monitoring well boring advancement in the Southern Area, subsurface investigations will extend at least to the terminus depth of approximately 10 feet bgs which is the approximate depth of the tunnels.

Migration of VOCs and/or SVOCs as well as mercury vapor (likely occurring from confirmed presence of an unknown source of mercury onsite) in soil and groundwater has been identified at the Site, particularly within the Southern Area. Trichloroethylene specifically has been identified in soil gas samples collected within the eastern right-of-way of Pinecrest Drive, within a residential area. As such, identification and delineation of the location of the tunnels and utility corridors and the effect these may contribute to COCs within soil/groundwater/soil gas will also be completed as part of the site-wide AOC as well as in individual AOCs. If potential evidence of off-site migration issues are identified during this RFI, additional delineation measurements may be needed to protect these sensitive offsite receptors.

5.0 Project Management Plan

5.1 Technical Approach

As noted in Section 4.0, the Site has been divided into 20 areas of concern (AOC) contained within five groupings called Margins and Areas (**Figure 2**) (Southern Area, Northern Margin, Northwestern Margin, Northcentral Area, and Northeastern Area), based upon previously identified SWMUs, historical uses or specific subareas, geophysical anomalies, EMI survey data and/or soil, groundwater and/or soil gas concentrations within those specific areas. The technical RFI approach for each AOC has been described in Section 4.0. Details of how the RFI will proceed, including standard operating procedures (SOPs) for undertaking field investigative activities, are further discussed in Section 6.0 and are included as **Appendix A.**

5.2 Schedules

Schedules for each Area and Margin's RFI are also included in Section 4.0. The projected investigation timeline is shown in the below table. It should be noted the schedule may be adjusted based on the findings of the investigation(s) and/or the identification of an additional exposure risk to human health or the environment during the work. This includes the eastern area vapor intrusion work currently underway. Depending on the results of the investigation, implementation of interim remedial measures may be necessary.

Area/Margin	AOC	Proposed Start Date	Proposed End Date
Southern Area	03, 07, 09, 10, 11, 12	3Q/4Q 2022	4Q 2023
Northwestern Margin	02,16,17	2Q 2024	3Q 2025
Northcentral Area	01, 04, 05, 06, 13, 18	1Q 2026	3Q 2027
Northeastern Area	14, 19, 20	1Q 2028	3Q 2029
Northern Margin	15	1Q 2030	3Q 2031
Side Wide	NA	Completed during Southern Area Investigation	

TRC will provide the Materials management Division (MMD) a minimum of two-weeks' notice prior to the implementation of any field work so that the MMD had adequate time to be onsite to observe and/or collect split sample(s) (if desired).

5.3 Personnel

Investigations performed by TRC, on behalf of Axle Holdings 1, LLC, will be conducted under the direction of a TRC Program Director, Project Manager/Field Operations Manager, and a Staff Geologist/Field Task Leader. Additional experienced and qualified field personnel will be assigned to the project, as necessary. Contractor personnel will be determined at the time of investigation scheduling for each specific AOC.

5.4 Health and Safety

TRC subscribes to Occupational Safety and Health Administration (OSHA) and United States Environmental Protection Agency (USEPA) mandated health and safety standards. Because of the wide range of potential exposures for our employees, TRC must make conservative judgments as to potential health risks. The services outlined in this work plan will be performed with Level D health and safety protection (coveralls, safety shoes, hard hats, and eye protection only). If additional protection is required for TRC employees to perform this work plan, then TRC will utilize the protection as needed. A site-specific health and safety plan has been developed for this Site and has been included as **Appendix B.**

6.0 Standard Operating Procedures

To ensure RFI goals are achieved, and decisions are technically sound, statistically valid and properly documented, TRC will conduct the field investigative activities following standard operating procedures (SOPs) as referenced and attached herein, during each investigation phase. Details pertaining to specific depths, number and location of soil borings/monitoring wells, test pits, as well as specific COCs for each AOC is outlined in Section 4.0.

SOPs pertaining to field activities for this RFI are presented in **Appendix A**. A summary of the referenced SOPs include:

SOP #	Title
01	Groundwater Sampling (Includes procedures for PFAS)
02	Soil Sampling (Includes procedures for PFAS)
03	Headspace Field Screening Procedure
04	Water Level and Product Measurements (Includes procedures for PFAS)
05	Soil Vapor Point Installation and Active Vapor Sampling
06	Equipment Decontamination (Includes procedures for PFAS)
07	Groundwater Monitoring Well Installation (Includes procedures for PFAS)
08	Well Development (Includes procedures for PFAS)
09	Test Pit Installation
10	Slug Test Procedures

Supplemental site-specific instructions and details for implementing select field activities referenced in Section 4.0 are as summarized below. A summary of proposed sampling numbers, proposed analyses associated with each AOC, and estimated numbers of QA/QC samples with the investigative scope are presented in **Table 1**.

6.1 Test Pits

Test pit activities will be completed following instructions in SOPs No. 02, 03, 06 and 09 biased towards GPR and EMI anomalies and historically identified reported waste locations. Based on the age of any buried containers, if remnants of containers are encountered, the number, description, location, and description of the encountered containers will be documented and the remnants will be carefully recovered returning cuttings to the hole in the reverse order then when excavated.

Under no circumstances will the containers be attempted to be moved or removed over concerns for loss of former material contained. There is no way to predict the hazardous characteristics or reactive possibilities of buried waste. If exposed containers with visible waste can be safely sampled without disturbing the remnants, then samples will be collected. Analytical laboratory analysis will include VOCs, SVOCs, PCBs and metals to properly characterize the contents as Hazardous or Non- Hazardous materials. If solids are present within the containers, they will be additionally extracted for toxicity characterization leaching procedure (TCLP) analysis of these same parameters to determine their suitability for landfill disposal. A plan will be developed to identify and characterize the visible material upon receipt of the analytical results for safely removing the materials for proper disposal. Visible un-containerized materials discovered during test pit excavations will be targeted for biased sampling during test pit activities and RFI characterization.

The following procedure will be followed for found closed containers:

- For closed containers that appear in good condition, are not bulging or corroded, and can be safely sampled, TRC will arrange for a qualified contractor to open and sample the container contents. If the contents are suitable for nonhazardous disposal, the container and the contents will be disposed with the investigation derived waste (IDW) discussed in Section 8.6.
- For closed containers that do not appear in good condition, or are bulging, corroded or damaged, TRC will arrange for a qualified contractor to open and sample the container contents. If the contents are suitable for nonhazardous disposal, the containers and the contents will be disposed with the investigation derived waste (IDW) discussed in Section 8.6. Care will be taken to be sure no contents spill into uncontaminated areas during the removal.
- If any contents are determined to be hazardous waste after sampling is completed, TRC will arrange for the disposal of the waste by a qualified hazardous waste contractor.
- Any found containers will not be stored and handled at the Site after removal. Direct disposal upon removal will be facilitated by TRC. If containers cannot be directly disposed of in a reasonable timeframe due to subcontractor scheduling, they will remain in place in the excavated area (which will remain open and safely barricaded) until they can be directly disposed of.

6.2 Records will be kept on the number of containers removed and disposed of and their contents. Soil Boring/Monitoring Well Installation

Soil samples will be collected from soil borings and well borings specific to each AOC, as detailed in Section 4.0 following general instructions and guidance presented in SOPs No. 02, 03, 06, 07 and 08.

The monitoring wells will be installed to allow for the collection of groundwater samples and will be screened at depths specific to each AOC, as further discussed in Section 4.0. Some wells may be nested to specifically target the bottom of the overburden at the clay interface to evaluate COCs that tend to sink and accumulate on a semi-confining layer. These wells will be installed to be screened with the bottom of the screened interval at the top of the clay layer interface to facilitate the accumulation of any dense non aqueous phase liquids (DNAPL) that may sink and accumulate at depth.

6.3 Groundwater Sampling

TRC will conduct low-flow groundwater sampling at installed monitoring wells depending on the needs of the investigation following SOPs No. 01, 04 and 06. Groundwater samples will be analyzed for the presence of select COCs, specific to each AOC, as detailed in Section 4.0.

6.4 Soil Vapor Sampling

Soil vapor samples will be collected in select AOCs as described in Section 4.0 following SOP No. 05 for soil gas point installation and soil vapor point installation and sampling, respectively.

Historical environmental samples have reported detections of VOCs in soil and groundwater and preliminary soil vapor sampling, particularly in the southern and eastern areas of the Site.

7.0 Data Collection Quality Assurance Project Plan

7.1 Data Quality

Data quality objectives (DQOs) are to obtain data that are sufficiently accurate and representative of site media that reliable assessment of exposure pathways and risks may be identified. Field data will be obtained in a consistent manner using standard protocols developed by the USEPA, EGLE, ASTM, or other appropriate developer of scientific methods. Laboratory data will be obtained in accordance with standard protocols similarly developed, targeting analytical method detection limits less than the lowest applicable regulatory standards and levels of toxicological risk to the extent possible and data that are reproducible and verifiable, such as documented in EGLE's March 2016 *Application of Target Detection Limits and Designated Analytical Methods*. Where analytical results cannot be determined to the target levels, such as because of analytical interference, documentation of data limitations and effect on assessment conclusions will be evaluated. Data accuracy, reproducibility, and absence of cross-contamination will be evaluated using field and laboratory quality assurance and quality control (QA/QC) measures including the use of sample blanks, replicates, and comparative standards.

7.2 Analysis and Testing

Field screening for total VOCs will be performed following SOP No. 03. Laboratory analysis will be performed in accordance with EGLE's March 2016 *Application of Target Detection Limits and Designated Analytical Methods*, where applicable. Analytical methods will follow RCRA Test Methods for Evaluating Solid Waste SW-846. The COC list for the various methods for VOCs (8260B), alcohols (8015B), SVOCs (8270C), metals (6020/7470), PCBs (8082), PFAS (8327), and dioxins and furans (8290A) along with their associated reporting limits (RLs) and method detection limits (MDLs) are presented in **Table 2**. As additionally shown in **Table 2**, tetraethyl lead and hexavalent chromium will individually be analyzed by SW-846 Methods (8270D Organo Lead by GC/MS) and (7196A), respectively, when applicable. The VOC 1,4-dioxane will be separately analyzed using 8270C with Selective Ion Monitoring to be able to have RLs low enough to screen against criteria for undiluted water samples.

Vapor samples will be analyzed for the site-specific target list VOCs by Method TO-15.

If new site-specific COCs are identified as part of the TIC analysis as part of the VOC or SVOC GC/MS analyses or if analytical reporting limits are not achievable by their identified analytical method, alternate analytical methods will be selected in cooperation with the analyzing laboratory and documented as an addendum to this RFI.

MMD review and approval is required to utilize alternate analytical methods as described in this Section.

7.3 Quality Assurance/Quality Control

QA/QC samples of all media will be collected as measures of the precision, accuracy, and representativeness of the DQOs for this project. Trip blanks will be collected as needed with each sample event to ensure no cross contamination. Trip blanks are prepared by the laboratory and accompany empty sample containers and any coolers containing water samples for VOC analyses.

If reusable sampling equipment is utilized rather than single-use disposable or if the sampling media comes into contact with any decontaminated field equipment, an equipment field blank will be collected by running deionized water over the equipment once cleaned. Field blanks, if needed, will be analyzed at a frequency one per 20 samples per equipment type cleaned.

Field duplicate (or split samples for soil vapor) samples will be collected every ten samples per media. The estimated number of QA/QC samples to be collected per AOC Area are presented in **Table 1**.

Sample containers are pre-preserved by the analytical laboratory, when necessary. Soil VOC samples will be collected using methanol preservation, as recommended by EGLE.

Laboratory reagent blanks (method blanks) will be prepared and analyzed at the appropriate frequency; surrogate, lab control sample, and matrix spiked recoveries will be performed by the laboratory at appropriate frequencies and specifications stipulated by the associated SW-846 analytical methods, as identified by EGLE's March 2016 *Application of Target Detection Limits and Designated Analytical Methods*.

Reagents, preservation chemicals, and analytical standards will be prepared freshly, as appropriate, by the analyzing laboratory. Reagent transfer will employ clean transfer devices such as sanitizer pipets sealed in plastic following decontamination.

7.4 Project Documentation

Data will be fully documented at the time of collection, using prepared forms, including those for field observations, water level logs, sampling logs for water, soil and soil vapor, boring and well logs and instrument calibration and use logs. All field and analytical forms will be scanned to a project server and evaluated by the Project Manager daily to determine if modifications or additional sampling is required. Ongoing data tabulation, including comparison to applicable risk standards, and graphical representation will be used to assist with data evaluation. Examples of the field forms that may be used are included in select SOPs and in Appendix C.

Soil sample locations will be flagged and those locations will be obtained using a GPS unit and well top of casing and ground surface coordinates and elevations will be obtained by a certified land-surveyor using high resolution equipment. Geospatial coordinates for the Site will be tied into State Plane Coordinates by establishing on-site benchmarks and working from that demarcation.

Investigative reports will be prepared and confirmed by the Project Manager, reviewed by the Program Manager, undergo in-house technical and administrative review, client review, stepwise revisions, and submittal for regulatory review and approval.

7.5 Organization Performing Field or Laboratory Operations

Field data will be recorded on standard forms and scanned to electronic databases immediately upon return from the field. Laboratory oversight will be provided by the Project Manager.

Laboratory analyses primarily will be performed by either Test America/Eurofins or Merit Laboratories. Both analytical laboratories are in good standing and hold relevant NELAP certifications plus Michigan Drinking Water certifications, although that does not necessarily apply in this case.

7.6 Performance Evaluation

The Project Manager will be responsible for verifying that field crews and other individuals and contractors conduct their work in accordance with prescribed SOPs and document all data necessary to verify sampling and analysis methods are followed to generate a robust and complete data set of reliable, precise, and accurate data.

7.7 Field Activities

All field equipment and instrumentation will be calibrated and used in accordance with manufacturer’s recommendations and applicable regulatory guidelines. Standard and blank samples will be used, as appropriate, to verify the validity of data collected, and the efficacy of decontamination procedures employed.

When evaluating areas previously identified as contaminated, investigations will be performed from areas anticipated to be least contaminated to those expected to be more contaminated. Decontamination protocols will be implemented between each location following the SOP No. 06 (**Appendix A**).

Field records will be thoroughly documented on prepared forms and in field logbooks using permanent pen or marker, scanned onto the TRC server, and evaluated for inconsistencies or indications of possible error. All entries will be legible, with dates and people present annotated, and corrections made with a single line through, initialed and dated by the corrector.

7.8 Laboratory Activities

Laboratory sample handling, analysis, and QA/QC evaluation will be performed in accordance with the Laboratory Quality Assurance Manual prepared for each of the laboratory facilities.

Analytical data will be evaluated by the laboratory prior to reporting relative to holding times, preservation methods and proper temperature and/or pH, laboratory blanks, surrogate recoveries, laboratory control sample recoveries, matrix spike recoveries, duplicate analyses, and method detection limit reporting. Data relative to periodic QA sample analyses, performance evaluation testing, and calibration time relative to analytical determinations also will be provided and evaluated by the laboratory.

Internal laboratory QA evaluations will be documented in each laboratory data report. The outcome is typically provided in the case narrative so the data user can understand any complications in sample handling or analyses, determine the effect on data quality, and make an independent determination of the data’s utility. Independent data validation outside the laboratory is discussed below.

8.0 Field Operations / Data Management And Reporting

Field operations subject to QA/QC oversight by the Project Manager include all field activities – subsurface drilling and soil classification, sampling of each media, geophysical investigations for subsurface structures and features, physiochemical monitoring with various field meters, data logging, and field crew and contractor performance and decontamination. Field logistics will conform to TRC SOPs and EGLE guidelines, as appropriate, as discussed in Section 6.0.

8.1 Sample Management

Samples will be collected directly into laboratory-prepared containers suitable for the media, preserved consistent with analytical guidelines, and maintained in an appropriate container (such as an iced cooler) for transport at a temperature consistent with preservation guidelines. Samples will be labeled with unique numbers keyed to location, media, and depth; with date and time of collection; preservation; and intended analyses. Samples will be delivered under completed chain-of-custody form to the analyzing laboratory within appropriate holding times for analysis.

Samples will be identified using a standardized sample naming nomenclature for all RFI samples for ease of sorting as described below. To facilitate quick identification as RFI samples, soil borings will begin sequentially counting using the naming structure (or similar) AOC-13-22-SB-01 using the AOC in the soil boring name, followed by the year and soil boring identification. The soil depth intervals will be in feet to feet format. For example, a surface sample from soil boring AOC-13-22-SB-01 would be identified as AOC-13-22-SB-01 (0-0.5').

Similarly, newly installed monitoring wells will start sequentially counting using the naming nomenclature (or similar) AOC-13-22-MW-01, etc., with the AOC location, and year the well was installed to differentiate between multiple investigation events. Any nested well installations may be designated with an S for shallow and a D deep, or the depth of the well screen. Groundwater samples from monitoring wells will be named the same as the well identification (ID) with a differentiator between samples from the same well as the date sampled. TRC may evaluate renaming the existing wells if appropriate using a similar naming convention.

Soil gas sample vapor points will be similarly labeled like monitoring wells to permit multiple samples to be collected from the same point in the form VP-22-01, VP-22-02, etc. Multiple samples from the same vapor point location will be differentiated based on the date sampled.

8.2 Field Measurements

Field measurements using geophysical and survey equipment will be performed in accordance with manufacturers' guidelines. Principal field measurements will include total VOC screening using a properly calibrated PID and physiochemical measurements using a multi-parameter meter during low-stress groundwater sampling.

8.3 Data Reduction and Validation

Soil and groundwater concentrations will be compared to applicable residential and non-residential September 28, 2012 Environmental Remediation Part 201 Criteria of the Natural

Resources and Environmental Protection Act (NREPA) (Michigan Part 201 Criteria). All soil data will be determined in parts per billion by dry weight and groundwater data will be determined in parts per billion by volume, except for PFAS analysis results which are reported in units of parts per trillion by volume and dioxin/furan analysis results which are reported in units of parts per quadrillion. Soil vapor data will be reported in units of parts per billion by volume and converted to micrograms per cubic meter. Concentrations will be verified for precision by evaluation of field duplicate samples collected and analyzed every tenth sample by media.

Qualifications of the data based on laboratory and field QA/QC results associated with the sample analyses and interpretations of usability of the data quality will be incorporated into the data summaries. Limitations of potential utility based on the data validation findings and resulting data qualifications will be examined prior to their use in any risk assessment or remedial design.

8.4 Reporting

Progress reports will be prepared upon the completion of each investigative phase. An RFI Report will be prepared upon completion of each AOC Area investigation phase and the cumulative RFI Report will serve as the basis for preparing the Corrective Measures Study, evaluating remedial alternatives. Each additional RFI phase will be used to build expectation, clarifications and modifications, as applicable or appropriate, for subsequent phases.

Progress reports will include a narrative summary of the results, conclusions and recommended next steps. The reports shall include data summary tables, figures, lab reports, data quality assurance/quality control, field notes and any applicable manifests. Tables included shall be all encompassing and shall include historical results as well as current results for each area.

8.5 Records Management

Field records and boring logs will be maintained on standard forms, scanned secured server locations, and maintained in notebooks. Laboratory analytical reports will be electronically maintained in a similar fashion. Electronic databases will be manipulated to evaluate concentrations of individual contaminants spatially and temporally. Spatial evaluations will be performed by overlying contaminant concentrations on a surveyed base map in AutoCAD, with surveyed locations of sampling points, potential contaminant source structures, and potential conduits for contaminant migration. Spatial evaluations also will be performed using cross-sections to visualize migration pathways, stratigraphic controls, and vertical contaminant spread by media. Figures presenting contaminant distributions focusing on risk-based exceedances in on-site media will be incorporated in the RFI Reports.

8.6 Waste Disposal

IDW generated by field sampling, including used PPE, soil cuttings, well development and purge water, will be drummed for appropriate off-site disposal. IDW will be labeled as “Hazardous Waste Pending Analysis” and stored in a secured singular onsite location where it will not be disturbed and will not interfere with investigations or other onsite operations. IDW characterization samples will be collected and analyzed to guide disposal protocols. Waste manifests will be maintained in project records and included for documentation proof in the RFI

Reports.

Investigation derived waste will be characterized and stored at the Site per regulatory standards, and properly treated and/or disposed of within statutory timeframes. Reports of proper disposal (text and manifests) will be included in reports.

Wastes generated by laboratory analytical procedures will be managed and disposed by the contract laboratory including residual sample material following aliquots needed for analyses.

9.0 Community Relations Plan

This Public Involvement Plan (PIP) was prepared in general accordance with RCRA Public Involvement Manual (EPA/530-R-93-006, September 1993). TRC's goal is to provide access to neighbors and other interested and involved parties to review available existing site reports and investigative plans and provide opportunity for questions and comments, as it pertains to COCs at the Site including PFAS. Due to PFAS concentrations detected at the Site, the Site has been considered a candidate for Michigan PFAS Action Response Team (MPART) Program.

TRC envisions that the implementation of the PIP includes public involvement consisting of the following activities:

- TRC will work with the City of Ferndale (City) to determine the best way to approach public involvement.
- If in person meetings with the public to discuss the Site are necessary or desirable, TRC will work with the City to arrange for and host such meetings.
- If deemed desirable by the City, TRC will prepare a public facing website to house reports and results for the Site to provide the public access to this information. The website will also house a Public Fact Sheet to present a summary of the following: historical operations at the Site and a generalized overview of proposed/ongoing activities being conducted at the Site by TRC to mitigate the threat of any potential contamination migration to off-site receptors.

10.0 References

Applied EcoSystems, Inc. (AE), November 26, 2019, Proposal & Eastern Area Investigation Work Plan, Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Pinecrest Holdings, LLC.

Applied EcoSystems, Inc. (AE), November 27, 2019, RCRA Corrective Action Description of Current Conditions Report; Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Pinecrest Holdings, LLC.

Atlas Technical Consultants (Atlas), April 5, 2021, RCRA Corrective Action Description of Current Conditions and Interim Measures Report, Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Michigan Department of Environment. Great Lakes, and Energy

Atlas Technical Consultants (Atlas), September 21, 2021, RCRA Corrective Action Description of Current Conditions and Interim Measures Report, Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Michigan Department of Environment. Great Lakes, and Energy

Atlas Technical Consultants (Atlas), February 17, 2022, RCRA Corrective Action facility Investigation Work Plan – Former Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Michigan Department of Environment. Great Lakes, and Energy

Atlas Technical Consultants (Atlas), April 19, 2022, RCRA Interim Work Plan Investigation Report – Eastern Site Boundary – Former Hayes Lemmerz (Former Ethyl Corp.) Site, 1600 West Eight Mile Road, Ferndale, Michigan: Prepared for Michigan Department of Environment. Great Lakes, and Energy

Neyer, Tiseo & Hindo Ltd., December 26, 1985, Preliminary Site Assessment Investigation, Ethyl Corporation, Ferndale, Michigan: Prepared for Oakland County Michigan Economic Development Group.

Neyer, Tiseo & Hindo Ltd., January 3, 1986, Preliminary Site Assessment Investigation, Ethyl Corporation, Ferndale, Michigan: Prepared for Oakland County Michigan Economic Development Group.

PM Environmental, November 3, 2015, Phase I Environmental Site Assessment of the Vacant Industrial Property Located at 1600 West 8 Mile Road, Ferndale, Michigan: Prepared for CG Emerson Real Estate Group.

PM Environmental, June 17, 2016, Baseline Environmental Assessment, 1600 West 8 Mile Road, Ferndale, Michigan: Prepared for Pinecrest Holdings, LLC.

PM Environmental, June 16, 2016, Phase I Environmental Site Assessment Update, 1600 West 8 Mile Road, Ferndale, Michigan: Prepared for CG Emerson Real Estate Group.

PM Environmental, November 14, 2016, Site Investigation Report, 1600 West 8 Mile Road, Ferndale, Michigan: Prepared for Pinecrest Holdings, LLC.

PM Environmental, May 24, 2019, Phase I Environmental Site Assessment; 1600 West Eight Mile Road and Identified as Parcel ID 24-25-33-451-005, Ferndale, Michigan: Prepared for Axle of Dearborn.

PM Environmental, June 12, 2019, Baseline Environmental Assessment; 1600 West Eight Mile Road and Identified as Parcel ID 24-25-33-451-005, Ferndale, Michigan: Prepared for Axle of Dearborn.

RJN Environmental, November 27, 2012, Phase I Environmental Site Assessment, Former Ethyl Corporation Laboratory, 1600 West Eight Mile Road, City of Ferndale, Oakland County, Michigan: Prepared for Cedan Holdings VI, LLC.

RJN Environmental, December 5, 2012, Baseline Environmental Assessment, 1600 West Eight Mile Road, City of Ferndale, Oakland County, Michigan: Prepared for Cedan Holdings VI, LLC.

RJN Environmental, December 18, 2012, Phase II Environmental Site Assessment, Former Ethyl Corporation Laboratories, 1600 West Eight Mile Road, City of Ferndale, Oakland County, Michigan: Prepared for Cedan Holdings VI, LLC.

RJN Environmental, Inc., November 1, 2013, Phase II Environmental Site Assessment, North Half Former Ethyl Corporation Laboratories, 1600 West Eight Mile Road, City of Ferndale, Oakland County, Michigan: Prepared for Cedan Holdings VI, LLC.

TRC Environmental Corporation (TRC), August 8, 2022, Response to EGLE Comments and Addendum to the RCRA Interim Work Plan Investigation Report – Eastern Site Boundary; Former Hayes Lemmerz; Ferndale Michigan: Prepared for Michigan Department of Environment. Great Lakes, and Energy

City of Ferndale Zoning Map (ArcGIS) https://www.ferndalemi.gov/services/planning-zoning

City of Ferndale Master Plan, updated January 2017 https://www.ferndalemi.gov/resources/project-3

U.S.D.A. Web Soil Survey http://websoilsurvey.nrcs.usda.gov/app/

USFWS on-line Wetland Mapper: http://www.fws.gov/wetlands/data/Mapper.html

EGLE Water Well Viewer: https://www.mcgi.state.mi.us/waterwellviewer/

Wellogic Water Well Record Search:

https://www.egle.state.mi.us/wellogic/Login.aspx?ReturnUrl=%2fwellogic%2fdefault.aspx

11.0 Signatures

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Kelly C. Cratsenburg
Kelly Cratsenburg
Project Manager

9/7/2022
Date

Ast
Andrew Stuart
National Program Director

9/7/2022
Date

Tables

TABLE 1
PROPOSED SAMPLE LOCATIONS AND PARAMETERS BY AREA OF CONCERN

	SOIL							GROUNDWATER						
	VOCS + TICS	SVOCS + TICS	Metals	PCBS	Tetraethyl Lead	Dioxins/Furans	PFAS	VOCS + TICS	SVOCS + TICS	Metals	PCBs	Tetraethyl lead	Dioxins/Furans	PFAS
Southern / Site Wide														
AOC 3	24	24	24	24			24	4	4	4	4			4
AOC 7	4	4	4	4	4		4	4	4	4	4	4		4
AOC 8	4	4	4	4			4	6	6	6	6			6
AOC 9	6	6	6	6	6		6	3	3	3	3	3		3
AOC 10	14	14	14	14			14	5	5	5	5			5
AOC 11	26	26	26	26	26		26	4	4	4	4	4		4
AOC 12	19	19	19	19			19	5	5	5				5
Northeastern														
AOC 14	24	24	24	24			24	6	6	6				6
AOC 19	6	6	6	6			6	10	10	10				10
AOC 20	19	19	19	19			19	4	4	4				4
Northwestern														
AOC 2	24	24	24	24	24		24	6	6	6		6		6
AOC 16	4	4	4	4			4	2	2	2				2
AOC 17	14	14	14	14			14	5	5	5				5

TABLE 1
PROPOSED SAMPLE LOCATIONS AND PARAMETERS BY AREA OF CONCERN

	SOIL							GROUNDWATER						
	VOCS + TICS	SVOCS + TICS	Metals	PCBS	Tetraethyl Lead	Dioxins/Furans	PFAS	VOCS + TICS	SVOCS + TICS	Metals	PCBs	Tetraethyl lead	Dioxins/Furans	PFAS
Northern														
AOC 15	38	38	38	38			38	6	6	6	6			4
North Central														
AOC 1	9	9	9	9	9		9	7	7	7	7	7		7
AOC 4	8	8	8	8	8		8	4	4	4	4	4		4
AOC 5	26	26	26	26	26		26	4	4	4	4	4		4
AOC 6	28	28	28	28		28	28	4	4	4	4		4	4
AOC 13	14	14	14	14			14	3	3	3	3			3
AOC 18	19	19	19	19	19		19	2	2	2	2	2		2

QA/QC Samples:
One duplicate sample collected every 10 samples, per media. One field blank, trip blank (VOCs only groundwater) and equipment blank per event, per media.
AOC 7 groundwater includes groundwater sample from planned sitewide deep well.

Table 2
Analytical Constituent of Concern and Associated Reporting and Method Detection Limits

Compound	SW-846 Method	Water (ug/L) RDL ug/L	Water (ug/L) MDL ug/L	Soil (ug/kg) RDL ug/kg	Soil (ug/kg) MDL ug/kg
Volatiles	**8260C**				
Acetone	8260C	50	1.385	2500	276.7
Benzene	8260C	1	0.160	50	6.4
Bromochloromethane	8260C	1	0.381	50	12.2
Bromodichloromethane	8260C	1	0.313	50	8.0
Bromoform	8260C	1	0.292	50	12.9
Bromomethane	8260C	5	0.276	250	11.4
2-Butanone	8260C	25	3.972	1250	26.7
Carbon Disulfide	8260C	5	0.139	250	6.4
Carbon Tetrachloride	8260C	1	0.259	50	8.1
Chlorobenzene	8260C	1	0.229	50	11.7
Chloroethane	8260C	5	0.267	250	10.7
Chloroform	8260C	1	0.200	50	8.8
Chloromethane	8260C	5	0.165	250	6.4
Cyclohexane	8260C	1	0.152	50	12.4
Dibromochloromethane	8260C	5	0.127	250	8.0
1,2-Dibromo-3-chloropropane	8260C	5	0.262	250	43.9
1,2-Dibromoethane	8260C	1	0.187	50	9.5
Dichlordifluoromethane	8260C	5	0.333	250	10.6
1,2-Dichlorobenzene	8260C	1	0.137	50	10.9
1,3-Dichlorobenzene	8260C	1	0.209	50	9.9
1,4-Dichlorobenzene	8260C	1	0.165	50	9.3
1,1-Dichloroethane	8260C	1	0.225	50	4.9
1,2-Dichloroethane	8260C	1	0.262	50	8.5
1,1-Dichloroethene	8260C	1	0.242	50	7.1
cis-1,2-Dichloroethene	8260C	1	0.311	50	11.7
trans-1,2-Dichloroethene	8260C	1	0.221	50	7.7
1,2-Dichloropropane	8260C	1	0.261	50	10.9
cis-1,3-Dichloropropene	8260C	1	0.198	50	7.1
trans-1,3-Dichloropropene	8260C	1	0.166	50	8.4
1,4-Dioxane (SIMS)	8260C	0.003	0.0007	0.15	0.046
Ethylbenzene	8260C	1	0.224	50	7.9
2-Hexanone	8260C	50	0.377	2500	21.3
Isopropylbenzene	8260C	5	0.240	250	8.9
Methyl Acetate	8260C	10	0.328	500	21.9
Methyl Cyclohexane	8260C	1	0.237	50	7.6
4-Methyl-2-pentanone	8260C	50	0.343	2500	19.0
Methyl tert-butyl ether	8260C	5	0.185	250	7.9
Methylene Chloride	8260C	5	0.237	250	10.7
Styrene	8260C	1	0.194	50	6.1
1,1,2,2-Tetrachloroethane	8260C	1	0.468	50	14.5
Tetrachloroethene	8260C	1	0.213	50	8.2
Toluene	8260C	1	0.173	50	6.4
1,1,1-Trichloroethane	8260C	1	0.277	50	6.7
1,1,2-Trichloroethane	8260C	1	0.285	50	13.0
Trichloroethene	8260C	1	0.352	50	7.0
1,2,3-Trichlorobenzene	8260C	1	0.202	50	9.8
1,2,4-Trichlorobenzene	8260C	5	0.180	250	14.2
Trichlorofluoromethane	8260C	1	0.204	50	8.4
Trifluorotrichloroethane	8260C	1	0.283	50	12.5
Vinyl Chloride	8260C	1	0.332	50	8.3

Table 2
Analytical Constituent of Concern and Associated Reporting and Method Detection Limits

Compound	SW-846 Method	Water (ug/L)		Soil (ug/kg)	
		RDL ug/L	MDL ug/L	RDL ug/kg	MDL ug/kg
m&p-Xylene	8260C	2	0.395	100	14.7
o-Xylene	8260C	1	0.196	50	8.5
1,4 Dioxane SIMS	8260C	1	0.240	50	4.4
Tetrahydrofuran	8260C	90	1.300	1000	165.0
Semivolatiles	**8270D**				
Acenaphthene	8270D	5	0.238	330	7.7
Acenaphthylene	8270D	5	0.237	330	7.6
Acetophenone	8270D	5	0.240	330	6.7
Anthracene	8270D	5	0.232	330	6.8
Atrazine	8270D	5	0.267	330	7.3
1,1-Biphenyl	8270D	5	0.215	330	5.4
Benzaldehyde	8270D	5	0.243	330	7.8
Benzo(a)anthracene	8270D	1	0.235	330	6.2
Benzo(a)pyrene	8270D	1	0.216	330	5.9
Benzo(b)fluoranthene	8270D	1	0.196	330	6.2
Benzo(g,h,i)perylene	8270D	1	0.232	330	6.5
Benzo(k)fluoranthene	8270D	1	0.212	330	5.7
bis(2-Chloroethoxy)methane	8270D	5	0.207	330	6.1
bis(2-Chloroethyl)ether	8270D	5	0.214	330	6.3
bis(2-Chloroisopropyl)ether	8270D	5	0.510	330	5.2
bis(2-Ethylhexyl)phthalate	8270D	5	0.412	330	33.2
4-Bromophenyl-phenylether	8270D	5	0.220	330	6.5
Butylbenzylphthalate	8270D	5	0.234	330	8.2
Caprolactam	8270D	10	0.206	330	7.1
Carbazole	8270D	10	0.211	330	6.6
4-Chloro-3-Methylphenol	8270D	5	0.193	280	5.9
4-Chloroaniline	8270D	10	0.981	330	8.5
2-Chloronaphthalene	8270D	5	0.244	330	6.0
2-Chlorophenol	8270D	10	0.220	330	6.6
4-Chlorophenyl-phenylether	8270D	5	0.236	330	7.3
Chrysene	8270D	1	0.242	330	6.7
2-Methylphenol	8270D	10	0.199	330	7.0
3-, 4-Methylphenol	8270D	20	0.404	330	12.0
Di-n-Butylphthalate	8270D	5	0.349	330	18.0
Di-n-Octylphthalate	8270D	5	0.299	330	11.4
Dibenzo(a,h)anthracene	8270D	2	0.231	330	6.4
Dibenzofuran	8270D	5	0.216	330	6.1
3,3'-Dichlorobenzidine	8270D	5	0.190	2000	9.2
2,4-Dichlorophenol	8270D	10	0.218	330	5.5
Diethylphthalate	8270D	5	0.678	330	8.0
Dimethylphthalate	8270D	5	0.201	330	6.0
2,4-Dimethylphenol	8270D	5	0.224	330	5.9
4,6-Dinitro-2-methylphenol	8270D	20	0.150	830	5.6
2,4-Dinitrophenol	8270D	25	0.181	830	2.2
2,4-Dinitrotoluene	8270D	5	0.183	330	15.1
2,6-Dinitrotoluene	8270D	5	0.228	330	20.2
Fluoranthene	8270D	1	0.247	330	6.6
Fluorene	8270D	5	0.198	330	5.3
Hexachlorobenzene	8270D	5	0.204	330	5.0
Hexachlorobutadiene	8270D	10	0.200	330	5.1
Hexachlorocyclopentadiene	8270D	5	0.156	330	5.5

Table 2
Analytical Constituent of Concern and Associated Reporting and Method Detection Limits

Compound	SW-846 Method	Water (ug/L)		Soil (ug/kg)	
		RDL ug/L	MDL ug/L	RDL ug/kg	MDL ug/kg
Hexachloroethane	8270D	5	0.245	330	6.4
Indeno(1,2,3-cd)pyrene	8270D	2	0.211	330	6.2
Isophorone	8270D	5	0.240	330	7.1
2-Methylnaphthalene	8270D	5	0.255	330	6.7
Naphthalene	8270D	5	0.247	330	5.9
2-Nitroaniline	8270D	25	0.180	830	16.9
3-Nitroaniline	8270D	25	0.235	830	15.2
4-Nitroaniline	8270D	25	0.204	830	13.6
Nitrobenzene	8270D	5	0.219	330	20.0
2-Nitrophenol	8270D	5	0.200	330	13.3
4-Nitrophenol	8270D	25	0.183	830	11.0
N-Nitroso-di-n-propylamine	8270D	5	0.234	330	7.6
N-Nitrosodiphenylamine	8270D	5	0.244	330	7.2
Pentachlorophenol	8270D	5	0.208	330	7.4
Phenanthrene	8270D	2	0.263	330	6.3
Phenol	8270D	5	0.213	330	6.8
Pyrene	8270D	5	0.235	330	6.9
2,4,5-Trichlorophenol	8270D	5	0.224	330	6.1
2,4,6-Trichlorophenol	8270D	5	0.188	330	6.2
1,2,4,5-Tetrachlorobenzene	8270D	5	0.310	330	4.4
2,3,4,6-Tetrachlorophenol	8270D	5	0.260	330	4.5
Tetraethyl lead	8270D	10	2.00	1000	162
PCBs (Aroclor-Specific)	**8082A**				
Aroclor-1016	8082A	0.10	0.013	330	0.7
Aroclor-1221	8082A	0.10	0.015	330	0.5
Aroclor-1232	8082A	0.10	0.014	330	0.7
Aroclor-1242	8082A	0.10	0.019	330	1.3
Aroclor-1248	8082A	0.10	0.012	330	1.4
Aroclor-1254	8082A	0.10	0.041	330	0.6
Aroclor-1260	8082A	0.10	0.012	330	0.5
Total PCBs	8082A	NA	NA	NA	NA
Metals	**6020A**				
Aluminum	6020A	5.0	0.368	100	101.4
Antimony	6020A	2.0	0.017	300	1.8
Arsenic	6020A	1.0	0.085	100	14.0
Barium	6020A	5.0	0.156	1000	9.6
Beryllium	6020A	1.0	0.054	500	5.4
Boron	6020A	50.0	0.351	2000	0.900
Cadmium	6020A	0.5	0.030	200	5.0
Calcium	6020A	1000	4.000	1000	720.0
Chromium	6020A	5.0	0.041	2000	3.6
Cobalt	6020A	5.0	0.014	500	2.6
Copper	6020A	1.0	0.038	1000	2.8
Iron	6020A	20	2.043	1000	48.6
Lead-Total	6020A	3.0	0.019	1000	3.8
Coarse	6020A	NA	NA	1000	3.8
Fine	6020A	NA	NA	1000	3.8
Magnesium	6020A	1000	2.000	5000	42.4
Manganese	6020A	5.0	0.052	1000	2.0
Molybdenum	6020A	5.0	0.0434	500	0.0483

Table 2
Analytical Constituent of Concern and Associated Reporting and Method Detection Limits

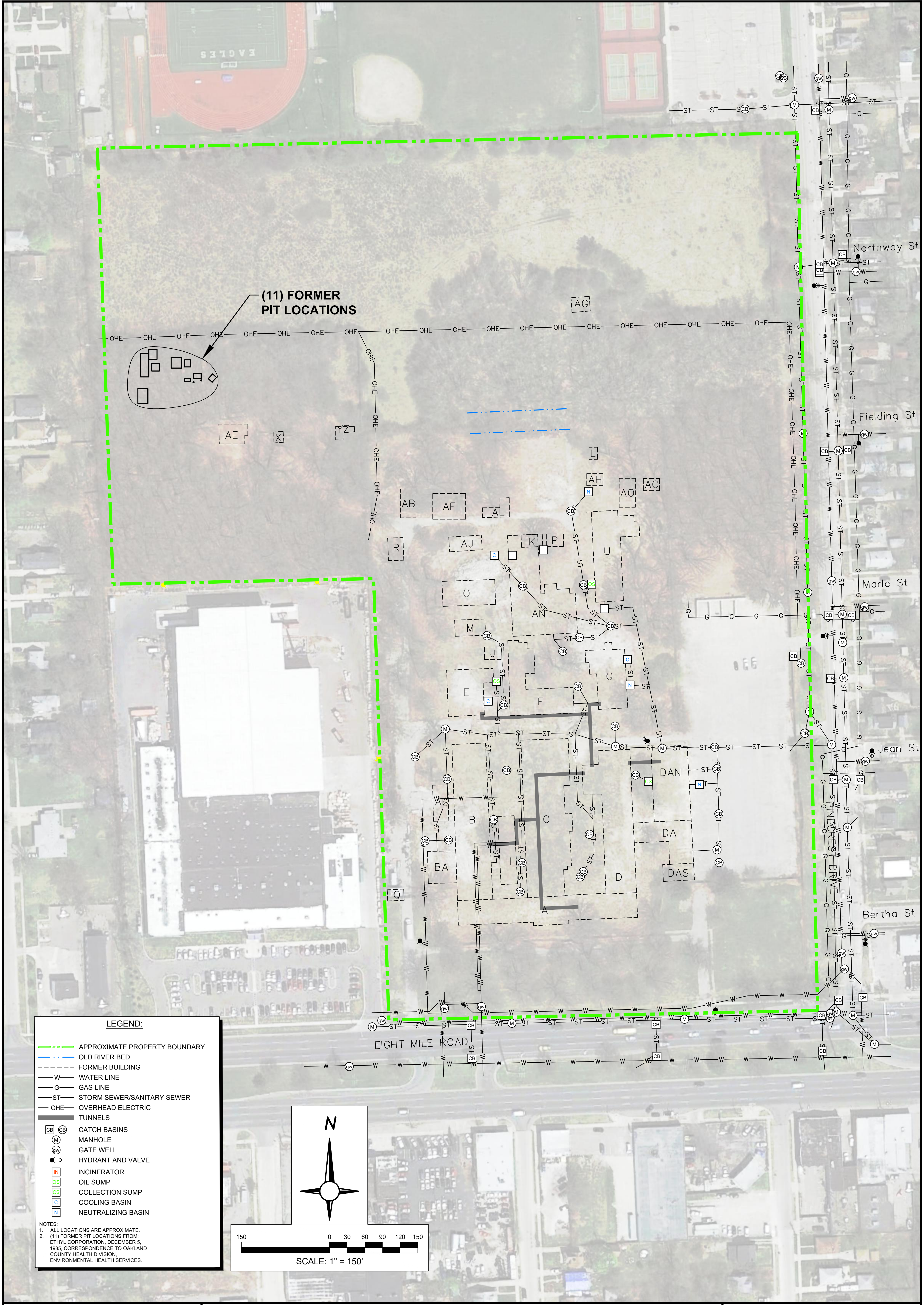
Compound	**SW-846 Method**	**Water (ug/L)**		**Soil (ug/kg)**	
		RDL ug/L	**MDL ug/L**	**RDL ug/kg**	**MDL ug/kg**
Mercury	7471B	0.2	0.009	50	0.7
Nickel	6020A	5.0	0.044	1000	5.2
Potassium	6020A	1000	8.9	1000	480.0
Strontium	6020A	5	0.0148	1000	0.030
Selenium	6020A	5.0	0.480	200	49.0
Silver	6020A	0.2	0.014	100	9.8
Sodium	6020A	1000	8.2	5000	218.0
Tin	6020A	20	0.460	1000	0.164
Titanium	6020A	5	0.220	500	0.238
Thallium	6020A	1.0	0.019	5.0	8.8
Thorium	6020B	2.0	0.570	0.2	0.0320
Vanadium	6020A	2.0	0.015	1000	1.4
Zinc	6020A	5.0	0.128	1000	27.6
Alcohols					
Ethanol	8015C DAI	5	0.52	5	0.50
Methanol	8015C DAI	5	2.00	5	2.00
n-Butanol	8015C DAI	5	0.25	5	0.760
Inorganics					
Hexavalent Chromium	7196A	20	6	1000	60

Table 2
Analytical Constituent of Concern and Associated Reporting and Method Detection Limits

Volatiles Analysis in Air (TO-15) by Merit

Analyte	MDL (ppbv)	RL (ppbv)	MDL (ug/m3)	RL (ug/m3)
1,1,1-Trichloroethane	0.016	0.20	0.085	1.10
1,1,2,2-Tetrachloroethane	0.011	0.20	0.073	1.40
1,1,2-Trichloroethane	0.011	0.20	0.058	1.10
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	0.016	0.20	0.119	1.50
1,1-Dichloroethane	0.016	0.20	0.065	0.81
1,1-Dichloroethene	0.016	0.20	0.064	0.79
1,2,4-Trichlorobenzene	0.024	0.50	0.168	3.70
1,2,4-Trimethylbenzene	0.011	0.20	0.064	0.98
1,2-Dichlorobenzene	0.011	0.20	0.064	1.20
1,2-Dichloroethane	0.011	0.20	0.044	0.81
1,2-Dichloropropane	0.011	0.20	0.051	0.92
1,3,5-Trimethylbenzene	0.016	0.20	0.076	0.98
1,3-Butadiene	0.019	0.20	0.042	0.44
1,3-Dichlorobenzene	0.011	0.20	0.064	1.20
1,4-Dichlorobenzene	0.014	0.20	0.083	1.20
1,4-Dioxane	0.023	2.50	0.082	9.00
2-Butanone	0.016	2.00	0.047	5.90
2-Chloro-1,3-butadiene	0.016	0.20	0.058	0.72
2-Hexanone	0.011	0.50	0.043	2.00
4-Methyl-2-pentanone	0.016	0.50	0.064	2.00
4-Ethyltoluene	0.014	0.20	0.068	0.98
Acetone	0.019	2.00	0.046	4.80
Benzene	0.016	0.20	0.051	0.64
Benzyl Chloride	0.016	0.20	0.083	1.00
Bromodichloromethane	0.011	0.20	0.071	1.30
Bromoform	0.014	0.20	0.143	2.10
Bromomethane	0.016	0.20	0.060	0.78
Carbon Disulfide	0.022	0.50	0.069	1.60
Carbon Tetrachloride	0.011	0.20	0.067	1.30
Chlorobenzene	0.014	0.20	0.064	0.92
Chloroethane	0.019	2.00	0.051	5.30
Chloroform	0.011	0.20	0.054	0.98
Chloromethane	0.016	2.00	0.033	4.10
cis-1,2-Dichloroethene	0.011	0.20	0.043	0.79
cis-1,3-Dichloropropene	0.016	0.20	0.073	0.91
Cyclohexane	0.016	0.20	0.053	0.69
Dibromochloromethane	0.011	0.20	0.090	1.70
Dichlorodifluoromethane	0.011	0.20	0.052	0.99
Dichlorotetrafluoroethane (Freon 114)	0.019	0.20	0.042	1.40
Ethanol	0.038	2.50	0.070	4.70
Ethyl acetate	0.028	2.00	0.100	7.20
Ethylbenzene	0.011	0.20	0.046	0.87
Ethylene dibromide	0.011	0.20	0.082	1.50
Hexachlorobutadiene	0.014	0.20	0.148	2.10
Isopropylbenzene	0.011	0.20	0.054	0.98
Isopropyl Alcohol	0.011	2.00	0.054	4.90
m&p-Xylene	0.022	0.40	0.092	1.70
Methylene Chloride	0.014	0.50	0.048	1.70
MTBE	0.016	0.20	0.056	0.72
n-Heptane	0.011	0.20	0.043	0.82
n-Hexane	0.011	0.20	0.037	0.70
o-Xylene	0.011	0.20	0.046	0.87
Propylene	0.019	10.00	0.033	17.00
Styrene	0.014	0.20	0.059	0.85
Tetrachloroethene	0.011	0.20	0.072	1.40
Tetrahydrofuran	0.035	0.20	0.103	0.59
Toluene	0.016	0.20	0.058	0.75
trans-1,2-Dichloroethene	0.014	0.20	0.055	0.79
trans-1,3-Dichloropropene	0.014	0.20	0.063	0.91
Trichloroethene	0.016	0.20	0.086	1.10
Trichlorofluoromethane	0.016	0.20	0.087	1.10
Vinyl Acetate	0.019	0.20	0.068	0.70
Vinyl Chloride	0.021	0.20	0.054	0.51

Figures



LEGEND:

- APPROXIMATE PROPERTY BOUNDARY
- OLD RIVER BED
- FORMER BUILDING
- W — WATER LINE
- G — GAS LINE
- ST — STORM SEWER/SANITARY SEWER
- OHE — OVERHEAD ELECTRIC
- ▬ TUNNELS
- CB CB CATCH BASINS
- M MANHOLE
- gw GATE WELL
- HYDRANT AND VALVE
- IN INCINERATOR
- OS OIL SUMP
- CS COLLECTION SUMP
- C COOLING BASIN
- N NEUTRALIZING BASIN

NOTES:
1. ALL LOCATIONS ARE APPROXIMATE.
2. (11) FORMER PIT LOCATIONS FROM: ETHYL CORPORATION, DECEMBER 5, 1985, CORRESPONDENCE TO OAKLAND COUNTY HEALTH DIVISION, ENVIRONMENTAL HEALTH SERVICES.

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PROJECT:
DETROIT AXLE FERNDALE
FORMER HAYES LEMMERZ SITE
WEST EIGHT MILE ROAD
FERNDALE, MI

TITLE:
SITE DETAILS MAP

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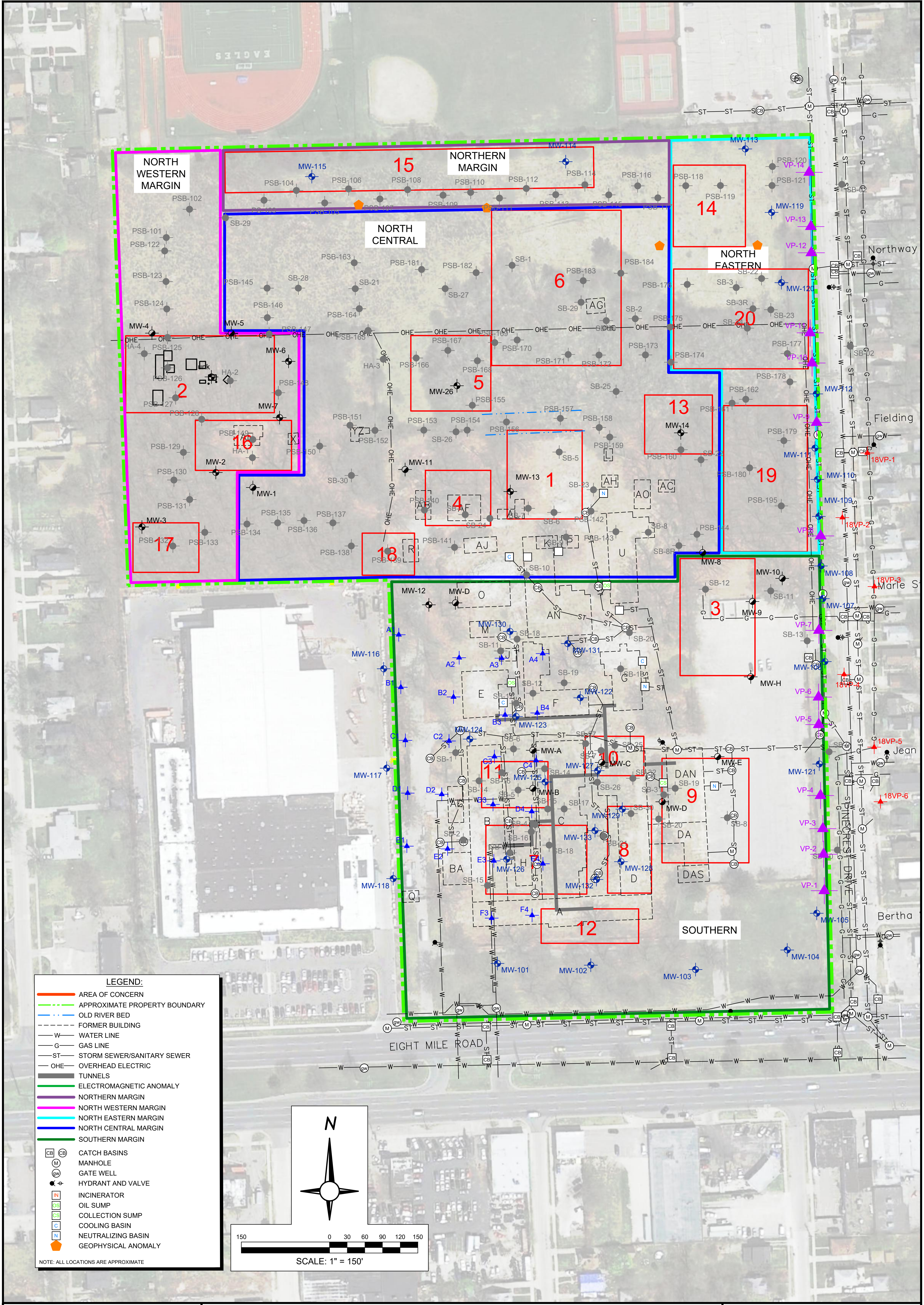
DRAWN BY:	E.ALEXANDER
CHECKED BY:	K. CRATSENBERG
APPROVED BY:	---
DATE:	AUGUST 2022
PROJ. NO.:	495430.0000.0000
FILE:	495530-SDM.dwg

FIGURE 1

11x17 --- USER: EAlexander --- ATTACHED XREF'S: XREF-BUILDINGS; XREF M-WELLS --- ATTACHED IMAGES: Mosaic-1-part0x0; Mosaic-2-part0x0;
DRAWING NAME: J:\Detroit Axle Ferndale\495430\0000\ 495530-AOC.dwg --- PLOT DATE: August 31, 2022 - 8:55AM --- LAYOUT: AOCM

Version: 2017-10-21



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TITLE:

AERAS OF CONCERN MAP

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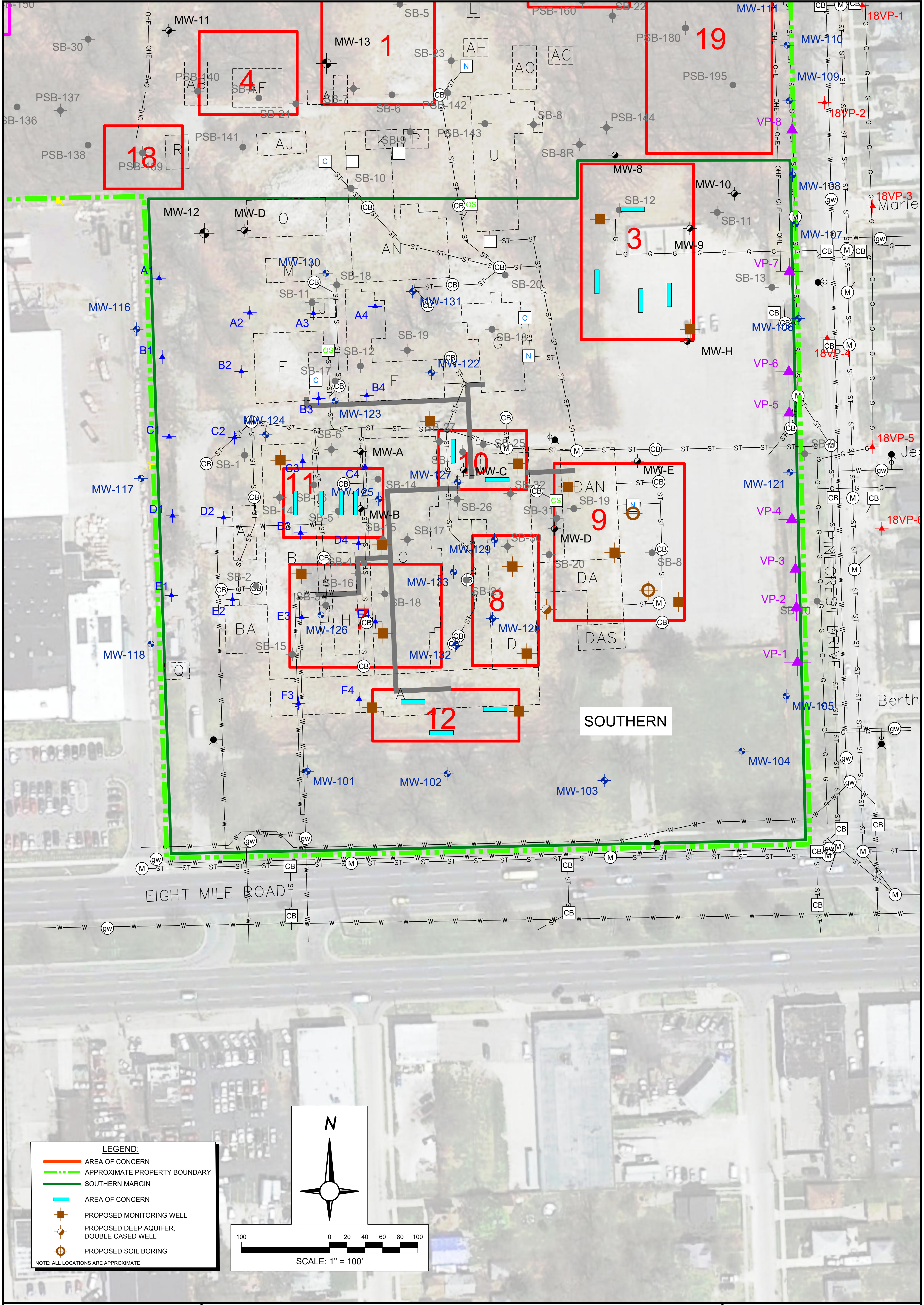
FILE:	495530-AOC.dwg

FIGURE 2

11x17 --- USER: EAlexander --- ATTACHED XREF'S: XREF-BUILDINGS; XREF M-WELLS --- ATTACHED IMAGES: Mosaic-1-part0x0; Mosaic-2-part0x0;
DRAWING NAME: J:\Detroit Axle Ferndale\495430\0000\ 495530-SWP PL.dwg --- PLOT DATE: August 31, 2022 - 8:55AM --- LAYOUT: SWP PL

Version: 2017-10-21



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FERNDALE, MI

TITLE:

SOUTHERN WORK PLAN - PROPOSED LOCATIONS

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FIGURE 3

11x17 --- USER: EAlexander --- ATTACHED XREF'S: XREF-BUILDINGS; XREF M-WELLS --- ATTACHED IMAGES: Mosaic-1-part0x0; Mosaic-2-part0x0;
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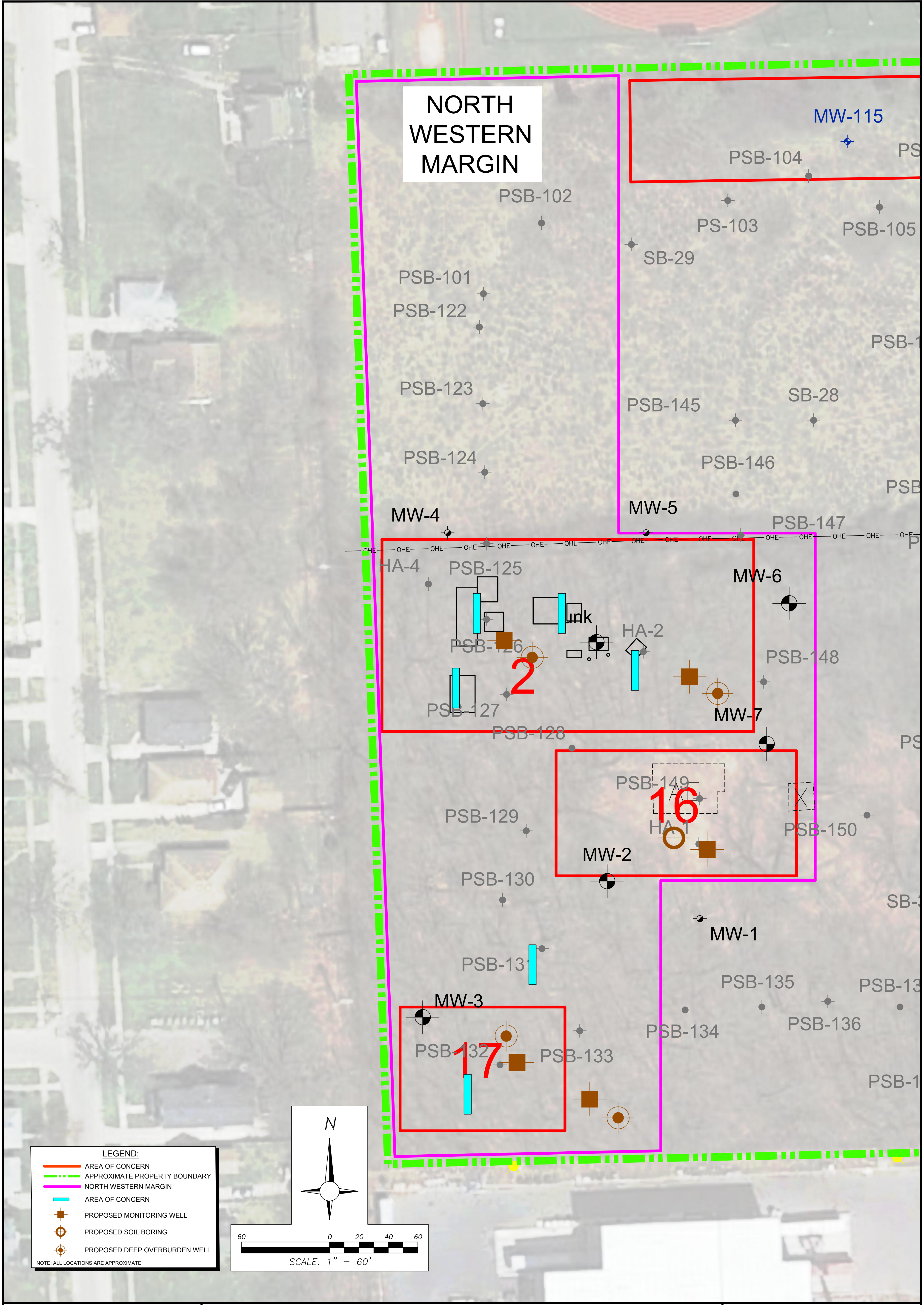
Version: 2017-10-21



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NORTHWESTERN MARGIN WORK PLAN - PROPOSED LOCATIONS

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FIGURE 4

11x17 --- USER: EAlexander --- ATTACHED XREF'S: XREF-BUILDINGS; XREF M-WELLS --- ATTACHED IMAGES: Mosaic-1-part0x0; Mosaic-2-part0x0;
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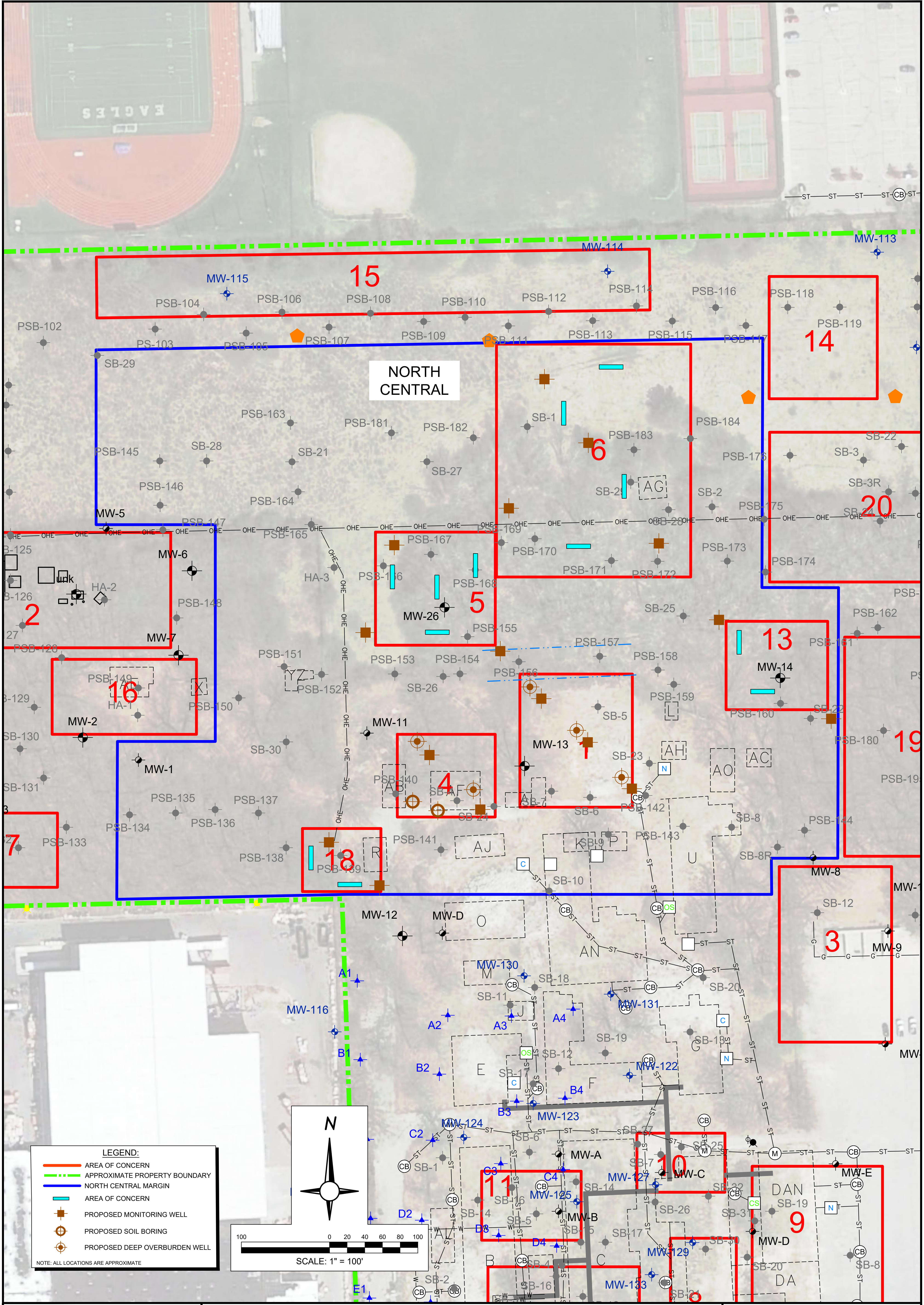
Version: 2017-10-21



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TITLE:

NORTH CENTRAL WORK PLAN - PROPOSED LOCATIONS

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FIGURE 5

11x17 --- USER: EAlexander --- ATTACHED XREF'S: XREF-BUILDINGS; XREF M-WELLS --- ATTACHED IMAGES: Mosaic-1-part0x0; Mosaic-2-part0x0;
DRAWING NAME: J:\Detroit Axle Ferndale\495430\0000\ 495530-NE WP PL.dwg --- PLOT DATE: August 31, 2022 - 8:56AM --- LAYOUT: NE WP PL

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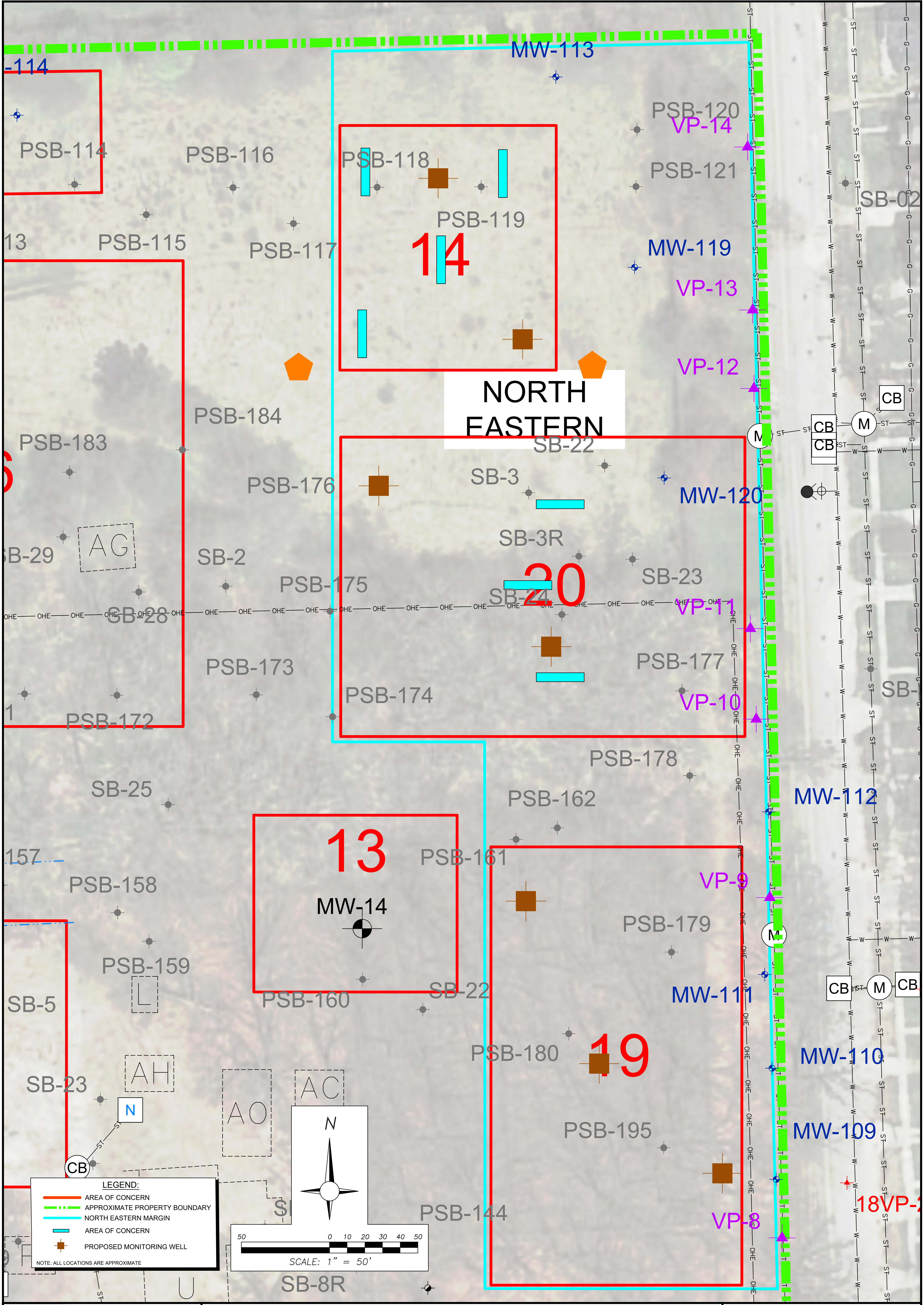

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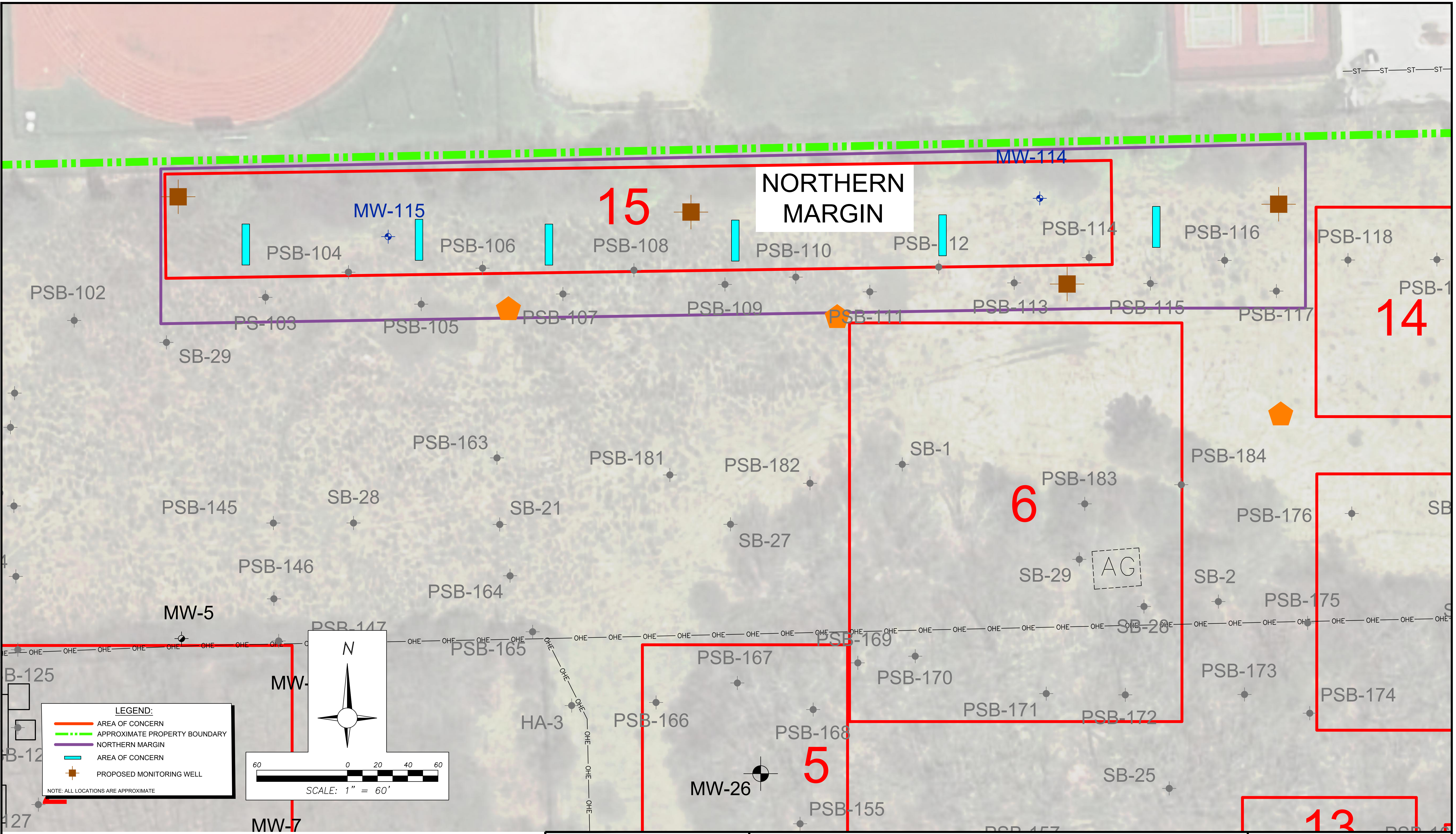
PROJ. NO.:	495430.0000.0000
FILE:	495530-NE WP PL.dwg

FIGURE 6



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DRAWING NAME: J:\Detroit Axle Ferndale\495430\0000\495530-NM WP PL.dwg --- PLOT DATE: August 31, 2022 - 8:56AM --- LAYOUT: NE WP PL

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TITLE:
NORTHERN MARGIN WORK PLAN - PROPOSED LOCATIONS

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FILE:	495530-NM WP PL.dwg

FIGURE 7

Appendix A
Standard Operating Procedures

01

Groundwater Sampling (Includes SOP for PFAS)

Title: **Groundwater Sampling**	Procedure Number: **ECR 009**
	Revision Number: **4**
	Effective Date: **August 2020**

Authorization Signatures

Darby Litz		Elizabeth Denly	
Technical Reviewer	Date	Environmental Sector Quality Director	Date
Darby Litz	8/4/20	Elizabeth Denly	8/4/20

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TABLE OF CONTENTS

Page No.

ATTACHMENTS

Attachment A	Groundwater Field Parameter Stabilization Criteria for Selected Jurisdictions
Attachment B	Example Groundwater Field Data Records
Attachment C	SOP Fact Sheet
Attachment D	SOP Modifications for PFAS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to provide TRC personnel with general guidance in performing groundwater sampling activities. This SOP details equipment and sampling procedures for low-flow sampling, multi-volume purge sampling and passive diffusion bag sampling from monitoring wells. Various regulatory agencies and project-specific work plans may have specific requirements (e.g., equipment/instrument, flow rate, etc.) that may be applicable and take precedence, depending on the program.

The objective of groundwater sampling is to obtain a representative sample of water from a saturated zone or groundwater-bearing unit (i.e., aquifer) with minimal disturbance of groundwater chemistry. This requires that the sample being collected is representative of groundwater within the formation surrounding the well bore as opposed to stagnant water within the well casing or within the filter pack immediately surrounding the well casing.

1.2 Summary of Method

There are three general approaches to groundwater purging/sampling that can be used to obtain a representative groundwater sample for analysis: 1) the low-flow or micropurge method where the mixing of the stagnant water is minimized using low-flow pumping rates during the collection of the groundwater sample; 2) the multiple well volume removal approach in which the stagnant water is removed from the well and the filter pack prior to sample collection; and 3) the passive sampler procedure where water quality equilibration with the surroundings is achieved through deployment of the passive sampler for a sufficient amount of time prior to sampling.

For low-flow and multiple well volume removal, there are various types of equipment available to perform groundwater sampling. The most common of these are the submersible pump, peristaltic pump, and bailer. However, the equipment selected and the purge method used, if any, will depend on project goals, data quality objectives (DQOs), hydrogeologic conditions, and regulatory requirements. Care should be taken when choosing the sampling procedures and device(s), as some procedures have the potential to affect the representativeness of the sample more than others. For repeated monitoring events, the sampling methodology and operating equipment employed should be consistent to minimize potential variability due to sampling procedures. The type of sampling method utilized is dependent upon site-specific conditions and it is not within the scope of this document to recommend a specific methodology. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details. Information on applicability of sampling methods can be found on Interstate Technology & Regulatory Council (ITRC) and United States Environmental Protection Agency (EPA) websites.

1.3 Equipment

The following equipment is commonly used to collect groundwater samples from a monitoring well. Site-specific conditions may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator capable of measuring to 0.01 foot accuracy
- Oil/water interface probe
- Extra batteries for water level/interface probe
- Submersible pump with low-flow capabilities (less than 1 liter/min) constructed of inert materials (e.g., stainless steel and Teflon®), such as a bladder pump (with sufficient quantity of bladders, o-rings, grab plates, etc.)
- Peristaltic pump
- Source of power for use with submersible or peristaltic pump (e.g., 12-volt battery, compressor, generator, compressed gas tanks, etc.)
- Flow controller for use with submersible pump (varies depending on type of pump used)
- Bottom-filling bailer constructed of inert materials (i.e., polyethylene, polyvinyl chloride [PVC], stainless steel or Teflon®)
- Bailer cord or wire (recommended Teflon®-coated, stainless steel cable; bailer wire; or contaminant-free rope with a Teflon®-coated stainless steel leader to connect bailer and rope)
- Tubing (Teflon®, Teflon®–lined polyethylene, or high density polyethylene [HDPE], type dependent upon project objectives)
- Silicone tubing (only used for peristaltic pump head and/or flow-through cell connections)
- Water quality meter(s) capable of measuring parameters, such as pH, temperature, specific conductivity, oxidation-reduction potential (ORP), and dissolved oxygen (DO)
- Flow-through cell
- T-connector
- Turbidity meter
- Passive sampling device (and any device-specific accessories)
    - Passive diffusion bags (PDBs)
    - Tether (stainless steel cable or marine-grade polyethylene rope), well cap, and weights, unless already installed
    - Funnel (Fill kit)
    - PVC cable ties
    - Tool to cut cable ties
    - PVC discharge tubes
    - Tether reel

- Well lock keys
- Bolt cutters

- Appropriate tools for equipment and to open well box (e.g., socket wrench, pry bar, etc.)
- Containers with lids for purge water (i.e., 5-gallon buckets, drums, etc.)
- Stopwatch or timer
- Graduated measuring container appropriately sized to measure flow rate
- Sample bottle labels
- Laboratory-grade water (can request from lab – for equipment blanks)
- Chain-of-custody (COC) forms
- Sample cooler(s)
- Photoionization detector (PID) or flame ionization detector (FID) for well head monitoring
- Sample containers (may be supplied by the laboratory depending upon the regulatory program): The proper containers should be determined in conjunction with the analytical laboratory in the planning stages of the project. If not included in sample containers provided by laboratory, sample preservatives will need to be kept with sample containers, and added to sample containers prior to sample collection.
- Field book and/or Groundwater Field Data Record (multiple copies)
- Filtration equipment
- In-line filter (0.45 micron [µm]) or as otherwise required by the project-specific work plan.
- Bubble wrap/Bubble wrap bags
- Lint-free, non-abrasive, disposable towels (e.g., Kimwipes®)
- Indelible marking pens
- Plastic bags (e.g., Ziploc®)
- Ice
- Teflon® tape
- Plastic sheeting or large trash bags which can be cut open
- Umbrella, tent, or equivalent for shading equipment (particularly the flow-through cell) from sunlight or blocking rain
- Equipment decontamination supplies
- Container for bailing water out of water-logged road boxes or well vaults
- Map of well locations and well construction data
- Copy of field notes from previous sampling event for reference
- Project-specific work plan

1.4 Definitions

Bailer	A cylindrical device suspended from a rope or cable, which is used to remove water, non-aqueous phase liquid (NAPL), sediment or other materials from a well or open borehole. Usually equipped with some type of check valve at the base to allow water, NAPL, and/or sediment to enter the bailer and be retained as it is lifted to the surface. A bailer may be made in varying diameters; however a bailer that fits in a two-inch well is the most common. In some instances a < 1-inch diameter bailer (a.k.a. pencil bailer) is used for small diameter wells.
Borehole	A hole drilled into the soil or bedrock using a drill rig or similar equipment.
Dense Non-aqueous Phase Liquid (DNAPL)	Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.
Depth To Water (DTW)	The distance to the groundwater surface from an established measuring point.
Drawdown	The response to purging/pumping a well resulting in the lowering of groundwater within the water column in the well or in a water-bearing zone.
FID	An instrument that uses a flame to break down volatile organic compounds (VOCs) into ions that can be measured.
Flow-Through Cell	The container used to immerse the multi-parameter probes in well purge water during pre-sampling well purging. The flow-through cell is usually made of transparent acrylic and is connected to the end of the discharge tubing creating an in-line, sealed container in which purge water circulates around the measurement probes. The discharge from the pump prior to the flow-through cell may be fitted with a check valve or T-connector for collection of water for turbidity measurement.
Flush Mount	The type of well completion where the riser terminates at or below grade. Flush-mounted wells are typically completed with a “curb box” which is an “at-grade” enclosure designed to protect the well riser.
Light Non-aqueous Phase Liquid (LNAPL)	Separate-phase product that is less dense than water and therefore floats on the surface of the water.

Monitoring Well	A well made from a PVC pipe, or other appropriate material, with slotted screen installed across or within a saturated zone. A monitoring well is typically constructed with a PVC or stainless steel pipe in unconsolidated deposits and with steel casing in bedrock.
PID	An instrument that uses an ultraviolet light source to break down VOCs into ions that can be measured.
Piezometer	A well made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Potentiometric Surface	A surface representing the hydraulic head of groundwater.
Protective Casing	The pipe installed around the well riser that sticks up from the ground (above-grade completions) or is flush with the ground (at-grade completions, e.g., curb box) in order to protect the well integrity. Protective casings are typically constructed of steel or aluminum and usually closeable with a locking cover/hasp to maintain well integrity between sampling events.
Recharge Rate	The rate at which groundwater returns to the water column in the well.
Separate-Phase Product	A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column.
Static Water Level	Level at which water resides in a well when the water level is at equilibrium with atmospheric pressure.
Well Cover	The cap or lid constructed at the end of the protective casing (above-grade completions) or flush-mounted curb box (ground surface completions) to secure access to the well. Well covers for stick-up wells are often equipped with a hasp to accommodate a padlock. Well covers for flush-mounted road boxes or vaults are opened and closed using a threaded bolt.
Well Filter Pack	A material composed of clean silica sand or sand and gravel of selected grain size and gradation that is placed in the annulus between the screened interval and the borehole wall in a well for the purpose of retaining and stabilizing the formation material.

Well Plug/Expansion Plug	The plug fashioned into a cap placed into the top of the well riser (e.g., J-Plug). Well plugs are usually designed with an expandable gasket that is activated by turning a locking wing nut or removable key latch, closing a snap cap or engaging a magnetic clutch cap to seal the well riser.
Well Riser	Sections of blank (non-slotted) pipe that extend from the well screen to or above the ground surface.
Well Screen	Pipe (typically PVC or stainless steel) used to retain the formation or filter pack materials outside of the well. The pipe has openings/slots of a uniform width, orientation, and spacing. The openings/slots can vary based on formation and filter pack material specifications.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

The well head should be pre-screened using a PID/FID to avoid inhalation of contaminants venting from the well. If monitoring results indicate sustained elevated concentrations of organic contaminants, the level of PPE may need to be increased in accordance with the HASP or work could be conducted upwind of the well.

When present, special care should be taken to avoid contact with LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards.

Implementing this SOP may require the use of reagents and/or compressed gases for the calibration and operation of field equipment. These substances may be hazardous and TRC personnel must appropriately handle, store, and dispose of them at all times. Skin contact with liquid from preserved sample bottles must be avoided as they may contain strong acids or bases. When filling bottles pre-preserved with acid (e.g., hydrochloric acid, nitric acid, sulfuric acid), vapors may be released and should not be inhaled. Do not allow bottles with acid to be exposed to elevated atmospheric temperatures or sunlight as this will facilitate fumes from the acids.

1.6 Cautions and Potential Problems

The following sections highlight issues that may be encountered and should be discussed with the Project Manager prior to mobilization into the field. Special care should be taken when sampling for PFAS. Please refer to Attachment D for details.

1.6.1 Pre-Sampling Issues

(a) Selection of equipment for groundwater sampling should consider multiple factors, including: DTW, well specifications (e.g., depth and length of well screen intervals), desired flow rate, possible weather conditions, type and concentration of contaminant(s), and remoteness/accessibility to the site. The benefits and limits of each type of groundwater sampling equipment should be fully reviewed during project planning or prior to mobilization if the project-specific work plan does not identify the required equipment. For example, peristaltic pumps are incapable of withdrawing water in wells in which the depth to water is greater than approximately 20-25 feet below ground surface (bgs).

(b) If the screen or open borehole is greater than 10 feet in length, consult the project-specific work plans for the target sampling interval. Generally, pumps are either placed in the middle of the saturated zone if the water level is below the top of the screen or in the middle of the screen interval if the water level is above the top of the screen.

(c) The need for redevelopment of the monitoring wells should be evaluated periodically in accordance with the project-specific requirements. This is assessed by comparing the measured total depth of the well with the constructed depth. If the measured depth is less than the constructed depth, this may indicate siltation of the well and/or the presence of an obstruction in the well. If it is determined that redevelopment is necessary, it should be performed in accordance with ECR SOP 006, *Well Development.* The time necessary for a well to restabilize after redevelopment will be determined on a project-specific basis and may depend on regulatory requirements.

(d) During the total well depth measurement, there is the potential for sediment, if present at the bottom of the well, to be disturbed, thereby increasing the turbidity of the groundwater. Therefore, the total well depth measurement should be collected the day prior to collecting groundwater samples, if possible.

(e) Use caution if using compressed gas cylinders (e.g., nitrogen, carbon dioxide) for purging/sampling of groundwater. Check for leaks around regulator connections by spraying soapy water on the connections. If a leak is discovered, the connection to the regulator should be disassembled, wrapped with Teflon® tape, and reconnected to the cylinder. If the leak continues, the regulator should be replaced. It should be noted that Department of Transportation (DOT) regulations apply to the transportation and handling of compressed gas cylinders (see 49 Code of Federal Regulations [CFR] 171). Never transport cylinders with the regulator attached. Replace the cylinder valve cover on the compressed gas cylinder before transport.

(f) All field personnel must be made aware of the water level measurement reference point being used for each well at a site (i.e., must be clearly marked) in order to ensure collection of comparable data between events.

(g) Bolt cutters may be necessary to remove rusted locks. Dipping rusted locks in a soapy solution may help with opening difficult locks. Oils and other products containing VOCs (e.g., WD-40) should not be used on locks as these compounds may cause contamination of water samples collected at the well. Replace cut locks and note in the field book.

(h) Prior to accessing the well, physical conditions around the well head should be assessed for situations that might result in cross-contamination or the introduction of foreign material/debris into the well. For example, flush-mounted wells may have water or road sand/salt/debris inside the curb box. Rodents and insects (e.g., bees, wasps) have been known to construct nests within the protective casing of a well. If bees, wasps, or other insects are encountered, insecticides should be used with caution as the chemicals may cause contamination of water samples collected at the well. If water or foreign material is introduced into the well, the Project Manager should be immediately notified.

1.6.2 General Purging and Sampling Issues

(a) Prior to installation of a submersible pump into a well, ensure that the tubing is properly sealed to the pump to avoid losing the pump down the well and to prevent escape of air or water from the pump, which could result in poor pump performance and the aeration of the well water. Do not do this by tugging on tubing. Never lower pumps into the well using only tubing; instead a security line attached to the pump is required to prevent potentially losing the pump down the well.

(b) A submersible pump should not be lowered to the bottom of the well to avoid stirring up any sediment at the bottom of the well and prevent getting the pump stuck (fine sediment accumulation in the bottom of the well can create a strong suction with a flat bottom pump such as a bladder pump, which may require jetting to retrieve the pump).

(c) Start with the lowest pumping rate possible and increase until a sustainable rate is reached. Avoid high pumping rates (> 1 liter/min), as this could lead to damage of the well filter pack, if present. Where practical and/or possible, refer to previous sampling events to establish consistent flow rates.

(d) Some regulatory agencies may have concern about the use of peristaltic pumps when sampling for VOCs due to the potential for loss of VOCs during sampling and alteration of other water quality parameters such as pH and alkalinity. Samplers should review the requirements in the project-specific work plan and/or regulatory guidelines prior to performing the work. Explicit approval to use a peristaltic pump for the collection of VOCs may be required by the governing regulatory agency. An option may be to use the "soda straw" method to collect the VOC sample which does not allow the water to go through the pump head:

  (1) After purging the well with the peristaltic pump, collect all fractions <u>except VOCs</u> from the outlet side of the pump (i.e., VOCs will be collected last instead of first).
  (2) Turn the pump off.
  (3) Change into clean gloves.
  (4) Disconnect the tubing coming out of the well from the inlet side of the pump and <u>immediately</u> put a finger over the end of this tubing to prevent water from draining out of the tubing.
  (5) Retrieve tubing from the well, coiling it in one hand as it is being retrieved (maintain finger over end of tubing).
  (6) Open VOC vials. Briefly remove finger from end of tubing to allow water to flow into vial. Replace finger on end of tubing to stop flow. Do this for remaining VOC vials.

(e) In the event that a well cannot be purged and sampled with a pump, the alternative to pumping may be the use of a bottom-filling bailer. The applicable regulatory agency requirements and the Project Manager should be consulted if in doubt about the appropriateness of using a bailer at a site or during a particular sampling event.

(f) During purging and sampling, the tubing should remain filled with water to minimize possible changes in water chemistry due to contact with the atmosphere. All flow-through cells should be shaded from direct sunlight to minimize the potential for off-gassing and temperature fluctuations.

(g) Ensure monitoring instruments (i.e., multi-parameter water quality instrument, turbidity meter, water level measuring device) are maintained in good condition and properly calibrated to ensure accurate readings. Be sure to have appropriate-sized extra batteries on hand.

(h) Adverse weather conditions may present challenges that need to be dealt with on a case-by-case basis. For example, air temperatures below 32°F may cause ice formation in the tubing, flow-through cell, and on the sampling equipment, or heavy rain could cause standing water issues with flush-mounted wells. Heavy rain can also impact electronic sampling equipment; preventative measures should be taken to keep electronic equipment dry.

(i) Observe and avoid any uncontrolled ambient/surrounding air conditions that could affect analytical results (e.g., truck/vehicle exhaust nearby, industrial building vents). Always ensure that vehicles are turned off during sampling to avoid introducing vehicle exhaust into the sample. If uncontrolled ambient/surrounding air conditions cannot be avoided, contact the Project Manager for further instruction; collection of a field blank sample may be warranted in this situation.

(j) Procedures should be established to minimize potential cross-contamination. For example:

- Wrap monitoring and sampling equipment with protective material (e.g., aluminum foil, polyethylene sheeting, Ziploc® bags) after decontamination and between sampling locations to minimize the potential for cross-contamination between well purging events at different locations.
- Use dedicated or disposable sampling equipment or new tubing at each sampling point when appropriate to minimize the need for decontamination.
- Protect sampling equipment and/or the open well head from blowing soil and dust by covering with plastic sheeting as needed.
- If a bailer and rope are used to purge and/or sample the well, then there is the possibility of contamination from the rope used to lower the bailer. New or dedicated rope should be used when appropriate. Alternatively, a decontaminated, Teflon®-coated stainless steel leader can be attached between the rope and the bailer. The leader acts as an extension to the rope and allows for the top of the bailer to enter the water column without immediately placing the rope into the water. It is important to keep the rope clean and not allow contact with the ground surface during bailing.

(k) Disposal of the groundwater collected during purging must be performed in accordance with all applicable regulations and the project-specific work plan.

(l) Clear tape should not be used to cover labels on containers used for certain analyses (e.g., 40-mL vials for VOC analysis) due to potential interference with analytical equipment.

(m) In cases where it is difficult to obtain sufficient sample volume for multiple analytical fractions as well as required quality control (QC) analyses (*e.g.*, field duplicates, matrix spike/matrix spike duplicate [MS/MSD] analyses), discuss this situation with the Project Manager and laboratory prior to sample collection. Laboratories can often “make do” with less volume, especially for inorganic parameters, or increase the reporting limit proportional to the sample volume obtained.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Procedures for collecting groundwater samples from monitoring wells are described below. The project-specific work plan should also be consulted for specific details regarding sampling.

When possible, sampling should always begin at the monitoring well with the least contaminated groundwater and systematically proceed to the well with the most contaminated groundwater, including sites which may have nested wells.

2.1 Pre-sampling Activities

(a) It should be determined if there is the requirement to determine static water level measurements on all wells at the site prior to sampling, regardless if the well is being sampled.

(b) Prior to field activities, review historical groundwater sampling logs (if available) to maintain consistency for the current sampling event (e.g., equipment type, pump intake depth setting, flow rate, etc.)

(c) Organize monitoring, purging, and sampling equipment taking care not to allow cross-contamination. This can be accomplished by laying new polyethylene sheeting near the well or using new buckets, etc.

(d) Calibrate (or perform a calibration check on) all field monitoring equipment on the same day before collecting groundwater samples. Refer to TRC SOPs and manufacturer’s equipment calibration instructions. A calibration check may also be required during or at the end of each sampling day. Consult the project-specific work plan.

(e) Unlock the well cover on the well.

(f) Record the sample location, time, and date in the field book and/or on the Groundwater Field Data Record.

(g) On the Groundwater Field Data Record, note the physical condition of the well, including damage, deterioration, and signs of tampering, if any. Collect photographic documentation of serious damage to present to the Project Manager.

(h) Open the well cap and expansion plug, and stay upwind of and not directly over the well. Note any unusual odors, sounds, or difficulties in opening the well and, if required, measure the organic vapor reading at the rim of the well with a suitable organic vapor screening device (e.g., PID or FID), and record the reading in the field book and/or on the Groundwater Field Data Record. If pressure or vacuum is noted or suspected in the well, allow sufficient time for the water level elevation in the well to equilibrate.

(i) Gently lower a clean, decontaminated water level measuring device into the well to determine the static water level. If appropriate for site conditions, check for the presence of LNAPL or DNAPL using an oil/water interface probe (refer to ECR SOP 004, *Water Level and Product Measurements*). If LNAPL or DNAPL is detected, contact the Project Manager before proceeding with purging and sampling activities. Record the information on depth to groundwater to the nearest 0.01 feet, depth to LNAPL or DNAPL, and/or thickness of NAPL in the field book and/or the Groundwater Field Data Record. Refer to ECR SOP 004, *Water Level and Product Measurements*, for proper procedures in performing these measurements.

(j) If required in the project-specific work plan, measure the depth to the bottom of the well to assist in calculating the well volume of the well. If possible, avoid making total well depth measurements on the same day as sampling due to the tendency to disturb sediment during this measurement. If NAPL is suspected, use a decontaminated oil/water interface probe. If the measured depth is less than the constructed depth, this may indicate that the well needs to be redeveloped (see ECR SOP 006, *Well Development*). Consult the project-specific work plan or Project Manager for further instructions.

2.2 Groundwater Purging Activities

Purging is conducted to ensure that representative groundwater is obtained from the water-bearing unit for analysis. The multiple-volume or low-flow purging approach may be used to remove water from the well and monitor the water in order to determine when a well has been adequately purged (i.e., stabilized); at a minimum, the pH, specific conductance and temperature of the groundwater removed during purging should be monitored and recorded in the field notes. Other parameters may be required in some regulatory jurisdictions (e.g., turbidity). Additionally, the purge volume should be monitored and recorded. In some instances, such as when monitoring at solid waste disposal facilities, simply removing an adequate volume of water (e.g., three well volumes) may be suitable for adequate purging, and sampling can commence. Check with the project-specific work plan and appropriate regulatory guidance to determine any specific purging requirements.

If the well has been previously sampled consistent with this SOP, then the prior purging strategy (e.g., method, pump intake depth and the flow rates) should be followed during subsequent sampling events to maintain consistency and minimize potential variability due to the sampling procedure.

2.2.1 Multiple-Volume Purging Approach

The multiple-volume purging approach is typically performed using bailers or submersible or peristaltic pumps. In the multiple-volume purging approach, there are two measurements used to determine adequate purge volume removal prior to sample collection: 1) purge volume and 2) field parameter stabilization. The field parameters should be recorded at regular volumetric intervals. There are no set criteria for establishing how many total sets of measurements are adequate to document stability of parameters. If the calculated purge volume is small, the measurements should be taken frequently enough (e.g., every 3 to 5 minutes) to provide a sufficient number of measurements to evaluate stability. If the purge volume is large, measurements taken every 15 minutes may be sufficient.

Purge Volume

Prior to purging a well, the amount of water inside the well riser and well screen (i.e., water column) should be determined, if possible. To do this, the diameter of the well should be determined and the water level and total depth of the well should be measured and recorded. The specific methodology for obtaining these measurements is included in ECR SOP 004 *Water Level and Product Measurements.*

Once this information is known, the well volume can be calculated using Equation 1:

Well Volume (V) = πr^2 h (cf) **Equation 1**

where:
π = pi (3.14)
r = radius of well in feet (ft)
h = height of the water column in ft. [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
cf = conversion factor in gallons per cubic foot (gal/ft^3) = 7.48 gal/ft^3.

The volume in gallons/linear foot (gal/ft) and liters/linear foot (L/ft) for common-size wells are as follows:

Well Inside Diameter (inches)	Volume (gal/ft)	Volume (L/ft)
1	0.0408	0.1529
2	0.1631	0.6174
3	0.3670	1.3892
4	0.6524	2.4696
6	1.4680	5.5570

If the volumes for the common-size wells above are utilized, Equation 1 is modified as follows:

Well volume = (h)(f) **Equation 2**

where:
h = height of water column (feet)

f = the volume in gal/ft or L/ft

For volumetric purging, an adequate purge is typically achieved when 3 to 5 well volumes have been removed. The field notes should reflect the single-well volume calculations or determinations according to one of the above methods and a reference to the appropriate multiplication of that volume, (i.e., a minimum of 3 well volumes) clearly identified as a purge volume goal.

For volumetric purging, it is suggested that field readings are collected every ½ well/well screen volume after an initial 1 to ½ well volumes are purged. The volume removed between readings can be adjusted as well-specific information is developed.

If removing a specified volume of water (e.g., 3 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume. In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection. If, after 3 well volumes have been removed, the field parameters have not stabilized (see discussion in Section 2.2.3), additional well volumes (up to a total of 5 well volumes), should be removed. If the parameters have not stabilized within five well volumes, it is at the discretion of the Project Manager whether or not to collect a sample or to continue purging. If, after 5 well volumes, pH and conductivity have stabilized and the turbidity is still decreasing and approaching an acceptable level, additional purging should be considered to obtain the best sample possible with respect to turbidity. The conditions of sampling should be noted in the field book.

2.2.2 Low-flow Purging Approach

The low-flow purging approach is typically performed using peristaltic pumps or submersible pumps. Low-flow purging (also referred to as low-stress purging, low-volume purging, or Micropurging®) is a method of well purging/sampling that minimizes the volume of water withdrawn from a well in obtaining a representative sample. The term low-flow refers to the low velocity with which water enters the pump intake during purging and sampling. The objective is to draw representative saturated zone water through the well screen to the pump intake while avoiding disturbance of the stagnant water above the well screen through minimizing drawdown of the water column in the well. To achieve this, the flow rate should be adjusted to less than 1 L/min (usually, this will be a rate less than 500 ml/min and may be as low as 100 ml/min). Once drawdown stabilizes, the sampled water is isolated from the stagnant water in the well casing, thus eliminating the need for its removal. This sampling method is based on the principle that water within the screened zone passes through continuously and does not mix with water above the screen. Water entering the pump can be considered representative of water in the formation after drawdown and indicator parameters have stabilized.

When performing low-flow purging and sampling, it is recommended that the pump intake be set in the center of the well screen interval (or center of the water column within the well screen if the water level is below the top of the well screen) to help prevent disturbance of any sediment at the bottom of the well. If known, the pump can be placed adjacent to the areas with the highest hydraulic conductivity or highest level of contaminants. Dedicated pumps can be utilized to minimize disturbance of the water column. Subsequent sampling events should duplicate as closely as possible the pump intake depth and the stabilized flow rate from the previous events.

To begin purging, the pump should be started at the lowest pressure/power flow rate setting (e.g., 100 mL/min) and then slowly increased until water begins discharging. Monitor the water level and slowly adjust the pump speed until there is little or no drawdown or drawdown has stabilized. The pump pressure/power may need to be increased for discharge to occur.

The stabilization of drawdown should be documented. Measure and record the flow rate and water level every 3 to 5 minutes during purging. The flow rate should be reduced if drawdown is greater than 0.3 feet over three consecutive 3 to 5 minute interval readings. Note any flow rate adjustments on the Groundwater Field Data Record. Once an appropriate purge rate has been achieved, record this information, continue purging until water quality indicator parameters have stabilized (see Section 2.2.3), and then sample the well.

Attempts should be made to avoid pumping a well dry. If drawdown cannot be maintained at less than 0.3 feet and the falling water level is approaching the top of the screened interval (or the top of the pump for sampling that began with the water level below the top of the screen), perform the following steps:

1. Reduce the flow rate, or turn the pump off and allow for recovery. (The pump must have a check valve to prevent backflow if it is shut off).
2. Begin pumping again at a lower flow rate.
3. If water draws down to the top of the screened interval again (or the top of the pump for sampling that began with the water level below the top of the screen), turn the pump off and allow for recovery.
4. If two tubing volumes (including volume of water in the pump and flow-through cell) have been removed during purging, sampling can proceed the next time the pump is turned on without waiting for indicator field parameters to stabilize. The project-specific work plan or Project Manager should be consulted for guidance.
5. If this procedure is used, this should be recorded in the field book and/or on the Groundwater Field Data Record.

2.2.3 Field Parameter Stabilization During Purging

Stabilization criteria may depend on project objectives or regulatory-specific requirements. Refer to Appendix A for some of the regulatory-specific requirements for field parameter stabilization. Generally, an adequate purge with respect to the ground water chemistry is achieved when, stability for at least three consecutive measurements is as follows:

- pH ± 0.1 standard unit (SU)
- specific conductance within 3%
- turbidity within 10% for values greater than 5 nephelometric turbidity units (NTUs). If three turbidity readings are less than 5 NTUs, the values are considered as stabilized

Other parameters, such as DO, may also be used as a stabilization parameter. Typical stabilization goals for DO are within 0.2 mg/L or 10% saturation, whichever is greater. DO measurements should be conducted using either a flow-through cell or an over-topping cell to minimize or reduce potential oxygenation of the sample.

Because groundwater temperature is generally not very sensitive in distinguishing between stagnant casing water and formation water and is subject to rapid changes during purging, its usefulness is subject to question for the purpose of determining parameter stability. Even if temperature is not used to determine stability during well purging, it is still advisable to record the sample temperature, along with the other groundwater chemistry parameters, during well purging, as it may be needed to interpret other parameter results.

ORP is not always used as a stabilization parameter since it may also be subject to rapid changes during the purging process; however, it may be measured and recorded during well purging.

2.2.4 Special Considerations During Purging

<u>Wells Purged Dry/Purge Adequacy</u>

For wells with slow groundwater recovery, attempts should be made to avoid purging the well dry. This may be accomplished by slowing the purge rate. As water enters a well that has been purged dry, the water may cascade down the sand pack and/or the well screen, potentially stripping VOCs that may be present and/or potentially mobilizing soil fines into the re-accumulating water column.

However, even with slower purge rates, in some situations, a well may be pumped or bailed dry (evacuated) during the purging process. In these situations, evacuation generally constitutes an adequate purge and the well may be sampled following sufficient recovery (enough volume to allow filling of all sample containers). **It is not necessary that the well be evacuated three times before it is sampled.** Purging parameters should be measured and recorded during sample collection to serve as the measurements of record for the sampling event.

It is particularly important that wells be sampled as soon as possible after purging to maintain sample representativeness. If adequate volume is available upon completion of purging, the well should be sampled immediately. If not, sampling should occur as soon as adequate volume has recovered. If possible, sampling of wells that have a slow recovery should be scheduled so that they can be purged and sampled in the same day after adequate volume has recovered. Wells of this type should, unless it is unavoidable, not be purged at the end of one day and sampled the following day.

<u>Temporary Monitoring Wells</u>

Procedures used to purge temporary groundwater monitoring wells may differ from permanent wells, because temporary wells are installed with different DQOs for immediate sample acquisition. Wells of this type may include standard well screens and risers placed in boreholes created by hand augering, power augering, or by drilling. Alternatively, they may consist of a rigid rod and screen that is pushed, driven, or hammered into place to the desired sampling interval, such as a direct push Wellpoint®, a Geoprobe® Screen Point 15/16 sampler, or a Hydropunch® sampler.

Purging to address stagnant water may not necessarily apply to temporary wells, because stagnant water is not typically present. It is important to note, however, that the longer a temporary well is in place and not sampled, the more stagnant the water column may become, and the more appropriate it may be to apply, to the extent possible, standard permanent monitoring well purging criteria.

In cases where the temporary well is to be sampled immediately after installation, purging is conducted primarily to mitigate the impacts of installation. In most cases, temporary well installation procedures disturb the existing saturated conditions, resulting primarily in increased turbidity. Therefore, the goal of purging, if conducted, may be to reduce the turbidity and remove the volume of water in the area directly impacted by the installation procedure. Low turbidity conditions in these types of wells that are completed within the limit of suction are typically and routinely achieved by the use of low-flow/low-stress purging techniques using variable-speed peristaltic pumps.

2.2.5 Equipment Considerations for Purging

Monitoring well purging is accomplished by using in-place plumbing and dedicated pumps or by using portable pumps/equipment when dedicated systems are not present. The pump of choice is usually a function of the purging approach (e.g., multiple-volume vs. low-flow), well diameter, the DTW, the total depth of the well, the amount of water that is to be removed during purging, the specific analytical testing program for the well, and the equipment previously used during purging and sampling of the well. A peristaltic pump is appropriate for purging whenever the head difference between the sampling location and the water level is less than the limit of suction (approximately 25’ to 30’) and the volume to be removed is reasonably small. For wells where the water level is below the limit of suction, and/or where there is a large volume of water to be purged, the variable-speed electric submersible pump or adjustable-rate bladder pumps would be appropriate. Bailers may also be used for purging in appropriate situations (e.g., shallow wells with small purge volumes); bailers are not suitable for low-flow purging.

The following subsections describe well evacuation devices that are most commonly used. Other devices are available but are not discussed in this SOP due to their limited use. Site-specific operating procedures should be developed in the case that an uncommon purge device is used.

2.2.5.1 Purging with a Suction Pump

There are many different types of suction pumps. They commonly include: centrifugal, peristaltic and diaphragm. Diaphragm pumps can be used for well evacuation at a fast pumping rate and sampling at a low pumping rate. The peristaltic pump is a low-volume pump that incorporates a roller to squeeze flexible tubing, thereby creating suction. This tubing can be dedicated to a well for re-use or discarded. It is recommended that 1/4 inch or 3/8 inch (inner diameter) tubing be used to help ensure that the sample tubing remains filled with water and to prevent water from being aerated as it flows through the tubing. Purging procedures are as follows.

(a) Determine the volume of water to be purged as described in Section 2.2.1 or follow the low-flow approach described in Section 2.2.2 (applicable to peristaltic pumps only).
(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of pumps, tubing or other purging/sampling equipment with foreign materials.
(c) Assemble the pump, tubing and power source, if necessary, in accordance with manufacturer’s specifications.
(d) Ensure that the pump tubing is set at the pre-determined pump intake depth.
(e) Connect the discharge line from the pump to the flow-through cell for parameter measurements. Use a T-connection or valve prior to the flow-through cell to allow for

collection of water for turbidity measurements. Direct the discharge line from the flow-through cell to a 5-gallon bucket (or equivalent) to contain the purge water for proper disposal. Verify the end of the tubing is not submerged in the purge bucket. Manage purge water as specified in the project-specific work plan.

(f) Do not allow the pump to run dry. If the pumping rate exceeds the well recharge rate, adjust the rate accordingly or, if consistent with the purging and sampling objectives, lower the tubing further into the well and continue pumping.

(g) Using the water quality meter, take an initial reading of the required indicator parameters. All measurements, except turbidity, must be obtained using a transparent flow-through cell unless an unforeseen situation makes this impractical or inadvisable. Initially, turbidity may be elevated. Once turbidity has decreased to a measurable range, begin monitoring indicator parameters at approximately every 3-5 minutes, or as appropriate. Please note that flow-through cell size should be taken into account in conjunction with the flow rate to determine the length of time between water quality parameter readings. At least one flow-through cell volume should be turned over between readings. For example, if the flow through cell size is 500 mL and the flow rate is 100 mL/min, then it would be appropriate to measure water quality parameters every 5 minutes.

(h) Record the readings on the Groundwater Field Data Record. The monitoring probes must be submerged in water at all times. Record the indicator parameters, along with the water level, as described in Step (g) above. If removing a specified volume of water (e.g., 3-5 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume. In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection. Stabilization criteria are discussed in Section 2.2.3.

Particulate build-up in the flow-through cell may impact indicator parameters. If the cell must be cleaned during pumping operations, continue pumping and disconnect the cell for cleaning, then reconnect and continue monitoring. Record the start and stop times, and describe the cleaning steps in the field book.

If indicator parameter stabilization is required and parameters have not stabilized after 2-hours of purging (or other pre-determined length of time), one of three options may be taken after consultation with the Project Manager:

1) continue purging until stabilization is achieved;
2) discontinue purging, do not collect any samples, and record in the field book and/or on the Groundwater Field Data Record the stabilization conditions and steps taken to attempt to achieve stabilization; or,
3) discontinue purging, collect samples and document attempts to achieve stabilization.

NOTE: If parameters do not stabilize, or turbidity remains greater than 5 NTU within the project-determined time range (EPA recommends up to 2 hours), contact the Project Manager to develop a modified sampling approach.

(i) Record the volume of water purged on the Groundwater Field Data Record. Record the disposal method used for purge water in the field book.

(j) Once the required volume of water is removed (typically 3 to 5 well volumes) from the well and/or parameters are stabilized to the satisfaction of the project-specific work plan, proceed to Section 2.3, Post-purging Groundwater Sample Collection.

2.2.5.2 Purging with a Submersible Pump

Submersible pumps generally use one of two types of power supplies, either electric or compressed gas. Electric pumps can be powered by a 12-volt DC rechargeable battery, or a 110- or 220-volt AC power supply. Those units powered by compressed gas (e.g., bladder pump) normally use a small electric controller that also needs a 12-volt DC battery or 110-volt AC power. They may also utilize compressed gas from bottles. Pumps differ according to the depth and diameter of the monitoring wells and the height of the potentiometric surface/water table (e.g., pressure head). It is recommended that 1/4-inch or 3/8-inch (inner diameter) tubing be used to help ensure that the sample tubing remains filled with water and to prevent water from being aerated as it flows through the tubing. Purging procedures are as follows.

(a) Determine the volume of water to be purged as described in Section 2.2.1 or follow the low-flow approach described in Section 2.2.2.

(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of pumps, tubing or other purging/sampling equipment with foreign materials.

(c) Assemble the pump, tubing and power source, if necessary, in accordance with manufacturer's specifications. If the pump itself is being lowered into the well, ensure a safety line is attached.

(d) Non-dedicated purge/sampling vs. dedicated purge/sampling systems.

Dedicated systems: Pump has already been installed. Refer to historical monitoring well information, and record the depth of the pump intake in the field book and/or on the Groundwater Field Data Record.

Non-dedicated systems: Determine the target depth of the pump intake. Note that this may be a historical intake depth; see well construction data or the project-specific work plan. If there is not an established intake depth, the center of the screened interval should be targeted. If the measured water level is lower than the top of the well screen, position the pump intake at the midpoint of the water column. The intake should be generally 1 to 2 feet above the bottom of the well to minimize potential mobilization of any settled sediment, the risk of the pumping suction being broken, or the entrainment of air in the pump tubing and resulting sample. Slowly lower the pump, safety line, and tubing into the well to the pre-determined pump intake depth. The tubing should be cut to the desired length to assist in installing the pump. Measure the depth of the pump intake while lowering the tubing/pump into location. Record the pump intake depth in the field book and/or on the Groundwater Field Data Record. For deeper wells and large diameter wells, two staff members may be necessary to accomplish this task.

(e) Connect the discharge line from the pump to the flow-through cell for parameter measurements. Use a T-connection or valve prior to the flow-through cell to allow for collection of water for turbidity measurements. Direct the discharge line from the flow-through cell to a 5-gallon bucket (or equivalent) to contain the purge water for proper disposal. Verify the end of the tubing is not submerged in the purge bucket. Manage purge water as specified in the project-specific work plan.

(f) Measure the flow rate of the pump with a graduated container and stop watch. The pump pressure may need to be increased for discharge to occur. Record the volume of water collected for a period of 1 minute and calculate the flow rate as follows.

$$Flowrate\,(mL\,/\,min)\;=\;\frac{volume\ collected\ (mL)}{1\,minute}$$

(g) Measure the water level and record the flow rate and the water level. This should be performed every 3 to 5 minutes during purging. For low-flow purging, the flow rate should be adjusted to result in a rate between 100 to 500 mL/min; however, if drawdown of the well is observed, a slower flow rate may be necessary. If using a bladder pump, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL volatile organic analysis (VOA) vial, if possible.

(h) Prior to recording the water quality indicator parameters, a minimum of one tubing volume should be purged. Note that this includes the volume of the flow-through cell.

(i) Proceed to steps (g) through (j) in Section 2.2.5.1.

2.2.5.3 Purging with a Bailer

(a) Determine the volume of water to be purged as described in Section 2.2.1.

(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of tubing or other purging/sampling equipment with foreign materials.

(c) Use a well-dedicated bailer (i.e., used exclusively for that well only), a decontaminated bailer or an unused, disposable bailer.

(d) Attach an appropriate length of (a) bailing line, (b) Teflon®-coated bailing wire or (c) rope with Teflon®-coated stainless steel leader to reach the bottom of the well. Secure a knot or series of knots to the top of the bailer. Be sure to have additional length of line to facilitate handling of the bailer at the surface (typically 10 ft).

(e) Lower the bailer gently into the well until it reaches the water column and fills with water from the bottom. Note: It is recommended that the bailer be lowered into the water to a depth that prevents the water from entering the top of the bailer. This is done to prevent excess turbulence caused by filling from the bottom and the top simultaneously. Controlling the line attached to the bailer as it is lowered into the well is also important to prevent degassing of the water as the bailer impacts the water. In shallow wells, controlling the line is not too difficult; however, for wells of greater depths it is common to utilize a hand-over-hand (windmill) approach using both hands to control longer lengths of line and prevent the loops in the line from tangling with one another. This procedure is simple to learn and saves a good deal of time by preventing tangles. Do not allow the bailing line or rope to become contaminated by surface soil.

(f) Once the bailer is full of water, gently withdraw the bailer from the well until it comes out of the top of the well. Be sure to control excess line in your hands to prevent the rope and bailer from touching the ground, and then grasp the bailer as it appears at the top of the well.

(g) Immediately pour the water into a vessel for water quality measurements, and record the measurements in the field book or on the Groundwater Field Data Record (at the project-required frequency). Otherwise, pour water into a 5-gallon bucket or other vessel to track the volume purged. As a general rule, standard 2-inch bailers are able to hold about 1 liter of water when full. This process will have to be repeated several times to complete adequate purging of the well (e.g., three to five well volumes).

(h) Record the volume of water purged on the Groundwater Field Data Record. Record the disposal method used for purge water in the field book.

(i) Once the required volume of water is removed (typically 3 to 5 well volumes) from the well and/or parameters are stabilized to the satisfaction of the project-specific work plan, proceed to Section 2.3, Post-purging Groundwater Sample Collection.

2.3 *Post-purging Groundwater Sample Collection*

(a) New, disposable gloves should be donned immediately prior to sample collection and should be changed at any point that their cleanliness becomes compromised during sample collection.

(b) If using a submersible or peristaltic pump, maintain the same flow rate as used during purging. Disconnect the pump tubing from the flow-through cell or sample from the T-connector, if used. Samples must be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. This is critically important to avoid cross-contamination between wells.

(c) If using bottom-filling bailers,

- Slowly lower the bailer into the well until it is submerged to the point where water does not enter the top (i.e., bottom-filling).
- Retrieve the bailer. The first bailer recovered after well purging must be used for sample collection.

2.3.1 Sample Collection Order

Fractions of the groundwater sample should be collected in the following order (i.e., decreasing volatility) unless otherwise specified in the project-specific work plan:

1. VOCs;
2. Semivolatile organic compounds (SVOCs);
3. Other organic parameters;
4. Unfiltered inorganic constituents (e.g., total metals);
5. Filtered inorganic constituents (e.g., dissolved metals); and
6. Other constituents.

During sample collection, allow the water to flow directly down the side of the sample container without allowing the tubing to touch the inside of the sample container or lid in order to minimize aeration and turbulence and maintain sample integrity. The tubing should remain filled with water.

2.3.2 VOC Sample Collection

<u>Collection of VOCs/Volatile Petroleum Hydrocarbons (VPH):</u> Samples for VOCs will be collected first unless they are being collected by the "straw" method described in Section 1.6.2 (d), and the sample vial must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, the vial should be topped off using a minimal amount of sample to re-establish the

meniscus. Care should be taken to not flush any preservative out of the vial when topping off. If, after topping off and capping the vial, bubbles are still present, a new vial should be obtained and the sample re-collected. Note: Extra VOC vials should be obtained prior to the sampling event in case this situation occurs.

Note: When using a bladder pump, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 ml VOA vial, if possible.

When acid preservation is used for the collection of VOCs, the acid must be added to the vials before sample collection. However, in most cases 40-ml VOA vials come pre-preserved. If a pre-preserved vial effervesces upon the addition of sample, the acid preservative can be rinsed out of the vial with sample water and then used to collect the sample. The laboratory should be made aware that the affected sample will not be acid-preserved as this may affect the sample holding time. Note effervescence in the field book for future reference.

2.3.3 Non-VOC Sample Collection

Completely fill the remaining sample containers for all non-VOC analyses.

Preserve the non-VOC samples in accordance with method and project-specific requirements following sample collection if the sample containers are not pre-preserved. (**NOTE:** Pre-preserved vials may be supplied by the laboratory, depending on the program).

2.3.4 Field Filtering

Depending upon project requirements, field filtering may be performed for non-VOC analyses. An in-line filter should be fitted at the end of the discharge tubing and the sample should be collected after the filter. Pre-rinse the in-line filter by allowing a minimum of 0.5 to 1 liter of groundwater from the well to pass through the filter prior to sampling. Ensure the filter is free of air bubbles prior to collecting samples. Preserve the filtered water sample immediately or directly fill pre-preserved containers (if provided). Clearly note “filtered” or “dissolved” on sample label and COC document.

2.4 Groundwater Sample Collection Without Purging (Passive Sampling)

Passive sampling can be defined as the free flow of contaminants from the media being sampled to a receiving phase in a sampling device. Depending upon the sampler, the receiving phase can be a solvent (e.g., water), chemical reagent, or porous adsorbent (e.g., activated carbon). While there are many different types of passive samplers, most have a barrier between the medium being sampled and the receiving phase. The barrier determines the sampling rate that contaminants are collected at a given concentration and can be used to selectively permit or restrict various classes of chemicals from entering the receiving phase.

There are three generic forms of passive (no purge) samplers: thief (grab) samplers, diffusion (equilibrium) samplers, and integrating (kinetic) samplers. However, this SOP focuses on the more commonly used diffusion (equilibrium) samplers.

Passive samplers are deployed down a well to the desired depth within the screened interval or open borehole to obtain a discrete sample without using pumping or a purging technique. Most samplers are able to be stacked to obtain samples at multiple depths. Some samplers can also be used to measure contaminants in groundwater as it enters a surface water body.

Diffusion, or equilibrium, samplers are devices that rely on diffusion of the analytes to reach equilibrium between the sampler fluid and the well water. Samples are time-weighted toward conditions at the sampling point during the latter portion of the deployment period. The degree of weighting depends on analyte and device-specific diffusion rates. Typically, conditions during only the last few days of sampler deployment are represented. Depending upon the contaminant of concern, equilibration times range from a few days to several weeks. Diffusion samplers are less versatile than grab samplers as they are not generally effective for all chemical classes.

Both the diffusion and integrating samplers depend upon permeation or diffusion through barriers that hold the receiving phase. This diffusion process is chemical and barrier specific. Diffusion samplers are commonly known as PDBs or rigid porous polyethylene (RPP) samplers. PDBs may be used to sample for VOCs, and RPPs may be used to sample for various organic and inorganic constituents. PDBs must be allowed to remain in the well for a sufficient period of time to allow the deionized water in the sampler to come into equilibrium with the constituents in the ambient groundwater.

Some regulatory agencies allow groundwater samples to be collected without purging the well. This may be accomplished by suspending a passive sampler in the well for a period of time appropriate for the type of passive sampler being used. It is important to confirm that the chosen sampler is compatible with the contaminants of concern including all VOCs of interest at the site.

Diffusion passive samplers are used most commonly and the procedure for their use is as follows:

(a) Passive samplers are deployed at a predetermined depth across the well screen. Typically, the initial sampling event may deploy multiple passive samplers across 5-foot intervals of saturated well screen to observe any potential stratification. Long-term sampling depths typically target a zone of higher concentration, if present.

(b) New passive samplers are attached via PVC cable ties to a tether (a pre-made marine-grade polyethylene rope or stainless steel cable with a weight at the bottom) that is then suspended within the well. There should be sufficient well screen saturation within the well to completely cover the passive sampler. For VOCs, it is recommended that there should be several feet of groundwater above the top of the PDB.

(c) The passive sampler should be allowed to equilibrate with groundwater for an appropriate period of time (e.g., at least 2 weeks for PDB samplers). Longer equilibration times may be necessary in lower permeability formations. Once sufficient time for equilibration has passed, the PDB samplers can be retrieved when convenient.

(d) Raise the passive sampler to the surface using a tether reel. Examine the surface of the passive sampler for evidence of algae, iron, or other coatings, and for tears to the membrane. Note observations in the field book. If tears are present and water is leaking out, the sample is not considered viable. Contact the Project Manager.

(e) Detach the passive sampler from the tether.

(f) Remove excess beaded water from the passive sampler with a clean gloved hand, running top to bottom; this is to minimize the contact of beaded water with water in the passive sampler.

(g) Use a small diameter discharge tube (<0.15 inch diameter to reduce volatilization) and pierce near the bottom, allowing water to smoothly flow into the VOA vial. Tilting the passive sampler will control the flow rate. The VOA vials must be filled within the first several minutes of passive sampler retrieval. (Note that sample vials should be prepared and opened on a stable surface or holding device such as a foam pack. Decanting sample from passive samplers into containers requires techniques that may require some practice and patience.) Refer to Section 2.3.2 for special circumstances regarding the filling of VOA vials.

(h) A small amount of water may remain within the passive sampler after filling the VOA vials and can be used for field parameter measurements if required.

(i) Dispose of the passive sampler after use.

2.5 Post-sampling Activities

(a) Cease pumping and, if system is non-dedicated, disassemble and decontaminate the purging and sampling equipment. Verify the end of the tubing is not submerged in the purge bucket prior to turning off the pump.

(b) Dispose of the bailer (if disposable) and/or rope and/or other disposable equipment in accordance with the project-specific work plan, or store the bailer in a plastic bag for transport to the site decontamination area.

(c) Dispose of the empty passive sampler and/or rope and/or other disposable equipment in accordance with the project-specific work plan, or store the empty passive sampler in a plastic bag for transport to the site decontamination area

(d) Replace the well cap and well cover on the well and lock the outer casing (if present).

(e) Label each sample. If the labels are covered with clear tape, ensure this is not performed for VOA vials.

(f) Place all samples in a cooler with ice.

(g) Ensure samples are delivered to the laboratory well before the required holding time expires.

(h) Consult the project-specific work plan to determine if a calibration check is required at the end of the day for the water quality parameters.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of QC samples is dependent upon the DQOs. Project-specific work plans should be consulted to determine the required frequency of QC sample collection.

4.1 Field Duplicates

The following procedures should be used for collecting field duplicates of groundwater samples:

(a) For QC purposes, each duplicate sample will be typically submitted to the laboratory as a "blind" duplicate sample, in that a unique sample identification not tied to the primary sample identification will be assigned to the duplicate (e.g., DUP-01). Standard labeling procedures used for groundwater sampling will be employed. However, a sample collection time will not be included on the sample label or the COC form. The actual source of the duplicate sample will be recorded in the field book and/or on the Groundwater Field Data Record.

(b) Each duplicate sample will be collected simultaneously with the actual sample by alternately filling sample and duplicate bottles. Following the order of collection specified for each set of containers (VOCs, SVOCs, other organic parameters, unfiltered inorganic constituents, and filtered inorganic constituents), the duplicate sample containers will be alternately filled with groundwater for each parameter.

(c) All collection and preservation procedures outlined for groundwater sampling will be followed for each duplicate sample.

4.2 Equipment Blanks

Equipment blanks include reagent water that is run through the bailer (if not disposable), rope, leader line, decontaminated pump, a representative section of the pump's tubing, or any other piece of sampling equipment that may have come in contact with the sample. The equipment blanks are collected and preserved in the same sample containers as field samples. If dedicated or disposable systems are used, equipment blanks are not required, although an initial blank could be performed to demonstrate that the dedicated equipment is clean prior to use. If only dedicated tubing is used, the equipment blank will include only the pump in subsequent sampling events. A passive sampler is considered a dedicated device and no equipment blank is required.

Ideally, the reagent water should come from the laboratory and be certified clean. If not certified and/or if not from the laboratory performing the analyses, a separate water blank that has not run through the sampling equipment should be sent to the laboratory for analysis.

4.3 Trip Blanks

Trip blanks will be used to check for potential contamination of VOCs via migration during storage and shipping. Trip blanks typically consist of two to three 40 mL VOA vials filled with analyte-free water and preserved with hydrochloric acid (HCl) to pH <2 SU. Trip blank containers are usually supplied pre-filled by the laboratory. Trip blanks are typically submitted to the laboratory at a frequency of one per cooler for coolers that contain samples for VOC and/or VPH analysis. Trip blanks are analyzed by the laboratory for VOCs and/or VPH, depending on field sample analyses.

4.4 Field Blanks

Field blanks consists of analyte free water exposed to the atmosphere during field sample collection. The water is containerized in an appropriate bottle and preservative for the analytical suite and shipped to the laboratory with the other field samples. The results are used to assess whether or ambient/surrounding air conditions may have influenced analytical results.

4.5 MS/MSDs and MS/Duplicates

MSs are an additional analysis of a sample spiked by the laboratory with a subset or all of the target analytes and are used to demonstrate the accuracy of analytical methods for a given matrix. MSDs are an additional analysis of a sample spiked with a subset or all of the target analytes and are also used to demonstrate the accuracy of analytical methods for a given matrix. MS/MSDs also provide a measure of analytical precision for a given matrix. Duplicates are an additional analysis of a sample and are used to demonstrate the precision of analytical methods for a given matrix.

Triplicate volumes of a field sample must be collected in order for the laboratory to have enough volume to perform the MS/MSD analyses for organic parameters. Duplicate volumes of a field sample must be collected in order for the laboratory to have enough volume to perform MS/Duplicate analyses for inorganic parameters. The sample designated for MS/MSD or MS/Duplicate analyses should be noted in the Comments column of the COC document.

4.6 Temperature Blanks

Temperature blanks consist of a sample container filled with non-preserved water (potable or distilled) and typically are included in all coolers that contain samples that require temperature preservation. These may be added to the coolers by the field team if not provided by the laboratory. Temperature blanks must remain inside the coolers on ice during the sampling process.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record the sample location, sample identification, and date and time of collection in the field book and/or the Groundwater Field Data Record. The Groundwater Field Data Record (Attachment B) should be used to record the following information:

- Volume of each sample

- Sample identification number
- Sample location (sketch of the sample point)
- Time and date sample was collected
- Personnel performing the task
- Volume of water removed
- Purging time
- Flow rate during purging and sampling
- Weather conditions during sampling (e.g. temperature, wind)
- Field parameters such as water level, pH, temperature, conductivity, turbidity, ORP, and DO
- Sample collection equipment and method used
- Decontamination procedures
- Analytical parameters
- Preservation method and amount of preservative

All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the records management procedures specified in the project-specific work plan must be approved by the Project Manager and documented in the field book.

6.0 REFERENCES

Interstate Technology Regulatory Council (ITRC). March 2006. *Technology Overview of Passive Sampler Technologies.*

USEPA. November 1992. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001. USEPA Office of Solid Waste.

USEPA. April 1996. *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*. EPA Ground Water Issue. EPA/540-S-95-504. USEPA Office of Solid Waste and Emergency Response.

USEPA. May 2002. *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers*. EPA/542-S-02-001. USEPA Office of Solid Waste and Emergency Response.

USEPA. September 2004. Field Sampling Guidance Document #1220: Groundwater Well Sampling. USEPA Region 9 Laboratory Richmond, California.

USEPA, January 19, 2010. *Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells*. USEPA Region 1, Rev. 3.

USEPA. March 6, 2013. *Groundwater Sampling.* SESDPROC-301-R3. USEPA Region 4, Science and Ecosystem Support Division. Athens, Georgia.

USEPA. April 22, 2014. Passive (No Purge) Samples.
http://www.clu-in.org/characterization/technologies/default.focus/sec/Passive_%28no%20purge%29_Samplers/cat/Overview/

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	AUGUST 2014	NOT APPLICABLE
1	JULY 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFCS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	NOVEMBER 2016	ADDED ADDITIONAL INFORMATION REGARDING PFAS.
3	JANUARY 2020	TRC RE-BRANDING; ADDED FIELD BLANKS TO SECTION 4
4	AUGUST 2020	ADDITIONAL PFAS-SPECIFIC INFORMATION INCLUDED

Attachment A:

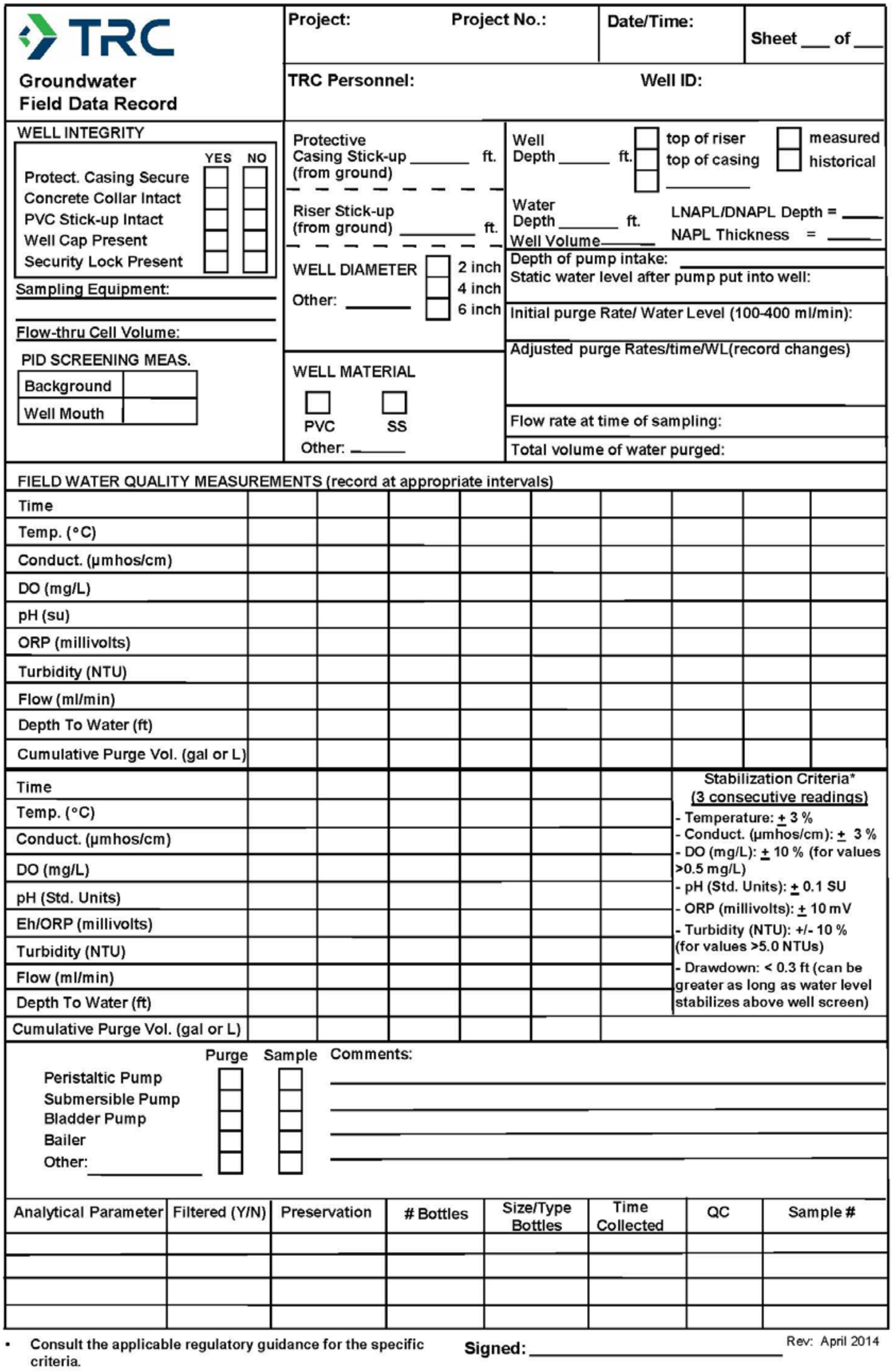
Groundwater Field Parameter Stabilization Criteria for Selected Jurisdictions

Jurisdiction	Information Source	Applicable Stabilization Criteria
USEPA Region 1	Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells; U.S. Environmental Protection Agency Region 1, January 19, 2010. http://www.epa.gov/region1/lab/qa/pdfs/EQASOP-GW001.pdf (for low flow PDF) http://www.epa.gov/region1/lab/qa/qualsys.html (for EPA's Quality System Documents)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: ±3% Turbidity: ±10% if >5 NTUs; if three Turbidity values are <5 NTU, consider the values as stabilized Dissolved Oxygen: ±10% if >0.5 mg/L, if three Dissolved Oxygen values are <0.5 mg/L, consider the values as stabilized Oxidation/Reduction Potential: ±10 millivolts
USEPA Region 2	Groundwater Sampling Procedure: Low Stress (Low Flow) Purging and Sampling, SOP # SST-7, Revision No. 1, November 2010.	Same as above
USEPA Region 4	USEPA Region 4 SOPs: http://www.epa.gov/region4/sesd/fbqstp/index.html See Chemical Parameter Stabilization Criteria (section 3.2.1.1.2 of Groundwater Sampling SOP, revision 3/6/2013: http://www.epa.gov/region4/sesd/fbqstp/Groundwater-Sampling.pdf	pH: ±0.1 unit Specific Conductance: ±5% Temperature: Not used Turbidity: "Stabilized" (no criteria specified) if >10 NTUs ; if three Turbidity values are <10 NTUs, consider the values as stabilized Dissolved Oxygen (optional parameter): ±0.2 mg/L or ±10% of saturation, whichever is greater Oxidation/Reduction Potential: Not used
USEPA Region 5	Ground Water Forum Issue Paper (May 2002, Yeskis and Zavala) http://www.epa.gov/superfund/remedytech/tsp/download/gw_sampling_guide.pdf A minimum set of parameters would include pH, conductivity, and turbidity or DO. Puls and Barcelona, 1996 (pH, specific conductance, ORP, turbidity) Wilde et al., 1998 (pH, turbidity, DO)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: Not used Turbidity: ±10% if >10 NTUs Dissolved Oxygen: ±0.3 mg/L Oxidation/Reduction Potential: ±10 millivolts
USEPA Region 9	See USEPA Region 1 (above)	
USEPA Region 10	See USEPA Region 5 (above)	
Alabama	Alabama Environmental Investigation and Remediation Guidance (section C.3.1) http://www.adem.state.al.us/MoreInfo/pubs/AEIRGInvestigation.pdf	pH: ±0.1 unit Specific Conductance: ±10% Temperature: "Constant" (no criteria specified) Turbidity: Stabilized (no criteria specified), or <10 NTUs Dissolved Oxygen: No criteria specified Oxidation/Reduction Potential: No criteria specified

Jurisdiction	Information Source	Applicable Stabilization Criteria
Indiana	Indiana Department of Environmental Management The Micro-Purge Sampling Option http://www.in.gov/idem/files/remediation_tech_guidance_micro-purge.pdf The parameters normally measured for stability (listed in increasing order of sensitivity) are pH, temperature, specific conductivity, oxidation-reduction potential, DO and turbidity. At least one of the last three listed must be used.	pH: ±0.1 unit Specific Conductance: ±3% Temperature: ±3% Turbidity: ±10% Dissolved Oxygen: ±10% Oxidation/Reduction Potential: ±10 millivolts (document says microvolts, but that may be an error)
Michigan	MDEQ Part 201 Op Memo 2, Attachment 5 http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_2_Attachment5_249853_7.pdf	No specific values to determine stabilization are listed, but the Op Memo lists several other groundwater sampling guidance documents. If a valid reference exists, then it can be used to justify a sampling approach and stabilization parameters.
New Jersey	New Jersey Department of Environmental Protection http://www.state.nj.us/dep/srp/guidance/fspm/	pH: ± 0.1 unit Specific Conductance: ± 3% Temperature: ± 3% Dissolved Oxygen: ± 10% Turbidity: ± 10% for values greater than 1 NTU ORP/Eh: ± 10 millivolts
Ohio	Ohio EPA SOPs: http://www.epa.state.oh.us/portals/30/rules/FSOPs.pdf See Purging Stabilization Criteria (SOP 2.2.4, dated January 2, 2007, review in progress)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: No criteria specified Turbidity: Below 10 NTUs ideal; ±10% if greater than 10 NTUs Dissolved Oxygen: ±0.3 mg/L Oxidation/Reduction Potential: ±10 millivolts
This table was last updated in July 2014.		

Attachment B:

Example Groundwater Field Data Records



TRC

Groundwater Field Data Record

Project: **Project No.:** **Date/Time:** **Sheet ___ of ___**

TRC Personnel: **Well ID:**

WELL INTEGRITY

	YES	NO
Protect. Casing Secure	☐	☐
Concrete Collar Intact	☐	☐
PVC Stick-up Intact	☐	☐
Well Cap Present	☐	☐
Security Lock Present	☐	☐

Sampling Equipment: ____________

Flow-thru Cell Volume: ____________

PID SCREENING MEAS.

Background	
Well Mouth	

Protective Casing Stick-up (from ground) ________ ft.

Riser Stick-up (from ground) __________ ft.

WELL DIAMETER ☐ 2 inch ☐ 4 inch ☐ 6 inch
Other: ________

WELL MATERIAL
☐ PVC ☐ SS
Other: ______

Well Depth ______ ft. ☐ top of riser ☐ top of casing ☐ __________ ☐ measured ☐ historical

Water Depth _______ ft.

LNAPL/DNAPL Depth = _____
NAPL Thickness = ______

Well Volume______

Depth of pump intake: ____________

Static water level after pump put into well:

Initial purge Rate/ Water Level (100-400 ml/min):

Adjusted purge Rates/time/WL(record changes)

Flow rate at time of sampling:

Total volume of water purged:

FIELD WATER QUALITY MEASUREMENTS (record at appropriate intervals)

Time									
Temp. (°C)									
Conduct. (µmhos/cm)									
DO (mg/L)									
pH (su)									
ORP (millivolts)									
Turbidity (NTU)									
Flow (ml/min)									
Depth To Water (ft)									
Cumulative Purge Vol. (gal or L)									

Time					
Temp. (°C)					
Conduct. (µmhos/cm)					
DO (mg/L)					
pH (Std. Units)					
Eh/ORP (millivolts)					
Turbidity (NTU)					
Flow (ml/min)					
Depth To Water (ft)					
Cumulative Purge Vol. (gal or L)					

Stabilization Criteria*
(3 consecutive readings)
- Temperature: + 3 %
- Conduct. (µmhos/cm): + 3 %
- DO (mg/L): + 10 % (for values >0.5 mg/L)
- pH (Std. Units): + 0.1 SU
- ORP (millivolts): + 10 mV
- Turbidity (NTU): +/- 10 % (for values >5.0 NTUs)
- Drawdown: < 0.3 ft (can be greater as long as water level stabilizes above well screen)

	Purge	Sample
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bladder Pump	☐	☐
Bailer	☐	☐
Other: ____________	☐	☐

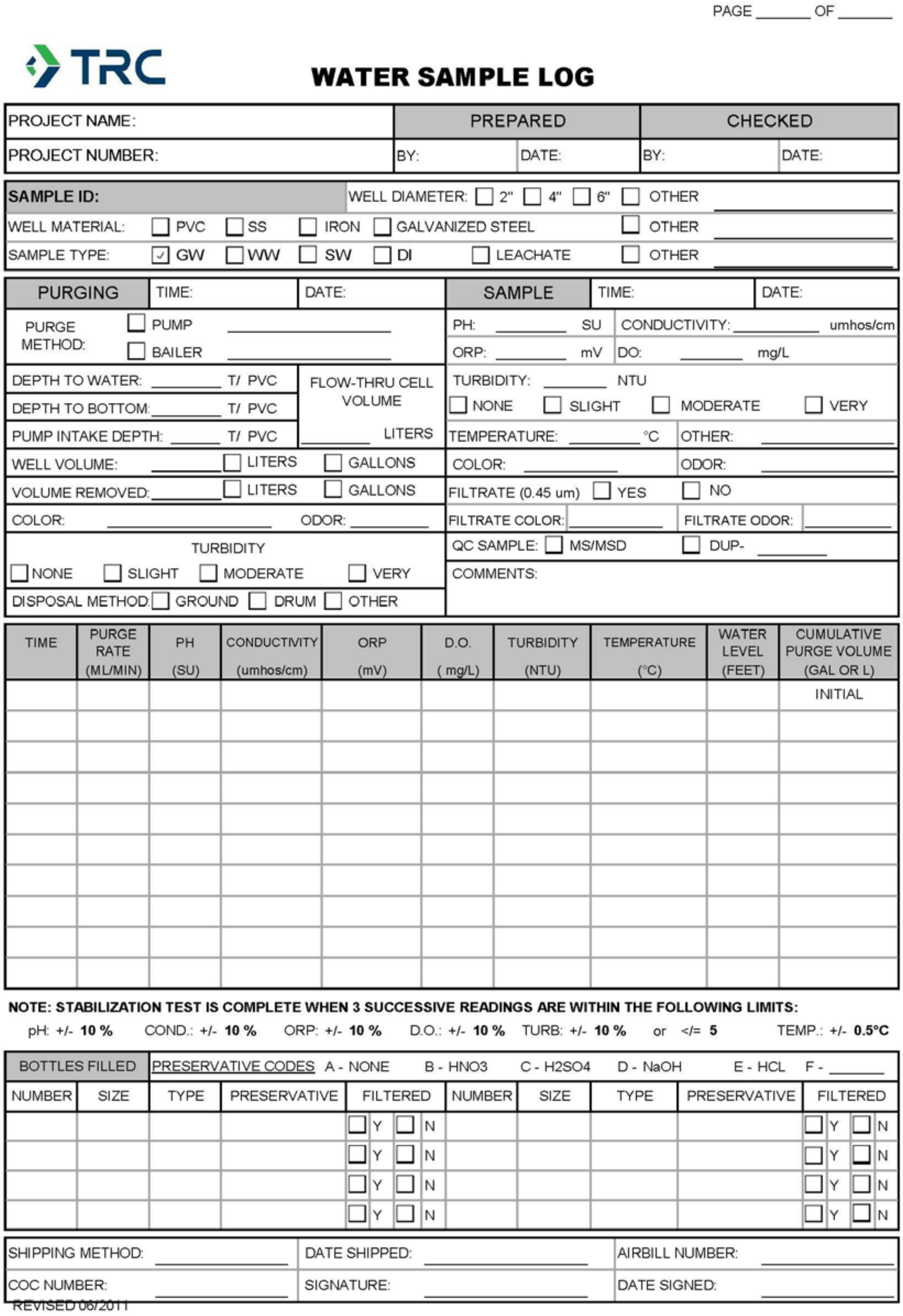
Comments:

Analytical Parameter	Filtered (Y/N)	Preservation	# Bottles	Size/Type Bottles	Time Collected	QC	Sample #

- Consult the applicable regulatory guidance for the specific criteria.

Signed: ____________________

Rev: April 2014



PAGE ______ OF ______

TRC

WATER SAMPLE LOG

PROJECT NAME:	PREPARED		CHECKED	
PROJECT NUMBER:	BY:	DATE:	BY:	DATE:

SAMPLE ID: WELL DIAMETER: ☐ 2" ☐ 4" ☐ 6" ☐ OTHER ____________

WELL MATERIAL: ☐ PVC ☐ SS ☐ IRON ☐ GALVANIZED STEEL ☐ OTHER ____________

SAMPLE TYPE: ☑ GW ☐ WW ☐ SW ☐ DI ☐ LEACHATE ☐ OTHER ____________

PURGING TIME: DATE:	SAMPLE TIME: DATE:
PURGE METHOD: ☐ PUMP ____________ ☐ BAILER ____________	PH: ________ SU CONDUCTIVITY: ________ umhos/cm ORP: ________ mV DO: ________ mg/L
DEPTH TO WATER: ________ T/ PVC DEPTH TO BOTTOM: ________ T/ PVC PUMP INTAKE DEPTH: ________ T/ PVC FLOW-THRU CELL VOLUME ________ LITERS	TURBIDITY: ________ NTU ☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY TEMPERATURE: ________ °C OTHER: ________
WELL VOLUME: ________ ☐ LITERS ☐ GALLONS	COLOR: ________ ODOR: ________
VOLUME REMOVED: ________ ☐ LITERS ☐ GALLONS	FILTRATE (0.45 um) ☐ YES ☐ NO
COLOR: ________ ODOR: ________	FILTRATE COLOR: ________ FILTRATE ODOR: ________
TURBIDITY ☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY	QC SAMPLE: ☐ MS/MSD ☐ DUP- ________
DISPOSAL METHOD: ☐ GROUND ☐ DRUM ☐ OTHER	COMMENTS:

TIME	PURGE RATE (ML/MIN)	PH (SU)	CONDUCTIVITY (umhos/cm)	ORP (mV)	D.O. (mg/L)	TURBIDITY (NTU)	TEMPERATURE (°C)	WATER LEVEL (FEET)	CUMULATIVE PURGE VOLUME (GAL OR L)
									INITIAL

NOTE: STABILIZATION TEST IS COMPLETE WHEN 3 SUCCESSIVE READINGS ARE WITHIN THE FOLLOWING LIMITS:

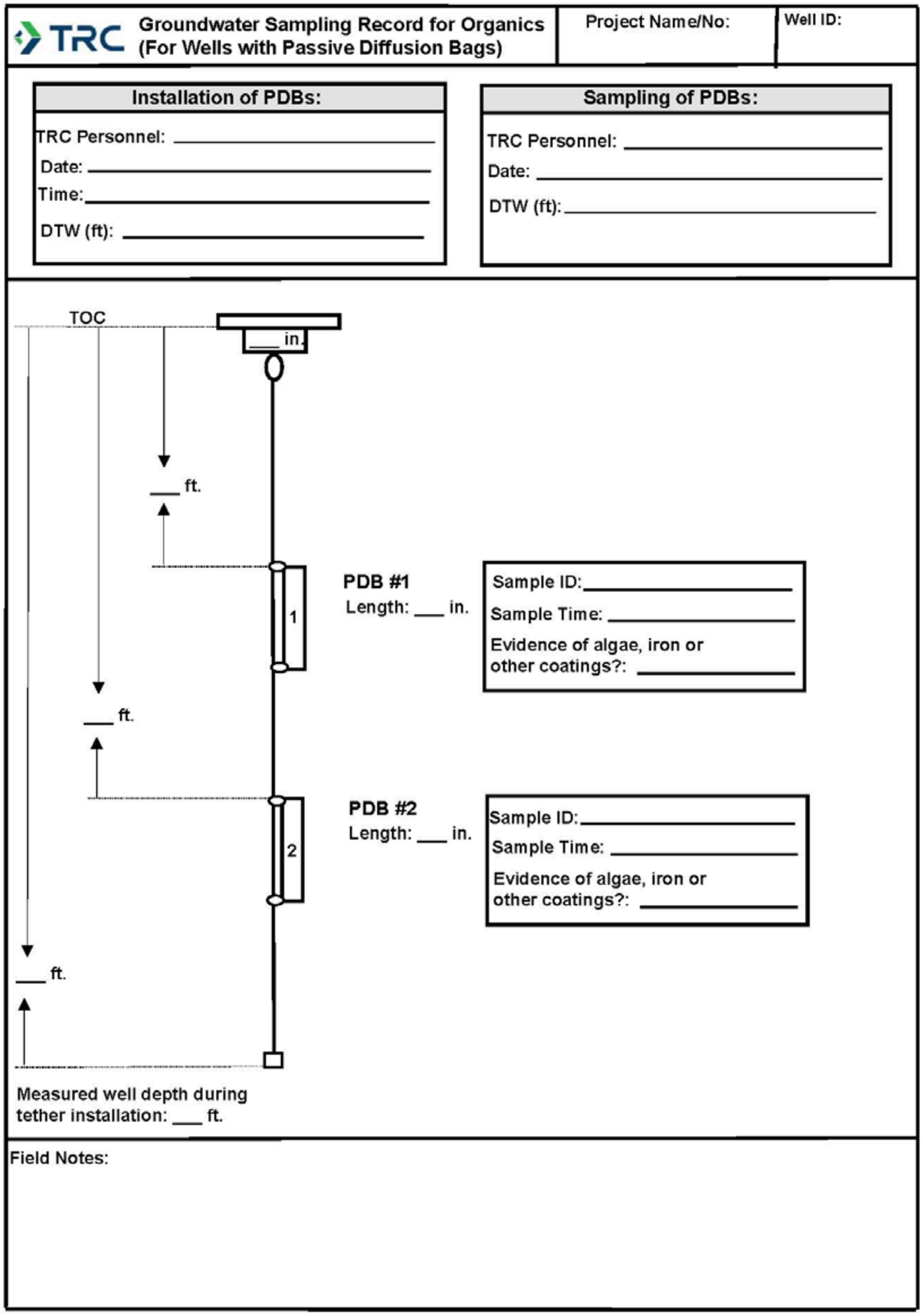
pH: +/- **10 %** COND.: +/- **10 %** ORP: +/- **10 %** D.O.: +/- **10 %** TURB: +/- **10 %** or </= **5** TEMP.: +/- **0.5°C**

BOTTLES FILLED — PRESERVATIVE CODES A - NONE B - HNO_3 C - H_2SO_4 D - NaOH E - HCL F - ________

NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N

SHIPPING METHOD: ____________	DATE SHIPPED: ____________	AIRBILL NUMBER: ____________
COC NUMBER: ____________	SIGNATURE: ____________	DATE SIGNED: ____________

REVISED 06/2011



Groundwater Sampling Record for Organics
(For Wells with Passive Diffusion Bags)

Project Name/No:

Well ID:

Installation of PDBs:

TRC Personnel: ____________________
Date: ____________________
Time: ____________________
DTW (ft): ____________________

Sampling of PDBs:

TRC Personnel: ____________________
Date: ____________________
DTW (ft): ____________________

TOC

___ in.

___ ft.

___ ft.

___ ft.

PDB #1
Length: ___ in.

1

Sample ID: ____________________
Sample Time: ____________________
Evidence of algae, iron or other coatings?: ____________

PDB #2
Length: ___ in.

2

Sample ID: ____________________
Sample Time: ____________________
Evidence of algae, iron or other coatings?: ____________

Measured well depth during tether installation: ___ ft.

Field Notes:

Rev: April 2014

Attachment C: SOP Fact Sheet

GROUNDWATER SAMPLING

PURPOSE AND OBJECTIVE

The objective of groundwater sampling is to obtain a representative sample of water from a saturated zone or groundwater-bearing unit (i.e., aquifer) with minimal disturbance of groundwater chemistry. This requires that the sample being collected is representative of groundwater within the formation surrounding the well bore as opposed to stagnant water within the well casing or within the filter pack immediately surrounding the well casing.

There are three general approaches to groundwater purging/sampling that can be used to obtain a representative groundwater sample for analysis: 1) the low-flow or micropurge method where the mixing of the stagnant water is minimized using low-flow pumping rates during the collection of the groundwater sample; 2) the multiple well volume removal approach in which the stagnant water is removed from the well and the filter pack prior to sample collection; and 3) the passive sampler procedure where water quality equilibration with the surroundings is achieved through deployment of the passive sampler for a sufficient amount of time prior to sampling. All three approaches are summarized in this document.

WHAT TO BRING

- Site-specific HASP and field book
- Project-specific work plan
- Figure or site map showing well locations and table showing well construction details
- Field data sheets from previous sampling event
- Well wrenches, ratchet set, and turkey baster to remove standing water from flushmount manholes
- Bolt cutters, padlocks and keys
- Water level meter of sufficient length
- Decontaminated pump, control box, power source (i.e., battery, generator, etc.)
- Tubing (Teflon®, Teflon®–lined polyethylene, or HDPE, type dependent upon project objectives)
- Multi-parameter instrument and flow-through cell (typically should include: pH, temperature, conductivity, ORP, and DO)
- Turbidity meter
- Equipment decontamination supplies (refer to ECR SOP 010, *Equipment Decontamination*)
- Appropriate PPE
- Field book
- Sample bottleware, labeled cooler, ice, temperature blank and blank COC forms; may also need field blank bottles and reagent-grade water
- Zip-loc® plastic bags
- Groundwater field data records
- Graduated cylinder and stop-watch
- Rope for tying off pump at desired intake
- Indelible marking pens
- Bubble wrap
- 5-gallon bucket(s)

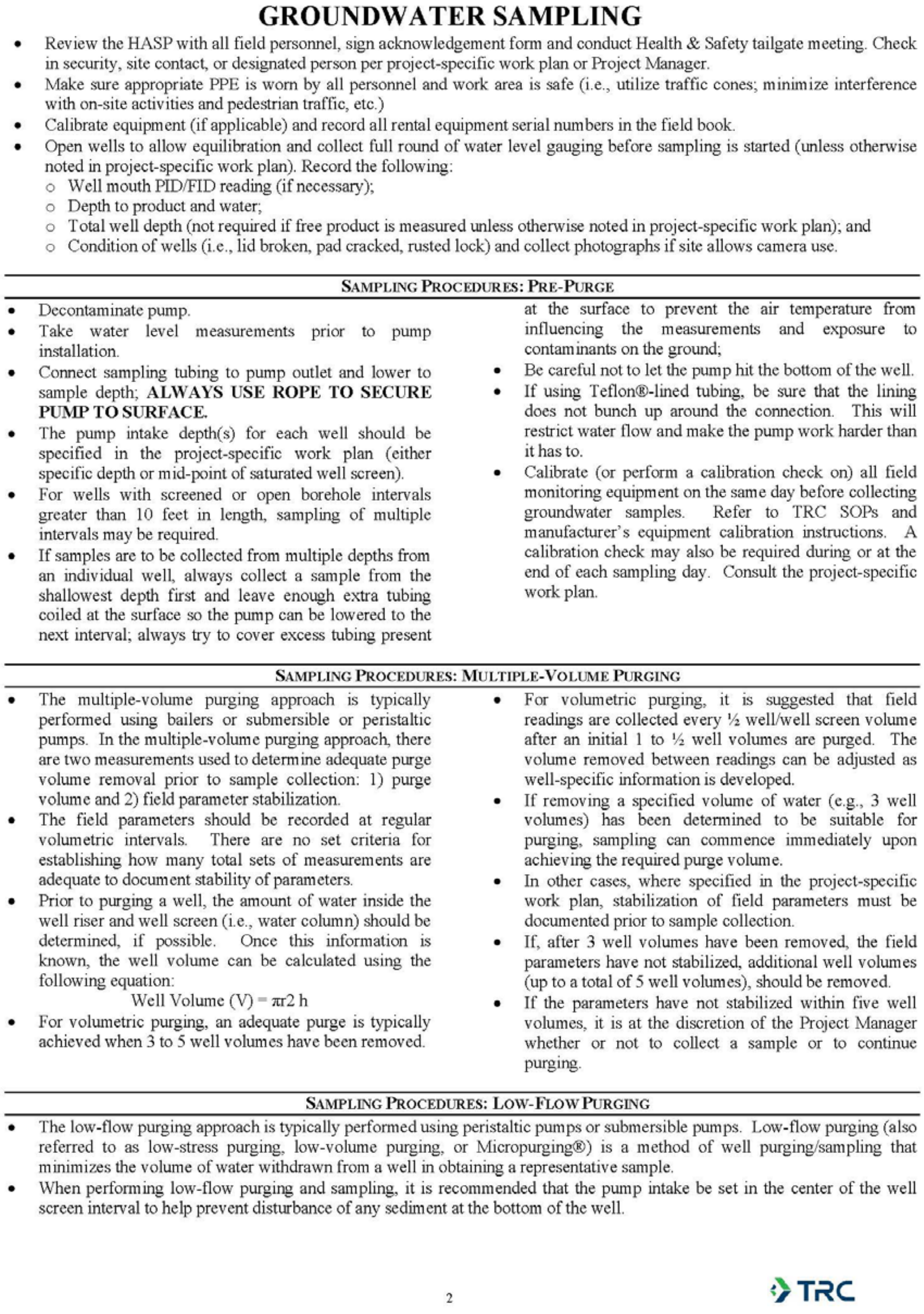
As Needed:

- Calibrated PID or FID for well mouth readings
- Oil/water interface probe of sufficient length
- Drums for purge water, grease pen and adhesive drum labels; appropriate crescent or socket wrench
- Filtration equipment, if required (0.45 micron filters, or as otherwise required for the project)
- Other non-routine PPE such as Tyvek coveralls or respirators
- Traffic cones
- Field calibration sheets and calibration solutions

OFFICE

- Prepare/update the site-specific HASP; make sure the field team is familiar with the most recent version.
- Review the project-specific work plan with the Project Manager and/or the field team leader. Discuss the following:
  - Communication procedures;
  - Sampling order and designation;
  - Collection and sample method;
  - Analytical parameters, holding times and turn-around times;
  - Laboratory (contact/shipping info, COC, billing references);
  - Purge water management (Drums? Discharge to ground?);
  - QC sample collection; and
  - Decontamination procedures.
- Verify that monitoring wells will be accessible and/or coordinate to have a site contact available to assist.
- Make sure that monitoring well sample designations and QC sample designations/frequency are understood.
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure or mobilization to site, test equipment and make sure it is in proper working order. Have rental equipment supplier contact information available for use in field.
- Review sample bottle order for accuracy and completeness and damaged bottles.
- Discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager

ON-SITE



GROUNDWATER SAMPLING

- Review the HASP with all field personnel, sign acknowledgement form and conduct Health & Safety tailgate meeting. Check in security, site contact, or designated person per project-specific work plan or Project Manager.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities and pedestrian traffic, etc.)
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.
- Open wells to allow equilibration and collect full round of water level gauging before sampling is started (unless otherwise noted in project-specific work plan). Record the following:
  - Well mouth PID/FID reading (if necessary);
  - Depth to product and water;
  - Total well depth (not required if free product is measured unless otherwise noted in project-specific work plan); and
  - Condition of wells (i.e., lid broken, pad cracked, rusted lock) and collect photographs if site allows camera use.

SAMPLING PROCEDURES: PRE-PURGE

- Decontaminate pump.
- Take water level measurements prior to pump installation.
- Connect sampling tubing to pump outlet and lower to sample depth; **ALWAYS USE ROPE TO SECURE PUMP TO SURFACE.**
- The pump intake depth(s) for each well should be specified in the project-specific work plan (either specific depth or mid-point of saturated well screen).
- For wells with screened or open borehole intervals greater than 10 feet in length, sampling of multiple intervals may be required.
- If samples are to be collected from multiple depths from an individual well, always collect a sample from the shallowest depth first and leave enough extra tubing coiled at the surface so the pump can be lowered to the next interval; always try to cover excess tubing present at the surface to prevent the air temperature from influencing the measurements and exposure to contaminants on the ground;
- Be careful not to let the pump hit the bottom of the well.
- If using Teflon®-lined tubing, be sure that the lining does not bunch up around the connection. This will restrict water flow and make the pump work harder than it has to.
- Calibrate (or perform a calibration check on) all field monitoring equipment on the same day before collecting groundwater samples. Refer to TRC SOPs and manufacturer's equipment calibration instructions. A calibration check may also be required during or at the end of each sampling day. Consult the project-specific work plan.

SAMPLING PROCEDURES: MULTIPLE-VOLUME PURGING

- The multiple-volume purging approach is typically performed using bailers or submersible or peristaltic pumps. In the multiple-volume purging approach, there are two measurements used to determine adequate purge volume removal prior to sample collection: 1) purge volume and 2) field parameter stabilization.
- The field parameters should be recorded at regular volumetric intervals. There are no set criteria for establishing how many total sets of measurements are adequate to document stability of parameters.
- Prior to purging a well, the amount of water inside the well riser and well screen (i.e., water column) should be determined, if possible. Once this information is known, the well volume can be calculated using the following equation:

  Well Volume (V) = πr2 h
- For volumetric purging, an adequate purge is typically achieved when 3 to 5 well volumes have been removed.
- For volumetric purging, it is suggested that field readings are collected every ½ well/well screen volume after an initial 1 to ½ well volumes are purged. The volume removed between readings can be adjusted as well-specific information is developed.
- If removing a specified volume of water (e.g., 3 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume.
- In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection.
- If, after 3 well volumes have been removed, the field parameters have not stabilized, additional well volumes (up to a total of 5 well volumes), should be removed.
- If the parameters have not stabilized within five well volumes, it is at the discretion of the Project Manager whether or not to collect a sample or to continue purging.

SAMPLING PROCEDURES: LOW-FLOW PURGING

- The low-flow purging approach is typically performed using peristaltic pumps or submersible pumps. Low-flow purging (also referred to as low-stress purging, low-volume purging, or Micropurging®) is a method of well purging/sampling that minimizes the volume of water withdrawn from a well in obtaining a representative sample.
- When performing low-flow purging and sampling, it is recommended that the pump intake be set in the center of the well screen interval to help prevent disturbance of any sediment at the bottom of the well.

GROUNDWATER SAMPLING

- To begin purging, the pump should be started at the lowest pressure/power flow rate setting (e.g., 100 mL/min) and then slowly increased until water begins discharging. Monitor the water level and slowly adjust the pump speed until there is little or no drawdown or drawdown has stabilized. The pump pressure/power may need to be increased for discharge to occur.
- The stabilization of drawdown should be documented. Measure and record the flow rate and water level every 3 to 5 minutes during purging. The flow rate should be reduced if drawdown is greater than 0.3 feet over three consecutive 3 to 5 minute interval readings.
- Attempts should be made to avoid pumping a well dry.

Field Parameter Stabilization During Purging

- ○ Generally, an adequate purge with respect to the groundwater chemistry is achieved when stability for at least three consecutive measurements is achieved. See stability requirements in Appendix A of this SOP.

POST-PURGE GROUNDWATER SAMPLE COLLECTION

- New, disposable gloves should be donned immediately prior to sample collection and should be changed at any point that their cleanliness becomes compromised during sample collection.
- If using a submersible or peristaltic pump, maintain the same flow rate as used during purging. Disconnect the pump tubing from the flow-through cell. Samples must be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. This is critically important to avoid cross-contamination between wells.
- If using bottom-filling bailers, slowly lower the bailer into the well until it is submerged to the point where water does not enter the top (i.e., bottom-filling). Retrieve the bailer. The first bailer recovered after well purging must be used for sample collection.
- Collect groundwater samples in the following order:
  - ○ VOCs;
  - ○ SVOCs;
  - ○ Other organic parameters;
  - ○ Unfiltered inorganic constituents; and
  - ○ Filtered inorganic constituents.
- Note that sample vials for VOCs must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, see Section 2.3.2 of this SOP.
- Preserve the non-VOC samples in pre-preserved vials supplied by the laboratory or if the sample containers are not pre-preserved, preserve the non-VOC samples in accordance with method and project-specific requirements.
- Depending upon project requirements, filtering may be performed. See procedures listed in Section 2.3.4 of this SOP. Clearly note “filtered” on the sample label and the COC.
- Make sure all sample bottles are appropriately labeled.
- Package the samples with bubble wrap and/or organic absorbent, as necessary. Place into shipping container and cool to 4°C and complete the COC.
- Decontaminate non-disposable sampling equipment between uses.

PASSIVE SAMPLING

- There are three generic forms of passive (no purge) samplers: thief (grab) samplers, diffusion (equilibrium) samplers, and integrating (kinetic) samplers. However, this SOP focuses on the more commonly used diffusion (equilibrium) samplers. Be aware of sample holding times, and arrange for samples to be in the laboratory’s possession accordingly.
- Passive samplers are deployed at a predetermined depth across the well screen. Typically, the initial sampling event may deploy multiple passive samplers across 5-foot intervals of saturated well screen to observe any potential stratification. Long-term sampling depths typically target a zone of higher concentration, if present.
- New passive samplers are attached via PVC cable ties to a tether (pre-made marine-grade polyethylene rope or stainless steel cable with a weight at the bottom) that is then suspended within the well.
- The passive sampler should be allowed to equilibrate with groundwater for an appropriate period of time (e.g., at least 2 weeks for PDB samplers).
- Raise the passive sampler to the surface using a tether reel. Examine the surface of the passive sampler for evidence of algae, iron, or other coatings, and for tears to the membrane. Note observations in the field book. If tears are present and water is leaking out, the sample is not considered viable. Contact the Project Manager.
- Detach the passive sampler from the tether.
- Remove excess beaded water from the passive sampler with a clean gloved hand, running top to bottom; this is to minimize the contact of beaded water with water in the passive sampler.

GROUNDWATER SAMPLING

- Use a small diameter discharge tube (<0.15 inch diameter to reduce volatilization) and pierce near the bottom, allowing water to smoothly flow into the VOA vial. The VOA vials must be filled within the first several minutes of passive sampler retrieval.
- A small amount of water may remain within the passive sampler after filling the VOA vials and can be used for field parameter measurements if required.
- Dispose of the passive sampler after use.
- Note that sample vials for VOCs must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, see Section 2.3.2 of this SOP.
- Make sure all sample bottles are appropriately labeled.
- Package the samples with bubble wrap and/or organic absorbent, as necessary. Place into shipping container and cool to 4ºC and complete the COC.

DOs AND DO NOTs OF GROUNDWATER PURGING AND SAMPLING

DOs:

- DO have the following items when going into the field: site-specific work plan; site-Specific HASP; appropriate PPE (steel-toed boots, safety glasses, etc.) as required by the Site-Specific HASP; field book and a water-proof ball-point pen; business cards; nitrile gloves; well keys; copies of well installation forms and field data forms from previous sampling event.
- DO make sure that the equipment is set up properly and the bottleware is nearby and ready to be filled. There is little time between taking parameters.
- DO look at the water quality parameters from the previous round of sampling. If there is a large deviation from the previous round's measurements, make sure the meters are properly calibrated and the parameter units are the same. Otherwise, consult the Project Manager or field team leader.
- DO fill sample bottles slowly to make sure that they are not overfilled and that preservative does not become diluted. If collecting filtered samples, fill all non-filtered first, then fill filtered samples - if water is very silty, more than one filter might be required to fill sample bottles.
- DO record the time that purging begins and ends. "Purge Stop" and sample start time are the same.
- DO call your Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them. It is also recommended to call when sampling is winding down for the day to make sure that the project-specific work plan has been fully implemented and there are no additional tasks to complete. Provide shipping tracking numbers to the Project Manager and laboratory contact.
- DO have the numbers for laboratory, vehicle rental and equipment rental providers readily available while in the field.
- DO record sample locations and parameters in the field book and the Groundwater Field Data Records as you purge.
- DO check on the purging setup frequently to make sure proper equipment function is maintained.
- DO bring ice to the site in the morning so that samples are kept cool throughout the entire event. Storing samples in a warm cooler can invalidate sample results and may result in re-sampling on your own time.

DO NOTs:

- DO NOT sign anything in the field. This includes disposal documentation, statements, etc.; call the Project Manager if this is an issue.
- DO NOT allow the pump or sampling equipment to hit the bottom of the well - If the pump hits the bottom of the well, it can stir up mud. Remember, the goal of low-flow sampling is to collect non-turbid samples.
- DO NOT use non-indelible ink to label samples or record field notes – if the field book gets wet, notes become illegible.
- DO NOT leave air bubbles in VOA vials.
- DO NOT pour any extracted water back down into the well.
- DO NOT lean over wells with pens, keys, cell phones, tools, etc. in your pocket.
- DO NOT use clear tape to cover labels on certain analyses (e.g., 40-mL vials for VOC analysis) due to potential interference with analytical equipment.

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Attachment D: SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® or low density polyethylene (LDPE)[1] during sample handling or mobilization/demobilization. This includes bailers, tubing, bladders, bailer cord/wire, waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. High density polyethylene (HDPE) or silicone tubing should be used in lieu of Teflon® or Teflon®-lined tubing. • Passive diffusion bags (PDBs) should not be used due to the presence of LDPE material in PDBs. • Blue Ice® (chemical ice packs) must not be used to cool samples or be used in sample coolers. Regular ice in Ziploc® bags can be used. • Do not use LDPE or glass sample containers or containers with Teflon-lined lids. HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. • Do not use aluminum foil. • Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-It Notes during sample handling or mobilization/demobilization. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to field preparation during PFAS sampling: • Tyvek® suits should not be worn during PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
	• Personnel involved with sample collection and handling should wear nitrile gloves at all times while collecting and handling samples or sampling equipment. Avoid handling unnecessary items with nitrile gloves. A new pair of gloves must be donned prior to collecting each sample. • Wash hands with Alconox or Liquinox and deionized water after leaving vehicle before setting up to sample a well.
1.6.1	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering on the day of sampling. • Avoid using sunscreens or insect repellants that are not natural or chemical free.
1.6.2	• Consider collecting samples for total suspended solids which will become important for fate and transport and treatment considerations. Floc accumulates high concentrations of PFAS and specifically some of the longer-chain PFAS; when this floc settles out, concentrations can decrease by an order of magnitude. • Low-flow sampling is preferred for PFAS sampling. Bailers should be avoided due to the potential for PFAS to accumulate at the air/water interface. If bailers need to be used, purging of at least one well volume should be performed to remove static surface conditions. • If sampling for parameters other than PFAS, perform PFAS sampling first. Schedule PFAS sampling at the beginning of the work day to avoid other sources of contamination.
2.0	• Monitoring wells should always be sampled from the lowest contamination to the highest contamination, when possible. In source areas, if deep wells are anticipated to be less contaminated, the deep wells should be sampled prior to sampling the shallow wells to avoid cross-contamination from sampling equipment.
2.2.5	Tubing used to purge and sample groundwater for PFAS must not be LDPE or Teflon®. HDPE and silicone are acceptable.
2.3 and 2.3.3	LDPE and/or glass containers should not be used for sampling. Teflon®-lined caps should also not be used during sample collection. Instead, HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable.
2.4	Due to LDPE material in PDBs, PDBs cannot be used for PFAS sampling.
2.5 (e)	Avoid using waterproof labels for sample bottles. The use of paper labels covered with clear tape or placed in Ziploc® bags to avoid moisture on the sample label is acceptable.
2.5 (f)	Samples for PFAS analysis must be shipped at <10°C. Standard coolers are acceptable. Keep high-concentration PFAS samples in separate coolers from low-concentration PFAS samples.

Notes:

[1] – PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces and, in the case of LDPE tubing, to allow for less turbulent flow along the surface of the tubing.

02

Soil Sampling (Includes SOP for PFAS)

Title: **Soil Sampling**	Procedure Number: **ECR 003**
	Revision Number: **04**
	Effective Date: **February 2022**

Authorization Signatures

Technical Reviewer Date Chelsea Wenhardt 2/21/2022	SOP Work Group Co-Lead Date Ryan Jorrey 2/21/2022

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LIST OF ATTACHMENTS

Attachment A	Procedure for Collection of Samples for VOCs, VPH, or GRO (SW-846 Method 5035A)
Attachment B	Shipping Methanol-preserved Samples
Attachment C	SOP Fact Sheet
Attachment D	SOP Modifications for PFAS
Attachment E	Explanation of Subsurface Sampling Technologies

1.0 INTRODUCTION

1.2 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the logistics, collection techniques, and documentation requirements for collecting representative soil samples for chemical analysis. These are standard (i.e., typically applicable) operating procedures that may be changed, as required, depending on site conditions, equipment limitations, or limitations imposed by the procedure. In addition, other state or federal requirements may be above and beyond the scope of this SOP and will be followed, if applicable. In all instances, the actual procedures used should be documented and described in the field notes (see ECR SOP-001). Portions of this SOP may be applicable to soil sample collection for geotechnical analysis. However, specific instructions for collection of geotechnical samples are not provided; these samples should be collected in accordance with ASTM methods or other applicable standards.

1.3 Summary of Method

The objective of soil sampling is to obtain a representative sample of soil for laboratory analysis of constituents of interest at a given site. This objective requires that the sample be of sufficient quantity and quality for analysis by the selected analytical method. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details. Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be sampled using a spade, trowel, and/or scoop. Sampling at greater depths typically is performed using a hand auger, continuous flight auger, a split-spoon, direct-push methods (i.e., Geoprobe®), sonic drilling, a backhoe, or an excavator. The following reference may be used as a guide to aid in selecting an appropriate method or sampling device for the collection of subsurface soil samples with a drill rig: ASTM D6169–98 *Standard Guide for Selection of Soil and Rock Sampling Devices Used with Drill Rigs for Environmental Investigation*.

1.4 Equipment

The following equipment may be utilized when collecting soil samples. Project-specific conditions or laboratory requirements may warrant the addition or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP).
- Sample containers: The proper containers should be determined in conjunction with the analytical laboratory in the planning stages of the project, and will depend on the analytical program, laboratory SOPs, and regulatory requirements.

  For non-volatile organic compound (VOC) parameters, glass containers with Teflon®-lined caps are typically utilized. Typical containers used for VOC parameters are provided in Attachment A. Brass liners, steel liners, or soil core acetate liners with Teflon® tape and plastic end caps may also be used.
- Stainless steel mixing bowl or new aluminum pie pan.

- Stainless steel spoon or spatula or sterile individually wrapped single use scoop.
- Plastic bowl or plastic resealable bag for inorganics.
- Hand auger, mud auger, sand auger, bucket auger, and/or T-handle.
- Post hole auger.
- Extension rods.
- Stainless steel trowel.
- Shovel.
- Applicable field screening equipment with calibration solution/gas [i.e., pH meter, photoionization detector (PID), flame ionization detector (FID), etc.].
- Tape measure or folding ruler.
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags.
- Field book/field notes and/or boring log.
- Sample container labels.
- Chain-of-custody (COC) forms (TRC or laboratory, as appropriate).
  - Custody seals for sample coolers.
  - Tape to secure sample coolers and sample container labels (if necessary).
- Camera.
- Maps/site plan.
- Survey equipment, global positioning system (GPS), or other means of measuring sample locations.
- Indelible marking pens or markers.
- Organic absorbent material (e.g., Slickwick, ground corn cob, sawdust).
- Sample coolers.
- Bubble wrap.
- Ice (for sample storage/preservation).
- Zip-loc® plastic bags (for ice and COCs).
- Equipment decontamination supplies (see ECR SOP-010).

1.5 Definitions

Composite sample	Composed of two or more grab samples collected over a period of time or space during a single sampling event and mixed together.
En-Core® sampler	A disposable volumetric sampling device with an airtight sealing cap.
Grab sample	Individual discrete sample collected at a particular time.

High-level VOC analysis	VOC soil analysis that yields high reporting limits (approximately 50-200 µg/kg, depending on the laboratory). Samples are typically preserved in methanol and cooled to 4°C. High-level VOC analyses are used for samples that are expected to contain elevated concentrations of VOCs (>200 µg/kg).
Low-level VOC analysis	VOC soil analysis that yields low reporting limits (approximately 5 µg/kg, depending on the laboratory). Samples are typically preserved in water, cooled to 4°C, and can be frozen within 48 hours of collection. Low-level VOC analyses are used for samples that are expected to contain lower concentrations of VOCs (≤200 µg/kg).
Terra Core™ sampler	A disposable volumetric sampling device used to transfer soil samples to the appropriate sample containers.

1.6 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE, as defined in the HASP.

Soil samples containing chemical contaminants may be handled during implementation of this SOP. Additionally, sample preservatives including caustics and/or acids may be considered hazardous materials and TRC employees will appropriately handle and store them at all times. The HASP will address chemicals that pose specific toxicity or safety concerns and TRC employees will follow relevant requirements, as appropriate. Hazardous substances may be incompatible or may cause dangerous chemical reactions, including the production of heat, violent reactivity, or production of toxic vapors or other byproducts. Hazardous substances may be incompatible with clothing or equipment; some substances can permeate or degrade protective clothing or equipment. Also, hazardous substances may pose a direct health hazard to workers through inhalation or skin contact or if exposed to heat/flame resulting in combustion. Safety data sheets (SDS) for chemicals handled by TRC should be maintained in the field.

1.7 Cautions and Potential Problems

- Cross contamination: Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary.

- Improper sample collection: Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

- Special considerations for the different soil sampling techniques are provided below in the applicable sections. Cautions and potential problems associated with soil sampling for VOCs are provided in Attachment A.

- Special care should be taken when sampling for PFAS. Please refer to Attachment D for details.

1.8 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Always review the site-specific work plan and/or scope of work for any site-specific sampling procedures.

2.2 Pre-Sampling Activities

Pre-sampling activities that the sampling team should consider include the following:

- reviewing the work plan approved by the client and/or regulatory agency;
- developing a strategy to implement the work plan
- selecting a laboratory; and
- determining laboratory-specific procedures related to bottle orders, holding times, work orders, methods of analysis, COC procedures, data deliverables, schedule, and cost.

Additional activities include determining shipping logistics, utility clearance, and handling of investigation-derived waste (IDW) disposal. Pre-labeling bottles can help to reduce sampling and labeling errors.

The following steps should also be employed:

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.

2. Obtain necessary sampling and monitoring equipment.

3. Decontaminate or clean equipment and ensure that it is in working order.

4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site-specific HASP.

6. Use stakes, flagging, or paint, to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminants, should be considered when selecting sample locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

   NOTE: If spray paint is used to mark stakes, the spray paint should be carefully isolated from the space used to hold sample bottles, sampling equipment, etc.

7. Prior to any subsurface soil sampling, especially that completed with a drill rig or backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities by conducting a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to sampling. Client or project-specific utility clearances may also be required, such as air-knifing or ground-penetrating radar (GPR) and should be specified in the site-specific work plan.

2.3 General Soil Sampling Procedures

These are general soil sampling procedures. However, regulatory requirements may dictate a different procedure.

1. Refer to other TRC SOPs for the proper procedures for classifying soil samples (ECR SOP 005) and for screening of samples for VOCs (ECR SOP 014). Special care is required when sampling for PFAS - Please refer to Attachment D for details.

2. **For sampling in the State of California only:** When the sampling interval is predetermined and soil samples are collected by direct-push methods into an acetate liner, the section of the liner corresponding to the predetermined depth interval may be cut off and submitted to the laboratory for analysis with the exception of samples for VOC, volatile petroleum hydrocarbon (VPH), or gasoline-range organics (GRO) analysis. If VOC, VPH, or GRO analysis is required, then these samples can be collected from either open end of the acetate liner section according to the procedures outlined in Attachment A prior to packaging and submitting it to the laboratory. The laboratory should be consulted for the required length of liner tube (i.e., sample volume) depending on the analytical suite and to ensure that the use of acetate liners is appropriate for the analytical method(s). After collecting material for the VOC, VPH, or GRO analysis samples (if required), seal each end of the acetate liner section with Teflon tape and plastic end caps. Label the acetate liner with the sample identification (ID) and date and time of collection. Ensure that the laboratory will perform homogenization of the soil sample within the acetate liner and proceed to Step #9.

3. Prior to the collection of soil samples from a particular location or depth, the soil is typically screened for organic vapors with a portable meter equipped with a FID and/or PID depending upon the suspected contaminants of concern, site-specific work plan requirements, and/or regulatory requirements. Such organic vapor screening may be used to determine appropriate soil sample locations or depths for laboratory VOC analysis depending upon established site-specific work plan requirements. Soil should be screened *in situ* or immediately upon retrieval of the soil sample from the subsurface. It is good practice to photograph surface soil, stockpiles, etc. prior to sample collection with measurements and orientation identified for reference.

4. Samples for VOC, VPH, or GRO analysis are then collected as soon as possible after the soil has been exposed to the atmosphere and prior to sample collection for other analyses. Refer to Attachment A.

5. After collecting the sample(s) for VOC analysis, the sample portion for the remaining analyses should be well homogenized in a decontaminated stainless-steel bowl, disposable new aluminum pie pan, plastic bowl (for inorganics), or re-sealable plastic bag (for inorganics). These soil samples must be thoroughly mixed to ensure that the sample is uniform and as representative as possible of the sample media. Samples for VOC analysis are not homogenized. The most common method of mixing is referred to as quartering. The quartering procedure should be performed as follows:
    - The material in the sample pan should be divided into quarters and each quarter should be mixed individually.
    - Two quarters should then be mixed to form halves.
    - The two halves should be mixed to form a homogenous matrix.

   This procedure should be repeated several times until the sample is adequately mixed. If round bowls are used for sample mixing, adequate mixing is achieved by stirring the material in a circular fashion, reversing direction, and occasionally turning the material over. Soil can be homogenized and transferred to sample containers using soil sampling devices that have been decontaminated (e.g., stainless steel spoon) prior to use or individually wrapped or new devices (e.g., plastic scoopula). Such devices are generally for one-time use. Stainless steel devices may be decontaminated and individually foil wrapped, plastic bagged, or field decontaminated and foil wrapped between uses. Decontamination of sampling equipment shall be conducted in accordance with TRC's SOP on equipment decontamination.

6. Stones, gravel, or vegetation should be removed from the soil sample as much as practical prior to placement in sample containers, since these materials will not be analyzed. Visible asphalt, concrete, ash, slag, and coal debris should also be removed from the sample as much as possible to ensure sufficient soil quantity for laboratory analyses, unless these matrices are part of the overall characterization program. The soil sample must be representative of what the end user is trying to characterize. In addition, if such debris is to be tested, further sample preparation (e.g., pulverizing) will likely be necessary in the field or laboratory. In any case, the presence of any such materials in the soil at the sample location must be documented in the fieldnotes.

7. Filling of the sample bottles should be completed immediately after sample collection to minimize losses due to volatilization and biodegradation. Soil classification can be completed following VOC sample collection.

8. Place the sample into an appropriate, labeled container(s) by using the alternate shoveling method and secure the cap(s) tightly. The alternate shoveling method involves placing a spoonful of soil in each container in sequence and repeating until the containers are full or the sample volume has been exhausted. Threads on the container and lid should be cleaned to ensure a tight seal when closed.

9. Restore the sampling location to grade in accordance with applicable state or federal guidelines and/or the site-specific work plan. Options include backfilling the sample location

with the remaining removed soil, bentonite pellets, or cement/bentonite grout depending on site conditions/hole depth and patching the surface to match the surrounding area (e.g., topsoil with grass seed, asphalt, or concrete patch), as necessary. The site-specific work plan may prohibit the backfilling of sample locations with removed soil if there is evidence of contamination, site-specific restoration requirements, etc. Boreholes must be abandoned or backfilled after the completion of sampling. In general, shallow boreholes (e.g., less than 10 feet deep) that remain open and do not approach the water table may be abandoned by pouring a cement/bentonite grout mixture from the surface or pouring bentonite pellets from the surface and hydrating the pellets in lifts. The grout mixture should be based on site-specific conditions (e.g., boring depth, groundwater depth, and formation permeability), site-specific work plan procedures, and local regulatory requirements. Boreholes where bridging of the bentonite may be an issue, such as boreholes that intercept groundwater or are greater than approximately 10 feet in depth, should be backfilled by pressure grouting with a cement/bentonite grout mixture, either through a re-entry tool string or through a tremie pipe introduced to within several feet of the borehole bottom.

10. Record locations of soil borings/samples in the field notes by sketching a map and/or providing a description of the location. Always measure and record distances to fixed landmarks, such as buildings, fences, curbs, existing surveyed wells, etc. Additionally, photographs or a GPS unit with real-time sub-meter accuracy (not applicable for interior samples or other site conditions such as heavy tree/brush cover and thick cloud cover that limit unit connection with satellites) could be used to document sample locations. Note observations about elevation changes between sample locations.

3.0 SURFACE SOIL SAMPLING METHODS

The depth of surface soil samples will be determined on a site-specific basis and may be influenced by site-specific conditions and/or applicable local, state, or federal regulatory programs and potential exposure pathways. Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface (bgs). The most common interval is 0 to 6 inches; however, the data quality objectives of the investigation or regulatory requirements may dictate another interval, such as 0 to 3 inches for risk assessment purposes.

The following procedure should be used for surface soil sampling:

1. If a thick, matted root zone, leaf layer, gravel, surface debris, concrete, etc. is present at or near the surface, it should be carefully removed using clean, decontaminated tools or clean nitrile gloves before the soil sample is collected. The presence and thickness of any such material should be recorded in the field notes for each location. The depth measurement for the soil sample begins at the top of the soil horizon, immediately following any such removed materials.

2. A decontaminated stainless-steel spoon, scoop, or trowel is typically used for surface soil sampling depths from 0 to 12 inches bgs where conditions are generally soft and there is no problematic vegetative layer to penetrate. A hand auger or shovel may also be used to dig down to the desired depth, and then after careful removal of the dug soils from the hole, a decontaminated stainless-steel spoon, scoop, or trowel is used to collect the soil sample from the bottom of the hole for laboratory chemical analysis. Plated trowels typically available

from garden supply centers should not be used due to potential heavy metal impacts from the trowel plating.

3. When using stainless steel spoons or trowels, consideration must be given to the procedure used to collect a soil sample for VOC analysis. Samples for VOC, VPH, or GRO analysis must be collected first and never homogenized or composited. These samples are collected using an open-barrel disposable syringe, a Terra Core™ sampler, an En-Core® sampler, or equivalent. If the soil being sampled is cohesive and holds its *in-situ* texture in the spoon or trowel, the En-Core® sampler or disposable syringe used to collect the sub-sample should be plugged directly from the spoon or trowel. However, if the soil is not cohesive and crumbles when removed from the ground surface for sampling, the sub-sample should be plugged directly from the surface of the appropriate sample depth. Additionally, note that En-Core® samplers are not recommended for non-cohesive soils (see Attachment A). Generally, the sample portion for VOC analysis is collected from several inches below grade to minimize volatilization from the *in-situ* soil.

4. Continue by following the General Soil Sampling Procedures in Section 2.3.

4.0 SUBSURFACE SOIL SAMPLING METHODS

The general soil sampling procedures described above should be followed for subsurface sampling. There are numerous options available for subsurface soil retrieval for sampling, including the following:

- Hand auger methods
- Direct-push drilling (standard or dual tube)
- Hollow-stem auger drilling with split spoon or continuous core sampling
- Shelby tube/thin walled sampling
- Roto-sonic drilling
- Excavator sampling (remedial excavations/trenching and test pits)

Other drilling methods not covered are available and may be appropriate for specific project purposes. Project specific procedures should be defined in project documentation. Be sure that the drilling method selected is appropriate for required sample volumes. For information regarding the applicability and details of commonly used subsurface sampling technologies please refer to Attachment E.

4.2 Hand Auger Sampling Methods

The following procedure is used for collecting soil samples with a hand auger:

1. Attach the auger head to a rod extension and attach the T-handle to the rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first several inches of surface soil and any root layer for an area approximately 6 inches in radius around the borehole location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the borehole or other appropriate container. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding rod extensions. It also facilitates refilling the borehole and avoids possible contamination of the surrounding area.

4. When the sample depth is reached, remove the bucket used to advance the borehole and attach a decontaminated or clean bucket. Place the clean auger bucket in the borehole, advance the clean auger bucket to fill it with the soil sample, and then carefully remove the clean auger bucket.

5. If VOC analysis is to be performed, collect a sample directly at the bottom of the boring, if within reach, and not from the auger bucket. If not within reach, collect the sample directly from the auger bucket or from minimally disturbed material immediately after the auger bucket is emptied. Use an En-Core® sampler or other coring device (i.e., syringe, Terra Core™) to collect the sub-sample as described in Attachment A. Note: some regulatory agencies do not allow for subsurface VOC sample collection directly with a hand auger; refer to the site-specific work plan and regulatory requirements to ensure the collection of VOC samples with a hand auger is appropriate.

6. Continue by following the General Soil Sampling Procedures in Section 2.3. Note that if another sample is to be collected in the same borehole, but at a greater depth, reattach the auger bucket to the rod assembly, and follow steps 1 through 5 above, making sure to decontaminate the sampling device between samples.

Special Considerations for Hand Auger Sampling

- *Slough* - Because of the tendency for the auger bucket to scrape material from the sides of the auger hole while being extracted, the top several inches of soil in the auger bucket should be discarded prior to placing the bucket contents in the homogenization container for processing.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - If sampling equipment is to be reused at a new sampling location or at a deeper depth in the same location, proper decontamination of sampling equipment is required.

4.3 Direct-Push Sampling Methods

Direct-push sampling methods include but may not be limited to the following techniques:

- Macro-Core® Sampler (Direct-push)
- Dual-tube Soil Sampling System (Direct-push*)* -
- Discrete Sampling

The following procedure is used for collecting soil samples from direct-push soil cores:

1. The driller will advance and extract the soil sample liner which will then be given to the field sampler - confirm with the driller which end is top and which end is bottom. Record the time

of core collection (military time), the soil boring ID and the depth interval in feet bgs in the field notes, field log sheet, or electronic data collection form.

2. Measurement of vertical depth should start from the top of the ground surface. The presence and thickness of surface asphalt, surficial concrete slabs, or gravel sub-base should be noted on the boring log and in the field notes.

3. Measure the length of recovered soil in inches and record in the field notes.

4. Continue by following the General Soil Sampling Procedures in Section 2.3.

   If a specific depth interval is targeted for sampling, be sure to give consideration to the percent recovery of soil and use professional judgement when selecting the sample interval. For example, if the targeted sample interval was from 2.0 to 2.5-ft, and the core barrel was advanced from 0 to 4 ft bgs, and 30 inches (2.5 ft) of soil was recovered, the sample should be collected immediately below the mid-point of the recovered soil, or 15 inches below the top of the recovered soil (not including slough). If the sample interval is comprised of multiple soil types, there may be one or more materials that are underrepresented in the sample tube (e.g., when a more dense/stiff material overlies a softer material). The sampler should use their best professional judgement to select the sample interval. The sample designation will indicate that the depth was 2.0 to 2.5 ft bgs.

Special Considerations for Direct-push Sampling

- *Liner Use and Material Selection* - Direct-push soil samples are collected within a dedicated new or decontaminated liner to facilitate removal of sample material from the sample barrel. The liners may only be available in a limited number of materials for a given sample tool, although overall, liners are available in brass, stainless steel, cellulose acetate butyrate (CAB), polyethylene terephthalate glycol (PETG), polyvinyl chloride (PVC) and Teflon®. For most investigations, the standard disposable new polymer liner material for a sampling tool will be acceptable. When the study objectives require very low reporting levels or unusual contaminants of concern, the use of more inert liner materials such as Teflon® or stainless steel may be necessary. However, such costly liner materials typically are not disposable and therefore require decontamination between each use.
- *Sample Orientation* - When the liners and associated sample are removed from the sample tubes, it is important to confirm and maintain the proper orientation of the sample. This is particularly important when multiple sample depths are collected from the same push. It is also important to maintain proper orientation to define precisely the depth at which a sample was collected. Maintaining proper orientation is typically accomplished using vinyl end caps. Convention is to place red caps on the top of the liner and black caps on the bottom to maintain proper sample orientation. Orientation can also be indicated by marking on the exterior of the liner with a permanent marker.
- *Core Catchers* - Occasionally the material being sampled lacks cohesiveness and is subject to crumbling and falling out of the sample liner. In such cases, the use of core catchers on the leading end of the sampler may help retain the soil until it is retrieved to the surface. Core catchers may only be available in specific materials and should be evaluated for suitability. However, given the limited sample contact that core catchers have with the sample material, most standard core catchers available for a tool system will be acceptable.

- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - The cutting shoe and piston rod point are to be decontaminated between each sample interval. Within a borehole, the sample barrel, rods, and drive head may be subjected to an abbreviated cleaning to remove obvious and loose material, but must be cleaned between boreholes, such as with high-pressure water, steam, or soap solution with 5-gallon buckets and water rinse.
- *Health and Safety* – Liners should be cut open with the proper tools and in accordance with TRC's health and safety policies.

4.4 Split-spoon Sampling Methods

The following procedure is used for collecting soil samples from split-spoon soil cores:

1. Record the blow count per 6-inch interval when advancing split-spoon samplers with the hollow stem auger rig. Record the hammer weight (e.g., 140 pounds [lb] is standard, but 300 lb may also be used to advance the spoon). Blow counts are an indication of soil density and are a measure of the number of blows it takes for a 140 lb slide hammer falling over a distance of 30 inches to penetrate 6 inches of soil. The drillers will keep the count and will repeat them to the field sampler (e.g., 11, 13, 16 – means the number of blows the hammer advanced the spoon every 6 inches over a total depth interval of the split-spoon sampler, in this case over 18 inches). If refusal is encountered, the count is recorded in the field notes as "# of hammer blows / depth in inches the spoon is driven" (e.g., 50/3 – means 50 blows of the hammer advanced the spoon 3 inches).

2. The driller will advance, extract, and open the split spoon, which will then be given to the field sampler - confirm with the driller which end is top and which end is bottom, if a soil sample liner is used and removed from the spoon. Record the time of core collection (military time), the soil boring ID, and the depth interval in feet bgs in the field notes.

3. Measurement of vertical depth should start from the top of the ground surface.; The presence and thickness of surface asphalt, surficial concrete slabs, or gravel sub-base should be noted on the boring log and in the field notes.

4. Measure the length of recovered soil in inches and record in the field notes.

5. Continue by following the General Soil Sampling Procedures in Section 2.3.

Special Considerations for Split-spoon Sampling

- Split-spoon soil sampling for geotechnical purposes should be conducted in accordance with ASTM Method D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soil*.
- *Slough* - Generally discard the top several inches of material in the spoon before removing any portion for sampling. This material normally consists of borehole wall material that has sloughed off of the borehole wall after removal of the drill string prior to and during insertion of the split spoon.

- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - Within a borehole, the split spoon sample barrels must be cleaned between each sample - the driller typically has multiple barrels and can alternate between clean and dirty barrels so drilling progress is not affected by decontamination of the barrels. The augers should be decontaminated between boreholes (such as with high-pressure steam).

4.5 Shelby Tube/Thin-walled Sampling Methods

Shelby tube or thin-walled soil sampling should be conducted in accordance with ASTM Method D1587 *Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes*.

After retrieval to the surface, the tube containing the sample is then removed from the sampler head. If samples for chemical analyses are needed, the soil contained inside the tube is then removed for sample acquisition by following the direct-push sampling procedures in Section 4.3. If the sample is collected for geotechnical parameters, the tube is typically sealed, to maintain the sample in its relatively undisturbed state, capped, labeled appropriately (including sample ID, top end of sample, inches of recovery, etc.), and shipped to the appropriate geotechnical laboratory. The tube is typically stored in an upright position to maintain the integrity of the undisturbed sample. For geotechnical use, check with the laboratory prior to sampling to understand sample volume recoveries needed to perform the actual tests.

4.6 Sonic Drilling Sampling Methods

The soil core is extruded from the core barrel or casing into a flexible plastic sleeve. The sleeve is then placed on an appropriate surface or prepared sample area to contain spoils. The sleeve is opened to screen with a PID, log lithology and collect samples. The procedures for collecting soil samples from sonic cores are the same as the procedures presented for collecting soil samples from direct-push sampling methods in Section 4.3.

Special Considerations for Sonic Drilling Sampling

- *Utility Clearance* - Due to the ability of sonic drilling to advance through material that may normally cause refusal of standard DPT, extra care should be taken with clearances and borehole location selection.
- Sonic-generated soils are not undisturbed. The resonation of the core barrel during advancement energizes the skin of the sample immediately adjacent to the barrel, approximately ⅛ to ¼ inch around the OD of the sample. Heating of the soils is possible. VOC samples particularly may require permission, approval, or data quality review to be considered representative and/or applicable to the project requirements.
- Depending on site conditions, the outer casing may require adding some water to the borehole if heaving or flowing sand(s) and gravel are present. An adequate water supply should be considered in these site-specific conditions.
- Sonic drilling sleeves in general will produce more IDW to be disposed of than DPT. The sleeves themselves can be awkward and heavy to move to a sample processing area.

4.7 Excavator Sampling Methods

The following procedures are used for collecting soil samples excavated with a backhoe or excavator:

- Refer to the site-specific work plan for the number of floor and/or sidewall samples, which is typically driven by the surface area and can vary depending on the governing regulatory agency.
- For a shallow excavation where the soil samples can be collected directly from the excavation, samples can be collected using a trowel, spoon, or coring device at the desired intervals in the excavation. A clean shovel may be used to remove a 1 to 2- inch layer of soil from the vertical face of the pit that contacted the backhoe bucket and where soil sampling is planned. Scrape the vertical face at the point of sampling to remove any soil that may have fallen from above and to expose fresh soil for sampling.
- For deeper excavations where sample locations are inaccessible, soil samples can be collected directly from the excavator bucket. Do not enter an excavation to collect a sample.
- Soil samples should be collected from the top of the soil in the excavator bucket with special care taken that residual soil on the excavator bucket is not scrapped off and placed in the excavation sample. Collect enough sample volume into a clean, stainless-steel bowl so that the sample containers can be filled at a safe distance from the excavation equipment. Confirm with the equipment operator when the sampling is complete, and excavation can continue.
- Continue by following the General Soil Sampling Procedures in Section 2.3.

Special Considerations for Excavator Sampling

- Effective communication with the excavation equipment operator is critical to collecting the samples safely. Establish a set of hand signals that will be used with the equipment operator to conduct the sampling safely. Confirm with the operator which direction the excavator arm will swing and establish a safe zone where the field staff should stand by to collect the sample. Field staff should always stand at least 3 feet away from the edge of an open excavation. Samples should be collected from the excavator bucket only after the bucket is safely on the ground and confirmation from the equipment operator is received that the equipment is stationary.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- Do not physically enter backhoe excavations to collect a sample if the excavations are unstable or not sloped and protected with shoring. A trench with non-cohesive soils (i.e., sand, saturated/wet muds, or flowing water at the base) is particularly susceptible to collapsing suddenly. Never enter a trench without a confined space entry permit, as required by OSHA regulations.
- Smearing is a potential issue when sampling with a backhoe or excavator. Any time a vertical or near vertical surface is sampled, such as achieved when shovels or similar devices are used for subsurface sampling, the surface should be dressed (scraped) to remove smeared soil. This is necessary to minimize the effects of contaminant migration interferences due to smearing of material from other levels.

- The backhoe/excavator bucket should be decontaminated and loose paint, grease, and rust should be removed to the extent practical prior to use for sample collection if the bucket will come in direct contact with the material to be sampled. Care should be taken to collect the soil sample from the center of the excavated material within the bucket (i.e., material that has not touched the bucket walls).

4.8 Stockpile Soil Sampling Methods

Stockpiled soils are typically sampled to characterize the soils for reuse or disposal. The stockpile sampling strategy used must consider the source of the soil, available data, field observations, shape/dimensions and volume of the pile, and sampling frequency requirements established by oversight regulatory agencies or potential soil disposal facilities.

If the stockpile is known to be a representative mixture of soil with no known or suspected significant variability of contamination with depth in the pile, the stockpile sampling may be conducted according to the surface soil sampling method described in Section 3. However, if the soil characteristics are not known or are known or suspected to vary with depth in the pile, both surface soil and deeper subsurface soil samples will be required to properly characterize the soil pile.

A backhoe or excavator equipped with a bucket can be used to collect subsurface soil samples from stockpiles. This method is often preferred for collecting subsurface soil samples from a stockpile since it allows the sampler greater opportunity to inspect the physical characteristics of the pile for potential signs of variability for determining appropriate sample depths and locations.

Typically, based on the minimum required number of samples for the estimated stockpile volume, the stockpile is divided into the appropriate number of estimated volumes equal to that sample number. For example, if the specified sample frequency is 1 sample per 1,000 cubic yards (cy) and the estimated stockpile size is 4,000 cy, the stockpile would be broken down into approximately four equal volumes or quadrants. Grab VOC samples and composite non-VOC samples, as required, would then be collected from each of the areas for characterization of the stockpile.

5.0 POST-SAMPLING ACTIVITIES

1. After the samples have been collected, the sampling locations must be appropriately documented. The type of documentation will depend on the project specific data quality objectives (DQOs). Sampling locations may be marked with wooden stakes colored with highly visible spray paint and/or flagging in order to identify the sample location for surveying purposes, recorded immediately using a GPS receiver with sub-meter accuracy, recorded using GPS on a mobile device, measured from building corners or other fixed reference points, or a combination of the above. If stakes/markers are used to identify the locations for photos or to physically locate the point at a future date, sample and/or location identification should be written on each stake in indelible ink or marking pen. A sketch or photograph of the sampling locations should also be included in the field notes.

2. Package the samples with bubble wrap and/or organic absorbent, as necessary.

3. Place the samples into a shipping container and cool to 4ºC. If wet ice is used to cool the samples, place the ice in double-bags to prevent water from the melting ice from damaging the samples during shipment.

4. Complete the COC form.

5. Decontaminate non-disposable sampling equipment.

6.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of specific field quality control (QC) samples will be specified in the project-specific planning documents and/or specified by the regulatory agency. and may include one or more of the following: field blank, equipment blank, trip blank, field duplicate, and/or matrix spike/matrix spike duplicates.

7.2 Duplicate Soil Sample Collection

The following procedures should be used for collecting duplicate soil samples:

1. For QC purposes, each duplicate sample will be submitted to the laboratory as a "blind" duplicate sample, in that a unique sample identification not tied to the primary sample identification will be assigned to the duplicate (e.g., DUP-01). Standard labeling procedures used for soil sampling will be employed. However, a sample collection time will not be included on the sample label or the COC form. The actual source of the duplicate sample will be recorded in the field notes.

2. Each duplicate sample will be collected simultaneously with the actual sample in accordance with the same collection procedures. At the same step in the sampling procedures that the VOC, VPH, and/or GRO containers are filled and sealed, the duplicate sample VOC, VPH, and/or GRO containers will also be filled and sealed. Duplicates for all parameters other than VOCs, VPH, and GRO should be filled from the homogenized sample to ensure consistency between the sample and the duplicate. Following the order of collection specified for each set of containers (i.e., VOCs, VPH, GRO, semivolatile organic compounds [SVOCs], other organics and then inorganic compounds), the duplicate sample containers will be filled simultaneously with each parameter.

3. Collection and preservation procedures outlined for soil sampling will be followed for each duplicate sample.

8.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record the general sample collection information such as location, identification, and date/time in the field notes or on a field data sheet. Typical field documentation recorded in field notes includes the following information:

- Sample identification number
- Sample location (description or sketch of the sample point)
- Sample depth interval
- GPS coordinates and coordinate system
- Time and date sample was collected
- Personnel performing the task
- Visual or sensory description of the sample (e.g., odors, staining)
- Brief soil descriptions (e.g., color, texture, appearance)
- Presence of any fill materials (e.g., concrete, asphalt, ash)
- Readings from field screening equipment (e.g., PID)
- Weather conditions during sampling (e.g., temperature, wind)
- Other pertinent observations including whether photographs were taken
- Sample collection equipment used
- Decontamination procedure
- Analytical parameters

Affix a properly completed label to each sample container.

All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the record management procedures specified in the site-specific work plan must be approved by the Project Manager and documented in the field notes.

For projects using TRC's Environmental Data Management System (EDMS), the project team's Data Manager can assist in planning sampling events to prepopulate bottle labels and chain of custody forms and keep track of COC forms and laboratory EDDs generated for the project. The TRC EDMS system has a completeness report that can track the samples collected and the analyses performed as data are received from the laboratory.

TRC's EDMS includes an approved electronic mobile field data collection system (e.g., EQuIS Collect, Fulcrum, or esri Collector). A TRC Data Manager must be assigned for coordination and setup of the respective application to be used by the project team. The details and specifications of the sampling event should be discussed with the TRC Data Manager during the project kickoff meeting. The TRC Data Manager will work with the TRC project team and field personnel on configuring the system for efficient use in the field with pre-populated, project-specific menus following TRC's best practices for sample ID naming conventions compatible with TRC's EDMS.

For projects that do not use electronic mobile field data collection systems field notes containing sample IDs, sample date, sample matrix, sample start depth, sample end depth, sample method, sample event task code, and sample purpose, along with GPS coordinates for each sample location ID should be transcribed into TRC's standard Location and Field Sample EDDs for import into TRC's EDMS as soon as the soil sampling event is completed, preferably the same day in order to get data into the EDMS in as near real time as possible.

9.0 SUSTAINABLE RECOMMENDATIONS

Sustainable practices should be incorporated wherever practical. Items to consider for soil sampling are as follows:

- Utilize reusable equipment as appropriate;
- Utilize recycled material as appropriate (i.e., Recycle plastic bags or use green bags);
- Utilize laboratories with smaller sample containers;
- Utilize electronic data collection methods rather than paper for field notes and boring logs

10.0 REFERENCES

ASTM Methods D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soil,* D1587 *Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes*, ASTM D6169 *Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigation,* ASTM International, Most Current Version.

California EPA, *Guidance Document for the Implementation of United States Environmental Protection Agency Method 5035: Methodologies for Collection, Preservation, Storage, and Preparation of Soils to be Analyzed for Volatile Organic Compounds,* November 2004

MassDEP, *Method for the Determination of Volatile Petroleum Hydrocarbons (VPH)*, May 2004.

U.S, EPA, SW-846 Method 5035A, *Closed System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples*, Draft Revision 1, July 2002.

U.S. EPA Environmental Response Team, Soil Sampling SOP #2012, February 18, 2000.

U.S. EPA Science and Ecosystem Support Division, Soil Sampling Operating Procedure (SESDPROC-300-R2), December 20, 2011.

11.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	SEPTEMBER 2013	NOT APPLICABLE
1	NOVEMBER 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING
3	AUGUST 2020	ADDITIONAL MODIFICATIONS FOR PFAS SAMPLING
4	JANUARY 2022	SOP UPDATE

Attachment A:

Procedure for Collection of Samples for VOCs, VPH, or GRO (SW-846 Method 5035A)

1.0 SAMPLING FOR VOLATILE ORGANIC COMPOUNDS IN SOIL BY EPA METHOD 5035/5035A

The following sampling protocol is recommended for site investigations assessing the extent of VOCs (including VPH and GRO) in soils. Because of the large number of options available, careful coordination between field and laboratory personnel is needed. The specific sampling containers and sampling tools required will depend upon the required detection levels and intended data use. Once this information has been established, selection of the appropriate sampling procedure and preservation method best applicable to the investigation can be made.

SW-846 Method 5035 provides instructions and options on the preservation of soil samples for low-level and high-level VOC analyses:

- Low-level (≤ 200 µg/kg) and
- High-level (> 200 µg/kg).

The choice of low-level or high-level analysis is determined by the requirements of the project. However, since the low-level method is only valid for a certain concentration range, a sample for analysis by the high-level method must also be collected to ensure quantification of all target analytes is possible, if needed.

The low-level method uses one or more of the following options for the sampling/preservation of soils:

- Soil sampled into a vial with a sodium bisulfate ($NaHSO_4$) solution.
- Soil collected in an En-Core® sampler and immediately shipped to the laboratory for further preservation (within 48 hours).
- Soil collected in a vial with organic-free water, sealed in the field, and shipped to the laboratory immediately in order to meet the method preservation requirement to freeze within 48 hours of collection.

Based on project-specific requirements, trip blanks may be recommended. Refer to the site-specific work plan for quality assurance (QA)/QC requirements.

1.1 Low-level Method (VOCs)

Option A - Direct sampling into En-Core® samplers

- Three 5-gram size En-Core® samplers for each sample.
- One non-preserved container for moisture determination.

Option B - Direct sampling into vial with chemical preservative

- Two 5-gram size cores are added to volatile organic analysis (VOA) vials (one soil core is added to each of two VOA vials with sodium bisulfate solution) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). Once the vials are sealed in the field, these are not opened again.
- One non-preserved container for moisture determination.

Option C - Direct sampling into vial with water (to be frozen at the laboratory)

- Two 5-gram size cores are added to VOA vials (one soil core is added to each of two VOA vials with water) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). Once the vials are sealed in the field, these are not opened again.
- One non-preserved container for moisture determination.

1.2 High-level Method (VOC, VPH, GRO)

Option A - Direct sampling into En-Core® samplers

- One 5-gram size En-Core® sampler for each sample.
- One non-preserved container for moisture determination.

Option B - Direct sampling into a methanol-preserved vial

- For VOCs: 5 or 10 grams of soil is added to a VOA vial (with 5 or 10 grams of methanol, respectively) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). This may also depend upon the regulatory agency (e.g., New Jersey Department of Environmental Protection requires 8 to 12 grams in 25 mL methanol or 5 grams in 10 mL methanol).
- For VPH or GRO: The coring device will be filled with 25 grams of undisturbed soil if 60-ml vials with 25 ml of methanol are used, or 15 grams of undisturbed soil if 40-ml vials with 15 ml of methanol are used. The goal is to have a 1:1 ratio of soil- to- methanol.
- One non-preserved container for moisture determination.

1.3 Cautions and Potential Problems

1. Potential leaking sample containers for VOC, VPH, and GRO analyses:

   Options for evaluating containers for leaking preservatives:

   a. When ordering pre-preserved sample containers, laboratories should be encouraged to mark the meniscus of the preservative on all sample containers. The preservative level should be checked before sampling as a quick check that there has not been any loss of liquid.
   b. Compare preservative level in multiple bottles and select one for comparison purposes to subsequent sample bottles.
   c. Weigh methanol-preserved sample containers prior to sampling. Sample containers found to have lost greater than 0.2 grams of methanol compared to their initial weight should not be used. In order to perform this option, initial container weights must be provided by the laboratory.

2. Potential methanol absorption:

   Soil may be encountered that absorbs all of the methanol preservative (e.g., organic-rich soil, fine-grain soil). These soils can absorb the methanol leaving no methanol extract for the laboratory to analyze. In these instances, the use of additional methanol is required. The laboratory must be contacted for sample containers with an increased volume of methanol. Using a 1:2 ratio of soil to methanol will help to ensure that there will be adequate volume of methanol remaining for analysis. **NOTE: Additional methanol should not be added to the sample container by the sampler in the field. Containers with additional methanol must be obtained from the laboratory.**

3. Collection of samples with high moisture content:

   Soil samples with high (>50%) moisture content (e.g., sediments, soil samples below the water table) may prevent the attainment of the ideal 1:1 soil-to-preservative ratio. In these instances, depending on the data quality objectives, it may be necessary to evaluate the soil to determine what level in the disposable syringe corresponds to the required weight (typically 5 grams for VOCs and 15 or 25 grams for VPH). This can be performed by collecting several trial samples with disposable syringes. Weigh each trial sample and note the length of the soil in the syringe. These measurements would be used to determine how much soil in the syringe corresponds to 5 ± 0.5 grams (or the desired weight ± 0.5). All trial samples should be discarded and not used for analysis.

4. En-Core® sampler cautions:

   a. En-Core® samplers, or equivalent, should only be used on fine-grain or cohesive soils (soils that stay together in the En-Core® sampler and do not fall apart). En-Core® samplers should not be used to collect soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table). In the case of soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table), a stainless-steel spatula or scoop should be used with field preservation techniques.
   b. The En-Core® sampler is a single-use device and cannot be decontaminated and reused.

c. The volume of material collected in an En-Core® sampler should not cause excessive stress on the coring tool.
d. The volume of material collected should not be so large that the sample easily falls apart during extrusion.
e. The En-Core® sampler should not be used if any of the components are damaged as the seals may be compromised. Under no circumstances should any components be removed or disturbed.
f. It is important to make sure air is not trapped behind the sample, as this could cause air to pass through the sample, resulting in a loss of VOCs, or it could cause the sample to be pushed prematurely from the coring tool.

5. <u>Potential effervescence with use of sodium bisulfate as a preservative for low-level VOC analysis of soils:</u>

   This method of preservation is not preferred and, therefore, is not outlined below. If it is used, the following cautions exist:

   a. Carbonaceous or strongly alkaline soils may cause potential effervescence when reacting with the sodium bisulfate and may result in a loss of VOCs and a shattered vial. If effervescence occurs, sodium bisulfate should not be used. The laboratory must be contacted and low-level preservation techniques, using water only, should be followed.
   b. Loamy materials or materials containing decayed material may result in false positive results for acetone due to the interaction with the sodium bisulfate.
   c. Some VOCs may be lost due to the resulting acidification when sodium bisulfate is used (e.g., styrene, 2-chloroethyl vinyl ether, acrylonitrile).
   d. Some VOCs may be lost if the laboratory is using a heated purge in combination with the sodium bisulfate preservative (e.g., methyl tert butyl ether [MTBE] and other fuel oxygenates).

1.4 Sample Containers and VOC Sampling Equipment

- Method 5035A-compatible containers or kits (for VOCs, VPH, and GRO): Preservatives may be required for some samples with certain variations of SW-846 method 5035A – consult the governing regulatory agency or principal analytical chemist to determine which preservatives are necessary.

  Low-level VOCs: two 40-mL VOA vials pre-preserved with 5 mL organic-free water and also containing a magnetic stir bar.
  High-level (or medium-level) VOCs: one 40-mL VOA vial pre-preserved with 5 or 10 mL of purge-and-trap-grade methanol. Volume will be dependent upon laboratory's preference or regulatory agency requirements (e.g., New Jersey Department of Environmental Protection prefers vials with 10 or 25 mL of purge-and-trap-grade methanol).
  VPH and GRO: One 60-mL vial pre-preserved with 25 mL of purge-and-trap-grade methanol **or** One 40-mL VOA vial pre-preserved with 15 mL of purge-and-trap-grade methanol
  and
  One glass container (or other appropriate container) with no preservative to allow the laboratory to perform the percent solids measurement. NOTE: The laboratory typically requires a minimum of 20 grams to perform this test. Therefore, submitting a sample size less than 4 ounces may be acceptable. This additional container will not be required if the sample is also being submitted for other non-VOC parameters.

- En-Core® samplers, or equivalent, for VOC, VPH and/or GRO analysis:

  High-level VOC or GRO analysis: one 5-gram En-Core® sampler.
  Low-level VOC analysis: two 5-gram En-Core® samplers.
  VPH, GRO or toxicity characteristic leaching procedure (TCLP) VOC analysis: one 25-gram En-Core® sampler.

- Disposable plastic syringes or Terra Core™ samplers.

- Foam VOC vial holders.

- Portable digital scale (accurate to ± 0.01 grams) with calibration weights.

2.0 COLLECTION OF SAMPLES USING EN-CORE® SAMPLERS, OR EQUIVALENT

- The sample will be collected using an En-Core® sampler, or equivalent, as soon as possible after the soil has been exposed to the atmosphere.
- Check that the En-Core® sampler, or equivalent, is full using both of the following procedures:
  a. Be sure that the back o-ring on the plunger can be seen when looking through the viewing hole on the handle. This will mean that the soil has pushed the plunger fully to the back.
  b. The plunger can only be rotated when it is fully pushed to the back of the body. Therefore, it is important to twist the plunger to guarantee that the soil has filled the sampler and the back o-rings have sealed.
- Immediately seal the En-Core® sampler, or equivalent. Be sure to twist the cap as it is pushed on. The cap is properly sealed when the two locking arms are completely and symmetrically over the body ridge.
- The samples must be shipped to a laboratory within 24 hours of sampling to ensure the 48-hour hold time for preservation will be met.
- In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field notes. If the field screening technique does not indicate the presence of VOCs, this should also be noted.
- If samples are collected for only VOC and VPH analyses, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

3.0 COLLECTION OF SAMPLES USING FIELD PRESERVATION

- Samples for VOCs will be collected as soon as possible after the soil has been exposed to the atmosphere.
- Samples for VOCs will be collected first (prior to collection of samples for other parameters) using an open-barrel disposable syringe, Terra Core™ sampler, or equivalent. In the case of soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table), an open-barrel disposable syringe may not be practical; a stainless steel spatula or scoop can be used with field preservation techniques.
- Soil samples for VOC analyses should **never** be homogenized.
- Each pre-preserved sample container will be weighed prior to sample collection, and the container/preservative weight will be recorded. This procedure will generally be performed by the laboratory prior to shipping the containers to the field.
- Depending upon project requirements, samples for VOC analysis will be collected as low-level, high-level, or both.

A. Low-level VOCs

1. The syringe will be filled with undisturbed soil of the following volume: 5 grams of soil.

   As an option to the syringes, 5-gram Terra Core™ samplers, or equivalent, can be used. The goal is to have a 1:1 ratio of soil- to- preservative.
2. The soil will be extruded into a pre-preserved VOA vial containing a magnetic stir bar and 5 mL organic-free water. This will be done in replicate.
3. Any sand grains present on the container rim or cap must be removed to ensure an air-tight seal of the vial. The VOA vial will be capped quickly and labeled with the sample ID, date, and time of collection. Labels should not be written on the cap of the vial.
4. Gently swirl sample to break up the soil aggregate, if necessary, until the soil is covered with preservative. It is imperative that the soil sample be completely immersed in the preservative solution.

5. In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field notes. If the field screening technique does not indicate the presence of VOCs, this should also be noted.
6. If samples are collected for only VOC analysis, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

B. High-level VOCs, VPH, or GRO

1. High-level VOCs: The syringe will be filled with undisturbed soil of the following volume: 5 or 10 grams of soil for high-level analysis (added to the 5 or 10 ml of methanol, respectively). This may also depend upon the regulatory agency (e.g., New Jersey Department of Environmental Protection requires 8 to 12 grams in 25 mL methanol or 5 grams in 10 mL methanol).

   VPH or GRO: The syringe will be filled with 25 grams of undisturbed soil if 60-ml vials with 25 ml of methanol are used, or 15 grams of undisturbed soil if 40-ml vials with 15 ml of methanol are used. The goal is to have a 1:1 ratio of soil- to- methanol.

   As an option to the syringes, 5-gram Terra Core™ samplers, or equivalent, can be used. Typically, the goal is to have a 1:1 ratio of soil- to- preservative.
2. The sample will be extruded into a VOA vial containing purge-and-trap grade methanol
3. Any sand grains present on the container rim or cap must be removed to ensure an air-tight seal of the vial. The VOA vial will be capped quickly and labeled with the sample ID, date, and time of collection. Labels should not be written on the cap of the vial.
4. Gently swirl sample to break up the soil aggregate, if necessary, until the soil is covered with preservative. It is imperative that the soil sample be completely immersed in the preservative solution.
5. In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field notes. If the field screening technique does not indicate the presence of VOCs, this should also be noted.
6. Methanol is considered to be a hazardous material by the US Department of Transportation (DOT) and the International Air Transportation Association (IATA). Shipments containing methanol between the field and the laboratory must conform to the rules established in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179) and the most current edition of the IATA Dangerous Goods Regulations. The volumes of methanol recommended in the VOC method fall under the small quantity exemption of 49 CFR section 173.4. Refer to Attachment B for further details.
7. If samples are collected for only VOC analysis, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

Attachment B:

Shipping Methanol-preserved Samples

Shipping of Hazardous Materials

Methanol is considered a hazardous material by the US Department of Transportation (DOT) and the International Air Transport Association (IATA). Shipments of methanol between the field and the laboratory must conform to the rules established in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179) and the most current edition of the IATA Dangerous Goods Regulations. Consult these documents or your shipping company for complete details.

Small Quantity Exemption

The volumes of methanol recommended in the high-level VOC, VPH, and GRO methods fall under the small quantity exemption of 49 CFR section 173.4. To qualify for this exemption, all of the following conditions must be met:

◊ the maximum volume of methanol in each sample container must not exceed 30 mL
◊ the sample container must not be full of methanol
◊ the sample container must be securely packed and cushioned in an upright position and be surrounded by a sorbent material capable of absorbing spills from leaks or breakage of sample containers
◊ the package weight must not exceed 64 pounds
◊ the volume of methanol per shipping container must not exceed 500 mL
◊ the packaging and shipping container must be strong enough to hold up to the intended use
◊ the package must not be opened or altered while in transit
◊ the shipper must mark the shipping container as follows:

"This package conforms to 49 CFR 173.4"

When shipping domestically by Federal Express via ground or air, the following rules apply:

◊ follow the inner packaging requirements of 49 CFR 173.4
◊ no labels, placards, up arrows, or dangerous goods shipping papers are required
◊ if the Federal Express airbill has a shipper's declaration for hazardous goods on it, check the Yes box under *Shipper's Declaration not Required*

When shipping internationally by Federal Express, the following rules apply:

◊ follow the inner packaging requirements of 49 CFR 173.4
◊ use dangerous goods shipping papers
◊ apply orientation arrows on opposite vertical sides on the exterior of the package

Shipping Papers for International Shipments

International shipments must be accompanied by dangerous goods shipping papers that include the following:

Proper Shipping Name:	Methyl Alcohol
Hazardous Class:	Flammable Liquid
Identification Number:	UN1230
Total Quantity:	*(mL methanol/container x the number of containers)*
Emergency Response Info:	Methanol SDS attached
Emergency Response Phone:	1-800-424-9300

Attachment C:

SOP Fact Sheet

SOIL SAMPLING PROCEDURES – SOP 003 FACT SHEET

PURPOSE AND OBJECTIVE

Soil sampling is conducted in order to obtain a representative sample for laboratory analysis of constituents of interest at a given site. Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type.

WHAT TO BRING

- Appropriate level of personal protective equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP).
- Sample containers: The proper containers should be determined in conjunction with the analytical laboratory in the planning stages of the project, and will depend on the analytical program, laboratory SOPs, and regulatory requirements.
- For non-volatile organic compound (VOC) parameters, glass containers with Teflon®-lined caps are typically utilized. Typical containers used for VOC parameters are provided in Attachment A. Brass liners, steel liners, or soil core acetate liners with Teflon® tape and plastic end caps may also be used.
- Stainless steel mixing bowl or new aluminum pie pan.
- Plastic bowl or plastic resealable bag for inorganics.
- Stainless steel spoon or spatula or sterile individually wrapped single use scoop.
- Hand auger, mud auger, sand auger, bucket auger, and/or T-handle.
- Post hole auger.
- Extension rods.
- Stainless steel trowel.
- Shovel.
- Applicable field screening equipment with calibration solution/gas (i.e., pH meter, photoionization detector, flame ionization detector, etc.)
- Tape measure or folding ruler.
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags.
- Field book and/or boring log.
- Sample container labels.
- Chain-of-custody (COC) forms (TRC or laboratory, as appropriate).
- Custody seals for sample coolers.
- Tape to secure sample coolers and sample container labels (if necessary).
- Camera.
- Maps/site plan.
- Survey equipment, global positioning system (GPS), or other means of measuring sample locations.
- Indelible marking pens or markers.
- Organic absorbent material (e.g., Slickwick, ground corn cob, sawdust).
- Sample coolers.
- Bubble wrap.
- Ice (for sample storage/preservation).
- Zip-loc® plastic bags (for ice and COCs).
- Equipment decontamination supplies (see ECR SOP-010).
-

OFFICE

- Prepare/update the HASP; make sure the field team is familiar with the latest version.
- Review workplan, discuss the objective for the soil sampling program with the Project Manager and/or the field lead. Develop strategy including sample order, collection method, designation, analytical parameters, turn-around times, laboratory, etc.
  - Are the soil cuttings to be containerized in drums or returned to borehole?
  - Volume of soil required for each sample?
  - QA/QC sample collection?
  - Field decontamination required?
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure, test equipment and make sure it is in proper working order.
- Verify that a utility survey/mark-out has been performed to ensure that sample locations are clear of overhead and buried utilities. Obtain a copy of the mark out ticket or confirmation number. Additionally, a private geophysical sub-surface survey may be necessary.
- Review sample bottle order for accuracy and completeness.
- Confirm soil boring locations (or specific sampling areas) are clearly identified on figure and that soil boring and sample designations are understood.

SOIL SAMPLING PROCEDURES

ON-SITE

- Verify that underground utilities have been marked out and that the mark outs are clear. Stay at least two feet away from any marked utility. Identify if any overhead obstructions or limited access areas exist near proposed borings and contact the Project Manager if any proposed locations need to be moved. Sketch/photograph mark-out locations. Client or project-specific utility clearances such as air-knifing or GPR may also be required.
- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Ensure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones, minimize interference with on-site activities and pedestrian traffic, etc.)
- Calibrate equipment (if applicable) and record all equipment serial numbers in the field book.

GENERAL SOIL SAMPLING PROCEDURES

- Refer to other TRC SOPs for the proper procedures for classifying soil samples (ECR SOP 005) and for screening of samples for VOCs (ECR SOP 014).
- Refer to Attachment D of this SOP for specialized sampling requirements for PFAS.
- Refer to the appropriate guidance documents for state-specific sampling requirements.
- Perform any required field screening in-situ or immediately upon retrieval of the soil sample from the subsurface.
- Samples for VOC, VPH, or GRO analysis are collected as soon as possible after the soil has been exposed to the atmosphere and prior to sample collection for other analyses. Refer to Attachment A of this SOP for additional details.
- After collecting the sample(s) for VOC analysis, the sample portion for the remaining analyses should be well homogenized in a decontaminated stainless-steel bowl, disposable new aluminum pie pan, plastic bowl (for inorganics), or re-sealable plastic bag (for inorganics) to ensure the sample is uniform and as representative as possible of the sample media.
- Stones, gravel, vegetation, or debris (such as concrete, asphalt, ash or slag) should be removed from the soil sample as much as practical prior to placement in sample containers, unless these matrices are part of the overall characterization program.
- Transfer to sample containers using new, clean, or decontaminated spoons/scoops.
- Filling of the sample bottles should be completed immediately after sample collection to minimize losses due to volatilization and biodegradation. Soil classification can be completed following sample collection.
- Place the sample into an appropriate, labeled container(s) by using the alternate shoveling method and secure the cap(s) tightly. The alternate shoveling method involves placing a spoonful of soil in each container in sequence and repeating until the containers are full or the sample volume has been exhausted. Threads on the container and lid should be cleaned to ensure a tight seal when closed.
- Make sure ALL sample containers are clearly labeled with the site name, sample date, sample collection time and sample designation including depth in indelible ink. Make sure to clearly identify requested samples and analyses on the COC.
- Labeled samples should be immediately put into a cooler with ice; sample coolers should always be kept within eyesight or stored within the cab of the vehicle or other secured place such as a locked office.
- Be aware of sample holding times and arrange for samples to be in the laboratory's possession accordingly.
- Restore the sampling location to grade in accordance with applicable state or federal regulations and/or the site-specific work plan. Options include backfilling the sample location with the remaining removed soil, bentonite pellets, or cement/bentonite grout depending on site conditions/hole depth and patching the surface to match the surrounding area (e.g., topsoil with grass seed, asphalt, or concrete patch), as necessary.
- Record locations of soil borings/samples in the field book by sketching a map and/or providing a description of the location. When measuring locations of soil borings/samples, always use fixed landmarks such as buildings, fences, curbs, etc.
- Decontaminate sampling equipment in accordance with TRC's SOP (ECR SOP 010) on equipment decontamination.
- Ensure any IDW is appropriately managed. If IDW cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal, approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

SOIL SAMPLING PROCEDURES

SURFACE SOIL SAMPLING PROCEDURES

The depth of surface soil samples are typically from 0-6 in. or 0-12 in. and will be determined on a site-specific basis and may be influenced by site-specific conditions. The following procedure should be used for surface soil sampling:

- If a thick, matted root zone, leaf layer, gravel, surface debris, concrete, etc. is present at or near the surface, it should be carefully removed using clean, decontaminated tools before the soil sample is collected. The presence and thickness of any such material should be recorded in the field book for each location. The depth measurement for the soil sample begins at the top of the soil horizon, immediately following any such removed materials.
- A decontaminated stainless-steel spoon, scoop, or trowel is typically used for surface soil sampling depths from 0 to 12 inches bgs. A hand auger or shovel may also be used to dig down to the desired depth and then after careful removal of the dug soils from the hole, a decontaminated stainless-steel spoon, scoop, or trowel is used to collect the soil sample from the bottom of the hole for laboratory chemical analysis.
- Continue by following the General Soil Sampling Procedures.

HAND AUGER SAMPLING PROCEDURES

Hand augers may be used to advance boreholes and collect soil samples in shallow subsurface intervals. The auger is advanced by simultaneously pushing and turning using an attached T-handle with extensions (if needed). Auger holes are advanced one bucket at a time until the appropriate sample depth is achieved. The following procedure should be used for hand auger sampling:

- Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter).
- Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the borehole.
- When the sample depth is reached, remove the bucket used to advance the borehole and attach a decontaminated or clean bucket. Place the clean auger bucket in the borehole, advance the clean auger bucket to fill it with the soil sample and then carefully remove the clean auger bucket.
- If VOC analysis is to be performed, collect a sample directly at the bottom of the boring, if within reach, and not from the auger bucket. If not within reach, collect the sample directly from the auger bucket or from minimally disturbed material immediately after the auger bucket is emptied.
- Continue by following the General Soil Sampling Procedures.
- Refer to the SOP for special considerations for hand auger sampling.

DIRECT PUSH/SPLIT SPOON/SONIC DRILLING SAMPLING PROCEDURES

For some soil investigations, soil logs provide justification for sample locations and intervals, so be descriptive and precise.

- The driller will advance the soil sampler (macrocore, split spoon, sonic casing, etc.) which will then be given to the sampler - confirm with driller which end is top and which end is bottom. Record the time of core collection in the field book (military time). Begin the soil record by indicating the soil boring location and ID, followed by the depth interval in feet bgs [e.g., B-1/0-4].
- Record the blow count per six-inch interval when collecting split-spoon samplers with hollow stem auger rig. The drillers will keep the count and repeat them to you. If refusal is encountered, the count is recorded in the book as "# of hammer blows / depth in inches the spoon is driven" (e.g., 50/3 – means 50 blows of the hammer advanced the spoon 3 inches).
- Measurement of vertical depth should start from the top of the ground surface. The presence and thickness of surface asphalt, surficial concrete slabs or gravel sub-base should be noted in the field book and/or boring log.
- Measure the length of recovered soil in inches and record in the field book.
- Continue by following the General Soil Sampling Procedures. If a specific depth interval is targeted for sampling, be sure to account for percent recovery when selecting the sample interval.
- Refer to the SOP for special considerations for Direct Push, Split Spoon, and Sonic Drilling sampling.

SHELBY TUBE/THIN-WALLED SAMPLING PROCEDURES

Shelby tube or thin-walled soil sampling should be conducted in accordance with ASTM Method D1587 Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes.

To collect a sample, the tube is attached to a string of drill rod and is lowered into the borehole, where the sampler is then pressed into the undisturbed material by hydraulic force from the drill rig. After retrieval to the surface, the tube containing the sample is then removed from the sampler head.

- If samples for chemical analyses are needed, the soil contained inside the tube is then removed for sample acquisition by following the direct-push sampling procedures.
- If the sample is collected for geotechnical parameters, the tube is typically sealed to maintain the sample in its relatively undisturbed state, capped, labeled appropriately (including sample ID, top end of sample, inches of recovery, etc.), and shipped to the appropriate geotechnical laboratory. The tube is typically stored in an upright position to maintain the integrity of the undisturbed sample.

- For geotechnical use, check with the laboratory prior to sampling to understand sample volume recoveries needed to perform the actual tests.
    - Refer to the SOP for special considerations for Shelby Tube or Thin-Walled sampling.

EXCAVATOR SAMPLING PROCEDURES

A backhoe or excavator can be used to assist with soil sampling such as during remedial excavation activities (to collect floor and sidewall samples within the excavation), test pit installation, or trenching operations. The following procedures are used for collecting soil samples excavated with a backhoe or excavator:

- For test pits or trench excavation, excavate in accordance with the site-specific work plan. The work plan may also require that excavated soils be placed on plastic sheets or another impervious surface and protected from rain.
- Refer to the site-specific work plan for the number of floor and/or sidewall samples, which is typically driven by the surface area and can vary depending on the governing regulatory agency.
- Samples can be collected using a trowel, spoon, or coring device at the desired intervals. A clean shovel may be used to remove a 1 to 2- inch layer of soil from the vertical face of the pit that contacted the backhoe bucket and where soil sampling is planned. Scrape the vertical face at the point of sampling to remove any soil that may have fallen from above and to expose fresh soil for sampling.
- In many instances, soil sample locations within the excavation area are inaccessible (do not physically enter backhoe excavations to collect a sample). In these cases, soil samples can be collected directly from the backhoe bucket – use caution not to collect a soil sample from edges that may have come into contact with the backhoe bucket.
- Continue by following the General Soil Sampling Procedures.
- Abandon the pit or excavation according to applicable state regulations and the site-specific work plan. Generally, shallow excavations can simply be backfilled with the removed soil material.
    - Refer to the SOP for special considerations for Excavator sampling.

STOCKPILE SOIL SAMPLING PROCEDURES

Stockpiled soils are typically sampled to characterize the soils for reuse or disposal. The stockpile sampling strategy used must consider the source of the soil and all available data, field observations, shape/dimensions and volume of the pile, and sampling frequency requirements established by oversight regulatory agencies or potential soil disposal facilities.

If the stockpile is known to be a representative mixture of soil with no known or suspected significant variability of contamination with depth in the pile, the stockpile sampling may be conducted according to the surface soil sampling method described above. However, if the soil characteristics are not known or are known or suspected to vary with depth in the pile, both surface soil and deeper subsurface soil samples will be required to properly characterize the soil pile. Based on the minimum required number of samples for the estimated stockpile volume, the stockpile is divided into the appropriate number of estimated volumes equal to that sample number.

Refer to the SOP for special considerations for Stockpile Soil sampling.

POST SAMPLING ACTIVITIES

- After the samples have been collected, the sampling location should be surveyed in the field with a GPS unit if not surveyed later by some other means. A sketch or photograph of the sampling locations should also be included in the field book.
- Package the samples with bubble wrap and/or organic absorbent as necessary.
- Place the samples into a shipping container and cool to 4ºC. If wet ice is used to cool the samples, place the ice in double-bags to prevent water from the melting ice from damaging the samples during shipment.
- Complete and cross check the COC form.
- Refer to Attachment B in the SOP for specific guidance on shipping methanol-preserved samples.
- Decontaminate non-disposable sampling equipment.

DOS AND DO NOTS OF SOIL SAMPLING

DOs:

- No matter the work plan or the site, DO have the following items when going into the field:
    - Site-Specific HASP
    - Appropriate PPE
    - Field book and a pen with indelible ink
    -
    - Business cards
- DO review soil boring logs or cross sections from previous sampling events, if available.
- DO call the Project Manager or field team leader if unexpected conditions are encountered and at least twice during the workday to update them. Even if everything is fine and there are no questions, call or text with an update. It is also recommended to call when sampling is winding down for the day to make sure that the work plan has been fully implemented and there are no additional tasks to complete.
- DO have the numbers for laboratory, vehicle rental, and equipment rental providers readily available while in the field.
- DO decontaminate any heavy equipment used for the advancement of sampling devices by steam cleaning or high pressure/hot water wash prior to and between sample locations. This would include, but is not limited to auger flights, drill rods, backhoe buckets and other respective accessories.
- DO review and count the sample bottles and compare to the COC prior to leaving the site.
- DO record sampler type (e.g., macrocore, split spoon, etc.) and boring method (e.g., direct push, hammer, etc.) in the field book.
- DO record the hammer weight, the distance of the hammer drop and the method for hammer lift (i.e., cathead and rope, hydraulic, etc.) in the field book at least once per day when collecting split-spoon samples with a drill rig.

DO NOTs:

- DO NOT sign anything other than the COC in the field. This includes disposal documentation, statements, etc; call the Project Manager if there is an issue.
- DO NOT use non-indelible ink to label samples or record field notes – if the field book gets wet, notes become illegible.
- DO NOT include any upper soils which may “fall” as a result of the open borehole caving in (slough) when recording recovery.
- DO NOT use general terms such as “Fill” or “Till” as a sole description for layers – always give detailed description of soil components

Attachment D:

SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® during sample handling or mobilization/demobilization. This includes waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. • Blue Ice® (chemical ice packs) must not be used to cool samples or be used in sample coolers. Regular ice in Ziploc® bags can be used. • Do not use low density polyethylene (LDPE)[1] or glass sample containers or containers with Teflon-lined lids. HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. • Do not use aluminum foil. • Waterproof field notes, plastic clipboards and spiral bound notebooks should not be used. Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Field notes should be attached to the project-specific field notes or folder upon returning to the office. • Avoid using waterproof labels for sample bottles. The use of paper labels covered with clear tape or placed in Ziploc® bags to avoid moisture on the sample label is acceptable. • Do not use Post-It Notes during sample handling or mobilization/ demobilization. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan (HASP) prior to conducting field work. The following considerations should be made with regards to field preparation during PFAS sampling: • Tyvek® suits should not be worn during PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only. • Personnel involved with sample collection and handling should wear nitrile gloves at all times while collecting and handling

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
	samples or sampling equipment. Avoid handling unnecessary items with nitrile gloves. A new pair of gloves must be donned prior to collecting each sample. • Wash hands with Alconox or Liquinox and deionized water after leaving vehicle before setting up at a soil sampling location.
1.6	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering on the day of sampling. • Avoid using sunscreens or insect repellants that are not natural or chemical free. • If installing borings for PFAS sampling, assume the surface soil is contaminated with PFAS and remove the top six inches and transfer to drums prior to installing the borings. Clear an area of at least 1.5 feet by 1.5 feet. Keep all site surface soil in one drum, if possible. It is important to minimize PFAS in the surface soil from getting into the boring during soil sampling or well construction. • If sampling for PFAS under a roadway, move the dense aggregate subgrade out of the way prior to sampling. • Efficient and consistent homogenization procedures must be performed on soil samples; this is critical due to the small mass used by the laboratory. Do not homogenize soil in aluminum pie pans; use a decontaminated stainless steel bowl.
2.2	• LDPE and/or glass containers should not be used for sampling. Teflon®-lined caps should also not be used during sample collection. Instead, HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. Do not homogenize soil in aluminum pie pans. Use a decontaminated stainless steel bowl. • Stainless steel tools should not be wrapped in aluminum foil after decontaminating prior to and in between uses. • Homogenize the soil sample in a decontaminated, stainless steel bowl and place in an appropriate laboratory-provided sample container (as listed above) following the collection of VOC, VPH or GRO samples.
2.2.3	• Do not use Teflon® liners for direct push sampling methods. Cellulose acetate butyrate (CAB) liners are acceptable.
2.2.7	• Homogenize the soil sample in a decontaminated, stainless steel bowl and place in an appropriate laboratory-provided sample container (as listed above) following the collection of VOC, VPH or GRO samples.
2.3	• Samples for PFAS analysis must be shipped at <10°C. Standard coolers are acceptable. Keep high-concentration PFAS samples in separate coolers from low-concentration PFAS samples.

[1] PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces.

Attachment E:

Explanation of Common Subsurface Sampling Technologies

Hand Augering

Hand augers may be used to advance boreholes and collect soil samples in shallow subsurface intervals. Often, 4-inch diameter stainless steel auger buckets with cutting heads are used. The auger is advanced by simultaneously pushing and turning using an attached T-handle with extensions (if needed).

The practical depth of investigation using a hand auger largely depends upon the soil properties and depth of investigation. In sand, augering is typically easy to perform, but the depth of collection is limited to the depth at which the sand begins to flow or collapse. The use of hand augers may be of limited use in soils containing large amounts of unnatural fill (e.g., brick, slag, concrete), coarse gravel and cobbles (or larger grain size), and in tight clays or cemented sands. In these soil types, it becomes more difficult to recover a sample due to increased friction and torque of the hand auger extensions as the depth increases. At some point, these problems become so severe that alternate methods (i.e., power equipment) must be used.

Auger holes are advanced one bucket at a time until the appropriate sample depth is achieved. When the sample depth is reached, the bucket used to advance the hole is removed and decontaminated or a clean bucket is attached. The clean auger bucket is then placed in the hole and filled with soil to make up the sample and then carefully removed.

Direct Push

Direct-push sampling methods are used primarily to collect shallow and deep subsurface soil samples. Soil sampling probes may range from simple hand tools to truck-mounted or track-mounted hydraulically operated rigs. The sampling tool is hydraulically driven into the soil, filling the tube, and withdrawn. All of the sampling tools involve the collection and retrieval of the soil sample within a thin-walled liner. The following sections describe two specific sampling methods using direct-push techniques, along with details specific to each method.

- *Macro-Core® Sampler (Direct-push)* - The Macro-Core® (MC®) sampler is a solid barrel, direct-push sampler equipped with a piston-rod point assembly used primarily for collection of either continuous or depth-discrete subsurface soil samples. Other lengths are available, the standard MC® sampler comes in lengths of 48 or 60 inches (1219 or 1524 mm) with an outside diameter (OD) of 2.25 inches (57 mm). The MC® sampler is capable of recovering a discrete sample the length of the sample core used with a diameter of 1.5 inches (38 mm) contained inside a removable liner. The resultant sample volume is an approximate maximum of 1400 mL (for a 48-inch sampler). The MC® sampler may be used in either an open-tube or closed-point configuration.

- *Dual-tube Soil Sampling System (Direct-push)* - The Dual-tube soil sampling system is a direct-push system for collecting continuous core samples of unconsolidated materials from within a sealed outer casing of 2.25-inch (57 mm) to 6-inch (152 mm) OD probe rod. For the 2.25-inch OD probe rods, the samples are collected and retrieved within a liner that is threaded onto the leading end of a string of 1.25-inch (32 mm) OD diameter probe rods inserted into the bottom of the outer casing. Collected samples have a volume of up to 800 mL in the form of a 1.125-inch x 48-inch (29 mm x 1219 mm) core. In addition to the 48-inch length, nominal liner lengths include 36 inches, 1 meter, and 60 inches. Use of this method allows for collection of a continuous core inside a cased hole, minimizing or preventing cross contamination between different intervals during sample collection. The outer casing is advanced, one core length at a time, with only the inner probe rod and core being removed and replaced between samples. If the sampling zone of interest begins at some depth below ground surface, a solid drive tip must be used to drive the dual-tube assembly and core to its initial sample depth.

Split Spoon

All split-spoon samplers, regardless of size, are basically split cylindrical barrels that are threaded on each end. The leading end is held together with a beveled threaded collar that functions as a cutting shoe. The other end is held together with a threaded collar that serves as the stub used to attach the spoon to a string of drill rod.

- *Standard Split Spoon* - A drill rig auger is used to advance a borehole to the target depth. The drill auger string is then removed and a standard split spoon is attached to a string of drill rod. Split spoons used for soil sampling must be constructed of hardened carbon steel and are typically 2.0 inches OD (1.5 inches inside diameter) and 18 inches to 24 inches in length. Other diameters and lengths are common and may be used if constructed of the proper material. After the spoon is attached to the string of drill rod, it is lowered into the borehole. The safety hammer is then used to drive the split spoon into the soil at the bottom of the borehole. After the split spoon has been driven into the soil, filling the spoon, it is retrieved to the surface, where it is removed from the drill rod string and opened for sample acquisition.

Shelby Tubes

Shelby tubes, also referred to generically as thin-walled push tubes or Acker thin-walled samplers, are used to collect subsurface soil samples in cohesive soils and clays during drilling activities. In addition to samples for chemical analyses, Shelby tubes are also used to collect relatively undisturbed soil samples for geotechnical analyses of physical properties such as shear strength, grain size distribution, density, hydraulic conductivity and permeability, to support engineering design, construction, and hydrogeologic characterizations at hazardous waste and other sites.

A typical Shelby tube is 30 inches in length, has a 3.0-inch OD (2.875-inch inside diameter) and may be constructed of steel, stainless steel, galvanized steel, or brass. They are typically attached to push heads constructed with a ball check to aid in holding the sample in the tube during retrieval. If used for collecting samples for chemical analyses, it must be constructed of stainless steel. If used for collecting samples for standard geotechnical parameters, any material is acceptable. To collect a sample, the tube is attached to a string of drill rod and is lowered into the borehole, where the sampler is then pressed into the undisturbed material by hydraulic force from the drill rig.

Sonic Drilling

Sonic drilling/rotary vibratory drilling employs the use of high-frequency, resonant energy to advance a core barrel or casing into subsurface formations. Although sonic drilling is not technically a direct-push method of soil sampling, it is similar because soil sample collection from cores of recovered unconsolidated soil would follow the same procedures as described for direct-push methodologies.

Sonic drilling is different than conventional drilling, as sonic drilling minimizes the friction between the borehole wall and the drilling tool by maintaining the resonance of the drill string with a sonic drill head. It also allows for drilling in areas where standard DPT would be refused, potentially requiring multiple step-outs and/or not sampling the desired area. It is also generally faster to advance than HSA or DPT. Typically, the drilling method utilizes dual casings that independently resonate into the subsurface with an inner core barrel that is overrun by an outer casing, similar to dual tube DPT sampling.

Excavator

A backhoe or excavator can be used to assist with soil sampling. This method is typically used during remedial excavation activities (to collect floor and sidewall samples within the excavation), test pit installation, or trenching operations. Test pit excavations are commonly completed to allow for greater observation of physical soil characteristics (e.g., stockpiles) and/or to further investigate buried suspect areas of concern (e.g., petroleum tanks, drums, waste, fill).

03
Headspace Field Screening Procedure

Title: **Headspace Field Screening Procedure**	Procedure Number: **ECR 014**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Jamie Stapleton		Elizabeth Denly	
Technical Reviewer Jamie Stapleton	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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ATTACHMENTS

Attachment A	Example Documentation for Headspace Field Screening Results
Attachment B	Photoionization Characteristics of Selected Compounds
Attachment C	SOP Fact Sheet

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for conducting headspace field screening measurements of solid and aqueous samples during field investigations. This SOP does not cover screening for health & safety purposes or well mouth and tank headspace.

1.2 Summary of Method

The objective of headspace field screening is to obtain organic vapor/gas measurements of solid or aqueous media encountered during solid or aqueous sampling. The procedure involves collecting solid or aqueous samples, sealing them in airtight containers, and analyzing the Total Organic Vapors (TOVs) that form within the container using a portable vapor/gas detector.

Headspace field screening data can be used to pre-screen field samples or as a guide to direct subsequent investigations. Data collected using these methods are considered qualitative and specific compounds cannot be distinguished.

1.3 Equipment

The following list of equipment may be utilized when conducting headspace field screening measurements. Project-specific conditions or requirements may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Photoionization detector (PID) with appropriate electron volt (eV) lamp source (see Section 1.6.2 for selection of proper lamp source) or flame ionization detector (FID)
- Aluminum foil
- 500 ml clean jars or larger (for solid samples) - jars less than 8 oz. capacity should not be used
- One quart or one gallon resealable plastic bags (for solid samples)
- 40 ml to 1,000 ml clean jars (for aqueous samples)
- Field book
- Charcoal filter (for FID only, if methane present)
- Moisture filter/external water trap (for PID only)
- Tedlar bag(s)
- Isobutylene (100 parts per million by volume [ppmV], at a minimum): compressed gas cylinder (for PID)
- Methane (100 ppmV, at a minimum): compressed gas cylinder (for FID)

- Zero air: compressed gas cylinder or carbon filter with ambient air
- Sharpie pen

1.4 Definitions

FID	An instrument that uses a flame to break down volatile organic compounds (VOCs) into ions that can be measured by the detector.
Headspace	The area/space between the sample media and the top of the airtight container holding the sample. Organic vapors, if present, will collect in this area/space and can be measured.
PID	An instrument that uses an ultraviolet light source to break down VOCs into ions that can be measured by the detector.
VOCs	Any chemical compound based on carbon chains or rings with a vapor pressure greater than 2 mm of mercury.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Implementing this SOP will require the use of compressed gases for portable meter calibration. These gases may be hazardous materials and TRC will appropriately transport, handle and store them at all times.

1.6 Cautions and Potential Problems

1.6.1 Environmental Factors

Environmental factors may influence the performance of these methods. These factors include:

1. High moisture in soil or sediment. High moisture levels in soil/sediment can limit the amount of contaminants that volatilize into the container headspace. High moisture levels affect PID readings more than FID readings and may cause a positive or negative bias or inconsistent and non-comparable readings. For this reason, headspace field screening readings of aqueous samples using a PID may not be appropriate. A water trap or filter should be used with a PID to reduce these impacts.

2. A slowly increasing response on a PID may result from moisture levels interfering with instrument measurements. Instrumentation with digital (LED/LCD) displays may not be able to discern maximum headspace response unless equipped with a maximum hold feature or strip-chart recorder.

3. High organic levels in soil or sediment and organic matter in aqueous samples. Contaminants can sorb onto organic matter (i.e., leaves, peat), which can limit the amount of contaminants that volatilize into the container headspace and may cause inconsistent or non-comparable readings. The presence of organic matter in aqueous samples (i.e., microbial populations) can

reduce volatilization of contaminants. High levels of organics in soil/sediment and aqueous samples may also produce methane, a natural gas that is included in the TOV readings from FIDs, but not recorded by PIDs. A charcoal filter may be used with an FID to remove the methane from the vapor sample.

4. Limited pore space due to fines (e.g., clay or silt). It may be difficult to generate headspace measurements in a tight clay matrix.
5. Meteorological variations, especially humidity and ambient temperature. Normal ambient temperature variations could affect the amount of vapors that form in the headspace. Very cold temperatures will limit volatilization of VOCs. Increasing ambient temperature as the day progresses will result in more volatilization and higher readings, an effect that needs to be considered when using the data to make decisions. PIDs may not be able to operate in heavy rain so the Project Manager should be consulted if inclement weather is expected.
6. Background ambient levels of VOCs. Before beginning a headspace field screening program, identify background ambient levels of VOCs. Taking these levels into account when interpreting headspace field screening measurements will minimize the potential for false measurements. Data may be corrected for background measurements; however, the use of this procedure will be determined on a site-specific basis by the Project Manager.

7. Be aware of where the headspace readings are being obtained. Locations near potential sources of VOCs, such as operating vehicles, operating generators, or air handling equipment at a site, may contribute to transient volatile conditions and be a source of bias.

8. Certain instruments have multiple operating ranges. If the sample yields headspace field screening results higher than the upper limit of calibration, recalibration to accommodate a higher range may be necessary.

1.6.2 Ionization Potentials of Contaminants of Concern

The ionization potential of the contaminant is the energy required to completely remove an electron from its atom. In general, the ultraviolet lamp in the PID will either be 10.6 eV or 11.7 eV. When selecting the proper lamp, the ionization potential of the contaminant(s) of concern must be less than the ionization potential of the lamp. For example, if a PID is equipped with a 10.6 eV lamp, it will generally detect compounds with ionization potentials less than or equal to 10.6 eV. For most compounds, a 10.6 eV lamp is sufficient. Refer to Attachment B for a list of compounds and their ionization potentials. Two examples of proper lamp selection are provided below:

Example 1: Trichloroethene: Ionization potential = 9.47 eV.
Since the ionization potential is less than 10.6 eV, either the 10.6 eV or the 11.7 eV lamp could be used.

Example 2: 1,1,1-Trichloroethane: Ionization potential = 11 eV
Since the ionization potential is greater than 10.6 eV but is less than 11.7 eV, only the 11.7 eV lamp could be used.

It should also be noted that the life of an 11.7 eV lamp is considerably shorter (i.e., 1-3 months) than that of a 10.6 eV lamp (i.e., up to 3 years).

1.6.3 High Levels of Methane

If samples are suspected of containing high levels of methane (e.g., high levels of decaying organics or sites undergoing natural or enhanced degradation), representative readings of non-methane hydrocarbon vapors may be inhibited when using an FID. To avoid methane interference, a PID should be used or if an FID is used, it should be equipped with a charcoal filter on the inlet which will filter out all compounds except methane and ethane; the heavier organic compounds are adsorbed onto the charcoal filter. Measurements can be taken with and without the charcoal filter to determine the levels of methane/ethane in the sample and TOVs, respectively. The use of a PID and one FID (without a filter) or two FIDs (one with a charcoal filter and one without a charcoal filter) may be considered in order to obtain simultaneous readings.

- Measurement without charcoal filter = TOV Concentration (including methane and ethane)
- Measurement with charcoal filter = Methane and Ethane Concentration
- Measurement without charcoal filter – Measurement with charcoal filter = Total Non-Methane/Ethane Hydrocarbons provided that the sample only contains hydrocarbons and no other VOCs that would be detected by the FID.

NOTE: The loading capacity (amount of hydrocarbons which can be adsorbed on the charcoal filter before breakthrough will occur) and lifetime of the charcoal filter must be verified with the vendor prior to use. Depending on project needs, it may be advisable to have a supply of charcoal on hand to replace spent filter material.

1.6.4 Use of Headspace Field Screening Data

It is important to note that measurements obtained using portable vapor/gas detectors such as a PID or FID are considered qualitative and semi-quantitative. This type of data is sufficient for demonstrating the relative presence of contamination, determining "hot spots," and using as a guide to direct subsequent investigations. This type of field screening data cannot be used to identify specific contaminants and should not be used to determine whether a sample is "clean."

1.6.5 Use of Thermal Enhancement for Headspace Measurements

Certain compounds (e.g., xylenes and other high molecular weight VOCs) yield a better response when the headspace screening is performed with thermal enhancement. Thermal enhancement of a sample can be performed using direct sunlight, a heated vehicle, a heated building, a hot water bath, or a hot lamp. Refer to site-specific plans to determine the need for thermal enhancement. Thermal enhancement may also be useful for headspace screening in cold weather situations.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Refer to the site-specific work plan and/or Quality Assurance Project Plan (QAPP), if applicable, for any site-specific procedures. Other state or federal requirements may be above and beyond the scope of this SOP and will be followed if applicable. In all instances, the actual procedures used should be documented and described in the field notes. Attachment B lists the ionization potentials of specific compounds. Refer to Section 1.6.2 for instruction on selecting a PID with an appropriate lamp.

2.1 Calibration Procedures

PID and FID field instruments shall be operated and calibrated to yield TOVs in ppm volume/volume (v/v) as isobutylene for the PID and methane for the FID. In certain instances, other gases may be appropriate for calibration. Correction of results using response factors may be appropriate; refer to the instrument manufacturer’s manuals for the proper procedure. Batteries of the PID and FID should be checked prior to the beginning of the field event. Following calibration, response checks should periodically be performed throughout the day to demonstrate the responsiveness of the instrument. These checks can be performed by exposing the PID or FID to the tip of a Sharpie pen; the performance of this check and the presence of instrument response must be documented in the field notes. General calibration procedures are as follows:

PID AND FID

1. Turn the instrument on and allow it to warm up for at least 10 minutes.
2. Fill a separate tedlar bag ¼ full with zero air; depress the bag completely to expel any miscellaneous gases trapped in the bag. Fill the bag full with zero air. Alternatively, clean ambient air can be used instead of a tedlar bag filled with zero air.
3. Set the PID or FID to the appropriate zero gas Calibration Mode.
4. Attach the probe to the tedlar bag, open the bag valve, and begin the calibration mode on the instrument. Keep the bag attached until the meter finishes the calibration. Alternatively, expose the probe to clean ambient air until the meter finishes the calibration.
5. Fill a tedlar bag ¼ full with the isobutylene standard for the PID or the methane standard for the FID. Depress the bag completely to expel any miscellaneous gases trapped in the bag. Fill the bag full with the isobutylene standard (PID) or methane standard (FID). Alternatively, the instrument can be connected directly to the compressed gas standard cylinder.
6. Set the instrument to the appropriate span gas Calibration Mode. Enter the appropriate calibration gas concentration in the meter.
7. Attach the probe to the tedlar bag, open the bag valve, and begin the calibration mode on the instrument. Keep the bag attached until the meter finishes the calibration. Alternatively, attach the probe directly to the compressed gas standard cylinder, open the cylinder valve, and begin the calibration mode on the instrument; keep the cylinder attached until the meter finishes the calibration.
8. Calibration should be performed in accordance with the site-specific work plan, at least at the beginning of the day. Calibration checks should be performed as necessary. Calibration

should be checked if there is a substantial change in weather, if you have moved from an indoor location to an outdoor location (or vice versa), or if inconsistent or non-comparable readings are observed. The calibration check is performed using the compressed gas standard followed by the zero air check. The measured value of the standard must be within ±10% of the true value. The zero air check should not yield a reading above background. All calibration measurements must be recorded in the field book or on a field data form (see Attachment A).

2.2 Field Screening Procedures

The following procedures should be followed for headspace field screening measurements of solid and aqueous samples. For solid samples, a re-sealable plastic bag may be substituted for clean jars; however, this depends on site-specific requirements and must be verified with the Project Manager. Soil samples collected for field screening should not be used for laboratory chemical analysis due to potential loss of volatile contaminants in the sample from sample handling. Sample collection for headspace field screening and laboratory analysis of VOCs should occur as soon as possible (i.e., preferably within minutes) after the sample is exposed to air to minimize loss of TOVs due to volatilization.

1. Put on chemical-resistant gloves.

2. Fill a clean container one-third to one-half full with the sample to be analyzed. The type and size of the container, as well as the amount of sample collected, should be consistent for all samples collected at a site. See Section 1.3 for appropriate size containers for each matrix.

3. Quickly cover the open container top with one sheet of clean aluminum foil and apply the screw cap to tightly seal the jar. Plastic bags filled with soil should be sealed.

4. Vigorously shake the jar or bag for approximately 15 seconds. Be sure that all samples are shaken for approximately the same period of time.

5. Allow headspace development to occur for at least 10 minutes. The time allowed for headspace development should be approximately the same for all samples; differences should be noted. Where ambient temperatures are near or below 32ºF (0ºC), thermal enhancement of the sample may be considered and modified via direct sunlight, a heated vehicle or building, a hot water bath, a hot lamp, or similar. Site-specific conditions (e.g., sunlight, wind) may impact the actual temperature. Otherwise, headspace development can occur at ambient temperatures. Headspace development should not be allowed to occur so long that condensation forms in the container.

6. Determine the background ambient level of TOVs. Record this value in the field book.

7. Vigorously shake jar for approximately 15 seconds after the headspace development period. Be sure that all samples are shaken for approximately the same period of time.

8. Subsequent to headspace development, unscrew and remove lid to expose aluminum foil seal. Be sure to hold edge of foil during the removal of the lid to ensure the foil seal remains in place. Quickly puncture aluminum foil seal with instrument sampling probe, and insert probe to a point about one-half of the headspace depth. Alternatively, for solid samples in a re-sealable bag, partially open the seal, insert the probe into the bag, and re-seal the zipper

around the probe. Exercise care to avoid uptake of water droplets or soil particulates into the instrument.

9. Following probe insertion through the aluminum foil seal or into the plastic bag, record the highest meter response as the headspace concentration. Using the aluminum foil seal/probe insertion method, maximum response should occur between 2 and 5 seconds.

10. The headspace screening data should be recorded in the field book and/or on a field data form (see Attachment A).

11. All headspace screening waste should be returned to the original source site location or disposed of in accordance with Section 3.0.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste (IDW) disposal with the Project Manager.

Each project must consider IDW disposal methods and have a plan in place prior to performing the field work. Provisions must be in place regarding what will be done with IDW. If IDW cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following procedures should be used for collecting headspace field screening measurements:

1. Operate and calibrate field instruments according to the manufacturer's manuals.

2. Headspace measurements should be performed in duplicate on one sample each day, at a minimum. This requires collection of two separate aliquots of sample. All procedures, including the amount of time allowed for headspace development and the number of seconds the containers are shaken, should be the same for each container. Ensure that both of the containers are in the same environment during headspace development (e.g., both jars are in the sun, both jars are in a heated car).

3. The results of duplicate samples should be compared; generally, the relative percent differences (RPDs) of the replicate values should be $\leq$20 when readings are greater than 10 ppmV. RPDs may be higher when readings are less than or equal to 10 ppmV. If the RPD of the replicate values is not within these criteria, make sure that the cautions and potential problems listed in Section 1.6 were not encountered during the headspace measurements. If none of these factors were encountered, perform a calibration check to ensure the instrument is working properly. Document the test results as well as any performance or calibration checks in the field book. RPD is calculated using the following equation:

$$\mathrm{RPD} = \frac{\mathrm{Reading\ 1} - \mathrm{Reading\ 2}}{(\mathrm{Reading\ 1} + \mathrm{Reading\ 2})/2} \mathrm{X}\, 100$$

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All procedures and field screening results must be documented in the field book and/or on an appropriate field data form. Refer to Attachment A for an example of headspace field screening results documentation. Correction of headspace measurements for background values may be performed; the use of this procedure will be determined on a site-specific basis by the Project Manager. Any deviations from the headspace field screening procedures specified in this SOP, a site-specific work plan, or a site-specific QAPP must be approved by the Project Manager as well as documented in the field book. In such cases, compelling technical justification must be presented and documented for the methodology employed. Refer to ECR SOP 001 for field documentation procedures.

6.0 REFERENCES

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

Expedited Site Assessment Tools For Underground Storage Tank Sites. EPA 510/B-97/001. March 1997.

Attachment 11, Interim Remediation Waste Management Policy for Petroleum Contaminated Soils. MassDEP WSC-94-400. April 1994.

Commonwealth of Massachusetts Underground Storage Tank Closure Assessment Manual. MassDEP WSC-402-96. April 9, 1996.

RAE Systems, Inc. Technical Note TN-106, *A Guideline for PID Instrument Response*, 07/16.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	APRIL 2015	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Attachment A

Example Documentation for Headspace Field Screening Results

Headspace Field Screening Log

Site Name ___________________________
Site Location ________________________
TRC Personnel_______________________

Instrument Used (make/model)____________________
Calibration Gas Used/Concentration_______________
Matrix/Sampling Method__________________________

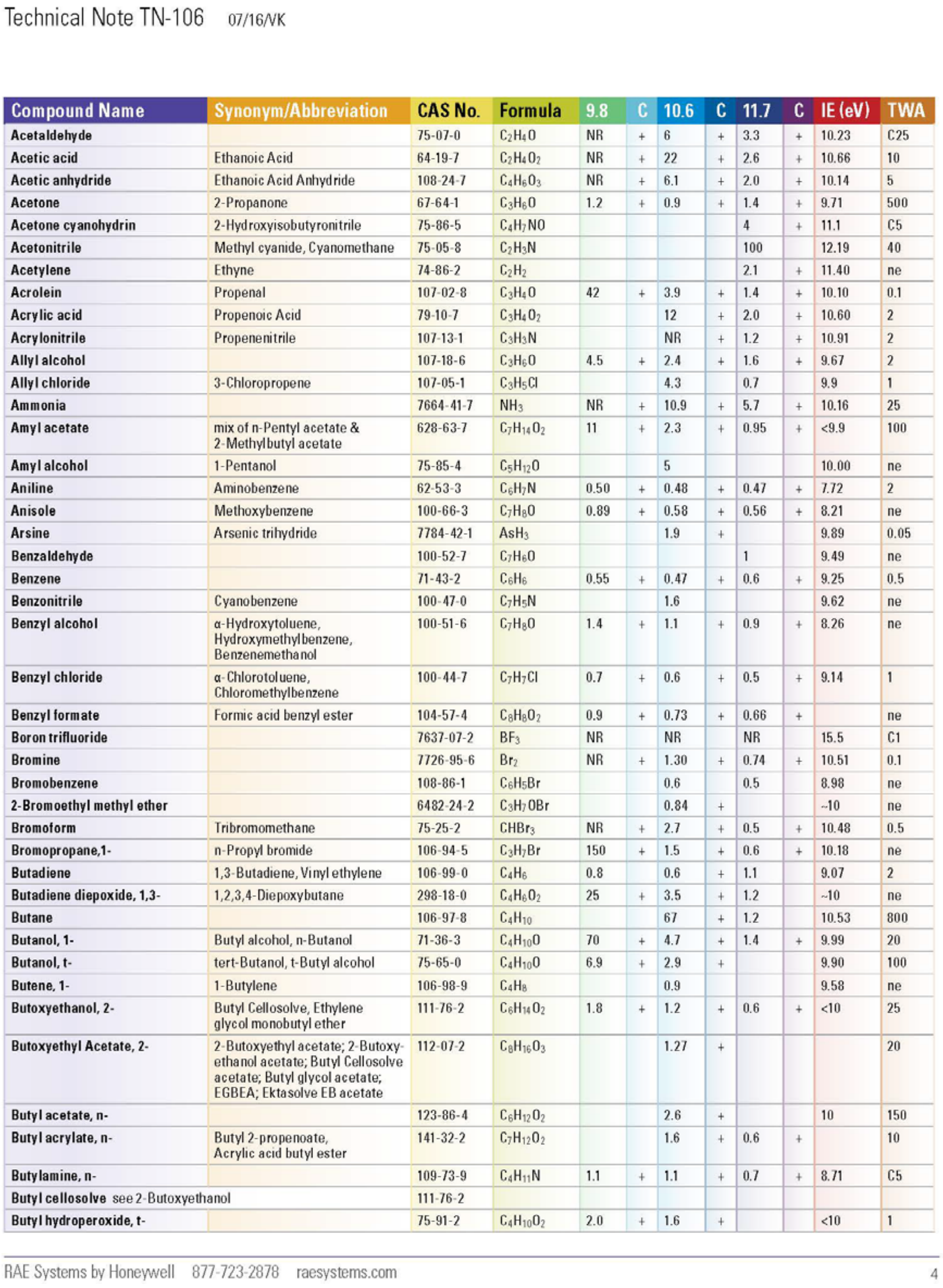
Sample ID	Location	Depth	Date/Time	Background Reading (ppmV)	Screening Results (ppmv)			Comments	Instrument/Lamp Used
					Reading 1	Reading 2	RPD		
Soil Boring – 01, 2-4’			*8/5/03-0700*	*2*	*24.6*	*25.3*	*2.8*	*South side of excavation*	*PID / 10.2 eV*
Soil Boring – 02, 0-2’			*8/5/03-0815*	*2*	*1.5*	*1.2*	*22*	*North side of excavation*	*PID / 10.2 eV*

ppmV = parts per million by volume
RPD = relative percent difference

Attachment B

Photoionization Characteristics of Selected Compounds

NR – No Response
IE – Ionization Energy
C – Confirmed values (correction factors) indicated by "+" in this column; all others are preliminary or estimated values and are subject to change
ne – Not Established ACGIH 8-hr. TWA
C## - Ceiling value, given where 8-hr. TWA is not available
TWA – Time-weighted average



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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C_2H_4O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	$C_2H_4O_2$	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	$C_4H_6O_3$	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C_3H_6O	1.2	+	0.9	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C_4H_7NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C_2H_3N					100		12.19	40
Acetylene	Ethyne	74-86-2	C_2H_2					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C_3H_4O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	$C_3H_4O_2$			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C_3H_3N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C_3H_6O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C_3H_5Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	NH_3	NR	+	10.9	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	$C_7H_{14}O_2$	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	$C_5H_{12}O$			5				10.00	ne
Aniline	Aminobenzene	62-53-3	C_6H_7N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C_7H_8O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH_3			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C_7H_6O					1		9.49	ne
Benzene		71-43-2	C_6H_6	0.55	+	0.47	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C_7H_5N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C_7H_8O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C_7H_7Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	$C_8H_8O_2$	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF_3	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br_2	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C_6H_5Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C_3H_7OBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	$CHBr_3$	NR	+	2.7	+	0.5	+	10.48	0.5
Bromopropane,1-	n-Propyl bromide	106-94-5	C_3H_7Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C_4H_6	0.8		0.6	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	$C_4H_6O_2$	25	+	3.5	+	1.2		~10	ne
Butane		106-97-8	C_4H_{10}			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	$C_4H_{10}O$	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	$C_4H_{10}O$	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C_4H_8			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	$C_6H_{14}O_2$	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethyl Acetate, 2-	2-Butoxyethyl acetate; 2-Butoxyethanol acetate; Butyl Cellosolve acetate; Butyl glycol acetate; EGBEA; Ektasolve EB acetate	112-07-2	$C_8H_{16}O_3$			1.27	+				20
Butyl acetate, n-		123-86-4	$C_6H_{12}O_2$			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	$C_7H_{12}O_2$			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	$C_4H_{11}N$	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve see 2-Butoxyethanol		111-76-2									
Butyl hydroperoxide, t-		75-91-2	$C_4H_{10}O_2$	2.0	+	1.6	+			<10	1

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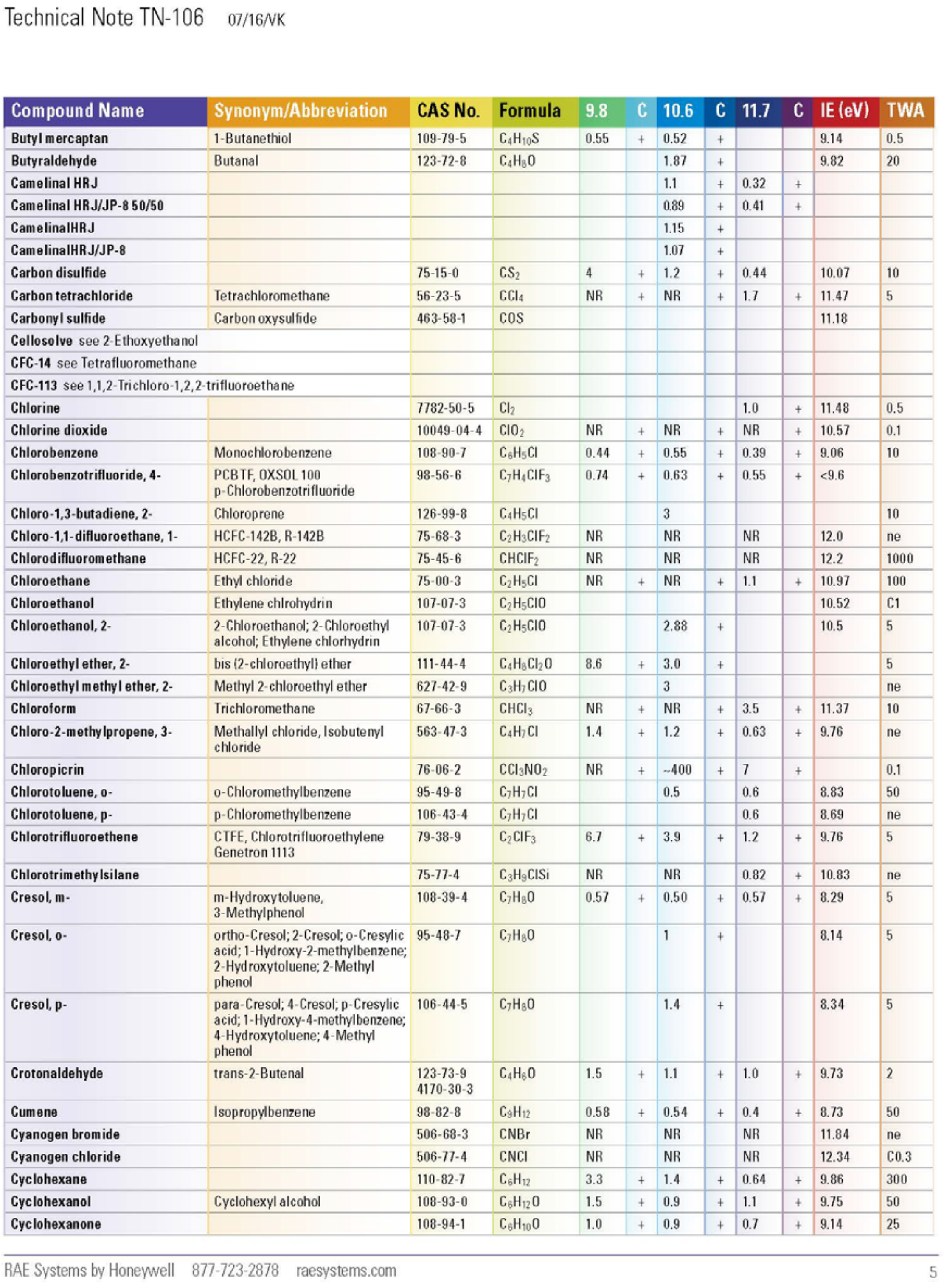

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Butyl mercaptan	1-Butanethiol	109-79-5	$C_4H_{10}S$	0.55	+	0.52	+			9.14	0.5
Butyraldehyde	Butanal	123-72-8	C_4H_8O			1.87	+			9.82	20
Camelinal HRJ						1.1	+	0.32	+		
Camelinal HRJ/JP-8 50/50						0.89	+	0.41	+		
CamelinalHRJ						1.15	+				
CamelinalHRJ/JP-8						1.07	+				
Carbon disulfide		75-15-0	CS_2	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl_4	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve see 2-Ethoxyethanol											
CFC-14 see Tetrafluoromethane											
CFC-113 see 1,1,2-Trichloro-1,2,2-trifluoroethane											
Chlorine		7782-50-5	Cl_2					1.0	+	11.48	0.5
Chlorine dioxide		10049-04-4	ClO_2	NR	+	NR	+	NR	+	10.57	0.1
Chlorobenzene	Monochlorobenzene	108-90-7	C_6H_5Cl	0.44	+	0.55	+	0.39	+	9.06	10
Chlorobenzotrifluoride, 4-	PCBTF, OXSOL 100 p-Chlorobenzotrifluoride	98-56-6	$C_7H_4ClF_3$	0.74	+	0.63	+	0.55	+	<9.6	
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C_4H_5Cl			3					10
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	$C_2H_3ClF_2$	NR		NR		NR		12.0	ne
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	$CHClF_2$	NR		NR		NR		12.2	1000
Chloroethane	Ethyl chloride	75-00-3	C_2H_5Cl	NR	+	NR	+	1.1	+	10.97	100
Chloroethanol	Ethylene chlrohydrin	107-07-3	C_2H_5ClO							10.52	C1
Chloroethanol, 2-	2-Chloroethanol; 2-Chloroethyl alcohol; Ethylene chlorhydrin	107-07-3	C_2H_5ClO			2.88	+			10.5	5
Chloroethyl ether, 2-	bis (2-chloroethyl) ether	111-44-4	$C_4H_8Cl_2O$	8.6	+	3.0	+				5
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C_3H_7ClO			3					ne
Chloroform	Trichloromethane	67-66-3	$CHCl_3$	NR	+	NR	+	3.5	+	11.37	10
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C_4H_7Cl	1.4	+	1.2	+	0.63	+	9.76	ne
Chloropicrin		76-06-2	CCl_3NO_2	NR	+	~400	+	7	+		0.1
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C_7H_7Cl			0.5		0.6		8.83	50
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C_7H_7Cl					0.6		8.69	ne
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene Genetron 1113	79-38-9	C_2ClF_3	6.7	+	3.9	+	1.2	+	9.76	5
Chlorotrimethylsilane		75-77-4	C_3H_9ClSi	NR		NR		0.82	+	10.83	ne
Cresol, m-	m-Hydroxytoluene, 3-Methylphenol	108-39-4	C_7H_8O	0.57	+	0.50	+	0.57	+	8.29	5
Cresol, o-	ortho-Cresol; 2-Cresol; o-Cresylic acid; 1-Hydroxy-2-methylbenzene; 2-Hydroxytoluene; 2-Methyl phenol	95-48-7	C_7H_8O			1	+			8.14	5
Cresol, p-	para-Cresol; 4-Cresol; p-Cresylic acid; 1-Hydroxy-4-methylbenzene; 4-Hydroxytoluene; 4-Methyl phenol	106-44-5	C_7H_8O			1.4	+			8.34	5
Crotonaldehyde	trans-2-Butenal	123-73-9 4170-30-3	C_4H_6O	1.5	+	1.1	+	1.0	+	9.73	2
Cumene	Isopropylbenzene	98-82-8	C_9H_{12}	0.58	+	0.54	+	0.4	+	8.73	50
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3
Cyclohexane		110-82-7	C_6H_{12}	3.3	+	1.4	+	0.64	+	9.86	300
Cyclohexanol	Cyclohexyl alcohol	108-93-0	$C_6H_{12}O$	1.5	+	0.9	+	1.1	+	9.75	50
Cyclohexanone		108-94-1	$C_6H_{10}O$	1.0	+	0.9	+	0.7	+	9.14	25

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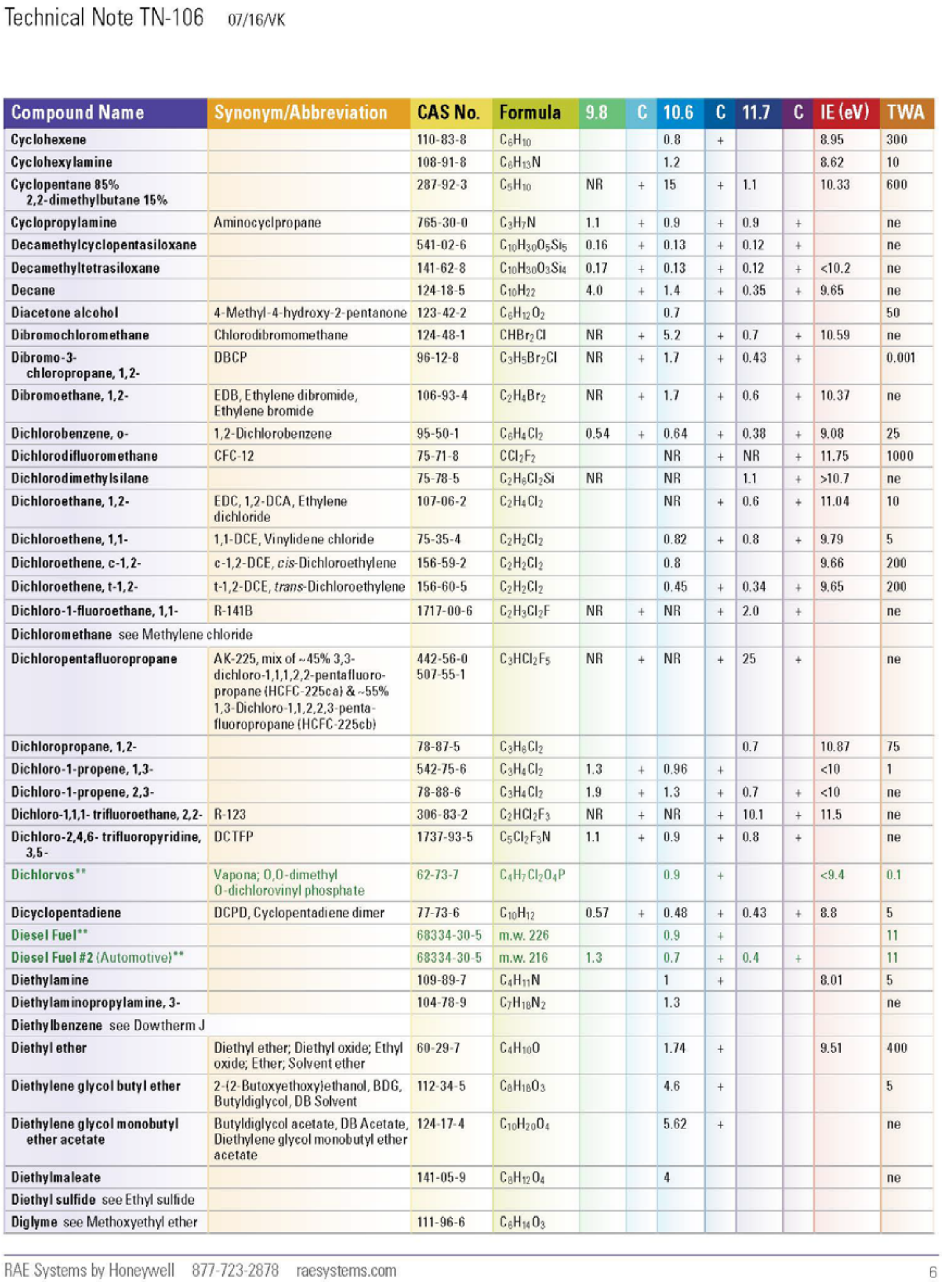

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Cyclohexene		110-83-8	C_6H_{10}			0.8	+			8.95	300
Cyclohexylamine		108-91-8	$C_6H_{13}N$			1.2				8.62	10
Cyclopentane 85% 2,2-dimethylbutane 15%		287-92-3	C_5H_{10}	NR	+	15	+	1.1		10.33	600
Cyclopropylamine	Aminocyclpropane	765-30-0	C_3H_7N	1.1	+	0.9	+	0.9	+		ne
Decamethylcyclopentasiloxane		541-02-6	$C_{10}H_{30}O_5Si_5$	0.16	+	0.13	+	0.12	+		ne
Decamethyltetrasiloxane		141-62-8	$C_{10}H_{30}O_3Si_4$	0.17	+	0.13	+	0.12	+	<10.2	ne
Decane		124-18-5	$C_{10}H_{22}$	4.0	+	1.4	+	0.35	+	9.65	ne
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	$C_6H_{12}O_2$			0.7					50
Dibromochloromethane	Chlorodibromomethane	124-48-1	$CHBr_2Cl$	NR	+	5.2	+	0.7	+	10.59	ne
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	$C_3H_5Br_2Cl$	NR	+	1.7	+	0.43	+		0.001
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	$C_2H_4Br_2$	NR	+	1.7	+	0.6	+	10.37	ne
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	$C_6H_4Cl_2$	0.54	+	0.64	+	0.38	+	9.08	25
Dichlorodifluoromethane	CFC-12	75-71-8	CCl_2F_2			NR	+	NR	+	11.75	1000
Dichlorodimethylsilane		75-78-5	$C_2H_6Cl_2Si$	NR		NR		1.1	+	>10.7	ne
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	$C_2H_4Cl_2$			NR	+	0.6	+	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	$C_2H_2Cl_2$			0.82	+	0.8	+	9.79	5
Dichloroethene, c-1,2-	c-1,2-DCE, *cis*-Dichloroethylene	156-59-2	$C_2H_2Cl_2$			0.8				9.66	200
Dichloroethene, t-1,2-	t-1,2-DCE, *trans*-Dichloroethylene	156-60-5	$C_2H_2Cl_2$			0.45	+	0.34	+	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	$C_2H_3Cl_2F$	NR	+	NR	+	2.0	+		ne
Dichloromethane see Methylene chloride											
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)	442-56-0 507-55-1	$C_3HCl_2F_5$	NR	+	NR	+	25	+		ne
Dichloropropane, 1,2-		78-87-5	$C_3H_6Cl_2$					0.7		10.87	75
Dichloro-1-propene, 1,3-		542-75-6	$C_3H_4Cl_2$	1.3	+	0.96	+			<10	1
Dichloro-1-propene, 2,3-		78-88-6	$C_3H_4Cl_2$	1.9	+	1.3	+	0.7	+	<10	ne
Dichloro-1,1,1- trifluoroethane, 2,2-	R-123	306-83-2	$C_2HCl_2F_3$	NR	+	NR	+	10.1	+	11.5	ne
Dichloro-2,4,6- trifluoropyridine, 3,5-	DCTFP	1737-93-5	$C_5Cl_2F_3N$	1.1	+	0.9	+	0.8	+		ne
Dichlorvos**	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	$C_4H_7Cl_2O_4P$			0.9	+			<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	$C_{10}H_{12}$	0.57	+	0.48	+	0.43	+	8.8	5
Diesel Fuel**		68334-30-5	m.w. 226			0.9	+				11
Diesel Fuel #2 (Automotive)**		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+		11
Diethylamine		109-89-7	$C_4H_{11}N$			1	+			8.01	5
Diethylaminopropylamine, 3-		104-78-9	$C_7H_{18}N_2$			1.3					ne
Diethylbenzene see Dowtherm J											
Diethyl ether	Diethyl ether; Diethyl oxide; Ethyl oxide; Ether; Solvent ether	60-29-7	$C_4H_{10}O$			1.74	+			9.51	400
Diethylene glycol butyl ether	2-(2-Butoxyethoxy)ethanol, BDG, Butyldiglycol, DB Solvent	112-34-5	$C_8H_{18}O_3$			4.6	+				5
Diethylene glycol monobutyl ether acetate	Butyldiglycol acetate, DB Acetate, Diethylene glycol monobutyl ether acetate	124-17-4	$C_{10}H_{20}O_4$			5.62	+				ne
Diethylmaleate		141-05-9	$C_8H_{12}O_4$			4					ne
Diethyl sulfide see Ethyl sulfide											
Diglyme see Methoxyethyl ether		111-96-6	$C_6H_{14}O_3$								

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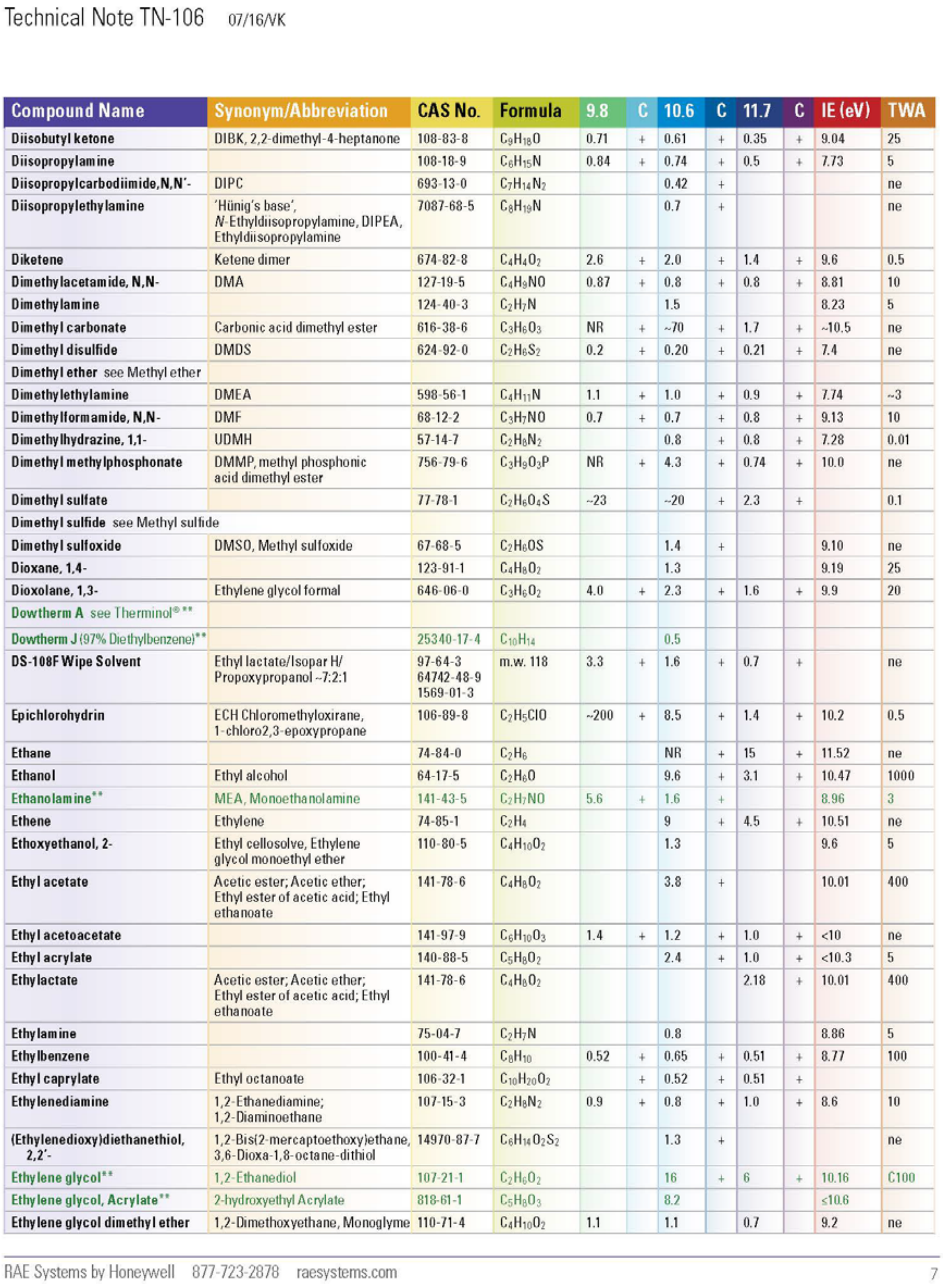

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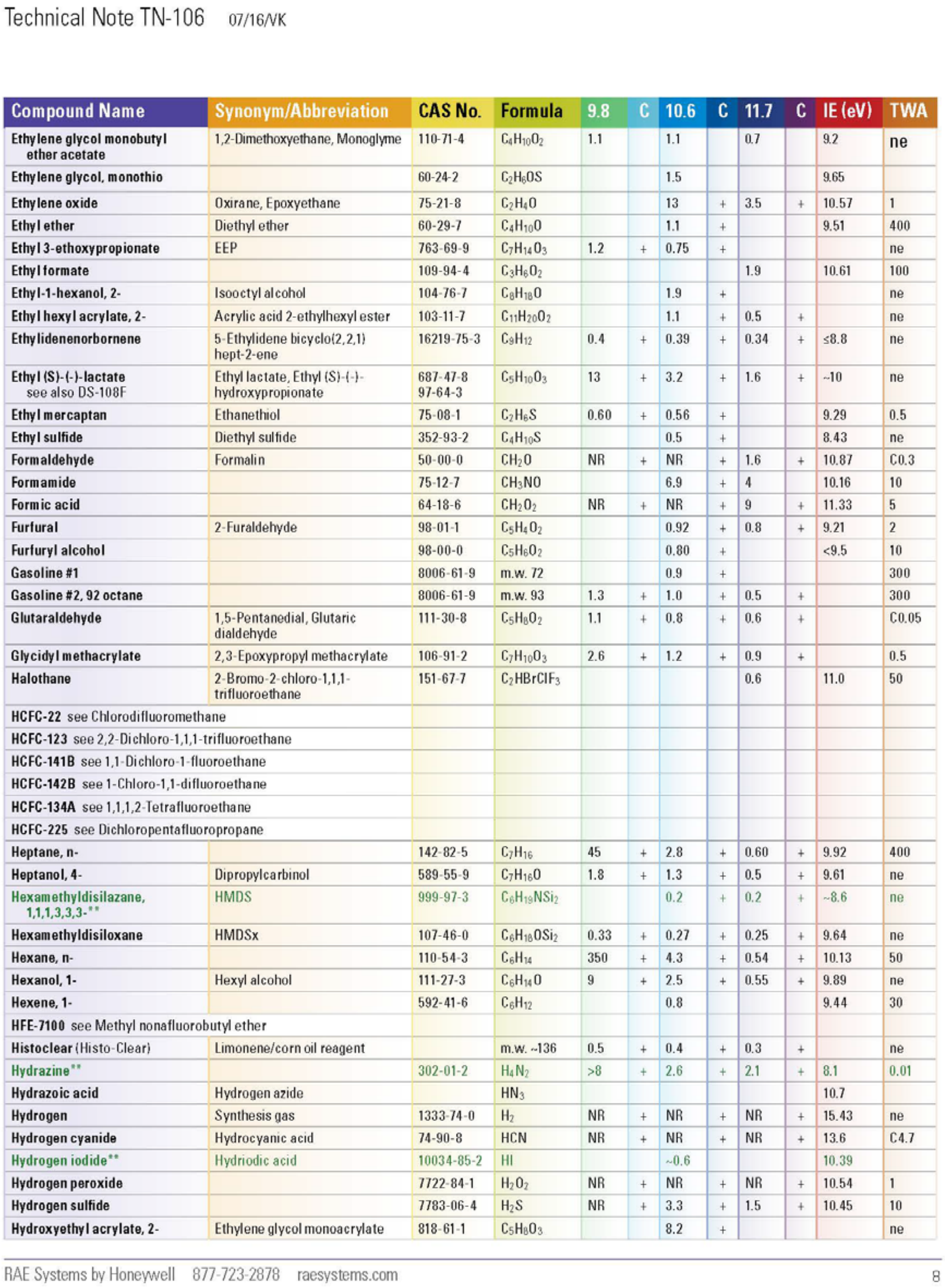
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	$C_9H_{18}O$	0.71	+	0.61	+	0.35	+	9.04	25
Diisopropylamine		108-18-9	$C_6H_{15}N$	0.84	+	0.74	+	0.5	+	7.73	5
Diisopropylcarbodiimide,N,N'-	DIPC	693-13-0	$C_7H_{14}N_2$			0.42	+				ne
Diisopropylethylamine	'Hünig's base', *N*-Ethyldiisopropylamine, DIPEA, Ethyldiisopropylamine	7087-68-5	$C_8H_{19}N$			0.7	+				ne
Diketene	Ketene dimer	674-82-8	$C_4H_4O_2$	2.6	+	2.0	+	1.4	+	9.6	0.5
Dimethylacetamide, N,N-	DMA	127-19-5	C_4H_9NO	0.87	+	0.8	+	0.8	+	8.81	10
Dimethylamine		124-40-3	C_2H_7N			1.5				8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	$C_3H_6O_3$	NR	+	~70	+	1.7	+	~10.5	ne
Dimethyl disulfide	DMDS	624-92-0	$C_2H_6S_2$	0.2	+	0.20	+	0.21	+	7.4	ne
Dimethyl ether see Methyl ether											
Dimethylethylamine	DMEA	598-56-1	$C_4H_{11}N$	1.1	+	1.0	+	0.9	+	7.74	~3
Dimethylformamide, N,N-	DMF	68-12-2	C_3H_7NO	0.7	+	0.7	+	0.8	+	9.13	10
Dimethylhydrazine, 1,1-	UDMH	57-14-7	$C_2H_8N_2$			0.8	+	0.8	+	7.28	0.01
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	$C_3H_9O_3P$	NR	+	4.3	+	0.74	+	10.0	ne
Dimethyl sulfate		77-78-1	$C_2H_6O_4S$	~23		~20	+	2.3	+		0.1
Dimethyl sulfide see Methyl sulfide											
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C_2H_6OS			1.4	+			9.10	ne
Dioxane, 1,4-		123-91-1	$C_4H_8O_2$			1.3				9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	$C_3H_6O_2$	4.0	+	2.3	+	1.6	+	9.9	20
Dowtherm A see Therminol®**											
Dowtherm J (97% Diethylbenzene)**		25340-17-4	$C_{10}H_{14}$			0.5					
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/ Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+		ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro2,3-epoxypropane	106-89-8	C_2H_5ClO	~200	+	8.5	+	1.4	+	10.2	0.5
Ethane		74-84-0	C_2H_6			NR	+	15	+	11.52	ne
Ethanol	Ethyl alcohol	64-17-5	C_2H_6O			9.6	+	3.1	+	10.47	1000
Ethanolamine**	MEA, Monoethanolamine	141-43-5	C_2H_7NO	5.6	+	1.6	+			8.96	3
Ethene	Ethylene	74-85-1	C_2H_4			9	+	4.5	+	10.51	ne
Ethoxyethanol, 2-	Ethyl cellosolve, Ethylene glycol monoethyl ether	110-80-5	$C_4H_{10}O_2$			1.3				9.6	5
Ethyl acetate	Acetic ester; Acetic ether; Ethyl ester of acetic acid; Ethyl ethanoate	141-78-6	$C_4H_8O_2$			3.8	+			10.01	400
Ethyl acetoacetate		141-97-9	$C_6H_{10}O_3$	1.4	+	1.2	+	1.0	+	<10	ne
Ethyl acrylate		140-88-5	$C_5H_8O_2$			2.4	+	1.0	+	<10.3	5
Ethylactate	Acetic ester; Acetic ether; Ethyl ester of acetic acid; Ethyl ethanoate	141-78-6	$C_4H_8O_2$					2.18	+	10.01	400
Ethylamine		75-04-7	C_2H_7N			0.8				8.86	5
Ethylbenzene		100-41-4	C_8H_{10}	0.52	+	0.65	+	0.51	+	8.77	100
Ethyl caprylate	Ethyl octanoate	106-32-1	$C_{10}H_{20}O_2$		+	0.52	+	0.51	+		
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	$C_2H_8N_2$	0.9	+	0.8	+	1.0	+	8.6	10
(Ethylenedioxy)diethanethiol, 2,2'-	1,2-Bis(2-mercaptoethoxy)ethane, 3,6-Dioxa-1,8-octane-dithiol	14970-87-7	$C_6H_{14}O_2S_2$			1.3	+				ne
Ethylene glycol**	1,2-Ethanediol	107-21-1	$C_2H_6O_2$			16	+	6	+	10.16	C100
Ethylene glycol, Acrylate**	2-hydroxyethyl Acrylate	818-61-1	$C_5H_8O_3$			8.2				≤10.6	
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	$C_4H_{10}O_2$	1.1		1.1		0.7		9.2	ne



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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Ethylene glycol monobutyl ether acetate	1,2-Dimethoxyethane, Monoglyme	110-71-4	$C_4H_{10}O_2$	1.1		1.1		0.7		9.2	ne
Ethylene glycol, monothio		60-24-2	C_2H_6OS			1.5				9.65	
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C_2H_4O			13	+	3.5	+	10.57	1
Ethyl ether	Diethyl ether	60-29-7	$C_4H_{10}O$			1.1	+			9.51	400
Ethyl 3-ethoxypropionate	EEP	763-69-9	$C_7H_{14}O_3$	1.2	+	0.75	+				ne
Ethyl formate		109-94-4	$C_3H_6O_2$					1.9		10.61	100
Ethyl-1-hexanol, 2-	Isooctyl alcohol	104-76-7	$C_8H_{18}O$			1.9	+				ne
Ethyl hexyl acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	$C_{11}H_{20}O_2$			1.1	+	0.5	+		ne
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1) hept-2-ene	16219-75-3	C_9H_{12}	0.4	+	0.39	+	0.34	+	≤8.8	ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	$C_5H_{10}O_3$	13	+	3.2	+	1.6	+	~10	ne
Ethyl mercaptan	Ethanethiol	75-08-1	C_2H_6S	0.60	+	0.56	+			9.29	0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	$C_4H_{10}S$			0.5	+			8.43	ne
Formaldehyde	Formalin	50-00-0	CH_2O	NR	+	NR	+	1.6	+	10.87	C0.3
Formamide		75-12-7	CH_3NO			6.9	+	4		10.16	10
Formic acid		64-18-6	CH_2O_2	NR	+	NR	+	9	+	11.33	5
Furfural	2-Furaldehyde	98-01-1	$C_5H_4O_2$			0.92	+	0.8	+	9.21	2
Furfuryl alcohol		98-00-0	$C_5H_6O_2$			0.80	+			<9.5	10
Gasoline #1		8006-61-9	m.w. 72			0.9	+				300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+		300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	$C_5H_8O_2$	1.1	+	0.8	+	0.6	+		C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	$C_7H_{10}O_3$	2.6	+	1.2	+	0.9	+		0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	$C_2HBrClF_3$					0.6		11.0	50
HCFC-22 see Chlorodifluoromethane											
HCFC-123 see 2,2-Dichloro-1,1,1-trifluoroethane											
HCFC-141B see 1,1-Dichloro-1-fluoroethane											
HCFC-142B see 1-Chloro-1,1-difluoroethane											
HCFC-134A see 1,1,1,2-Tetrafluoroethane											
HCFC-225 see Dichloropentafluoropropane											
Heptane, n-		142-82-5	C_7H_{16}	45	+	2.8	+	0.60	+	9.92	400
Heptanol, 4-	Dipropylcarbinol	589-55-9	$C_7H_{16}O$	1.8	+	1.3	+	0.5	+	9.61	ne
Hexamethyldisilazane, 1,1,1,3,3,3-**	HMDS	999-97-3	$C_6H_{19}NSi_2$			0.2	+	0.2	+	~8.6	ne
Hexamethyldisiloxane	HMDSx	107-46-0	$C_6H_{18}OSi_2$	0.33	+	0.27	+	0.25	+	9.64	ne
Hexane, n-		110-54-3	C_6H_{14}	350	+	4.3	+	0.54	+	10.13	50
Hexanol, 1-	Hexyl alcohol	111-27-3	$C_6H_{14}O$	9	+	2.5	+	0.55	+	9.89	ne
Hexene, 1-		592-41-6	C_6H_{12}			0.8				9.44	30
HFE-7100 see Methyl nonafluorobutyl ether											
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+		ne
Hydrazine**		302-01-2	H_4N_2	>8	+	2.6	+	2.1	+	8.1	0.01
Hydrazoic acid	Hydrogen azide		HN_3							10.7	
Hydrogen	Synthesis gas	1333-74-0	H_2	NR	+	NR	+	NR	+	15.43	ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+	13.6	C4.7
Hydrogen iodide**	Hydriodic acid	10034-85-2	HI			~0.6				10.39	
Hydrogen peroxide		7722-84-1	H_2O_2	NR	+	NR	+	NR	+	10.54	1
Hydrogen sulfide		7783-06-4	H_2S	NR	+	3.3	+	1.5	+	10.45	10
Hydroxyethyl acrylate, 2-	Ethylene glycol monoacrylate	818-61-1	$C_5H_8O_3$			8.2	+				ne

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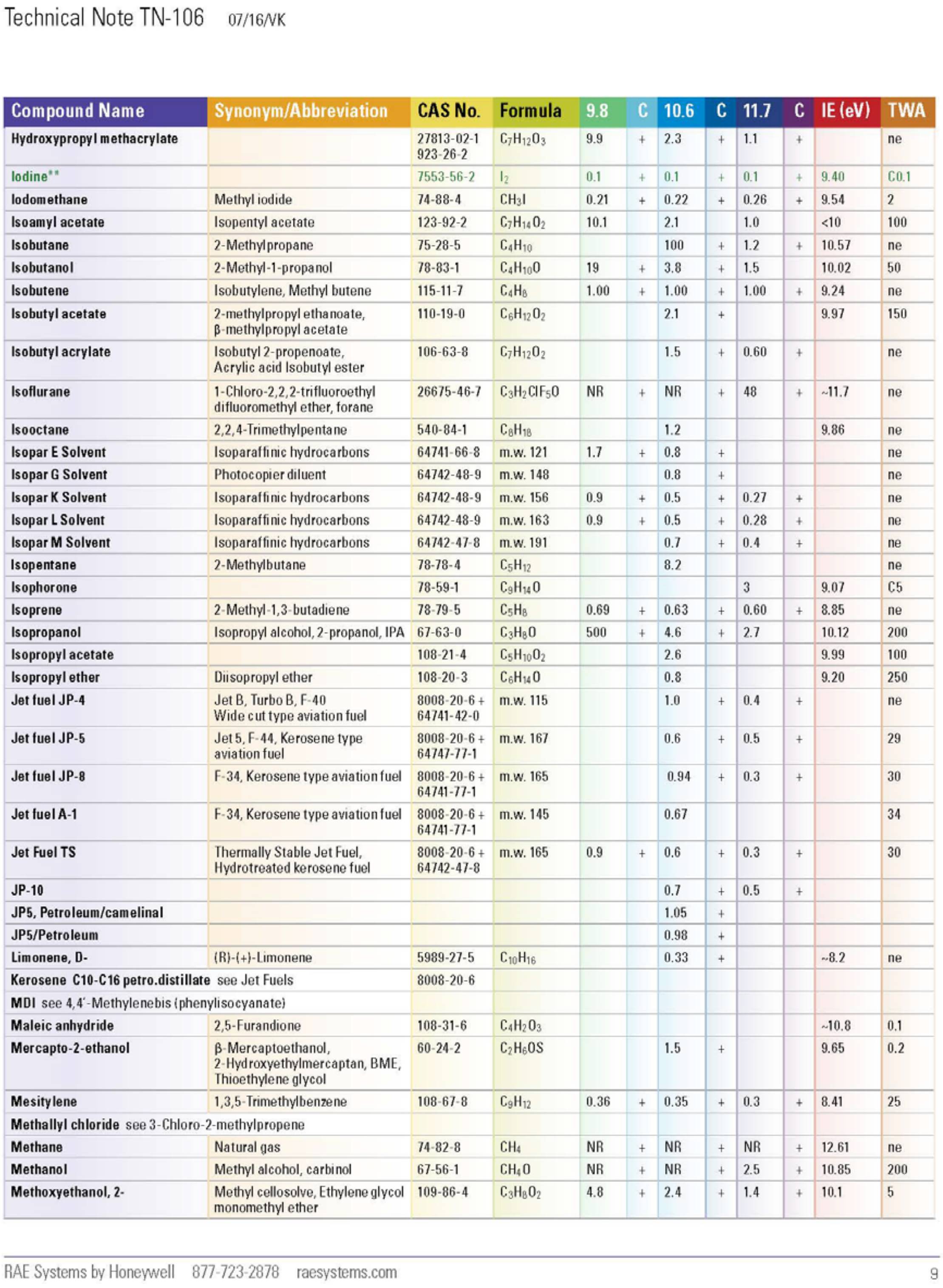

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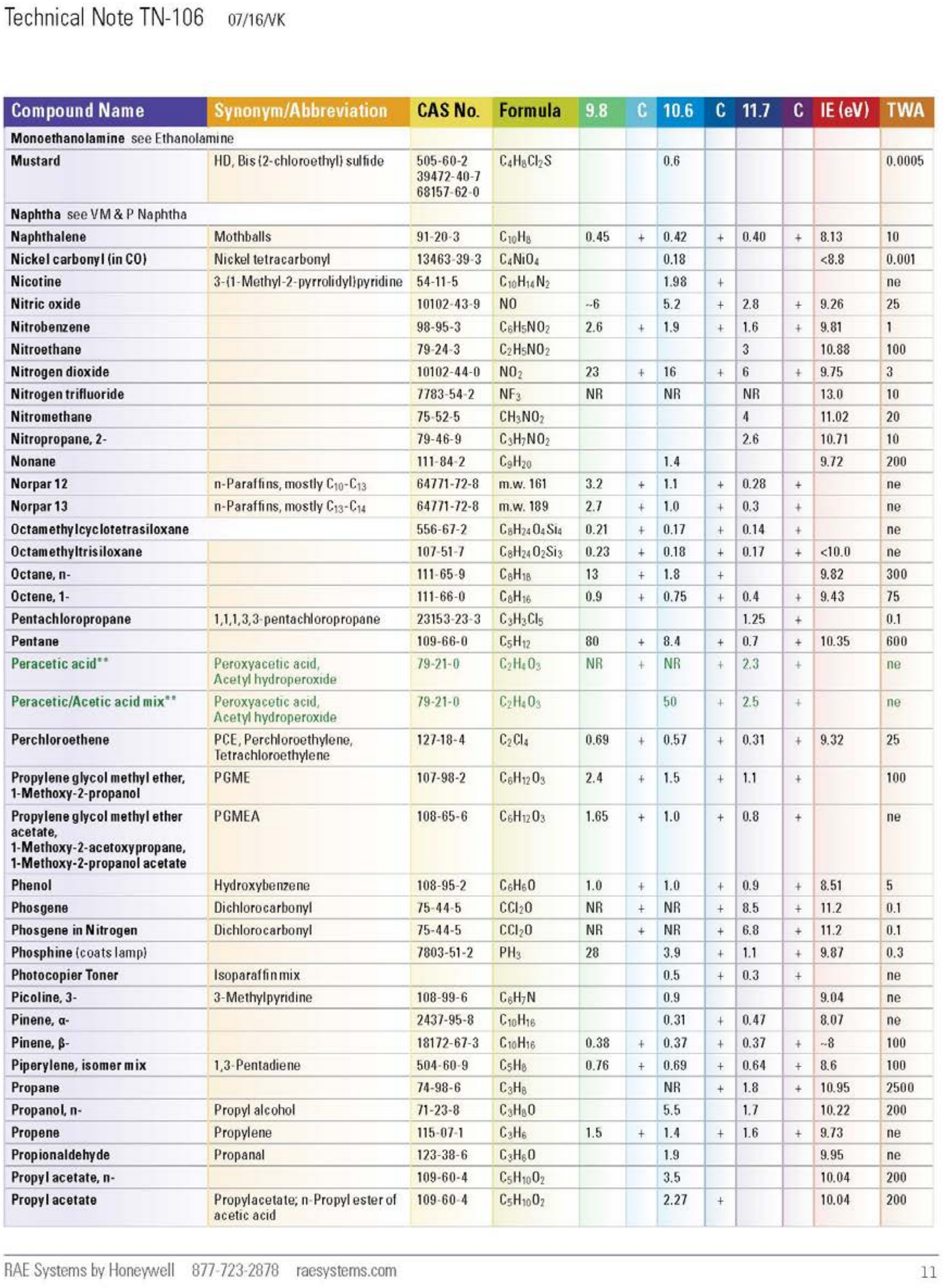
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Hydroxypropyl methacrylate		27813-02-1 923-26-2	$C_7H_{12}O_3$	9.9	+	2.3	+	1.1	+		ne
Iodine**		7553-56-2	I_2	0.1	+	0.1	+	0.1	+	9.40	C0.1
Iodomethane	Methyl iodide	74-88-4	CH_3I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	$C_7H_{14}O_2$	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C_4H_{10}			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	$C_4H_{10}O$	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C_4H_8	1.00	+	1.00	+	1.00	+	9.24	ne
Isobutyl acetate	2-methylpropyl ethanoate, β-methylpropyl acetate	110-19-0	$C_6H_{12}O_2$			2.1	+			9.97	150
Isobutyl acrylate	Isobutyl 2-propenoate, Acrylic acid Isobutyl ester	106-63-8	$C_7H_{12}O_2$			1.5	+	0.60	+		ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	$C_3H_2ClF_5O$	NR	+	NR	+	48	+	~11.7	ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C_8H_{18}			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		ne
Isopentane	2-Methylbutane	78-78-4	C_5H_{12}			8.2					ne
Isophorone		78-59-1	$C_9H_{14}O$					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C_5H_8	0.69	+	0.63	+	0.60	+	8.85	ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C_3H_8O	500	+	4.6	+	2.7		10.12	200
Isopropyl acetate		108-21-4	$C_5H_{10}O_2$			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	$C_6H_{14}O$			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40 Wide cut type aviation fuel	8008-20-6 + 64741-42-0	m.w. 115			1.0	+	0.4	+		ne
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 + 64747-77-1	m.w. 167			0.6	+	0.5	+		29
Jet fuel JP-8	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 165			0.94	+	0.3	+		30
Jet fuel A-1	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 145			0.67					34
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel	8008-20-6 + 64742-47-8	m.w. 165	0.9	+	0.6	+	0.3	+		30
JP-10						0.7	+	0.5	+		
JP5, Petroleum/camelinal						1.05	+				
JP5/Petroleum						0.98	+				
Limonene, D-	(R)-(+)-Limonene	5989-27-5	$C_{10}H_{16}$			0.33	+			~8.2	ne
Kerosene C10-C16 petro.distillate see Jet Fuels		8008-20-6									
MDI see 4,4′-Methylenebis (phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	$C_4H_2O_3$							~10.8	0.1
Mercapto-2-ethanol	β-Mercaptoethanol, 2-Hydroxyethylmercaptan, BME, Thioethylene glycol	60-24-2	C_2H_6OS			1.5	+			9.65	0.2
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C_9H_{12}	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride see 3-Chloro-2-methylpropene											
Methane	Natural gas	74-82-8	CH_4	NR	+	NR	+	NR	+	12.61	ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH_4O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	$C_3H_8O_2$	4.8	+	2.4	+	1.4	+	10.1	5

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol Diethylene glycol monomethyl ether	111-77-3	$C_7H_{16}O$	2.3	+	1.2	+	0.9	+	<10	ne
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	$C_6H_{14}O_3$	0.64	+	0.54	+	0.44	+	<9.8	ne
Methyl acetate		79-20-9	$C_3H_6O_2$	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	$C_4H_6O_2$			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH_5N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	$C_7H_{14}O$	0.9	+	0.85	+	0.5	+	9.30	50
Methylaniline, N-	MA; (Methylamino) benzene; N-Methyl aniline; Methylphenylamine; N-Phenylmethylamin	100-61-8	C_7H_9N			0.68	+			7.32	2
Methyl bromide	Bromomethane	74-83-9	CH_3Br	110	+	1.7	+	1.3	+	10.54	1
Methyl-2-butanol, 2-	*tert*-Amyl alcohol, *tert*-Pentyl alcohol	75-85-4	$C_5H_{12}O$			1.62	+			10.16	100
Methyl t-butyl ether	MTBE, tert-Butyl methyl ether	1634-04-4	$C_5H_{12}O$			0.9	+			9.24	40
Methyl cellosolve see 2-Methoxyethanol											
Methyl chloride	Chloromethane	74-87-3	CH_3Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C_7H_{14}	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis (phenyl-isocyanate), 4,4′-**	MDI, Mondur M		$C_{15}H_{10}N_2O_2$	Very slow ppb level response							0.005
Methylene chloride	Dichloromethane	75-09-2	CH_2Cl_2	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C_2H_6O	4.8	+	3.1	+	2.5	+	10.03	ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C_4H_8O	0.86	+	1.0	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	$C_2H_6N_2$	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAK, 5-Methyl-2-hexanone	110-12-3	$C_7H_{14}O$	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	$C_6H_{12}O$	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate		624-83-9	C_2H_3NO	NR	+	4.6	+	1.5		10.67	0.02
Methyl isothiocyanate		551-61-6	C_2H_3NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH_4S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	$C_5H_8O_2$	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	$C_5H_3F_9O$			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2- (coats lamp)**	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	$C_6H_{16}N_2$			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	$C_5H_{12}O$			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C_5H_9NO	1.0	+	0.8	+	0.9	+	9.17	ne
Methyl salicylate**	Methyl 2-hydroxybenzoate	119-36-8	$C_8H_8O_3$	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C_9H_{10}			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C_2H_6S	0.49	+	0.44	+	0.46	+	8.69	ne
Methyl tertiary-butyl ether	MTBE, Methyl *tert*-butyl ether	1634-04-4	$C_5H_{12}O$			1.43	+			9.24	50
Methyl vinyl ketone	MVK, 3-Buten-2-one	78-94-4	C_4H_6O			0.93	+			9.65	ne
Methyltetrahydrofuran	2-MeTHF, Tetrahydro-2-methylfuran, Tetrahydrosilvan	96-47-9	$C_5H_{10}O$			2.44	+			9.22	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5 8052-41-3 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits	Viscor 120B Calibration Fluid, b.p. 156-207°C	8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100



Technical Note TN-106 07/16/VK

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Monoethanolamine see Ethanolamine											
Mustard	HD, Bis (2-chloroethyl) sulfide	505-60-2 39472-40-7 68157-62-0	$C_4H_8Cl_2S$			0.6					0.0005
Naphtha see VM & P Naphtha											
Naphthalene	Mothballs	91-20-3	$C_{10}H_8$	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C_4NiO_4			0.18				<8.8	0.001
Nicotine	3-(1-Methyl-2-pyrrolidyl)pyridine	54-11-5	$C_{10}H_{14}N_2$			1.98	+				ne
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	$C_6H_5NO_2$	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	$C_2H_5NO_2$					3		10.88	100
Nitrogen dioxide		10102-44-0	NO_2	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF_3	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH_3NO_2					4		11.02	20
Nitropropane, 2-		79-46-9	$C_3H_7NO_2$					2.6		10.71	10
Nonane		111-84-2	C_9H_{20}			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C_{10}-C_{13}	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C_{13}-C_{14}	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	$C_8H_{24}O_4Si_4$	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	$C_8H_{24}O_2Si_3$	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C_8H_{18}	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C_8H_{16}	0.9	+	0.75	+	0.4	+	9.43	75
Pentachloropropane	1,1,1,3,3-pentachloropropane	23153-23-3	$C_3H_3Cl_5$					1.25	+		0.1
Pentane		109-66-0	C_5H_{12}	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid**	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix**	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C_2Cl_4	0.69	+	0.57	+	0.31	+	9.32	25
Propylene glycol methyl ether, 1-Methoxy-2-propanol	PGME	107-98-2	$C_6H_{12}O_3$	2.4	+	1.5	+	1.1	+		100
Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	PGMEA	108-65-6	$C_6H_{12}O_3$	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C_6H_6O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH_3	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C_6H_7N			0.9				9.04	ne
Pinene, α-		2437-95-8	$C_{10}H_{16}$			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	$C_{10}H_{16}$	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C_5H_8	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C_3H_8			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C_3H_8O			5.5		1.7		10.22	200
Propene	Propylene	115-07-1	C_3H_6	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C_3H_6O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	$C_5H_{10}O_2$			3.5				10.04	200
Propyl acetate	Propylacetate; n-Propyl ester of acetic acid	109-60-4	$C_5H_{10}O_2$			2.27	+			10.04	200

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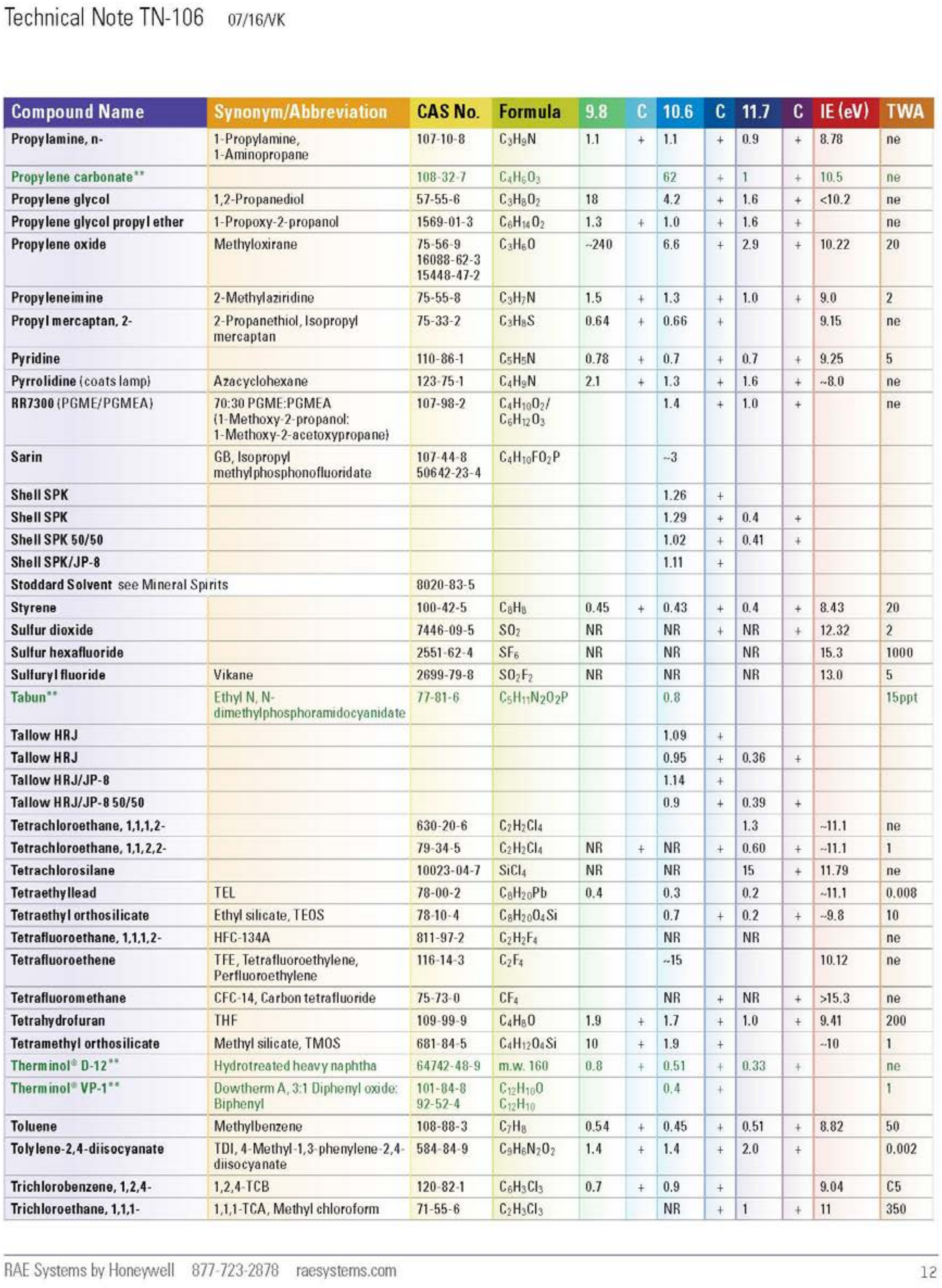
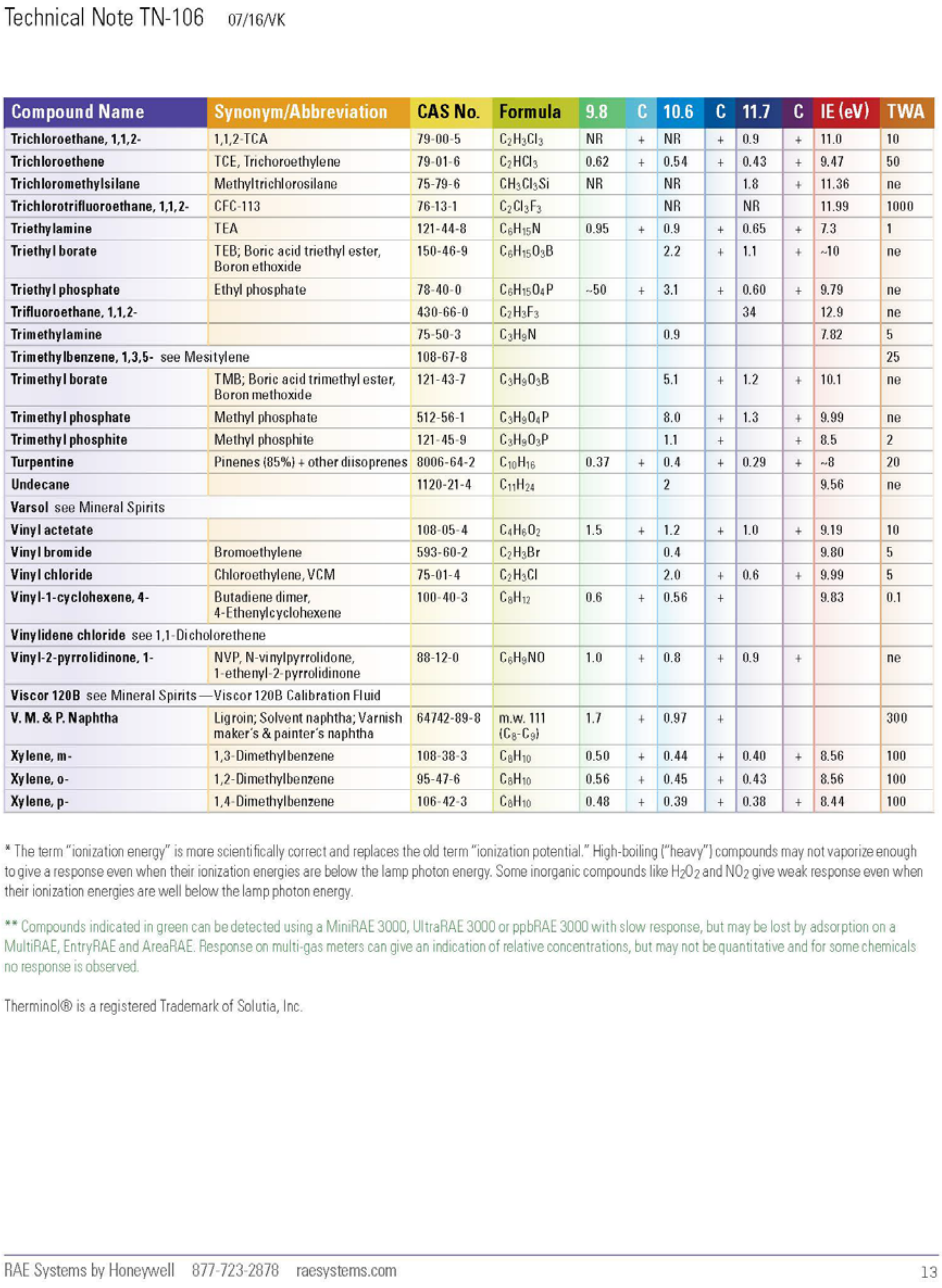


Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C_3H_9N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate**		108-32-7	$C_4H_6O_3$			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	$C_3H_8O_2$	18		4.2	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	$C_6H_{14}O_2$	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9 16088-62-3 15448-47-2	C_3H_6O	~240		6.6	+	2.9	+	10.22	20
Propyleneimine	2-Methylaziridine	75-55-8	C_3H_7N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C_3H_8S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C_5H_5N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C_4H_9N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol: 1-Methoxy-2-acetoxypropane)	107-98-2	$C_4H_{10}O_2$/ $C_6H_{12}O_3$			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8 50642-23-4	$C_4H_{10}FO_2P$			~3					
Shell SPK						1.26	+				
Shell SPK						1.29	+	0.4	+		
Shell SPK 50/50						1.02	+	0.41	+		
Shell SPK/JP-8						1.11	+				
Stoddard Solvent see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C_8H_8	0.45	+	0.43	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO_2	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF_6	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO_2F_2	NR		NR		NR		13.0	5
Tabun**	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	$C_5H_{11}N_2O_2P$			0.8					15ppt
Tallow HRJ						1.09	+				
Tallow HRJ						0.95	+	0.36	+		
Tallow HRJ/JP-8						1.14	+				
Tallow HRJ/JP-8 50/50						0.9	+	0.39	+		
Tetrachloroethane, 1,1,1,2-		630-20-6	$C_2H_2Cl_4$					1.3		~11.1	ne
Tetrachloroethane, 1,1,2,2-		79-34-5	$C_2H_2Cl_4$	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	$SiCl_4$	NR		NR		15	+	11.79	ne
Tetraethyllead	TEL	78-00-2	$C_8H_{20}Pb$	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	$C_8H_{20}O_4Si$			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	$C_2H_2F_4$			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C_2F_4			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF_4			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C_4H_8O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	$C_4H_{12}O_4Si$	10	+	1.9	+			~10	1
Therminol® D-12**	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1**	Dowtherm A, 3:1 Diphenyl oxide: Biphenyl	101-84-8 92-52-4	$C_{12}H_{10}O$ $C_{12}H_{10}$			0.4	+				1
Toluene	Methylbenzene	108-88-3	C_7H_8	0.54	+	0.45	+	0.51	+	8.82	50
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	$C_9H_6N_2O_2$	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	$C_6H_3Cl_3$	0.7	+	0.9	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	$C_2H_3Cl_3$			NR	+	1	+	11	350



Technical Note TN-106 07/16/VK

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	$C_2H_3Cl_3$	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichoroethylene	79-01-6	C_2HCl_3	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH_3Cl_3Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	$C_2Cl_3F_3$			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	$C_6H_{15}N$	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester, Boron ethoxide	150-46-9	$C_6H_{15}O_3B$			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	$C_6H_{15}O_4P$	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	$C_2H_3F_3$					34		12.9	ne
Trimethylamine		75-50-3	C_3H_9N			0.9				7.82	5
Trimethylbenzene, 1,3,5- see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	$C_3H_9O_3B$			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	$C_3H_9O_4P$			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	$C_3H_9O_3P$			1.1	+		+	8.5	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	$C_{10}H_{16}$	0.37	+	0.4	+	0.29	+	~8	20
Undecane		1120-21-4	$C_{11}H_{24}$			2				9.56	ne
Varsol see Mineral Spirits											
Vinyl actetate		108-05-4	$C_4H_6O_2$	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C_2H_3Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C_2H_3Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C_8H_{12}	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride see 1,1-Dicholorethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C_6H_9NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B see Mineral Spirits—Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naphtha	64742-89-8	m.w. 111 (C_8-C_9)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C_8H_{10}	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C_8H_{10}	0.56	+	0.45	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C_8H_{10}	0.48	+	0.39	+	0.38	+	8.44	100

* The term "ionization energy" is more scientifically correct and replaces the old term "ionization potential." High-boiling ("heavy") compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like H_2O_2 and NO_2 give weak response even when their ionization energies are well below the lamp photon energy.

** Compounds indicated in green can be detected using a MiniRAE 3000, UltraRAE 3000 or ppbRAE 3000 with slow response, but may be lost by adsorption on a MultiRAE, EntryRAE and AreaRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

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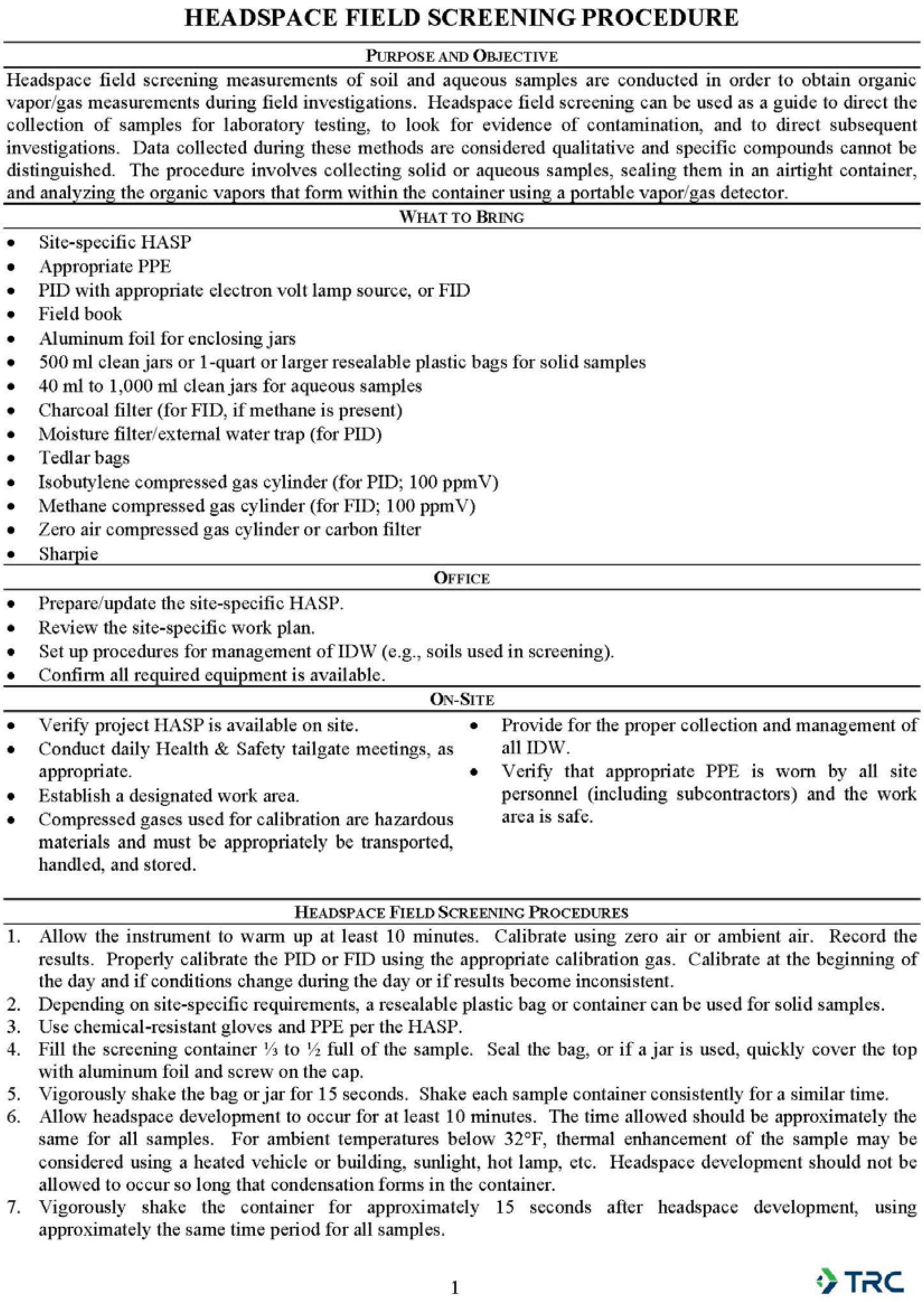
Attachment C:

SOP Fact Sheet



HEADSPACE FIELD SCREENING PROCEDURE

PURPOSE AND OBJECTIVE

Headspace field screening measurements of soil and aqueous samples are conducted in order to obtain organic vapor/gas measurements during field investigations. Headspace field screening can be used as a guide to direct the collection of samples for laboratory testing, to look for evidence of contamination, and to direct subsequent investigations. Data collected during these methods are considered qualitative and specific compounds cannot be distinguished. The procedure involves collecting solid or aqueous samples, sealing them in an airtight container, and analyzing the organic vapors that form within the container using a portable vapor/gas detector.

WHAT TO BRING

- Site-specific HASP
- Appropriate PPE
- PID with appropriate electron volt lamp source, or FID
- Field book
- Aluminum foil for enclosing jars
- 500 ml clean jars or 1-quart or larger resealable plastic bags for solid samples
- 40 ml to 1,000 ml clean jars for aqueous samples
- Charcoal filter (for FID, if methane is present)
- Moisture filter/external water trap (for PID)
- Tedlar bags
- Isobutylene compressed gas cylinder (for PID; 100 ppmV)
- Methane compressed gas cylinder (for FID; 100 ppmV)
- Zero air compressed gas cylinder or carbon filter
- Sharpie

OFFICE

- Prepare/update the site-specific HASP.
- Review the site-specific work plan.
- Set up procedures for management of IDW (e.g., soils used in screening).
- Confirm all required equipment is available.

ON-SITE

- Verify project HASP is available on site.
- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Establish a designated work area.
- Compressed gases used for calibration are hazardous materials and must be appropriately be transported, handled, and stored.
- Provide for the proper collection and management of all IDW.
- Verify that appropriate PPE is worn by all site personnel (including subcontractors) and the work area is safe.

HEADSPACE FIELD SCREENING PROCEDURES

1. Allow the instrument to warm up at least 10 minutes. Calibrate using zero air or ambient air. Record the results. Properly calibrate the PID or FID using the appropriate calibration gas. Calibrate at the beginning of the day and if conditions change during the day or if results become inconsistent.
2. Depending on site-specific requirements, a resealable plastic bag or container can be used for solid samples.
3. Use chemical-resistant gloves and PPE per the HASP.
4. Fill the screening container ⅓ to ½ full of the sample. Seal the bag, or if a jar is used, quickly cover the top with aluminum foil and screw on the cap.
5. Vigorously shake the bag or jar for 15 seconds. Shake each sample container consistently for a similar time.
6. Allow headspace development to occur for at least 10 minutes. The time allowed should be approximately the same for all samples. For ambient temperatures below 32°F, thermal enhancement of the sample may be considered using a heated vehicle or building, sunlight, hot lamp, etc. Headspace development should not be allowed to occur so long that condensation forms in the container.
7. Vigorously shake the container for approximately 15 seconds after headspace development, using approximately the same time period for all samples.

HEADSPACE FIELD SCREENING

8. Unscrew the lid of the jar to expose the aluminum foil seal. Quickly puncture the seal with the instrument probe, and insert the probe to about ½ of the headspace depth. For a resealable bag, partially open the seal, insert the probe, and re-seal the bag around the probe. Avoid contacting the probe with water droplets or soil particles.
9. Following probe insertion, record the highest meter response as the headspace concentration. Maximum response should be between 2 to 5 seconds.
10. A slowly increasing response on a PID may be due to high moisture levels. Repeat analysis may be needed taking care to avoid condensation or contact with moisture.
11. If the sample yields headspace readings higher than the upper limit of calibration, recalibration to a higher level may be necessary.
12. Record the headspace screening data in the field book and/or on a field data form.
13. Return the sample to the original source site location, or dispose of the sample in accordance with the IDW plan.

INVESTIGATION DERIVED WASTE (IDW) DISPOSAL

Field personnel should review the site-specific work plan and ensure project-specific IDW management documentation and containerization requirements are specified or discussed with the Project Manager before going to the project site. Containerize, label, or manage all IDW as specified in the plan.

QA/QC, DATA MANAGEMENT AND RECORDS MANAGEMENT

1. Headspace measurements should be performed in duplicate on one sample per day, at a minimum.
2. Procedures followed for sample preparation should be the same for all samples.
3. Operate and calibrate the instruments according to the manufacturer's manual.
4. Record the model name and number of the instrument in the field book.
5. All procedures and results must be documented in the field book and/or field forms. Correct values for background, if appropriate.
6. Document any deviations from the procedures specified in the work plan or QAPP in the field book. Any deviations must be approved by the Project Manager.

DOS AND DON'TS OF HEADSPACE FIELD SCREENING

DOs:

- DO call the Project Manager or field team leader if unexpected conditions are encountered, or at least daily to update them on site work.
- DO use properly trained staff.
- DO check the instrument batteries before each day.
- DO manage IDW in accordance with project requirements.
- DO properly calibrate the instrument using the compressed gas standard. Perform periodic response checks throughout the day. Record the results in the field notes.
- DO consider environmental factors such as high moisture and high organic content in the sample. High moisture may make using a PID inappropriate. A water trap or filter should be used to reduce moisture impacts. High organic matter can also affect results.
- DO use thermal enhancement such as a heated vehicle or building, or sunlight, to warm the samples to achieve a better response in cold conditions.
- DO use the proper lamp source in the PID based on the ionization potential of the contaminant of concern.
- DO collect samples for headspace or laboratory analysis within minutes of being exposed to air to minimize loss due to volatilization.

DON'Ts:

- DON'T perform headspace screening near potential sources of VOCs such as operating vehicles, generators, or air handling equipment.
- DON'T use samples collected for headspace screening for laboratory analysis.
- DON'T sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc.; call the PM if this issue arises.

04
Water Level and Product Measurements (Includes SOP for PFAS)

Title: **Water Level and Product Measurements**	Procedure Number: **ECR 004**
	Revision Number: **3**
	Effective Date: **February 2022**

Authorization Signatures

Technical Reviewer	Date	SOP Work Group Co-Lead	Date
Ryan Jorrey	12/10/2021	Chelsea Wenhardt	2/21/2022

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Attachment A	Example Water and Product Level Monitoring Form
Attachment B	Example Field Book Documentation for Water Levels
Attachment C	SOP Fact Sheet
Attachment D	SOP Modifications for PFAS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for conducting water level, separate-phase product, and/or total well depth measurements in monitoring wells, piezometers, and boreholes during field investigations.

1.2 Summary of Method

Depth-to-water (DTW) measurements are used to evaluate pressure and/or elevation changes within the aquifer. The procedure involves using a water level indicator capable of an accuracy of ±0.01 feet, or a similar piece of equipment, to measure the DTW in a monitoring well, piezometer, or borehole from a set reference point. When used in conjunction with an accurate site elevation survey, DTW data can be converted to potentiometric surface elevations to support groundwater flow direction analysis, as well as other aquifer characteristics. In addition, pressure changes recorded in a well during a slug, pumping, or packer test can be used to determine aquifer characteristics, such as hydraulic conductivity and storage parameters.

It is also a good practice to gauge the total depth of a monitoring well while taking water levels. This practice can help confirm: 1) the correct well in a cluster of wells screened at different depths; 2) that the well is clear of obstructions; 3) whether the well may be silting up and need further development; and 4) the correct purge volume for a well when sampling. Total depth measurements in a well may be necessary when TRC is taking over project work at a site with existing monitoring wells or the site wells have not been accessed for a significant amount of time.

The objective of separate-phase product measurements is to obtain measurements of the thickness of separate-phase product in the water column. The thickness of both dense non-aqueous phase liquid (DNAPL) and light non-aqueous phase liquid (LNAPL) can be determined using an oil/water interface probe. It should be noted that the thickness of LNAPL or DNAPL in a well ("apparent thickness") most likely differs from the thickness in the formation ("actual thickness").

- For LNAPL, the procedure involves measuring the depth to the separate-phase product and the depth to the underlying groundwater from a set reference point. The difference between these two measurements is the thickness of the LNAPL in the well.

- For DNAPL, the procedure involves measuring the depth to the separate-phase product and the depth to the bottom of the well, borehole, etc. The difference between these two measurements is the thickness of the DNAPL in the well.

1.3 Equipment

The following list of equipment may be utilized when conducting water level and separate-phase product measurements. Site-specific conditions may warrant the use of additional items or deletion of items from this list. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details.

- Appropriate level of personal protective equipment (PPE)
- Electronic water level indicator
- Oil/water interface probe
- Extra batteries for water level indicator/interface probe
- Field book and/or monitoring form
- Well keys
- Socket-wrench
- Containers to hold water and isopropanol for calibration
- Decontamination water and appropriate solution
- Decontamination supplies
- Previous measurement data (if available)
- Precision ruler or measuring tape
- Permanent marker (e.g., Sharpie®)
- Spool of cotton string and stainless steel nuts/weights for NAPL string test (for measuring DNAPL thickness)

1.4 Definitions

Borehole	A hole drilled into the soil or bedrock using a drill rig or similar equipment.
Dense Non-aqueous Phase Liquid (DNAPL)	Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.
Depth To Water (DTW)	The distance to the groundwater surface from an established measuring point.
Light Non-aqueous Phase Liquid (LNAPL)	Separate-phase product that is less dense than water and, therefore, floats on the surface of the water.
Low-permeability Formation	A geologic formation that has very slow recharge and discharge rates due to small pore spaces in the formation material. A clay formation is considered to have low permeability and has a very slow recharge rate compared to a more permeable formation, such as sand or gravel.
Monitoring Well	A well typically made from a polyvinyl chloride (PVC) pipe, or other appropriate material (e.g., stainless steel), with slotted screen installed across or within a saturated zone. Monitoring wells are primarily used for groundwater quality monitoring and sample collection.
Non-aqueous Phase Liquid (NAPL)	Petroleum or other fluid that is immiscible in water and tends to remain as a separate liquid in the subsurface.

Piezometer	A well typically made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Potentiometric Surface	A surface representing the hydraulic head of groundwater.
Separate-phase Product	A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column, depending on the liquid's specific density (i.e., lighter or heavier than water).
Total Depth of Well	Distance from the measuring point to the bottom of the well.
Well Casing	An impervious, durable pipe placed in a borehole to prevent the walls of the borehole from caving, and to seal off surface drainage or undesirable water, gas, or other fluid and prevent their entrance into the well.
Well Riser	A casing (usually steel or PVC) that extends from the well screen or open section of the well to above the ground surface.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific health and safety plan (HASP). TRC personnel will use the appropriate level of personal protective equipment (PPE) as defined in the HASP.

When present, special care should be taken to avoid contact with LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards.

1.6 Cautions and Potential Problems

Special care should be taken when using equipment if PFAS are known or suspected to be present. Please refer to Attachment D for details.

- DTW measurements of all wells in a water level survey should be collected within the shortest amount of time possible but, at a minimum, within a 24-hour period to ensure near contemporaneous data collection during a groundwater elevation recording event. However, note that certain conditions may produce relatively rapid changes in groundwater elevations, which might necessitate collecting readings over a shorter time period. Such conditions should be noted in the field book. Rapid groundwater elevation changes may occur due to:
    - Rapid changes in atmospheric pressure

  - Variable pumping of nearby wells
  - Precipitation events
  - Tidal influences
  - Rapid changes in nearby surface water levels (e.g., dam release, upstream thunderstorm)

- Allow water levels in newly installed wells to stabilize for approximately 24 hours before taking measurements for the purpose of a water level survey. Recharge might take longer in wells installed in low permeability formations.

- Because the tops of monitoring wells and piezometers are often cut unevenly, be sure to take DTW measurements from a pre-marked or notched spot on the well to ensure consistent data collection over time. If the tops of the monitoring wells and piezometers are not marked, the DTW measurement should be taken from the high point of the well riser/casing or the north side of the riser/casing. The measurement location should then be marked to maintain consistency.

- To limit the possibility of cross contamination, DTW measurements should be collected in order from the least to the most contaminated wells and piezometers when contamination is known or suspected. Be sure to decontaminate the entire length of tape lowered into the well between well measurements to reduce the potential for cross contamination. Refer to Attachment D and ECR SOP 010 for decontamination for PFAS. Some wells with NAPL or excessive condensation may have residues on the side of the riser that may also contaminate the tape.

- If the presence of NAPL is suspected at a site, an oil/water interface probe should be used to conduct water level measurements. When DNAPL is a suspected contaminant characteristic at a site, the interface probe should be lowered to the bottom of the well slowly, until DNAPL is encountered, if present.

- NAPL may foul the probe and could cause a delayed response when going from NAPL to water. Resolution may require taking repeated measurements by raising and/or lowering the probe through the interface.

- Note: Some NAPL may not be measurable with a conventional interface probe. Very old fuel oil, creosote, tar and manufactured gas plant (MGP) waste may require estimates of thickness using a steel tape and chalk method.

- If NAPL is present, a string test can be performed. Tie a weighted object (e.g., stainless steel nut) to the end of a cotton string and gently lower to the bottom of the well. Mark the top of riser on the string, gently remove the string, and measure the thickness of NAPL coating the string.

- Most water level meters have a "sensitivity" setting (e.g., gain), which is often located on the on/off dial. The sensitivity setting may need adjustment depending on the site water chemistry.

- Excessive condensation on the inside well materials may cause the tape to stick on the well riser/casing and/or cause a false reading above the water level. This is especially true of deeper wells. Previous elevation data (depth to water) should be consulted to determine if a reading is consistent and plausible for that well. The above-mentioned sensitivity adjustment can be used to compensate. In some cases, the water level tape may have to be weighted to remedy the line sticking to the well riser/casing.

- Tight well caps and low permeability formations may not have allowed the potentiometric surface to equilibrate in the well after seasonal, tidal, or other area groundwater level fluctuations. If this is the case, allow the wells to equilibrate before collecting measurements by taking readings several minutes after removing the well plug; in addition, re-measure the first well after the last well to verify that the water level is not fluctuating. Another round of water levels may need to be collected if a significant discrepancy from the first set of measurements is observed; this should be discussed with the Project Manager. If this is a concern, vented well caps or plugs may need to be used.

- In some instances, artesian well conditions (flowing wells) may exist, where the potentiometric surface is higher in elevation than the top of the well casing (TOC). In these situations, it is pertinent to note the water level elevation as above the TOC or add a known length of riser pipe in order to measure an actual elevation. Once the water level has equilibrated in the riser pipe, the same procedures can be followed for measuring water level when separate-phase product is not suspected. Note that when converting the DTW measurement to an elevation, the riser pipe length needs to be added to the surveyed TOC.

- Groundwater gradients at some sites can be very shallow and if gradient and groundwater flow pattern (gradient direction) determination are part of the project objectives, it is critical that groundwater level measurements obtained from wells are as accurate as possible. Special care should be taken to allow the water level to equilibrate after removing sealing caps, and the same water level indicator should be used for all measurements if possible. All wells should be measured within the minimum possible tim. This is particularly important in areas with potential tidal influences.

- If more than one measuring device must be used for multiple wells across an area with a shallow groundwater gradient, the "zero calibration check" (see Section 2.1.2) becomes especially important.

- If the monitoring well or piezometer is secured with an air- and water-tight lockable cap, caution should be taken when removing the cap due to the possible buildup of pressure in the well riser. Try to ease the cap off and relieve the pressure slowly in order to prevent injury. Do not stand or lean over top of well when releasing cap.

- Flush-mounted wells may be subject to water collection in the well can around the top of the riser pipe. In such instances, sufficient water should be evacuated from the well can prior to removing the well cap to ensure that ambient water does not enter the riser. The condition should be documented and the potential need for repair discussed with the Project Manager.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Workers (HAZWOPER)
- 8-hour annual refresher training

2.0 PROCEDURES

To be useful for establishing groundwater gradient, the reference point should be tied with a known vertical datum, such as the National Geodetic Vertical Datum (NGVD), or a local datum (e.g., site-specific arbitrary datum such as concrete foundation or top of a well).

Water levels should be allowed to equilibrate prior to measurement after removing sealing well caps. There are no set guidelines, and appropriate equilibration times can range from minutes to hours depending on well recharge, local geology, and project objectives.

If available, prior site water and product level measurement data should be reviewed and available to field personnel during the collection of new data for direct comparison to aid in identifying and resolving potential measurement errors while in the field.

When measuring well depths with an electronic water level indicator, measure and add the length of the probe beneath the circuit closing electrodes (i.e., a tape correction factor) to the depth measured to obtain the true depth. Depth measurements should be recorded in the field notes as the tape reading + the tape correction factor (e.g., “105.69 + 0.21”).

The following procedures should be followed during the collection of water level and product measurements. Procedures may vary depending on the equipment used and contaminants present at the site. Special care should be taken when using measurement equipment if PFAS are known or suspected to be present. Please refer to Attachment D for details.

2.1 Calibration and Operational Checks

Refer to the project’s Quality Assurance Project Plan (QAPP) or other planning documents for calibration frequency and any site-specific calibration procedures for water and separate-phase product level meters. The need for calibration and the frequency of calibration will be dependent upon the meter used and project-specific data quality objectives. Operational checks of meters will be performed prior to use in the field at the start of each day and several times throughout the day, as appropriate.

2.1.1 Operational Check of Water Level Meters

1. Push the Start or Test button (typically provided) on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound, and test light illuminate (if equipped).

2. Release the start/test button and lower the water level probe into a container filled with tap water until the meter audible indicator sounds or visual indicator light turns on. During this check, set sensitivity adjustment (if provided) to highest setting, then decrease if necessary (e.g., saline water).

Inspect the measuring tape and water level probe connection for any signs of visible damage (e.g., cuts, kinks, separating splices). If the tape appears damaged at the connection to the probe, while the meter is sounding, perform the procedure in Section 2.1.2. If necessary, repair and/or replace the water level meter.

2.1.2 Calibration Check of Water Level Meters

1. While the meter is sounding from the procedure used in Section 2.1.1, use a ruler or measuring tape to measure the distance between the water surface and the 1-foot increment mark on the water level tape.

2. Check that the 1-foot increment is actually 1 foot from the water surface. Note any discrepancy in the field book and discuss with the Project Manager. If necessary, repair and/or replace the water level meter.

2.1.3 Calibration and Operational Check of Oil/Water Interface Meters

1. Oil/water interface meters will have one distinguishing sound and/or colored light to represent detection of water and a separate distinguishing sound to represent detection of separate-phase product. Read the instrument manufacturer’s operations manual to determine the instrument’s audible sound or light differentiation for water and separate-phase product (e.g., continuous tone for product and intermittent beep for water).

2. Push the Start or Test button (typically provided) on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound and test light illuminate (if equipped).

3. Water Level Sensor Operational and Calibration Checks

   a. Lower the water level probe into a container filled with tap water until the appropriate sound for water is heard as determined in Step 1.
   b. While the meter is sounding, use a ruler or measuring tape to measure the distance between the water surface and the 1-foot increment mark on the water level tape.
   c. Check that the 1-foot increment is actually 1 foot from the water surface. Note any discrepancy in the field book and discuss with the Project Manager.

4. Oil Level Sensor Operational and Calibration Checks

   a. If the operation or calibration of the oil level probe is suspected to be faulty, consult with the meter manufacturer for additional troubleshooting.

2.2 Procedures for Measuring Depth to Water When Separate-phase Product is Not Suspected

If possible, and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated. Additionally, allow sufficient time for each monitoring well or piezometer to equilibrate after removing the protective cap prior to taking readings.

1. Record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.), equipment being used, and the current weather conditions in the field book or on the water level monitoring form or well inspection report.

2. Use HASP-specified gloves. Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure build up that may have occurred in the well casing/riser. Follow HASP requirements for well head and breathing zone air monitoring.

3. Identify the previous measuring point marking or notch on the well riser or casing (if present). If the tops of the monitoring wells and piezometers are not marked, the DTW measurement should be taken from the high point of the well riser/casing or the north side of the riser/casing. and the measurement location should then be marked on the casing top edge to maintain consistency

4. Using a previously decontaminated water level meter, turn on the meter, check the audible/visual indicator (push the "Test" button), reel the electronic probe into the well riser (with the increments visible) slowly until the meter sounds.

5. Grasp the tape with hand, withdraw the tape, and lower it again slowly until the sound is again audible. Check the DTW on the tape and make a mental note of the depth to within 0.01 feet.

6. Lower the probe again slowly and repeat the measurement for precision. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in Step #3 to the nearest 0.01 feet. If measuring the total depth of the well, proceed to Section 2.4).

7. Decontaminate the probe and the entire length of the submerged tape in accordance with the manufacturer specifications. Refer to Attachment D and ECR SOP 010, Equipment Decontamination, for decontamination procedures for sites with known or suspected PFAS contamination.

2.3 Procedure for Measuring Depth to Water and Product Levels When Separate-phase Product is Suspected

If possible, and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated. Additionally, allow sufficient time for each monitoring well or piezometer to equilibrate after removing the protective cap prior to taking readings.

1. Record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.), equipment being used, and the current weather conditions in the field book, water level monitoring form, or well inspection report.

2. Use HASP-specified gloves. Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure build up that may have occurred in the well casing/riser. Follow HASP requirements for well head and breathing zone air monitoring.

3. Identify the previous measuring point marking or notch on the riser or casing (if present). If the tops of the monitoring wells and piezometers are not marked, the DTW measurement

should be taken from the high point of the well riser/casing or the north side of the riser/casing. and the measurement location should then be marked on the casing top edge to maintain consistency.

4. Using a previously decontaminated oil/water interface probe, turn on the meter, check the audible indicator, and slowly reel the electronic probe into the well riser (with the increments visible) until the appropriate sound for water or separate-phase product is heard as determined in Section 2.1.3.

5. If water is encountered first (as determined by the audible sound on the meter, which represents water), follow steps 5 and 6 from Section 2.2. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in Step 3 to the nearest 0.01 feet.

6. If water is encountered first and DNAPL is suspected, continue lowering the probe slowly until product is encountered (as determined by the audible sound on the meter which represents product). Since some product may adhere to the probe sensors, the probe should be raised, lightly shaken, and slowly lowered again to confirm measurement. In the field book or on the water level monitoring form, record the depth to product from the measuring point noted in Step 3.

7. If DNAPL is present, measure the total depth of the well (Section 2.4), or determine the total depth of the well from historical records.

8. Calculate the thickness of the DNAPL in the well using the following equation:

   (Total depth of well) – (Depth to product) = DNAPL thickness

9. If LNAPL is encountered before water, record the depth to product from the measuring point noted in Step 3 in the field book and continue lowering the probe until water is encountered.

   NOTE: For LNAPL, it is necessary to take both the air/product interface measurement on the way down into the product and the water/product interface measurement on the way back up. This is required when passing through product into water, since some product may adhere to the probe sensors due to surface tension and, as a result, a greater product thickness measurement may be erroneously obtained. Therefore, when LNAPL is detected, the probe should be lightly shaken or raised and lowered rapidly in a short vertical motion while the probe is within the water column to remove any product that may have been carried down with the probe. After passing through the product, the water/product interface should then be measured as the probe is raised very slowly back up from the underlying water into the product. Once the interface is detected, the probe can be raised and lowered in small increments to precisely determine the interface and obtain accurate measurements. Repeat these measurements as needed to confirm water/product interfaces and product thickness on multiple measurements.

10. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in Step 3. If measuring the total depth of the well, proceed to Section 2.4.

11. Calculate the thickness of the LNAPL in the well using the following equation:

    (DTW) – (Depth to product) = LNAPL thickness

12. Decontaminate the probe and the entire length of the submerged tape in accordance with the manufacturer specifications. Refer to Attachment D for measurement equipment used at sites with known or suspected PFAS contamination and ECR SOP 010, Equipment Decontamination, for PFAS decontamination procedures.

2.4 Procedure for Measuring Total Well Depth

When measuring the total depth of a well, the water level and separate-phase product level, if present, should be determined first (see Section 2.2 or 2.3). It is recommended that the tone function of the instrument remain engaged during the total depth measurement.

1. After the water level and product level, if present, have been determined, continue reeling the electronic probe into the well riser (with the increments visible) until the probe encounters resistance. Resistance may be inferred when the probe appears to stop descending and the tape slackens against the side of the riser.

2. Determine whether the observed resistance likely represents the total depth of the well by raising and then lowering the probe to the level of the previously encountered resistance several times at different positions in the well. Then compare the observed level of resistance to available information about the total depth of the well, such as well log data or previous total depth measurements.

3. Measure the total depth of the well by 1) noting the depth (to the nearest 0.01 feet) at which the probe first touches bottom before the tape begins to slacken; 2) adding the measured length from the bottom of the probe to the fluid level sensor in the probe (i.e. tape correction factor); and 3) recording the combined lengths as the total depth (e.g., “105.69 + 0.21”).

4. In the field book or on the water level monitoring form, record the total depth of the well from the measuring point.

5. Also, note any observations about the conditions encountered in the well during the total depth measurement. A clear and distinct bottom reading would indicate little or no sediment in the bottom of the well. A soft and indistinct probe landing would indicate the presence of silt or sediment in the bottom of the well. A total depth measurement inconsistent with the well log or previous total depth measurements may indicate an obstruction in the well or significant sedimentation at the bottom of the well.

6. Decontaminate the probe and the portion of the tape inserted in the riser in accordance with the manufacturer specifications. Refer to Attachment D for measurement equipment used at sites with known or suspected PFAS contamination and ECR SOP 010, Equipment Decontamination, for PFAS decontamination procedures.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following Quality Assurance/Quality Control procedures apply:

- Operate field instruments according to the manufacturers' manuals.
- Calibrate field instruments at the proper frequency.
- Check the DTW at least two times in order to compare results. If results do not agree to within 0.02 feet, take a third measurement. If results still do not agree, check for possible equipment failure or review the cautions and potential problems listed in Section 1.6. Repeat the measurement when the cause of the precision nonconformance has been discovered and corrected.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

- Record water and separate-phase product level measurements on field forms or in a field book. See Attachment A for an example of a Water and Product Level Monitoring Form and Attachment B for an example of field book documentation.
- The following additional information may be recorded in the field book:
    - Well/piezometer or monitoring point identification number
    - Well/piezometer or monitoring point location (sketch of the sample point or reference to a location figure)
    - Visual or sensory description (e.g., odors, product, etc.)
    - Time and date measurements were taken
    - Personnel performing the task
    - Weather conditions during task
    - Other pertinent observations
    - Measurement equipment used
    - Calibration procedures used
    - Decontamination procedures used

  - Fixed measuring point used for DTW measurements
  - Well head and breathing zone air monitoring readings

- For projects using TRC's Environmental Data Management System (EDMS), an approved electronic mobile field data collection system (e.g., EQuIS Collect, Fulcrum, or esri Collector) can be configured to record water and separate-phase product level measurements as well as the additional information listed above. A TRC Data Manager must be assigned for coordination and setup of the respective application to be used by the project team. The details and specifications of the event should be discussed with the TRC Data Manager during the project kickoff meeting. The TRC Data Manager will work with TRC project team and field personnel on configuring the system for efficient use in the field with pre-populated, project-specific menus.
- For projects that do not use electronic mobile field data collection systems, field notes containing the information described in Section 5.0 above, along with global positioning system (GPS) coordinates for each location ID should be transcribed into TRC's standard Location and Water Level EDDs for import into TRC's EDMS as soon as the event is completed, preferably the same day in order to get data into the EDMS for use in as near real time as possible.

6.0 REFERENCES

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

U.S. EPA Environmental Response Team, Standard Operating Procedures, *Manual Water Level Measurements*, SOP 2043. February 11, 2000.

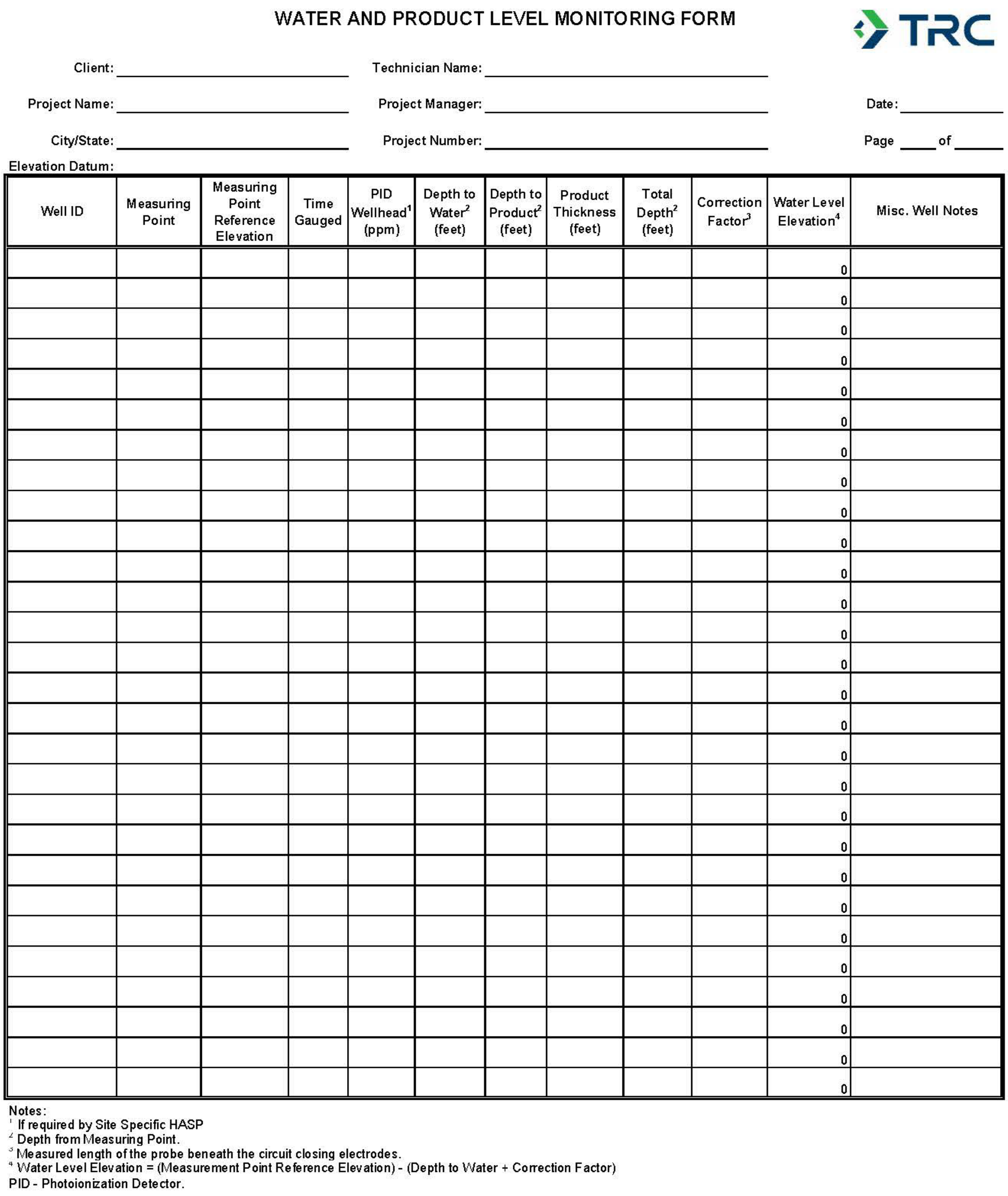
U.S. EPA Region 4. Science and Ecosystem Support Division (SESD) Operating Procedure, *Groundwater Level and Well Depth Measurement*, SESDPROC-105-R2. January 29, 2013.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
1	DECEMBER 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING
3	FEBRUARY 2022	SOP UPDATE

ATTACHMENT A

EXAMPLE WATER AND PRODUCT LEVEL MONITORING FORM



WATER AND PRODUCT LEVEL MONITORING FORM

Client: ______________________ Technician Name: ______________________

Project Name: ______________________ Project Manager: ______________________ Date: __________

City/State: ______________________ Project Number: ______________________ Page _____ of _____

Elevation Datum:

Well ID	Measuring Point	Measuring Point Reference Elevation	Time Gauged	PID Wellhead[1] (ppm)	Depth to Water[2] (feet)	Depth to Product[2] (feet)	Product Thickness (feet)	Total Depth[2] (feet)	Correction Factor[3]	Water Level Elevation[4]	Misc. Well Notes
										0	
										0	
										0	
										0	
										0	
										0	
										0	
										0	
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										0	

Notes:

[1] If required by Site Specific HASP

[2] Depth from Measuring Point.

[3] Measured length of the probe beneath the circuit closing electrodes.

[4] Water Level Elevation = (Measurement Point Reference Elevation) - (Depth to Water + Correction Factor)

PID - Photoionization Detector.

ATTACHMENT B

EXAMPLE FIELD BOOK DOCUMENTATION FOR WATER LEVELS

Location ______________________ Date 3/4/1999 109

Project / Client ______________________

sunny, 80°F, slight westerly breeze

WELL I.D.	Depth To Water (ft)	Depth To Product (ft)	Measuring Point	Comments
MW-1A	2.10	–	TOC	no lock present
MW-1B	2.15	–	TOR	–
MW-2A	3.42	–	TOR	–
MW-2B	3.41	–	TOR	expansion plug missing
MW-3A	3.64	3.60	TOR	petro odor
MW-3B	3.70	–	TOC	–
MW-4A	1.55	–	TOR	–
MW-4B	1.57	–	TOR	–
MW-5A	6.30	–	TOR	–
MW-5B	6.64	–	TOR	concrete collar gone
PZ-10	4.33	–	TOR	–
PZ-11	4.22	–	TOR	–
PZ-12	4.47	–	TOR	–
PZ-13	8.03	–	TOR	–
PZ-14	8.88	–	TOR	well cap broken
PZ-15	5.09	–	TOR	–

Note: TOC = Top of casing
TOR = Top of riser

Thomas S. Weyandt 3/4/99

ATTACHMENT C

SOP FACT SHEET

WATER LEVEL AND PRODUCT MEASUREMENT PROCEDURES

PURPOSE AND OBJECTIVE

The following procedures have been developed to direct TRC personnel in the methods of collecting water level, separate-phase product, and/or total well depth measurements in the field. Other state or federal requirements may be above and beyond the scope of this SOP and should be followed, if applicable. Depth-to-water (DTW) measurements are used to evaluate pressure and/or elevation changes within the aquifer. The objective of separate-phase product measurements is to obtain measurements of the thickness of separate-phase product in the water column. Both of these measurements are very important as they drive remediation decisions. Total well depth measurements can provide vital information to a project, such as confirmation of the correct well being screened, the well being free of obstructions, whether the well needs further development, and the correct purge volume for a well when sampling.

WHAT TO USE

- Appropriate PPE
- Water level meter/indicator
- Oil/Water interface probe
- Extra batteries
- Well keys
- Previous measurement data
- Precision ruler or measuring tape
- Spool of cotton string for NAPL string test
- Stainless steel nuts to weigh down string
- Socket-wrench set
- Containers to hold water and isopropanol for calibration
- Decontamination supplies, water, & solution
- Field book & monitoring form
- Indelible/waterproof ink

ON-SITE WELL GAUGING

- Prior to well gauging, site water level measurement data should be reviewed for direct comparison to aid in identifying and resolving potential measurement errors while in the field.
- Conduct an operational check of the water level meter by pushing the Start or Test button on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound and test light illuminate (if equipped).
- Inspect the measuring tape and water level probe connection for any signs of visible damage. Repair or replace if necessary.
- Calibrate the meter per the project's Quality Assurance Project Plan (QAPP) or other planning documents.
- If possible and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated.
- Prior to collecting a water level, record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.).
- Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure buildup that may have occurred in the well casing. Allow the well time to equilibrate.
- Identify the previous measuring point marking or notch on the riser or casing (if present). If no previous measuring point exists, use a permanent marker to mark a location on the rim of the riser or casing (typically the highest point). Record this location in the field book.
- Grasp the tape with hand, withdraw the tape, and lower it slowly until the sound is audible. Check the DTW on the tape and make a mental note of the depth to within 0.01 feet. Lower the probe again slowly and repeat the measurement for precision. Record the DTW from the measuring point in the field book or on the water level monitoring form.
- If total depth measurements were not recorded recently, advance the tape to the bottom of the well to record a total depth.
- Decontaminate the probe and tape between each well.
- If PFAS is a concern, refer to the full SOP for additional details on monitoring and decontamination.

ON-SITE PRODUCT MONITORING

- Follow the first 8 steps outlined in the section above, from conducting a direct comparison of water level measurement data to identifying the previous measuring point marking (or creating a new one if necessary).Using a previously decontaminated oil/water interface probe, turn on the meter, check the audible indicator, and slowly reel the electronic probe into the well riser (with the increments visible) until the appropriate sound for water or separate-phase product is heard (intermittent tone for water; steady tone for product).
- If water is encountered first (as determined by the audible sound on the meter), record the DTW from the measuring point to the nearest 0.01 feet.
- If water is encountered first and dense non-aqueous phase liquid (DNAPL) is suspected, continue lowering the probe until product is encountered (as determined by a different audible sound on the meter). In the field book or on the water level monitoring form, record the depth to product from the measuring point.
- If light non-aqueous phase liquid (LNAPL) is encountered before water, record the depth to product from the measuring point and continue lowering the probe until water is encountered and record the depth to water.
- After the water level and product level, if present, have been determined, continue reeling the electronic probe into the well riser until the probe encounters resistance in order to determine Total Well Depth.
- Decontaminate the probe and tape between each well. If PFAS is a concern, refer to the full SOP for additional details.

WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

ATTACHMENT D

SOP MODIFICATIONS FOR PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

Water Level and Product Measurement Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
1.3	• Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-it® Notes. • Use new plastic buckets for wash and rinse water. • Do not use "tap" water for operational check of the water level sensor of the oil/water interface meter. • Ensure that PFAS-free water is used during the decontamination procedure. • Do not use a plastic ruler to check measurements. • Refer to SOP 010, Equipment Decontamination, for decontamination supplies.
1.5	Always consult the Site-specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to procedures: • Tyvek® suits should not be worn. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Food and drink should not be allowed within the data measurement collection area. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only. • Personnel involved with measurement data collection should wear a new pair of nitrile gloves between each well measurement. Avoid handling unnecessary items with nitrile gloves. • Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended six washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work.
2.1.1	• Do not use potable "tap" water for operational check of the water level meter. Use deionized, distilled, or organic-free water.
2.1.2 and 2.1.3	• Do not use potable "tap" water for operational check of the water level sensor of the oil/water interface meter. Use deionized, distilled, or organic-free water. • Do not use a plastic ruler to check measurements.
2.2 (7) ; 2.3 (11); and 2.4 (6)	• Use only Alconox® or Liquinox® soap; do not use Decon 90. • Ensure that PFAS-free water is used during the decontamination procedure.
5.0	• Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards, and spiral bound notebooks should not be used.

05

Soil Vapor Point Installation and Active Vapor Sampling

Title: **Soil Vapor Point Installation and Active Vapor Sampling**	Procedure Number: **ECR 015**
	Revision Number: **2**
	Effective Date: **January 2020**

Authorization Signatures			
		Elizabeth Denly	
Technical Reviewer Stacy Metz	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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Attachment B	Soil Vapor Point Cross-Sectional Diagrams
Attachment C	Soil Vapor Point Installation and Sampling Field Forms
Attachment D	Detailed Leak Testing Procedures

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in active soil vapor sampling activities. This SOP details equipment and sampling procedures for low-flow sampling from temporary or permanent soil vapor points as well as the procedures for installation of these soil vapor points. The focus of this SOP is on evacuated canister sampling; other sampling containers such as evacuated bottles or Tedlar® sampling bags may be appropriate but are not covered in this SOP. Various regulatory agencies and project-specific work plans may have different specific requirements (e.g., equipment/instrument, flow rate) which may supersede this SOP, depending on the program.

The objective of soil vapor sampling is to obtain a representative sample of vapor from the vadose zone immediately below the floor of a building or other area of concern. Areas of concern may be within, above, or adjacent to a soil or groundwater contaminant source area.

1.2 Summary of Method

This method has been developed to describe how to collect representative samples of soil vapor from the vadose zone. Temporary or permanent points can be installed depending on project objectives. Installation of several types of permanent and temporary points are described herein. Sample collection methods include verification that a representative soil vapor sample has been collected and that the sample was not compromised by leakage of sampling components or the sampling point itself. Field verification of sample integrity may include a shut-in leak test, quantitative tracer testing, and/or semi-quantitative tracer testing, depending on project objectives and regulatory requirements. Leak detection is an integral part of soil vapor sampling and is explained in detail in Attachment D. Photographs referenced within this SOP are included in Attachment A. Soil vapor point diagrams referenced within this SOP are included in Attachment B.

1.3 Equipment

The following equipment list is meant to be a guide of the typical equipment that can be used to install a soil vapor point and collect a soil vapor sample, unless project needs dictate a different set of equipment. Site-specific conditions may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Applicable Safety Data Sheets (SDSs)
- Non-powdered, disposable gloves
- Field logbook and/or appropriate field forms
- Digital camera
- Calculator

Installation of Permanent Points via Flush-mount Well Cover Method (Section 2.1.2):

- Soil vapor probe materials (stainless-steel or brass):
  - $^1/_4$-inch diameter ball valve;
  - $^1/_4$-inch male thread by $^1/_8$-inch diameter hose barb fitting;
  - $^1/_4$-inch diameter nipple (length dependent upon slab thickness)
- Alconox® or equivalent
- Distilled water
- Teflon® tape
- Wrenches
- Appropriate field screening device(s), e.g., photoionization detector (PID), flame ionization detector (FID), and/or landfill gas meter (optional)
- If concrete coring is required*:
  - Concrete coring machine with diameter approximately 2-inches larger than well cover
  - Concrete core barrel
  - Extension cord(s)
  - Heavy-duty vacuum (e.g., Shop-Vac®)
  - Generator, if needed
- Source of clean water and buckets or hose
- Paper towels
- Aluminum flush-mount well cover, typically 4-inch diameter
- Reciprocating saw with metal cutting blades
- Hydraulic cement or equivalent
- Grout/Portland cement
- Trowel and other tools to mix and place cement

*Common to have driller or qualified subcontractor perform the coring; see Project Manager for instructions.

Installation of Permanent Points via Stainless-steel Probe Method (Section 2.1.3):

- Soil vapor probe materials:
  - $^1/_4$-inch outer diameter (OD), gas chromatography grade 316 stainless-steel tubing
  - $^1/_4$-inch stainless-steel coupling with a female National Pipe Thread (NPT) fitting (top) with ¼-inch OD tubing compression fitting (bottom)
  - $^1/_4$-inch male NPT plug
  - Stainless-steel washer, optional ($^3/_8$-inch inner diameter [ID], OD less than 1-inch and greater than $^1/_2$-inch)
- Alconox® or equivalent
- Distilled water
- $^7/_{16}$-inch socket
- Wrenches
- Appropriate field screening device(s), e.g., PID, FID, and/or landfill gas meter (optional)
- Rotary hammer drill equipped with 1-inch drill bit
- Rotary hammer drill equipped with $^3/_8$-inch or $^1/_2$-inch drill bit
- Extension cord(s)
- Paper towels
- Heavy-duty vacuum (e.g., Shop-Vac®), optional

- Stainless-steel tubing cutter
- Granular bentonite or bentonite/cement
- Flathead screwdriver
- Hydraulic cement or equivalent
- 1-inch diameter sink hole cover

Installation of Temporary Sub-slab Soil Vapor Points (Section 2.1.4):

- Appropriate field screening device(s), e.g., PID, FID, and/or landfill gas meter (optional)
- Rotary hammer drill equipped with 1-inch drill bit
- Rotary hammer drill equipped with $^3/_8$-inch or $^1/_2$-inch drill bit
- Extension cord(s)
- Generator, if needed
- Paper towels
- Distilled water
- Teflon® or Teflon®-lined polyethylene tubing
- Scissors or tubing cutter
- Granular bentonite
- Container for preparing bentonite
- Materials to close sample port during equilibration, one option outlined below:
  - Polycarbonate stopcock (such as Cole Parmer EW-30600-01)
  - $^1/_4$-inch barbed fitting (such as Cole Parmer EW-45503-19)
  - $^1/_8$-inch ID Tygon E-Lab Tubing (E-3603, L/S 16)
  - $^1/_4$-inch ID Tygon E-Lab Tubing (E-3603, L/S 17)
- Materials to create appropriate surface seal/patch on abandoned borehole
  - Pre-mixed, non-shrinking grout (quick-dry)
  - Container for preparing grout
  - Concrete tools (trowel and $^1/_4$-inch diameter rod)

Installation of Permanent Deep Soil Vapor Points (Section 2.1.5):

- Soil vapor probe materials:
  - Stainless-steel mesh vapor point with ¼-inch barb fitting or with a ¼-inch compression fitting
  - $^1/_4$-inch OD inert tubing (such as Teflon® or Teflon®-lined polyethylene)
- Alconox® or equivalent
- Distilled water
- Teflon® tape, if compression fitting is used
- Wrenches, if compression fitting is used
- Scissors or tubing cutter
- Zip ties, if barbed fitting is used
- Appropriate field screening device(s), e.g., PID, FID, and/or landfill gas meter (optional)
- If concrete coring is required*:
  - Concrete coring machine
  - Concrete core barrel with diameter approximately 2-inches greater than well cover
  - Extension cord(s)
  - Heavy-duty vacuum (e.g., Shop-Vac®)
  - Generator, if needed

- Hand auger
- Direct-push drilling equipment equipped with 3-inch rods, recommended**
- Measuring tape
- Appropriate materials to decontaminate drilling equipment between locations
- Source of water for decontaminating
- Paper towels
- Filter pack of glass beads (60-100 mesh) or fine sand (20-40 mesh), or other appropriately sized inert material based on stainless-steel probe manufacturer recommendations
- Medium sand (optional)
- Granular bentonite
- Grout/Portland cement, or equivalent
- Shovel
- Aluminum flush-mount well cover, typically 4- to 8-inch diameter
- Redi-Mix concrete
- Sand or gravel for drainage layer
- Materials to close sample port, one option outlined below:
    - Polycarbonate stopcock (such as Cole Parmer EW-30600-01)
    - $^{1}/_{4}$-inch barbed fitting (such as Cole Parmer EW-45503-19)
    - $^{1}/_{8}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 16)
    - $^{1}/_{4}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 17)

*****Common to have driller or qualified subcontractor perform the coring; see Project Manager for instructions.

******In certain geologic conditions (e.g., hole stays open to target depth), deep soil vapor points may be installed with a hand auger. However it is typically recommended that a qualified driller install the borehole with direct push drilling equipment. Direct push methods minimize the sub-surface disturbance, reducing the likelihood of leaks and short-circuiting during sample collection.

Installation of Temporary Deep Soil Vapor Points (Section 2.1.6):

- Appropriate field screening device(s), e.g., PID, FID, and/or landfill gas meter (optional)
- Hand auger, if required
- Direct-push drilling equipment, recommended*
- Appropriate materials to decontaminate drilling equipment between locations
- Source of water for decontaminating
- Teflon® or Teflon®-lined polyethylene tubing
- Scissors or tubing cutter
- Sand
- Measuring tape
- Granular bentonite
- Distilled water
- Materials to close sample port during equilibration, one option outlined below:
    - Polycarbonate stopcock (such as Cole Parmer EW-30600-01)
    - $^{1}/_{4}$-inch barbed fitting (such as Cole Parmer EW-45503-19)
    - $^{1}/_{8}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 16)
    - $^{1}/_{4}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 17)
- Materials to create appropriate surface seal/patch on abandoned borehole

  - Pre-mixed, non-shrinking grout (quick-dry)
  - Container for preparing grout
  - Concrete tools (trowel and $^{1}/_{4}$-inch diameter rod)

*In certain geologic conditions (e.g., hole stays open to target depth), deep soil vapor points may be installed with a hand auger. However, it is typically recommended that a qualified driller install the borehole with direct push drilling equipment. Direct push methods minimize the sub-surface disturbance, reducing the likelihood of leaks and short-circuiting during sample collection.

Sample Collection:

- Pre-cleaned, evacuated, passivated stainless-steel canister (hereafter - sampling canister), at least one extra for every 20 samples recommended in case of leakage
- Flow controller(s) with flow rate pre-set by laboratory to meet project objectives, typically between 100 and 200 milliliters per minute (mL/min)
- Digital vacuum gauge, optional
- $^{1}/_{4}$-inch diameter Teflon®, Teflon®-lined, Nylaflow® and/or other inert tubing (optional)
- Applicable components to form sample collection train; components will vary depending on sample point construction and project requirements, but may include:
  - Stopcock (such as Cole Parmer EW-30600-01, or similar)
  - In-line moisture filter (e.g., Millipore #SLGVS25US, or equivalent)
  - ¼-inch barbed fittings (such as Cole Parmer EW-45503-19)
  - Flexible tubing (do NOT use silicone)
    - $^{1}/_{8}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 16)
    - $^{1}/_{4}$-inch ID Tygon E-Lab Tubing (E-3603, L/S 17)
  - $^{1}/_{4}$-inch OD stainless-steel tee
  - $^{1}/_{4}$-inch OD stainless-steel port connectors
  - $^{1}/_{4}$-inch stainless-steel nuts and ferrules
  - $^{1}/_{4}$-inch OD stainless-steel ball valve
  - $^{1}/_{4}$-inch O-rings
  - $^{1}/_{4}$-inch OD, gas chromatography grade 316 stainless-steel male/male coupling
- Teflon® tape
- Zip ties
- Scissors or tubing cutter
- Appropriate tools to open sample collection points (project-specific)
  - Sockets ($^{7}/_{16}$-inch, $^{1}/_{2}$-inch, and/or $^{3}/_{8}$-inch) and driver;
  - Wrenches;
  - Allen wrench, and/or
  - Flat-head screwdriver
- Granular bentonite
- Distilled water
- 50 mL graduated syringe or pump to purge sample port (inert gas detector for tracer gas testing may also serve this purpose)
- Flexible tubing (material does not matter) to form connection between syringe or pump and sample point
- Air flow rate meter (e.g., DryCal® DC-Lite), optional (see Section 2.2.3)
- Watch or timer (capable of monitoring time to the nearest second)

- PID, FID, landfill gas meter and/or other project-specific field screening devices (optional)
- Materials required for completing project-specific leak-testing; equipment lists for various leak-test options are provided in Attachment D

1.4 Definitions

Active Soil Vapor Sampling	A volume of soil vapor or soil gas is pumped out of the vadose zone into a sample collection device for analysis.
Batch Certification	A laboratory will clean several sampling canisters at once. One canister from that group of canisters, i.e., the batch, is used to certify that all of the canisters in that batch are clean.
Building Stack Effects	The natural phenomenon of how air moves in and out of a building primarily due to pressure and temperature differences. Buildings are not totally sealed – they leak. Since air density decreases with increasing warmth, in cool or cold weather, warm interior air tends to leak from the upper portion of the building and cooler air tends to infiltrate the bottom of the building. In air conditioned buildings, this phenomenon is reversed causing warmer exterior air to infiltrate the upper portion of the building and cooler interior air to leak from the bottom portion of the building. These building stack effects can cause increased soil vapor flux around the building perimeter. This increased flux tends to be greater for large buildings because the total building area is relatively high in comparison to the building perimeter.
Individual Certification	A laboratory will clean several sampling canisters at once. Each canister from the batch is certified clean.
Passive Soil Gas Sampling	A sampler containing a sorbent material with an affinity for the target analytes is placed in the ground for a period of time, so that contaminant vapors can be adsorbed over time using the ambient flow of soil gas.
Purge Volume	The total volume, typically measured in milliliters (mL), of air/gas/vapor contained within the sample collection system and sampling point (e.g., tubing, void space within the boring, and/or void space below the slab).

Selected Ion Monitoring (SIM)	Analysis using gas chromatography/mass spectrometry (typically EPA TO-15), whereby only those masses of the known contaminants of interest in the known elution time period are scanned instead of scanning a wide range of masses (35-500 atomic mass units [amu]) every second. SIM analysis allows for greater specificity and much greater sensitivity than scanning in the full-scan mode, since the mass spectrometer is set to dwell for longer period times on a restricted number of masses. SIM analysis is most common for indoor air sample analysis, and is typically not required for soil vapor sample analysis.
Vadose Zone	The zone of soil above the water table and below the ground surface in which the pores between soil grains are at least partially filled with vapor.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Implementing this SOP may require the use of reagents and/or compressed gases for the calibration and operation of field equipment. These substances may be hazardous materials and TRC personnel must appropriately handle and store them at all times. SDSs must accompany reagents or compressed gases.

The rotary hammer drill bits can become extremely hot during drilling. The proper gloves should be worn during drilling to prevent serious burns.

Drilling equipment including the concrete coring machine, the rotary hammer drill, and the Geoprobe® may generate dust and noise; therefore, a dust mask and/or hearing protection should be worn during use, as conditions warrant.

The appropriate cut-/puncture-resistant gloves should be used for this task. Refer to the Glove Section Guidelines in TRC’s Hand Protection Policy.

1.6 Cautions and Potential Problems

(a) Compression fittings, where applicable, as opposed to tube-in-tube connections are typically recommended for air sampling. However, over tightening compression fittings may cause damage/deformation, resulting in leakage during subsequent use. Any leaks of ambient air through fittings between pieces of the sampling train will dilute the sample. The integrity of connections within the sampling train should be verified with a shut-in leak test, or equivalent.

(b) Leaks within the sample collection apparatus may result in leakage of ambient air, and a low sample bias. Leak testing must be performed to verify that a representative sample is collected. Note that certain laboratories, particularly those which specialize in ambient air, indoor air, or stack-testing rather than soil vapor testing, may not maintain their equipment to the standard required to pass a shut-in leak test. Typical leakage rates during shut-in leak tests should be less than 5-percent. If higher leakage rates are observed for the canister-flow controller connection, an alternative laboratory should be considered. If needed, experienced personnel on the TRC Vapor Intrusion CORE Team can provide a recommendation for a laboratory which maintains sampling canisters and flow controllers to the necessary standard for soil vapor sampling.

(c) Water vapor in the sample may compromise the laboratory instrumentation and prevent sample analysis. Measures should be taken to prevent moisture from entering the sampling canister. Soil vapor points should not be in contact with the water table. In many environments, soil vapors may be high in moisture, and condensate may form with temperature fluctuations (particularly at exterior locations or at inactive sites where heating/cooling systems are not operational). Sample collection lines should be monitored for visible moisture. Typically, an in-line moisture filter should be used during sample collection to prevent unacceptable levels of moisture from compromising the sample. If water is observed, the possible presence of water in the sample should be noted on the chain-of-custody. If the laboratory knows that water may be present, measures can be taken to prevent the water from entering the instrumentation.

(d) The inert gas detector may yield a false positive response in high moisture conditions. Under these conditions, it is recommended that an alternative semi-quantitative tracer, such as 1,1-difluoroethane (commercially available as electronic dusting spray), be used in place of inert gas tracer testing.

(e) Although sampling equipment (e.g., flow controllers and sampling canisters) is typically not damaged by extreme temperatures, the functionality of sampling equipment may be temporarily affected by extreme temperatures. Protect the flow controller and sampling canister from extreme temperatures (<20°F) immediately prior to and during sample collection.

(f) The sampler should be cognizant of the purge volume of the sample tubing and should remove at least one purge volume prior to inert gas testing and three purge volumes prior to sample collection. Purging a point is similar to purging a groundwater monitoring well in that under purging can create a low bias. Do not purge more than five volumes of the tubing and/or sampling point. Significant over purging can cause low bias and sample representativeness issues, as soil vapor that has accumulated adjacent to the sampling point could be evacuated and vapor from beyond the target sampling location would then migrate to fill the low-pressure zone. If a PID, FID, landfill gas meter or other field screening device is used prior to sample collection, caution should be used regarding the number of purge volumes being removed.

(g) Many common construction materials, particularly plastics have the potential to absorb volatile organic compounds (VOCs). Sampling points should be constructed using stainless-steel, brass, Teflon®, Teflon®-lined, Nylaflow® and/or other materials that have been demonstrated to be inert in soil vapor/air sampling applications.

(h) Teflon®, Teflon®-lined, Nylaflow®, and/or other tubing that has been shown to be inert should be used to the extent possible in the sample collection train. Flexible tubing has the potential to absorb small amounts of VOCs. Therefore the use of flexible tubing should be minimized to the extent reasonable. However short sections of flexible tubing are often required to make air-tight connections within the sample collection apparatus. Flexible silicone tubing should not be used for these connections. Depending on the manufacturing process, certain batches of silicone tubing may release siloxane vapors. These vapors may cause matrix interference and compromise sample reporting limits. Short sections of Tygon® tubing are recommended as opposed to silicon tubing where flexible tubing is necessary. Due to the potential for VOC absorption/desorption, flexible tubing within the sample collection train should be replaced prior to each sampling event.

(i) Many common materials can contain VOCs. Eliminate to the extent possible the use of VOC-containing materials (e.g., perfumes, glues, modeling clay, etc.) during sample point installation and sample collection. If possible, fuel your field vehicle prior to loading field equipment. Make sure hands are washed thoroughly after fueling a vehicle, and prior to handling sampling equipment. Note even sealants, glues, clay, etc. which are labeled "VOC-free" may contain VOCs at parts per billion levels, i.e., the anticipated sensitivity of the sample analysis. These materials also may contain other chemicals which affect analytical instrumentation, even if they are not target chemical (e.g., siloxanes). "Party" helium contains measurable concentrations of several VOCs and should not be used in place of laboratory-grade helium for inert gas tracer testing.

(j) If collecting indoor air at the same locations and at the same time as sub-slab vapor samples, purging should be performed into a Tedlar® bag instead of into ambient air to avoid cross-contamination.

(k) Low permeability soils can cause short-circuiting of soil vapor samples such that ambient air is pulled down through preferential pathways in the soil and collected in place of soil vapor.

(l) In low permeability soils exhibiting high moisture content, active soil vapor sampling methods have the potential to underestimate concentrations of constituents of interest, particularly if impacts are confined to a small area.

(m) If the sampling canister vacuum fails to drop, this may be the result of low permeability soils, cold weather, or other equipment-related issues, which may require troubleshooting. If the problem cannot be resolved, contact the Project Manager to determine how to proceed, as the sampling canister is not filling properly and inadequate sample volume will lead to elevated reporting limits and potential issues with the representativeness of the sample.

(n) Note that the final target vacuum may vary depending on the project and regulatory requirements. Verify appropriate requirements prior to collecting samples. Some projects require that there be some residual vacuum remaining in the canister (typically 2-6 inches mercury [in. Hg]). A field vacuum reading similar to the laboratory receipt vacuum provides a check of the integrity of the canister and demonstrates that no leaks occurred during shipment to the laboratory. Other guidance recommends letting the canister fill completely (e.g., final vacuum of 0 in. Hg); filling the canister to zero eliminates the pressure gradient between the canister and ambient air during sample shipment.

(o) Where constituents of interest exhibit moderate Henry's Law Coefficients (on the order of 10^{-5} atmospheres-meter^3/mole), a short sample period may result in false negatives or low biases potentially associated with the low exchange of air during active sampling. Examples of potential compounds of interest with moderate Henry's Law Coefficients include but are not limited to: Acetonitrile, 4,4'-DDT, dieldrin, and 1,4-dioxane.

(p) Caution should be used when collecting soil vapor at exterior soil vapor sampling locations.

- Depth of Exterior Soil Vapor Points: Typically sampling points that are less than 5 feet below ground surface (ft. bgs) are not recommended. Risk, estimated using shallow exterior soil vapor points, is likely to be underestimated due to leakage of ambient air, particularly adjacent to a building, where the air exchange rate in the soil vapor may be influenced by building stack effects due to heating/cooling systems.
- Moisture: Significant recharge events (e.g., rainfall or snow melt) can temporarily "wash" the vadose zone. Soil vapor sampling at exterior locations should be delayed for at least 48-hours after a significant recharge event. Significant recharge events by definition vary from state to state. If available, check applicable guidance to confirm definition of significant recharge.

(q) In certain situations, it may be more appropriate and cost effective to perform a screening level assessment using an alternative method to reduce or eliminate the need for active soil vapor sampling. For instance:

- Under some regulatory programs, it may be possible to use field screening (e.g., PID, FID) to eliminate the collection of canister samples.
- Passive soil gas sampling modules may be effective in overcoming many limitations to active soil vapor sampling such as low permeability soils, high moisture soils, constituents of interest with moderate Henry's Law Coefficients, and/or the high costs associated with large investigation areas. In certain situations, passive soil gas sampling may be used to eliminate or greatly reduce the need for more costly active soil vapor sampling.

(r) If using a generator during sample point installation, operate the unit away from the sampling area and be sure that the exhaust of the generator is not directed towards the sample or any of the field team members.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Always review the project-specific work plan and/or scope of work for any site-specific sampling procedures. The following sections detail the methods available for installing soil vapor sampling points and collecting active soil vapor samples.

2.1 Installation of Soil Vapor Sampling Points

This section describes several ways to install soil vapor sampling points. The methods described herein are not exhaustive. Other methods for sample point installation may be appropriate depending on regulatory requirements and project objectives. In general soil vapor sampling points must be constructed of inert materials which neither absorb nor desorb VOCs, e.g., stainless-steel, brass, Teflon®, Teflon®-lined, and/or Nylaflow® materials. Additionally soil vapor sampling points must be constructed in a manner that ensures the soil vapor sample is collected from the target sample location and sealed to prevent ambient air leakage.

2.1.1 Pre-installation Activities

Pre-installation activities may include, but are not limited to, the following:

- Premark sampling locations and contact the appropriate entity to locate underground utilities in the area. Confirm sampling locations with the site owner.
- Where soil vapor points are to be installed through concrete or similar, screen cracks, gaps and other annular spaces in the surrounding area with a PID that is approved by the local regulators or is otherwise appropriate for the application. For example, the RAE System ppbRAE model, which is sensitive to 1 part per billion volume (ppbv) is approved in some states and is recommended where allowed.
- Check the depth to water in nearby wells to determine if the slab may be in contact with the water table (especially if in the basement), or for deep points, to help ensure that the sampling point is installed above the water table and capillary fringe.

2.1.2 Installation of a Permanent Sub-slab Vapor Point – Flush-Mount Well Cover Method

This subsection describes the procedure for installing a permanent sub-slab vapor point using the Flush-mount Well Cover Method. Using the Flush-mount Well Cover Method, the sampling point is protected by a flush-mount well cover or small manhole cover. This installation method is recommended in commercial and industrial settings, particularly in areas of high and/or heavy traffic. See Figure B-1 in Attachment B for a cross-sectional diagram of a point installed using the Flush-mount Well Cover Method.

If the slab is thin (e.g., one-inch thick), caution should be used because the probe and flush-mount well cover skirt will need to be cut very short and should not extend more than one or two inches deeper than the base of the slab.

Construction: Permanent Flush-Mount Well Cover Sampling Point

(a) Components:

- $^1/_4$-inch diameter ball valve;
- $^1/_4$-inch male thread by $^1/_8$-inch diameter hose barb fitting; and,
- $^1/_4$-inch diameter nipple (length dependent upon slab thickness).

(b) Decontaminate any cutting oils from the components using Alconox® or equivalent, and rinse with distilled water.

(c) Attach Teflon® tape to all threads that will be attached to other components.

(d) Attach the hose barb fitting to the ball valve, and use a wrench to tighten securely. Ensure that the ball valve lever is up, toward the barb fitting, when open so that the valve can be opened and closed after installation.

(e) Attach the nipple to the base of the ball valve, and use a wrench to tighten securely.

Installation: Permanent Flush-Mount Well Cover Sampling Point

(a) Select drilling location. Advance core barrel through the concrete slab and remove the core. Recover the concrete coring water with a heavy-duty vacuum. The concrete core should be large enough to set, grout and seal the flush-mount well cover (typically about 2-inches larger in diameter than the flush-mount well cover).

(b) Place the flush-mount well cover in the center of the core. If needed, cut the skirt so the flush-mount well cover is flush with the floor.

(c) Remove the flush-mount well cover lid, and install the prepared sampling point in the center of the flush-mount well cover by placing it in the flush-mount well cover, so the base is in contact with the sub-base materials. Cut the base of the sampling point, so the top of the point sits just below the lid of the flush-mount well cover.

(d) Install hydraulic cement from the base of the flush-mount well cover up to the base of the ball valve on the sampling point. Then install hydraulic cement or grout/Portland cement between the flush-mount well cover and the concrete slab to match the flush-mount well cover and existing grade.

(e) Record sample point construction details as outlined in Section 5.1. Details should be sufficient to document that appropriate materials/procedures were used during construction and to calculate the purge volume as described in Section 2.2.3. An example field form is provided in Attachment C.

(f) Ensure the ball valve is in the closed position before closing the lid. Clean work area. Refer to Photograph 1 for a picture of a newly installed point prior to the placement of the lid.

(g) After vapor point installation, allow sub-surface conditions to stabilize prior to sampling. EPA typically recommends two hours for equilibration; however, the appropriate regulatory guidance associated with the project should be reviewed.

2.1.3 Installation of a Permanent Sub-slab Vapor Point – Stainless-steel Probe Method

This subsection describes the procedure for installing a permanent sub-slab vapor point using a stainless-steel probe, often referred to as the Swagelok® Method. This method was described in a United States Environmental Protection Agency report titled "Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples" (USEPA, 2006). Probes should be constructed prior to ground-intrusive activities.

Sub-slab vapor point installation with a stainless-steel probe does not require concrete coring. Consequently, the Stainless-steel Probe Method is typically less expensive than the Flush-mount Well Cover Method, and is generally recommended in residential settings. Using the Stainless-steel Probe Method, the sample point is largely unprotected. Dirt and debris may fill the sampling point. The threading on the stainless-steel coupling must be clean prior to sampling to ensure a good seal. See Figure B-2 in Attachment B for a cross-sectional diagram of a point installed using the Stainless-steel Probe Method.

Construction: Permanent Stainless-steel Probe Sampling Point

(a) Assemble soil vapor probes using a project-specific length of $^1/_4$-inch OD stainless-steel tubing connected to the $^1/_4$-inch compression fitting on a stainless-steel coupling. Install a $^1/_4$-inch male NPT plug in the female NPT fitting end of the stainless-steel coupling and tighten 270 degrees; this plug will be mounted flush with the ground surface and removed to access the soil vapor probe. See Photograph 2 for a picture of the components.

(b) Decontaminate any cutting oils from the components using Alconox® or equivalent, and rinse with distilled water.

Installation: Permanent Stainless-steel Probe Sampling Point

(a) Using a rotary hammer drill, advance a 1-inch diameter drill hole into the concrete floor to a depth approximately 2 inches below the surface. Photograph 3 is a picture of a typical rotary hammer drill.

(b) Remove the accumulated powdered concrete from the boring using a wet paper towel or vacuum.

(c) Switch to the $^3/_8$-inch diameter drill bit ($^3/_8$-inch diameter needed for the $^1/_4$-inch stainless-steel tubing) and advance the boring through the remainder of the concrete slab and into the sub-slab aggregate. **NOTE:** A different rotary hammer drill than the one used in step (a) will most likely be needed for the $^3/_8$-inch diameter drill bit. Do not advance the boring greater than 2 inches past the base of the concrete slab. Clean the inside of the boring with a wet towel or similar to remove powdered concrete. In order to eliminate the need for a second, smaller rotary hammer drill, a $^1/_2$-inch diameter bit can be used provided the probe does not slide down the $^1/_2$-inch diameter borehole. A decontaminated, stainless-steel washer can be placed at the base of the one-inch diameter borehole to ensure that the probe does not slip down.

(d) Measure the depth of the concrete slab using the drill bits.

(e) Compare the depth of the concrete slab to the length of the assembled probe. The plug should be either flush or very slightly below the surface grade of the concrete slab. Cut the base of the sampling point with a stainless-steel tubing cutter if the probe assembly is longer than the concrete slab is thick. The point should “float” in the concrete slab.

(f) Re-drill using the $^3/_8$-inch (or $^1/_2$-inch) diameter drill bit to push any extra concrete powder down the borehole, so it does not interfere when inserting the probe.

(g) Place the probe assembly into the borehole.

(h) Carefully add granular bentonite or a bentonite/cement mix around the probe. Hydrate with distilled water. Use a flat head screwdriver, to mix the bentonite and fill the annulus from the top of the tubing (i.e., the base of the 1-inch diameter borehole) to approximately 1-inch below grade. See Figure B-2 in Attachment B. Use a paper towel to remove excess bentonite.

(i) Photograph 4 is a picture of a point prior to the installation of the hydraulic cement. Install a hydraulic cement cap above the bentonite and below the threads of the plug. Non-shrinking or expanding cements that do not contain VOCs can be substituted.

(j) A 1-inch diameter pronged sink hole cover may be installed over the sampling point for aesthetic purposes, and to reduce the potential for dirt egress into the sampling point. The sink hole cover can be removed with a flat-head screwdriver prior to sampling.

(k) Record sample point construction details as outlined in Section 5.1. Details should be sufficient to document that appropriate materials/procedures were used during construction and to calculate the purge volume as described in Section 2.2.3. An example field form is provided in Attachment C.

(l) After vapor point installation, allow sub-surface conditions to stabilize prior to sampling. EPA typically recommends two hours for equilibration; however, the appropriate regulatory guidance associated with the project should be reviewed.

2.1.4 Installation of a Temporary Sub-Slab Soil Vapor Point

This subsection describes the procedure for installing a temporary sub-slab vapor point. See Figure B-4 in Attachment B for a cross-sectional diagram of an installed temporary sub-slab soil vapor sampling point.

Installation Temporary Sub-Slab Soil Vapor Sampling Point

(a) Use the rotary hammer drill to advance the 1-inch diameter drill bit approximately 1-inch into the concrete. See Photograph 3 for a picture of a typical rotary hammer drill.

(b) Remove the accumulated powdered concrete from the boring using a wet paper towel.

(c) Switch to the $^3/_8$- or $^1/_2$-inch diameter drill bit and advance the boring through the remainder of the concrete slab and into the sub-slab aggregate. **NOTE:** A different rotary hammer drill than the one used in step (a) will most likely be needed for the $^3/_8$-inch diameter drill bit. Do not advance the boring more than 2 inches past the base of the concrete slab. Clean the borehole with a wet paper towel; do not use a vacuum which could purge air from the sub-slab and affect the representativeness of the sample.

(d) Install Teflon® or Teflon®-lined polyethylene tubing into the base of the boring. Ensure the tubing is long enough to pass through an inert gas containment structure (if required for leak-testing) and connect to a sampling canister.

(e) Using the dedicated bentonite mixing container, hydrate a sufficient amount of granulated bentonite with distilled water to fill the boring diameter and seal around sampling tube. The bentonite seal will require monitoring as it will begin to dry. Rehydrate as necessary.

(f) Install stopcock, or equivalent, on sample tubing to close the sample point. If materials listed in Section 1.3 are used, sample closure is assembled as described below and illustrated in Photograph 5:

1. Install $^1/_8$-inch ID Tygon tubing over slip end of stopcock
2. Cut tubing flush with the end of the stopcock.
3. Form a tube-in-tube connection with ¼-inch ID Tygon tubing over $^1/_8$-inch ID Tygon tubing.
4. Cut ¼-inch ID Tygon tubing to extend approximately 1-inch beyond the end of the stopcock.
5. Form another tube-in-tube connection by placing the open end of the ¼-inch ID Tygon tubing over the ¼-inch Teflon® tubing of the sample point.

(g) Record sample point construction details as outlined in Section 5.1. Details should be sufficient to document that appropriate materials/procedures were used during construction and to calculate the purge volume as described in Section 2.2.3. An example field form is provided in Attachment C.

(h) After the vapor point has been installed, adequate time should be allowed for the subsurface to return to equilibrium conditions. The equilibration time will be dependent on the degree of soil disturbance during installation and regulatory requirements. The Project Manager should be consulted to determine the optimal/required equilibration time. Photograph 6 is a photograph of a temporary sub-slab vapor point during sample collection.

Decommission: Temporary Sub-Slab Soil Vapor Sampling Point

After sample collection is complete, decommission the temporary sampling point as described below.

(a) Remove the tubing from the boring.

(b) Either excavate the bentonite seal or push to the base of the boring.

(c) Abandon vapor point boring with non-shrinking grout or cement.

(d) Clean up the work area.

2.1.5 Installation of a Permanent Deep Soil Vapor Point

This subsection describes the procedure for installing a permanent deep soil vapor point. Unlike sub-slab sampling points, deep sampling points may be located at interior or exterior locations. The surficial completion of the point is similar to the sub-slab Flush-mount Well Cover Method; however the sampling point itself is a mesh, stainless-steel screen point, as shown in Photograph 7. See Figure B-3 in Attachment B for a cross-sectional diagram of a permanent deep soil vapor point. Multiple vapor points may be installed in the same borehole.

Construction: Deep Soil Vapor Point

(a) Decontaminate any cutting oils from the stainless-steel components of the vapor point using Alconox® or equivalent, and rinse with distilled water.

(b) Assemble the soil vapor probe using a stainless-steel mesh vapor point and $^1/_4$-inch OD Teflon® or Teflon®-lined tubing. The stainless-steel mesh vapor point may be constructed with either a compression fitting or a barbed fitting.
   1. Cut the tubing to a length approximately 24-inches longer than the target installation depth.
   2. Connect the tubing to the stainless-steel mesh vapor point. Use Teflon® tape and/or zip ties as appropriate to ensure a good seal.
      i. If a compression fitting is used, slide the nut and ferrule (from the vapor point) over the sample tubing. Insert tubing into the coupling on the vapor point. Slide ferrule down until seated firmly. Connect the nut to the coupling and tighten, but do not over tighten (approximately 270 degrees).
      ii. If a barbed fitting is used, make the tube-in-tube connection and verify tightness.

Installation: Deep Soil Vapor Point

(a) Select drilling location. Verify the utilities have been marked and ensure location is located safely away from subsurface utilities. Hand dig if appropriate. If sampling location has a concrete surface proceed to Step (b) below. If concrete is not present, skip Step (b) and proceed to Step (c) below.

(b) If concrete is present at sampling location, use concrete coring equipment to core through the concrete surface and remove the core. The concrete core should be large enough to set, grout and seal the flush-mount well cover (typically about 2-inches larger in diameter than the flush-mount well cover).

(c) Use direct push drilling technologies (e.g., Geoprobe®) to advance a borehole having a minimum diameter of 3-inches to approximately six inches below the target sampling depth.

(d) Install the deep soil vapor point, assembled as described in the Construction section above, to the total depth through the Geoprobe® rods.

(e) Carefully create a filter pack using appropriately sized glass beads or clean sand to approximately 6-inches above the top of the screened interval, backfilling the deep soil vapor point through the Geoprobe® rods if possible.

(f) Slowly remove rods, being careful not to pull or otherwise disturb the sampling point. Use a clean measuring tape to verify that the height of the filter pack remains at least 6-inches above the top of the screened interval. Add additional filter pack material as appropriate.

(g) A thin (1- to 4-inch) layer of clean medium sand may be placed above the filter pack to help prevent the egress of hydrated granular bentonite into the filter pack.

(h) Seal the well annulus using granular bentonite from the top of the filter pack, or medium sand layer, to a depth of approximately 2 ft. bgs. Place granular bentonite above the filter pack material in 3 to 6-inch lifts. Hydrate each lift in place with distilled water prior to the addition of the next lift to help ensure an effective seal above the monitoring point. If multiple stainless-steel deep soil vapor points are being installed in the same borehole, repeat steps (c) through (h), as necessary.

(i) Seal the remaining well annulus using grout/Portland cement mix, or similar, from approximately 1 to 2 ft. bgs.

(j) Cover and protect the sampling point by installing a 4 to 8-inch flush-mount well cover.

(k) Excavate an area around the borehole as needed to facilitate the installation of the flush-mount well cover.

(l) Open the flush-mount well cover. Being careful not to pull or otherwise disturb the sampling point, extend the sample collection tubing through the center of the flush-mount well cover and place the flush-mount well cover around the sampling point.

(m) The flush-mount well cover should be finished consistent with methods used for flush-mount groundwater monitoring well installations. The protective steel “skirt” should extend approximately 1 foot below the top of the road box. As many flush-mounted vapor points are installed in paved areas, the concrete used to set the flush-mount well cover should be compatible with the bearing capacity of the existing pavement. Depending on location considerations, the concrete may be sloped slightly away from the sampling point or completed truly flush with the surroundings. The inside of the manhole annulus should be filled with a drainage layer of sand or gravel with a weep hole so water that accumulates in the road box will drain. The pad should be sufficiently large to withstand anticipated traffic and weather conditions.

(n) Cut excess tubing and install stopcock, or equivalent, on sample tubing to close the sample point. If materials listed in Section 1.3 are used, refer to Section 2.1.4, Step f and Photograph 5 for assembly description.

(o) Verify sample port is closed and close flush-mount well cover. Clean work area.

(p) Sampling points should be permanently marked with the sampling point identification number either on the cover or an appropriate place (i.e., in concrete pad) that will not be easily damaged and/or vandalized.

(q) Record sample point construction details as outlined in Section 5.1. Details should be sufficient to document that appropriate materials/procedures were used during construction and to calculate the purge volume as described in Section 2.2.3. An example field form is provided in Attachment C.

(r) After vapor point installation, allow sub-surface conditions to stabilize prior to sampling. EPA typically recommends two hours for equilibration; however, the appropriate regulatory guidance associated with the project should be reviewed.

2.1.6 Installation of a Temporary Deep Soil Vapor Point

This subsection describes the procedure for installing a temporary deep soil vapor point. Unlike sub-slab sampling points, deep sampling points may be located at interior or exterior locations.

Installation: Temporary Deep Soil Vapor Point

(a) Select drilling location. Verify the utilities have been marked and ensure location is located safely away from subsurface utilities. Hand dig, if appropriate, for utility clearance purposes.

(b) Use direct push drilling technologies (e.g., Geoprobe®) to advance a borehole to 3-inches below the target sampling depth.

(c) Install Teflon® or Teflon®-lined polyethylene tubing through Geoprobe® rods to the target sampling depth. Ensure the tubing is long enough to pass through an inert gas containment structure (if required for leak-testing) and connect to a sampling canister.

(d) Carefully create a filter pack using clean sand to approximately 6-inches above the end of the tubing, backfilling the deep soil vapor point through the Geoprobe® rods if possible.

(e) Slowly remove rods, being careful not to pull or otherwise disturb the tubing. Use a clean measuring tape to verify that the height of the filter pack remains at least 6-inches above the end of the tubing. Add additional filter pack material as appropriate.

(f) Seal the well annulus using granular bentonite from the top of the filter pack to a depth of approximately 1 ft. bgs. Place granular bentonite above the filter pack material in 3 to 6-inch lifts. Hydrate each lift in place with distilled water prior to the addition of the next lift to help ensure an effective seal above the monitoring point.

(g) Cut excess tubing and install stopcock, or equivalent, on sample tubing to close the sample point. If materials listed in Section 1.3 are used, refer to Section 2.1.4, Step f and Photograph 5 for assembly description.

(h) Record sample point construction details as outlined in Section 5.1. Details should be sufficient to document that appropriate materials/procedures were used during construction and to calculate the purge volume as described in Section 2.2.3. An example field form is provided in Attachment C.

(i) After the vapor point has been installed, adequate time should be allowed for the subsurface to return to equilibrium conditions. The equilibration time will be dependent on the degree of soil disturbance during installation and regulatory requirements. The Project Manager should be consulted to determine the optimal/required equilibration time. Photograph 8 is a picture of a temporary deep soil vapor sampling point at an exterior location.

NOTE: As an alternative to installing temporary deep soil gas points as described above, soil gas samples can be collected in real time during drilling activities using specialty tooling such as the Geoprobe® post-run tubing (PRT) system. Additional information regarding the means and methods of using specialty tooling is available through vendor websites. If using an alternative installation method, the best practices outlined in this SOP should be considered. For example, if collecting samples through reusable tooling, such as the PRT system, care should be taken to ensure equipment is decontaminated between sample locations. Additionally care should be taken to ensure subcontractors do not use materials that may contain VOCs during installation of the temporary sampling point.

Decommission: Temporary Deep Soil Vapor Sampling Point

After sample collection is complete, decommission temporary sampling point as described below.

(a) Remove the tubing from the boring.

(b) Abandon vapor point boring with non-shrinking grout or cement, or other material consistent with surface conditions.

(c) Clean up the work area.

2.2 Active Soil Vapor Sample Collection

2.2.1 Pre-sampling Activities

Pre-sampling activities include, but are not limited to the following:

- Determine the analyses and reporting limits required prior to sampling and communicate with the analytical laboratory. If low reporting limits are required, then the sampling canister may need to be prepared by the laboratory for analysis via SIM or low-level analysis. If SIM analysis is required, it is recommended that each sampling canister be individually certified as clean.
- Determine the size of the sampling canister required and desired flow controller setting (100 to 200 mL per minute is common for soil vapor sampling). Typically 1-liter or smaller canisters are used. Six-liter canisters are often required to achieve the desired reporting limits for indoor air sampling. However smaller sample canisters are typically sufficient to achieve the desired reporting limits for active soil vapor sampling. Six liter canisters are very cumbersome to use and expensive to ship. Additionally 6-liter canisters take longer to fill, and due to the sample volume, are more likely to exhibit leaks (ambient air short-circuiting) particularly in lower permeability soils.

- Discuss project requirements for leak testing with the Project Manager. Acquire and assemble materials required for applicable leak detection testing, e.g., helium, inert gas containment device, sealing material for quantitative tracer testing.
- Verify that the laboratory analyte list includes the tracer, e.g., 1,1-difluoroethane or helium, if appropriate.
- Order and receive sampling canisters, flow controllers, and duplicate tees from the laboratory. A minimum 2-week lead time is recommended. Because sample canisters are re-used and expensive, laboratory stock is limited. For large projects or for projects in which individually-certified canisters are required, a longer lead time may be needed for the laboratory to fulfill the canister order.
- To the extent reasonable, assemble the sample collection train in advance, e.g., moisture filter and tubing connection from sample point to flow controller. Dirt, wind, cold, etc. can make assembling an air tight sample collection train difficult in the field. Photograph 9 is an example of a pre-assembled moisture filter apparatus than can be used to quickly form a connection with the regulator (equipped with a barbed fitting) and the ¼-inch sample collection point.
- Sampling equipment should be inspected prior to sampling. Sampling equipment provided by the laboratory typically includes an analog pressure gauge on the canister and/or the flow controller. See Photographs 10, 11, and 12 for examples.
    - The vacuum of the sampling canisters should be recorded in the field prior to sampling using the analog gauge provided by the laboratory. If the vacuum is less than 25 inches of mercury (in. Hg), the sampling canister should not be used because this indicates a potential leak. The sampling canister vacuum may also be checked with a digital vacuum gauge, which can be more accurate than the analog gauges provided by the laboratory.
    - Check the documentation attached to the flow controller to verify the flow rate has been set to the correct flow rate, typically between 100 and 200 mL/min.
- Use sample point construction documentation to determine the purge volume.
- Label the tag on the sampling canister with the pertinent sampling data, as well as the flow controller number.
- A clean pair of new, non-powdered, disposable gloves should be worn each time a different location is sampled, and the gloves should be donned immediately prior to sampling. The gloves should be changed any time during sample collection when their cleanliness may be compromised.

2.2.2 Connection of Flow Controller to Sampling Canister

The connection between the soil vapor flow controller and the sampling canister is likely to vary between laboratories. Be sure to follow the laboratory-provided directions when connecting the flow controller to the sampling canister. Photographs 10, 11, and 12 show several common soil vapor flow controllers and sampling canisters. Quick connect fittings are typically simple and trouble-free, whereas compression type fittings are more common, but may also be more troublesome due to preexisting imperceptible damage, i.e., minor abrasions caused by dust/dirt and/or deformation caused by overtightening. Common suggestions for connecting the flow controller to the sampling canister using compression type fittings are as follows:

(a) Confirm the valve is closed (knob should already be tightened clockwise), before unthreading the stainless-steel plug from the top of the canister.

(b) Check to see that the O-ring is still in place prior to making the connection. Ensure extra O-rings and ferrules are shipped with the flow controller in case they are damaged or missing.

(c) If present, remove the plastic cap from the flow controller outlet (male threads) before attempting to connect to the inlet on the sampling canister.

(d) Do not over tighten compression fittings.

2.2.3 Purge Sample Collection Point

The following section describes the procedure for purging the sample collection point prior to sample collection. In order to ensure a representative sample is collected, at least one purge volume should be removed prior to inert gas testing and three purge volumes should be removed prior to sample collection. However, no more than five purge volumes should be removed prior to sample collection. Both under purging and over purging can affect the representativeness of the sample, and create a low bias. If the project scope includes field screening/measurements with a PID, FID, and/or landfill gas meter, caution should be used regarding the number of purge volumes being removed during these measurements. In order to control the potential for over purging, field screening can be completed concurrent with sample point purging (after one purge volume has been removed). Alternatively field measurements may be collected after sample collection has been completed.

(a) Calculate the volume of air in the sample point and sample collection tubing or refer to Table 1 for pre-calculated volumes for select tubing sizes.

$$V_{\text{tubing}} = (\pi r_t^2 h_t)$$

Where:

$\pi = 3.14159265$
r_t = radius of the inner diameter of tubing (inches)
h_t = length of tubing (inches)
V_{tubing} = volume of air in entire length of tubing (in^3)

Table 1: Purge Volumes for Select Tubing/Vapor Point Sizes

Tubing/Vapor Point Size (inches ID)	**Volume/ft (milliliters/ft)**
$^3/_{16}$	5.4
$^1/_4$	10
$^3/_8$	22
$^1/_2$	39
$^3/_4$	87
1	150
2	620
4	2,470
6	5,560

ID = Inner Diameter

$$V_{\text{vapor probe}} = (\pi r_{vp}^2 h_{vp})$$

Where:

r_{vp} = radius of the inner diameter of vapor point (inches)
h_{vp} = length of vapor point (inches)
$V_{\text{vapor probe}}$ = volume of air in entire length of vapor probe (in^3)

$$V_{\text{filter pack-air}} = \eta * [\pi r_{fp}^2 h_{fp} - V_{\text{vapor probe}}]$$

Where:

η = air-filled porosity of the filter pack (typically 0.3 to 0.4)
r_{fp} = radius of the filter pack (inches)
h_{fp} = length of the filter pack (inches) – Refer to sample point construction details
$V_{\text{filter pack-air}}$ = air-filled volume of the filter pack (in^3)

$$V_T = V_{\text{tubing}} + V_{\text{vapor probe}} + V_{\text{filter pack}}$$

Where:

V_T = Total volume of air in the sample point, e.g., tubing, sampling probe, and filter pack (if present)
Convert in^3 to mL (1 in^3 = 16.387 mL)

(b) If applicable, use an air flow rate meter (Dry Cal® or equivalent) to determine the flow rate of the purge pump. Using tubing, connect the purge pump to the outlet of the flow rate meter. The type of tubing used here is optional; the only requirement is that there is a good fit in order to obtain an accurate flow rate reading. Record the flow rate of the purge pump (mL/min). Note: For low volume sample points (e.g., sub-slab points which typically have a total volume <200 mL) a graduated 50 mL manual syringe may be used as an alternative to a purge pump.

(c) If applicable, calculate the time required to purge one purge volume based on the flow rate of the purge pump (Note: If used, the inert gas detector may also be used as the purge pump).

Where

V_T in mL (calculated above) / purge pump flow rate (mL/min) *60 seconds/1 minute = Number of seconds required to purge one purge volume

(d) Connect the purge pump or syringe to the sample collection point.

(e) Use the purge pump or syringe to purge the sample point. If applicable, remove at least one sample point volume prior to inert gas tracer testing and/or field screening/measurements. Remove at least 3 sample point volumes and no more than 5 sample point volumes prior to sample collection.

(f) Disconnect purge pump or syringe from the sample point. Immediately connect the sample collection apparatus to the sample point and proceed with leak testing and sample collection as described in Section 2.2.4 and Section 2.2.5 below.

2.2.4 Leak Testing

Leak testing is performed to verify that a representative sample is collected. Leaks may occur in the sample collection train and/or the soil vapor sample point itself. ***Leak testing to verify the***

integrity of both the sample collection train and the soil vapor sample point itself must be completed for every soil vapor sample in order to establish air tightness. Leak testing of the sample collection train can be completed through a shut-in leak test. Leak testing using a tracer gas, referred to as tracer testing in this SOP, is typically used to test the integrity of the soil vapor sampling point itself, although it can also be used to test the integrity of the sampling train. Tracer testing may be either quantitative (e.g., helium) or semi-quantitative (e.g., 1,1-difluoroethane). Quantitative tracer testing is typically more difficult and labor intensive than the use of a semi-quantitative tracer. The selection of the appropriate tracer is dependent on project objectives and regulatory requirements. For example, in the State of New York, use of a quantitative tracer is required to verify the sample point integrity prior to each sampling event. For projects where state requirements do not mandate the use of a quantitative tracer, a semi-quantitative tracer may be appropriate and more cost effective. When permanent sampling points are installed, it may be appropriate to use a quantitative tracer to verify initial sample point integrity, and a semi-quantitative tracer may be used during subsequent sampling events to document that the sampling point integrity has not been compromised.

Attachment D describes recommended methods for completing leak testing to verify the integrity of the sample collection train prior to sample collection, as well as options for either semi-quantitative leak testing or quantitative leak testing to verify soil vapor sampling point integrity. Leak testing is required. However the leak-testing methods described in Attachment D are recommendations only. Actual leak test methods may vary based on project objectives and regulatory requirements.

2.2.5 Vapor Sample Collection

(a) Connect the flow controller to the canister as described in Section 2.2.2 and assemble the sample collection train. Depending on the sample set up, the sample collection train will typically include the following: the sampling canister, the flow controller, a moisture filter, a stopcock, as well as appropriate fittings and inert tubing (e.g., Teflon®, Teflon®-lined, or Nylaflow®) to connect these components. For an example, see Photograph 13. For duplicate samples a laboratory provided duplicate tee will also be included (see Photograph 14).

(b) On permanent sampling points, open/prepare the sample collection point as appropriate.

1. For permanent points protected with a road box or flush-mount well cover, open the lid to inspect the hydraulic cement or grout/Portland cement seal between the sampling point and the flush-mount well cover. Inspect seal between the concrete floor (or other surface material) and the flush-mount well cover. If the seal is visibly compromised, then place granular bentonite in the void(s) and hydrate.

2. For permanent points installed via the Stainless-steel Probe Method, remove sink hole cover (if present). Remove plug using a $^{7}/_{16}$–inch socket and thread a male/male coupling (see Photograph 2) onto the permanent point. Lock the ferrule and the nut to the sample tubing, then connect the sample tubing to the top of the coupling (do not use a wrench; this connection should be hand tight). Inspect the seal, if visibly compromised, then place additional granular bentonite in the void and hydrate.

(c) Purge the sample collection point as described in Section 2.2.3. Remove at least one sample point volume prior to inert gas tracer testing and/or field screening/measurements. Remove at least 3 sample point volumes and no more than 5 sample point volumes prior to sample collection.

(d) If applicable, field screening/measurements with a PID, FID, and/or landfill gas meter may be collected while the sample collection point is purged.

(e) Complete project-specific leak testing as described in Section 2.2.4. Leak testing to verify the air tightness of **both** the sample collection point and the sample collection apparatus is required. Sample point integrity is tested with **either** quantitative (inert gas) tracer testing or with semi-quantitative tracer testing, not both. Quantitative (inert gas) tracer testing is typically completed immediately after purging and prior to the shut-in leak test (to verify the integrity of sample collection train). By contrast, semi-quantitative tracer testing is completed concurrent with sample collection. Detailed procedures for recommended leak test options are provided in Attachment D.

(f) During pre-sampling leak testing procedures, the sample collection apparatus should be connected to the sample collection point. Verify the integrity of this connection, and tighten as appropriate.

(g) Open the sampling canister valve to begin sampling. Record the start time, flow controller rate, initial vacuum, and sampling canister size.

(h) Depending upon the soil type, the sampling canister may fill slower than anticipated based on the flow controller setting. It is preferable to wait until the vacuum reaches no more than 6 in. Hg, rather than wait a specified time period. Note, if vacuum fails to drop, this may be the result of tight soils, cold weather, or other equipment-related issues, which may require troubleshooting. If the problem cannot be resolved, contact the Project Manager to determine how to proceed, as the canister is not filling properly and inadequate sample volume may lead to elevated reporting limits and potential issues with the representativeness of the sample. Note that the final target vacuum may vary depending on the project and regulatory requirements. Verify appropriate requirements prior to collecting samples.

(i) When the canister reaches the final target vacuum, the sampling canister valve can be closed. Record the final vacuum and time the valve was closed.

(j) Remove the tracer gas containment device.

(k) Disconnect the sample collection apparatus from the sample collection point. Dismantle apparatus, and dispose of tubing, moisture filter, etc.

(l) Close permanent sample collection points or decommission temporary sampling points.

1. On permanent sub-slab points installed via the Flush-mount Well Cover Method, verify that the ball valve is in the off (closed) position and re-install the lid to close the sample collection point.

2. On permanent sub-slab points installed via the Stainless-Steel Probe Method, remove the tubing connected to the soil vapor probe and replace the plug. Hand tighten the threads of the plug, and then tighten slightly with a $^{7}/_{16}$-inch socket. Do not over-

tighten the plug, or the point may be damaged by the force of threading/unthreading the plug. Replace the sink hole cover (if present).

3. On permanent deep soil vapor points, verify that the stopcock is in the off (closed) position and re-install the lid to close the sample collection point.

4. On temporary sub-slab soil vapor sampling points, decommission the sampling point as described in Section 2.1.5.

5. On temporary deep soil vapor sampling points, decommission the sampling point as described in Section 2.1.6.

(m) Clean up the work area.

2.2.6 Post-sampling Activities

(a) Check the label on each sample.

(b) Re-install cap or plug on sample canister for shipment. Package canisters for shipment consistent with packaging upon receipt from the laboratory.

(c) Complete the chain-of-custody. Verify that the analyte list includes the tracer, if applicable.

(d) Air samples do not need to be refrigerated or shipped on ice.

(e) Ensure samples are delivered to the laboratory well before the required holding time expires.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of specific field quality control (QC) samples will be specified in the project-specific planning documents and may include one or more of the following samples: background/ambient samples, equipment blanks, and field duplicates.

4.1 Background or Ambient Sample

A background or ambient sample is an ambient air sample collected outside in the area proximate to the site. Analysis of the background or ambient sample can provide information about the ambient levels of site contaminants.

4.2 Equipment Blank

An equipment or material blank may be used to provide information about the levels of contaminants present in materials used to collect soil vapor. An equipment blank is collected by pulling ambient air through a constructed soil vapor probe and all relevant components of the soil collection train (e.g., moisture filter, tubing, etc.) prior to installation. If an equipment blank is collected, a background or ambient air sample, described in Section 4.1 above, must also be collected so that contaminants attributable to the sample point may be distinguished from contaminants present in ambient air.

4.3 Field Duplicates

The following procedures should be used for collecting field duplicates of soil vapor samples:

(a) For quality control purposes, each duplicate sample will be submitted to the laboratory as a "blind" duplicate sample, in that a non-existing sample identification will be assigned in labeling the duplicate. Labeling procedures used for sampling will be employed, and all parameters measured will also be recorded. Since the duplicate is collected simultaneously with the actual sample, a "blind" sample time, typically within 1 hour of the actual time, will also be assigned. The actual source and collection time of the duplicate sample will be recorded in the field book.

(b) Each duplicate sample will be collected by installing a T-connection (made of Teflon®, stainless-steel, or brass) at the end of the sample tubing and connecting one sampling canister to each side of the connector. Both sampling canister valves must be opened and closed at the same time. Photograph 15 is a picture of a duplicate sample being collected. Typically duplicate tees can be provided by the analytical laboratory upon request (Photograph 14).

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

5.1 Sample Point Installation

Record the general sample point installation information in the field book or on a field form. An example field form is provided in Attachment C. At a minimum, field documentation must include the following information:

- Sample point identification number
- Sample location (sketch of the sample point)
- Date/time of installation
- Technician(s) names, including subcontractors
- Slab thickness, if applicable
- Construction details including the following:

    - Installation method
    - Diameter and depth of borehole
    - Composition of probe, sealing, and finishing materials (to document that inert, VOC-free materials were used)
    - Material size including diameter and length/thickness (to allow purge volume to be calculated)
- Field screening results, if applicable
- Decontamination procedure, if applicable
- Presence of any materials that may interfere with soil vapor results

Representative tasks and the condition of areas within the area where soil vapor points are installed should be photographed.

5.2 Sample Collection

Record the general sample collection information, such as location, identification, and date/time in the field book or on a field form. Typical field documentation recorded in a field book may include the following information:

- Sampling canister ID
- Flow controller ID
- Initial vacuum
- Final vacuum
- Sample identification number
- Sample location (sketch of the sample point)
- Leak-test method(s) and applicable data associated with leak-testing, e.g., tracer used, final inert gas concentration detected in sample tubing, etc.
- Time and date sample collection started
- Time and date sample collection ended
- Personnel performing the task
- Volume of vapor purged prior to sampling
- Flow rate of purge pump and flow controller, if applicable
- Weather conditions during sampling
- Field screening results, if applicable
- Decontamination procedure, if applicable
- Analytical parameters
- Heating and air conditioning systems in use at the facility at the time of sampling (e.g., type of system, primary fuel, location of boiler/furnace, type of air conditioning, and air distribution system)
- Barometric pressure at sample collection start
- Barometric pressure at sample collection end
- Presence of any materials that may interfere with soil vapor results

Representative tasks and the condition of areas within the area where soil vapor sampling is performed should be photographed.

All sample numbers must be documented on the chain-of-custody form that accompanies the samples during shipment. Any deviations from the record management procedures specified in the project-specific work plan must be approved by the Project Manager and documented in the field book.

6.0 REFERENCES

H&P Mobile Geochemistry, Inc., 2013. Evaluation of Leak Check Procedures for Soil Vapor Sampling. Presented at AEHS in San Diego, California on March 20, 2013.

NYSDOH, 2006. Guidance for Evaluating Soil Vapor Intrusion in the State of New York, New York State Department of Health. October 2006.

USEPA, 2006. Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples. EPA/600/R-05/147. March 2006.

USEPA, 2007. Construction and Installation of Permanent Sub-slab Soil Gas Wells. SOP 2082. March 29, 2007.

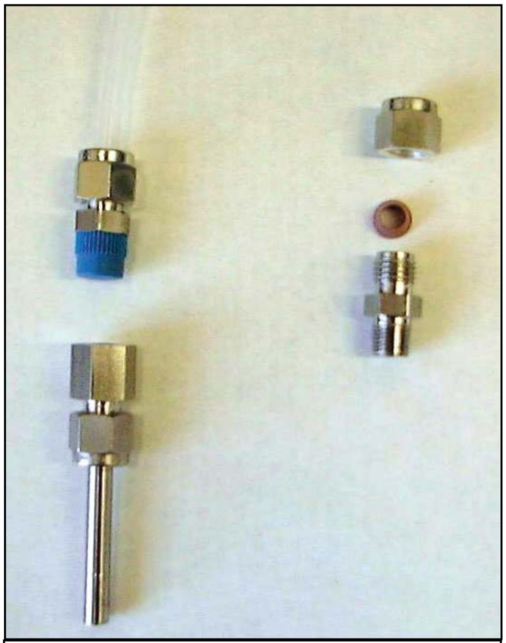
USEPA, 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, EPA OSWER Publication 9200.2-154. June 2015.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	JULY 2016	NOT APPLICABLE
1	AUGUST 2017	MADE CORRECTION IN TABLE 1 AND FIGURE B-2
2	JANUARY 2020	TRC RE-BRANDING

Attachment A:
Photographs

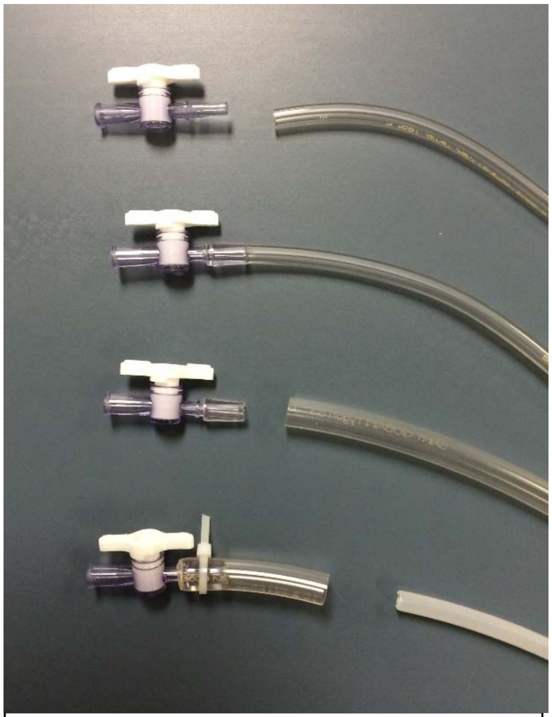
Photograph 1 - Overhead view of completed point via Flush-mount Well Cover Method



Photograph 2 - Stainless-steel Probe Method components

Photograph 3 – Rotary hammer drill

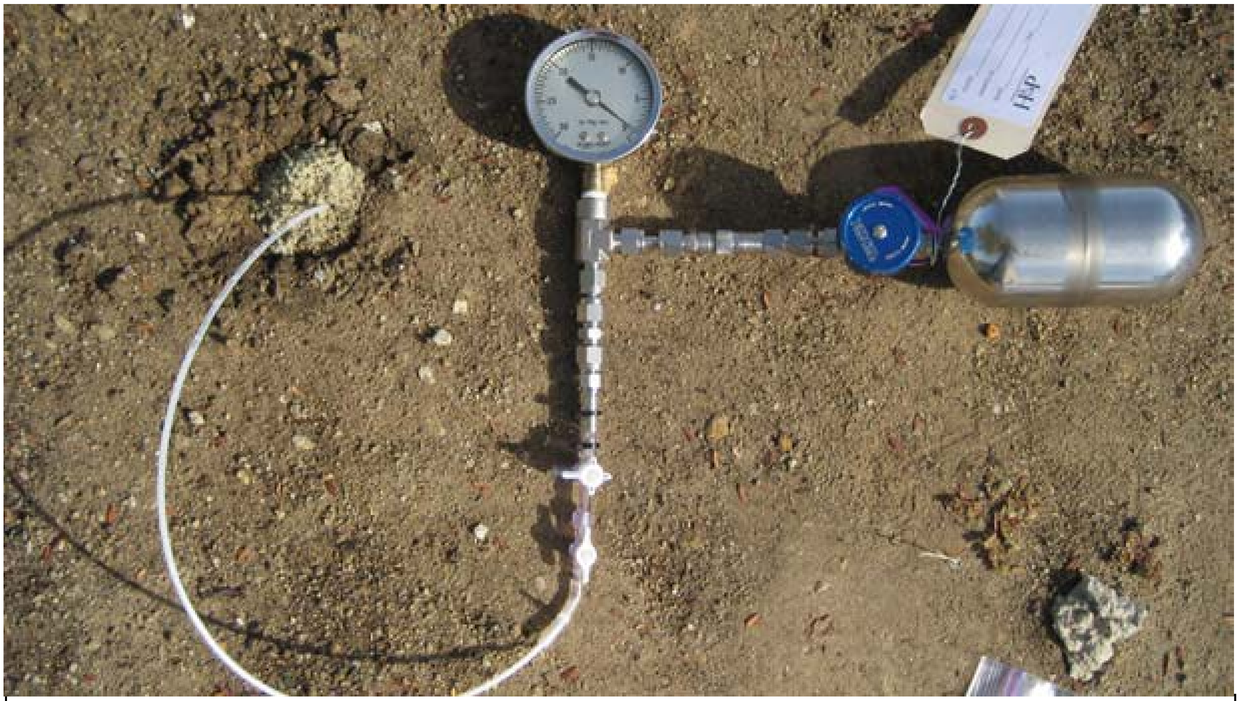
Photograph 4 - Plug and fitting on stainless-steel probe before installation of cement seal



Photograph 5 – Step-by-step process for assembling the end of a deep or temporary sampling point

Photograph 6 – Sample collection at temporary sub-slab vapor point

Photograph 7 – Stainless-steel mesh soil vapor point



Photograph 8 – Soil gas sampling set up at deep, exterior temporary soil vapor point

Photograph 9 – Inline moisture filter and stopcock assembly (See Photograph 13, Item [C])

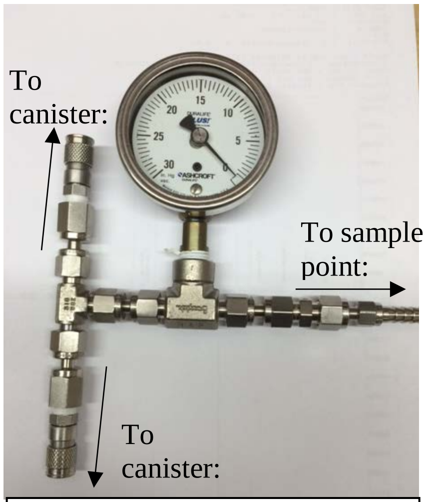
Photograph 10 – One-liter sampling canister with quick connect fitting (See Photograph 13, Item [A])

Photograph 11 – Flow controller with quick connect fitting to canister and barbed fitting to vapor point (See Photograph 13, Item [B])

Photograph 12 - Flow Controller and Sampling Canister

Flow controller (top) with inlet at top and outlet at base. Sampling Canister (bottom) with inlet at top. Note inverted nut at inlet of canister which threads onto flow controller outlet.

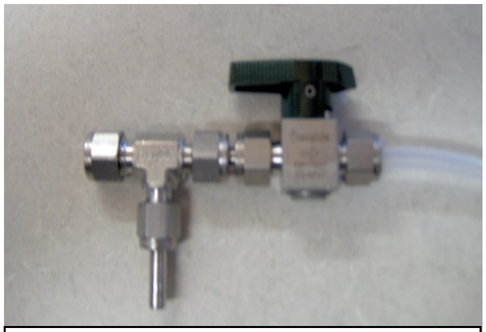
Photograph 13 – Soil gas sample collection set up at deep soil gas vapor point prior to placement of shroud for tracer testing.



Photograph 14 – Duplicate tee with quick connect fittings

Photograph 15 - Field duplicate sample collection setup

Photograph 16 - MGD-2002 Helium detector



Photograph 17 - T-connection for quantitative tracer gas testing

Photograph 18 – Exterior soil gas sampling point with moisture filter setup to begin shut-in leak test

Photograph 19 - Soil gas sampling set up with semi-quantitative leak testing applied via rags draped over vapor point and sampling apparatus.
Note: Although rags are placed around fittings here, a single rag placed immediately adjacent to the sampling apparatus is sufficient when using the Rag Method to apply a semi-quantitative tracer.

Photograph 20 – Soil gas sample collection set up at deep soil gas vapor point with shroud to contain 1,1-difluoroethane tracer during sample collection.

Photograph 21 - Plastic wrap leak detection method during sampling

Photograph 22 - Inverted container leak detection method with helium tank in background (right). Leak detection for vapor point only, canister outside of container.

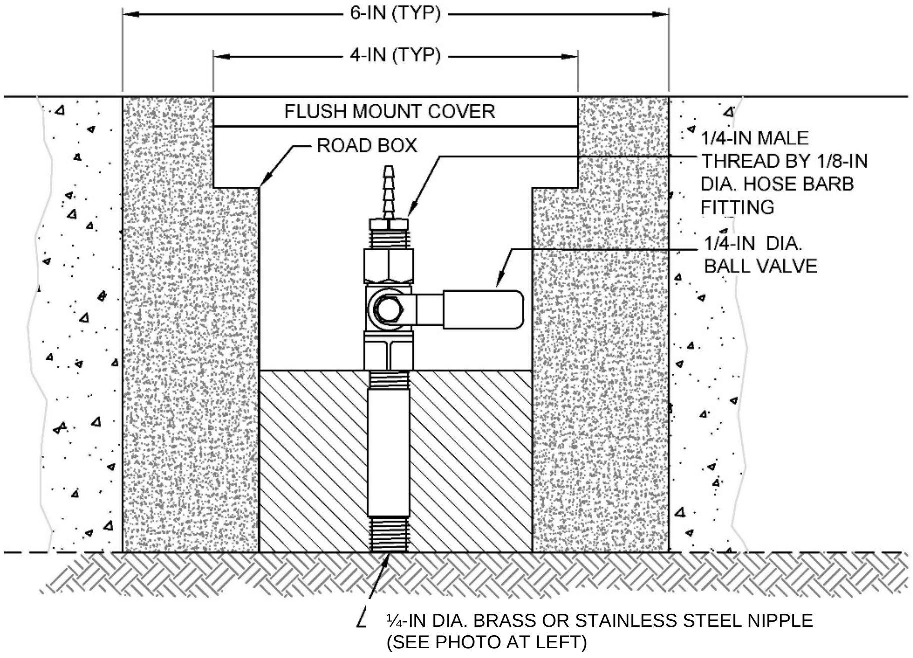
Photograph 23 - Inverted container leak detection method with canister inside of container. Leak detection for vapor point and sample collection apparatus. Helium tank to the left of container.

Attachment B:
Soil Vapor Point Cross-Sectional Diagrams

LEGEND

- ▨ EXISTING CONCRETE SLAB
- ▨ NATIVE SOIL / SUBSURFACE FILL
- ▨ GROUT / PORTLAND CEMENT MIX (OR SIMILAR)
- ▨ HYDRAULIC CEMENT

Assembled Sample Point Prior to Installation

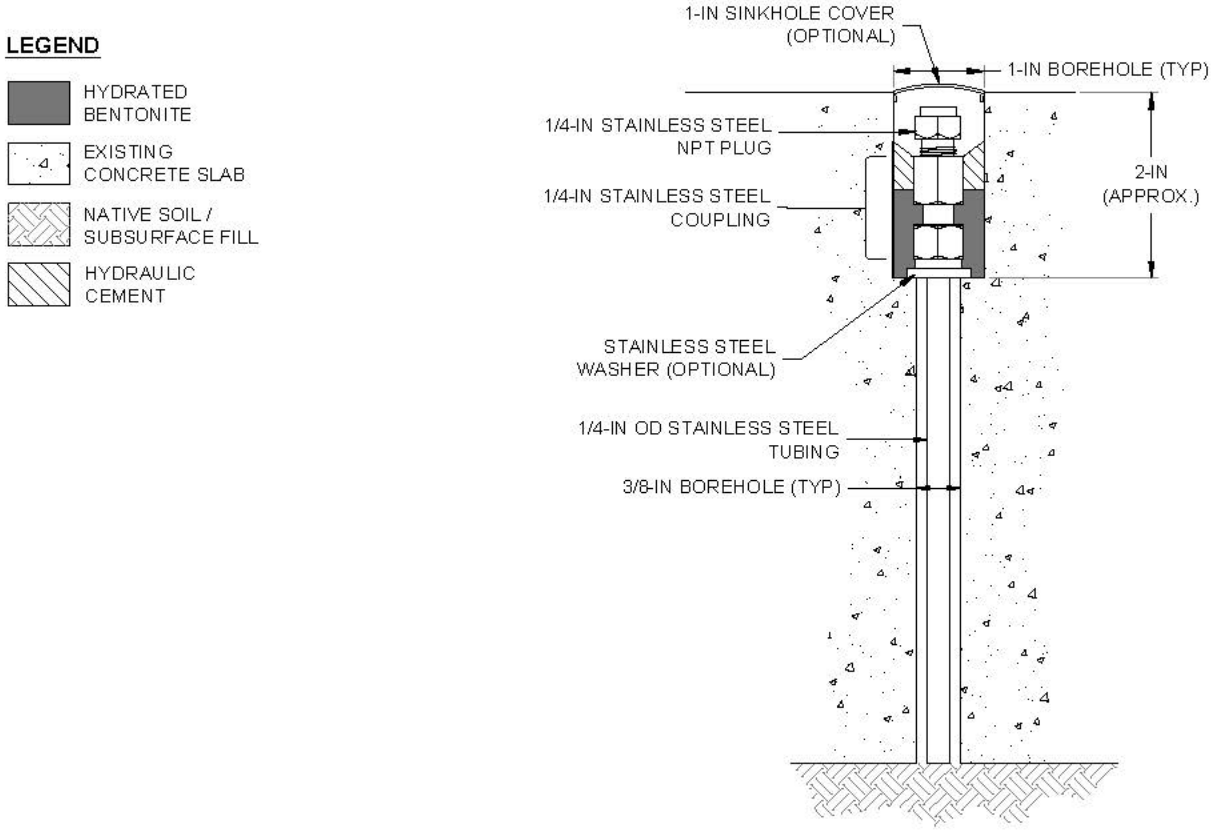


CROSS-SECTION OF SUB-SLAB VAPOR POINT FLUSH MOUNT WELL COVER CONSTRUCTION TYPICAL INSTALLATION DETAIL

NOT TO SCALE

Figure B-1

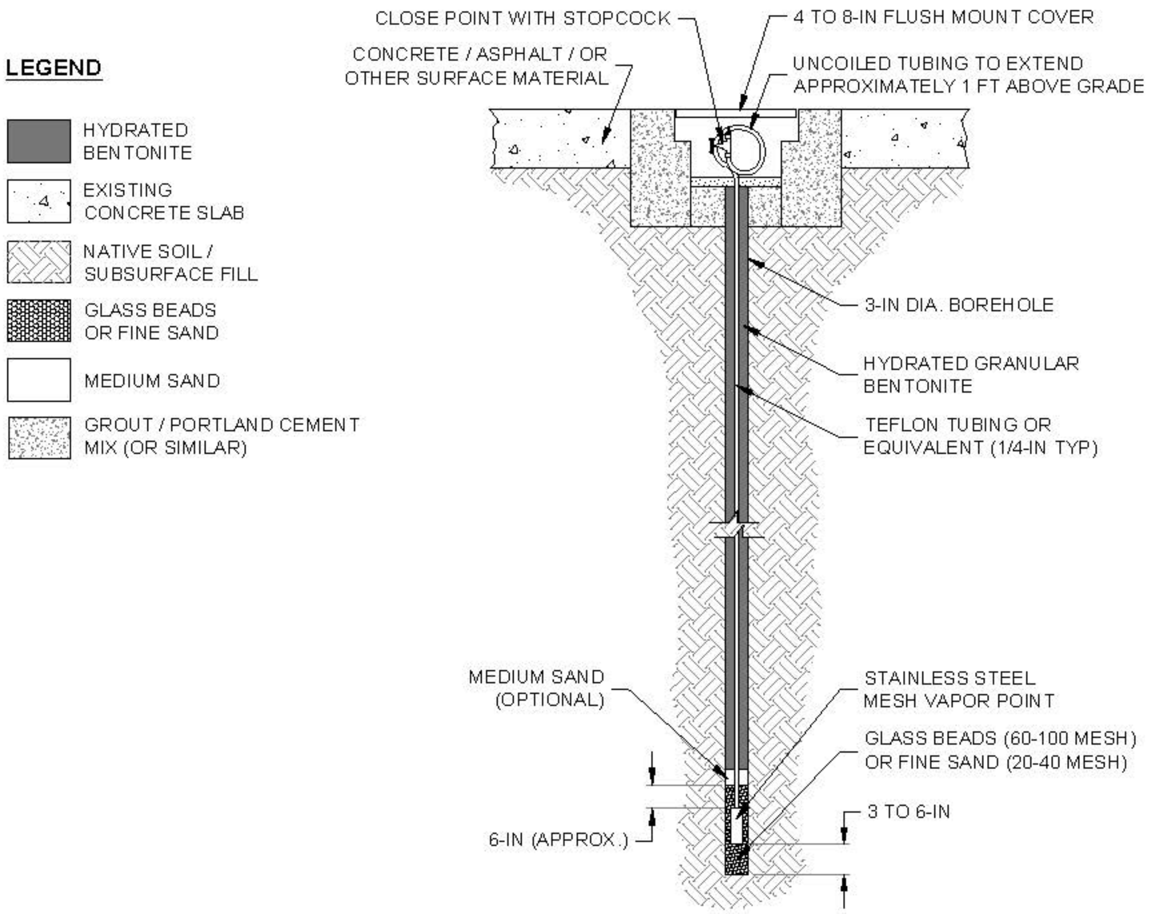
J:\PM SMetz_Soil Gas SOP\SG SOP Figs.dwg



CROSS-SECTION OF SUB-SLAB VAPOR POINT
PERMANENT STAINLESS STEEL PROBE CONSTRUCTION
TYPICAL INSTALLATION DETAIL
NOT TO SCALE

Figure B-2

J:\PM SMetz_Soil Gas SOP\SG SOP Figs.dwg

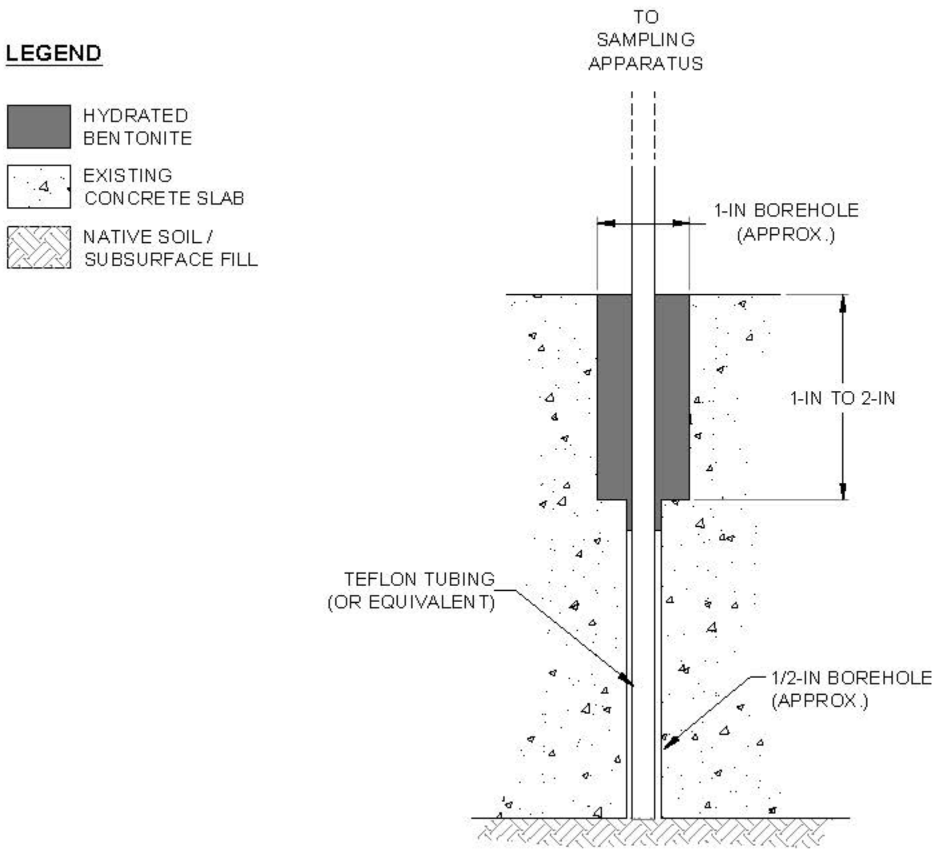


CROSS-SECTION OF DEEP VAPOR POINT PERMANENT CONSTRUCTION TYPICAL INSTALLATION DETAIL

NOT TO SCALE

Figure B-3

J:\PM SMetz_Soil Gas SOP\SG SOP Figs.dwg



CROSS-SECTION OF SUB-SLAB VAPOR POINT TEMPORARY LOCATION CONSTRUCTION TYPICAL INSTALLATION DETAIL

NOT TO SCALE

Figure B-4

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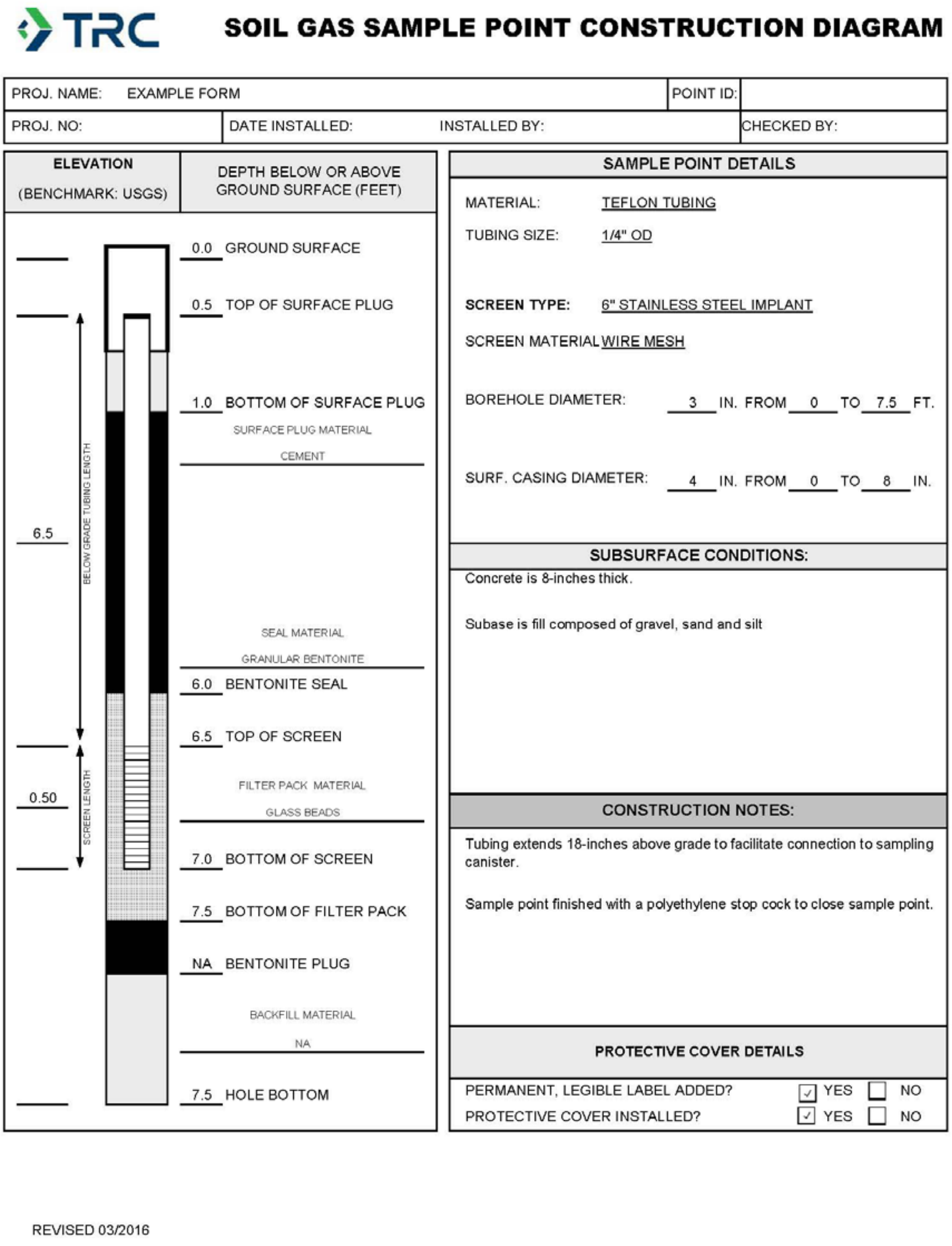
Attachment C:
Soil Vapor Point Installation and Sampling Field Forms



SOIL GAS SAMPLE POINT CONSTRUCTION DIAGRAM

PROJ. NAME: EXAMPLE FORM		POINT ID:	
PROJ. NO:	DATE INSTALLED:	INSTALLED BY:	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH BELOW OR ABOVE GROUND SURFACE (FEET)
	0.0 GROUND SURFACE
	0.5 TOP OF SURFACE PLUG
	1.0 BOTTOM OF SURFACE PLUG
	SURFACE PLUG MATERIAL: CEMENT
6.5	
	SEAL MATERIAL: GRANULAR BENTONITE
	6.0 BENTONITE SEAL
	6.5 TOP OF SCREEN
0.50	FILTER PACK MATERIAL: GLASS BEADS
	7.0 BOTTOM OF SCREEN
	7.5 BOTTOM OF FILTER PACK
	NA BENTONITE PLUG
	BACKFILL MATERIAL: NA
	7.5 HOLE BOTTOM

SAMPLE POINT DETAILS

MATERIAL: TEFLON TUBING

TUBING SIZE: 1/4" OD

SCREEN TYPE: 6" STAINLESS STEEL IMPLANT

SCREEN MATERIAL WIRE MESH

BOREHOLE DIAMETER: 3 IN. FROM 0 TO 7.5 FT.

SURF. CASING DIAMETER: 4 IN. FROM 0 TO 8 IN.

SUBSURFACE CONDITIONS:

Concrete is 8-inches thick.

Subase is fill composed of gravel, sand and silt

CONSTRUCTION NOTES:

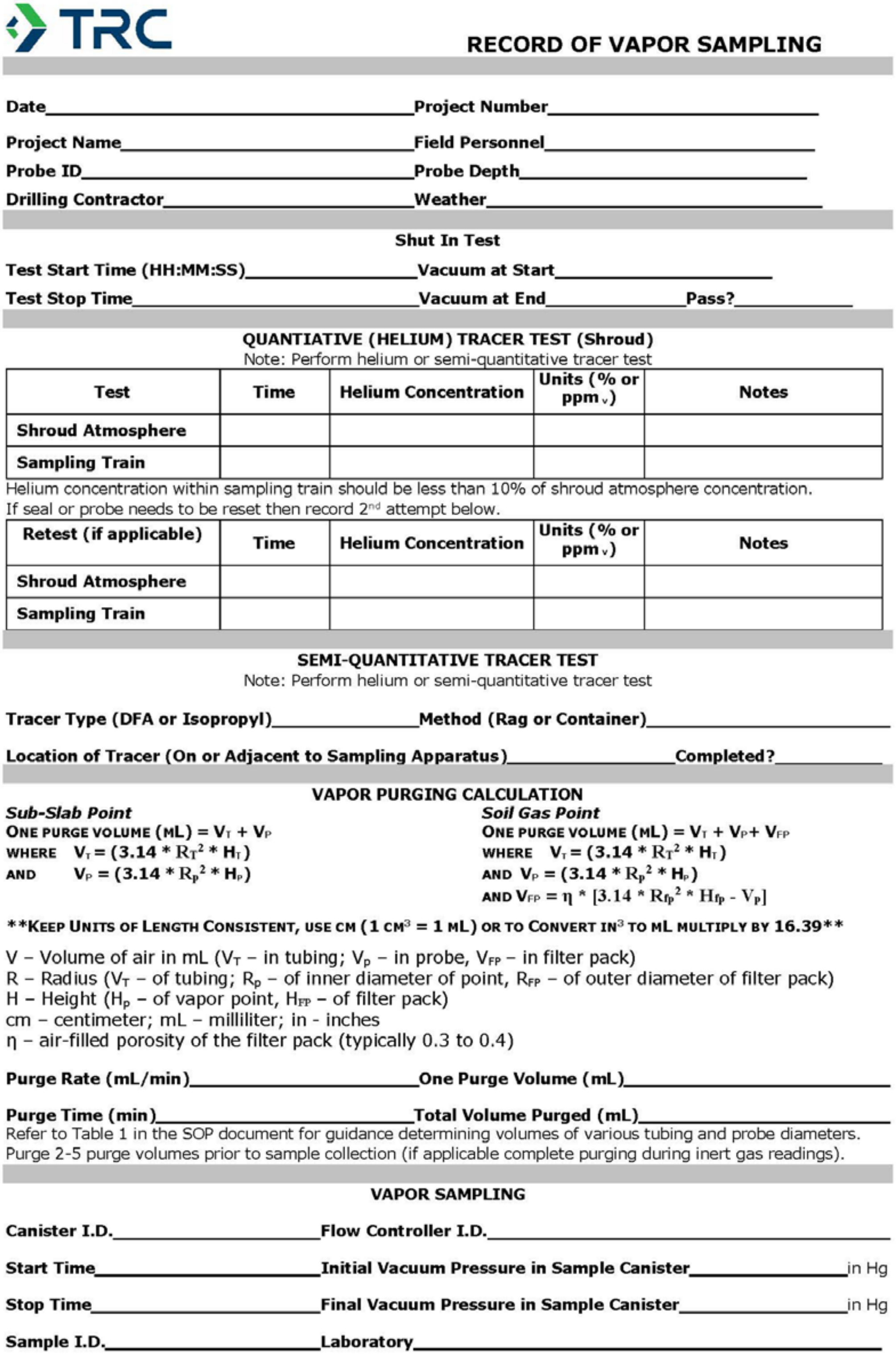
Tubing extends 18-inches above grade to facilitate connection to sampling canister.

Sample point finished with a polyethylene stop cock to close sample point.

PROTECTIVE COVER DETAILS

PERMANENT, LEGIBLE LABEL ADDED? ☑ YES ☐ NO
PROTECTIVE COVER INSTALLED? ☑ YES ☐ NO

REVISED 03/2016



RECORD OF VAPOR SAMPLING

Date________________________ **Project Number**________________________

Project Name________________________ **Field Personnel**________________________

Probe ID________________________ **Probe Depth**________________________

Drilling Contractor________________________ **Weather**________________________

Shut In Test

Test Start Time (HH:MM:SS)________________ **Vacuum at Start**________________

Test Stop Time________________ **Vacuum at End**____________ **Pass?**____________

QUANTIATIVE (HELIUM) TRACER TEST (Shroud)

Note: Perform helium or semi-quantitative tracer test

Test	Time	Helium Concentration	Units (% or ppm$_v$)	Notes
Shroud Atmosphere				
Sampling Train				

Helium concentration within sampling train should be less than 10% of shroud atmosphere concentration.
If seal or probe needs to be reset then record 2nd attempt below.

Retest (if applicable)	Time	Helium Concentration	Units (% or ppm$_v$)	Notes
Shroud Atmosphere				
Sampling Train				

SEMI-QUANTITATIVE TRACER TEST

Note: Perform helium or semi-quantitative tracer test

Tracer Type (DFA or Isopropyl)______________ **Method (Rag or Container)**______________

Location of Tracer (On or Adjacent to Sampling Apparatus)______________ **Completed?**__________

VAPOR PURGING CALCULATION

Sub-Slab Point
ONE PURGE VOLUME (ML) = $V_T + V_P$
WHERE $V_T = (3.14 * R_T^2 * H_T)$
AND $V_P = (3.14 * R_p^2 * H_P)$

Soil Gas Point
ONE PURGE VOLUME (ML) = $V_T + V_P + V_{FP}$
WHERE $V_T = (3.14 * R_T^2 * H_T)$
AND $V_P = (3.14 * R_p^2 * H_P)$
AND $V_{FP} = \eta * [3.14 * R_{fp}^2 * H_{fp} - V_p]$

****KEEP UNITS OF LENGTH CONSISTENT, USE CM (1 CM^3 = 1 ML) OR TO CONVERT IN^3 TO ML MULTIPLY BY 16.39****

V – Volume of air in mL (V_T – in tubing; V_p – in probe, V_{FP} – in filter pack)
R – Radius (V_T – of tubing; R_p – of inner diameter of point, R_{FP} – of outer diameter of filter pack)
H – Height (H_p – of vapor point, H_{FP} – of filter pack)
cm – centimeter; mL – milliliter; in - inches
η – air-filled porosity of the filter pack (typically 0.3 to 0.4)

Purge Rate (mL/min)________________ **One Purge Volume (mL)**________________

Purge Time (min)________________ **Total Volume Purged (mL)**________________
Refer to Table 1 in the SOP document for guidance determining volumes of various tubing and probe diameters.
Purge 2-5 purge volumes prior to sample collection (if applicable complete purging during inert gas readings).

VAPOR SAMPLING

Canister I.D.________________ **Flow Controller I.D.**________________

Start Time________________ **Initial Vacuum Pressure in Sample Canister**____________in Hg

Stop Time________________ **Final Vacuum Pressure in Sample Canister**____________in Hg

Sample I.D.________________ **Laboratory**________________

Attachment D:
Detailed Leak Testing Procedures

D.1 Overview

Leak testing is performed to verify that a representative sample is collected. Leaks may occur in the sample collection train and/or the soil vapor sample point itself. ***Leak testing to verify the integrity of both the sample collection train and the soil vapor sample point itself must be completed for every sub-slab vapor sample in order to establish air tightness***. Leak testing of the sample collection train can be completed through a shut-in leak test. Leak testing using a tracer gas, referred to as tracer testing in this SOP, is typically used to test the integrity of the soil vapor sampling point itself, although it can also be used to test the integrity of the sampling train. Tracer testing may be either quantitative (e.g., helium) or semi-quantitative (e.g., 1,1-difluoroethane). Quantitative tracer testing is typically more difficult and labor intensive than the use of a semi-quantitative tracer. The selection of the appropriate tracer is dependent on project objectives and regulatory requirements. For example in the State of New York, use of a quantitative tracer is required to verify the sample point integrity prior to each sampling event. For projects where state requirements do not mandate the use of a quantitative tracer, a semi- quantitative tracer may be appropriate and more cost effective. When permanent sampling points are installed, it may be appropriate to use a quantitative tracer to verify initial sample point integrity, and a semi-quantitative tracer may be used during subsequent sampling events to document that the sampling point integrity has not been compromised.

This attachment describes recommended methods for completing leak testing to verify the integrity of the sample collection train prior to sample collection, as well as options for either semi-quantitative leak testing or quantitative leak testing to verify soil vapor sampling point integrity. However the leak-testing methods described in this section are recommendations only. **Actual leak test methods may vary based on project objectives and regulatory requirements.**

D.2 Equipment for Leak-Testing

Shut-In Leak Test:

- Assembled sample collection train, including sampling canister, flow controller, and all other components necessary for sample collection. See Section 2.2.2 of this SOP.
- Stopcock or ball valve (may be part of sample collection train or sample collection point) to close sample collection train
- Vacuum gauge (typically an integral component of the sampling canister and/or the flow controller)
- Zip ties
- Wrenches or other tools necessary to tighten fittings
- Teflon tape (not to be used with compression fittings)
- Watch or timer (capable of monitoring time to the nearest second)

Semi-Quantitative (Inert Gas) Tracer Gas Testing:

- Assembled sample collection train, including sampling canister, flow controller, and all other components necessary for sample collection. See Section 2.2.2 of this SOP.
- Tracer (1,1-difluoroethane [electronic dusting spray, verify composition prior to use] is recommended; isopropyl alcohol may also be used)
- Rag (for rag method)
- Ziploc bag (for rag method)
- Large clear plastic bags (often marketed as recycling bags) (for container method)
- Weight(s) or similar to weigh down plastic bag (for container method)

- Duct tape (for container method)
- Paper towels (for container method)
- Distilled water (for container method)

Quantitative (Inert Gas) Tracer Gas Testing:

- Inert gas detector (e.g., Radiodetection® MGD-2002 for helium – See Photograph 16)
- Air flow meter (e.g., DryCal® DC-Lite)
- Polyethylene tubing to transfer inert gas to containment structure
- Stainless-steel T-connector with associated fittings for tubing (optional) – See Photograph 17
    - One – $^1/_4$-inch OD stainless-steel tee
    - Two – $^1/_4$-inch OD stainless-steel port connector
    - Five – $^1/_4$-inch stainless-steel nut and ferrule
    - One – $^1/_4$-inch OD stainless-steel ball valve
- Tubing and fittings necessary to form an air-tight connection between the inert gas detector and the sample collection port
- Wrenches or other tools necessary to tighten fittings
- Teflon® tape (not to be used with compression fittings)
- Zip ties
- High purity or ultra-high purity inert gas (e.g., helium) with tank regulator
- Tracer gas containment:
    - Plastic or stainless-steel container or
    - Plastic wrap
- Granular bentonite
- Drill and bits (if inverted container is used)
- Distilled water
- Paper towels
- Weather-stripping (if inverted container is used)
- Duct tape

D.3 Leak Test to Verify Air Tightness of Sample Collection Train, i.e., Shut-In Leak Test

Leak testing to verify the integrity of the sample collection train is required. This section describes a shut-in test, which is recommended to meet this objective. The shut-in leak test should include all fittings and connections between the sample canister and the sample port, including the moisture filter. Note, if the entire sample collection train is enclosed in the tracer containment device, tracer testing (described below) may also be used to verify the integrity of the sample collection train. The shut-in leak test is recommended because it allows the integrity of the sample collection train to be verified prior to sample collection and analysis.

a. Connect the flow controller to the canister, as described in Section 2.2.2.
b. Connect the moisture filter, if used, and any other necessary sampling components as described in Section 2.2.5(a).
c. Check all fittings and connections. With the exception of compression fittings, use Teflon® tape on threaded fittings and zip ties to help ensure tube-in-tube and barbed fitting connections are air-tight.
d. Purge sample collection point as described in Section 2.2.3, and immediately connect the sampling apparatus to the soil vapor sample point (or tee connection for quantitative tracer,

see below, if applicable). Cover the end of the tubing when changing the tubing over so ambient air does not enter the sample tubing.

e. If applicable, complete quantitative (inert gas) tracer gas testing as described in Section D.5 below.

f. Verify that the stopcock, ball valve or tee on the sampling point is closed. If the sample point does not have a stopcock (or equivalent), include a stopcock in the sample collection train as near as possible to the soil collection point, so that that flow between the soil vapor sampling point and sample canister can be interrupted, yet the air tightness of all other fittings and connections is tested by the shut-in leak test (Photograph 18).

g. Note the initial vacuum (It should be 0 if the vacuum gauge is on the flow controller, or it should be between 25 and 29 inches Hg if the vacuum gauge is on the sample canister itself).

h. Open the valve on the canister. Record the initial vacuum and time. If the vacuum gauge is on the flow controller, the vacuum reading on the gauge should immediately increase to between 25 and 29 inches Hg. If the vacuum gauge is on the sample canister, the vacuum reading on the gauge may decrease slightly (<1 inches Hg) as air in the sample collection train enters the canister.

i. If any of the fittings are not air-tight, there will be a noticeable reduction in the vacuum reading when compared to the initial vacuum reading. If the fittings are air-tight, the vacuum will not change.

j. Monitor the vacuum reading for period of time sufficient to observe a noticeable drop in vacuum, e.g., a period sufficient to fill approximately 10 to 20-percent of the canister. This period will vary depending on the size of the sample canister and the flow controller setting. One minute is sufficient for a 1-liter canister paired with a 200 mL/min flow controller. The duration of the shut-in test should increase if the canister size is larger and/or if the flow rate is lower.

k. If the vacuum does not change, the sampling apparatus has passed the shut-in test. If the vacuum does change, the sampling apparatus has failed the shut-in test; check fittings and/or repeat using a new canister.

l. After the shut-in leak test is complete, begin sample collection immediately, or close the valve on the canister until sample collection begins (e.g., during inert gas tracer testing).

D.4 Leak Test to Verify Air Tightness of Sample Collection Point – Semi-Quantitative Tracer

Leak testing to verify the integrity of the sample collection point is required. This section describes a semi-quantitative inert gas tracer test, which is one of the options recommended to meet this objective. Common semi-quantitative tracers include 1,1-difluoroethane [commercially available as electronic dusting spray] and isopropyl alcohol [commercially available as rubbing alcohol].

Field Procedures

a. Complete shut-in leak test or equivalent to verify the air-tightness of the sample collection train as described in Section D.3 above.

b. Apply tracer using one of the following methods. Note that the application method is project/site geology dependent, and should be selected on a project-by-project basis. When using the container method (described below), surface concentrations of the tracer are very high, and even a small (<1%) leak may result in a large peak in the VOC analysis. This could result in cross contamination of equipment during analysis or unnecessary sample dilution (elevated reporting limits). However, using the rag method, the tracer is not persistent over time. Therefore use of the container method may be more appropriate when the sample collection time exceeds 10 minutes.

- Rag Method
    1. Place rag in a clean resealable bag (e.g., Ziploc). Apply tracer to the rag by spraying 1,1-difluoroethane (electronic dusting spray, verify composition prior to use) to fill the inside the bag or if using isopropyl alcohol, pour a small volume of tracer onto the rag (<10 mL).
    2. Seal the bag and agitate for a few seconds to allow the tracer to be fully absorbed into the rag.
    3. Place the rag around the sampling apparatus. Rag can be dumped from the bag onto the ground next to the sampling point to limit contact with the saturated rag and minimize the potential for contamination of sampling equipment with the tracer (Photograph 19).

Note that tracer may be reapplied to the same rag at each sampling point. However use extreme care when handling tracer-soaked rag and bag to minimize the potential from false positives due to contamination of sampling equipment. Contain rag in an air-tight bag between uses to prevent volatilization into field vehicle. Change gloves immediately after handling rag. Never touch sampling equipment with gloves that could be contaminated with tracer.

- Container Method
    1. To the extent feasible, prepare the surface around the sample point so that a seal between the surface and the containment device can be formed. For example, wipe down the floor with a wet paper towel in the vicinity of the sampling location and allow the floor to dry.
    2. Use a clear plastic bag to contain the sample collection apparatus and sample collection point. Note a new plastic bag should be used for each sample to reduce the likelihood for residual tracer contamination of the sampling assembly and potential false positives.
    3. If using 1,1-difluorethane as the tracer skip to Step iv below. If using isopropyl alcohol, wet a small section of paper towel (<10 mL) and place the wetted paper towel inside the bag. Be sure the towel is placed next to, not in direct contact with, the sampling apparatus.
    4. Close and seal containment apparatus. Use duct tape and/or weights to form the best seal possible for the surface around the sample collection point (Photograph 20).
    5. If using isopropyl alcohol as the tracer, skip this step. Spray 1,1-difluorethane (electronic dusting spray, verify composition prior to use) into the inside of the containment apparatus through a small hole in the plastic bag. Be sure that spray is directed into the plastic bag and not onto the sample collection train itself.

c. Immediately proceed with sample collection as described in Section 2.2.5 of the SOP.

d. Verify that analysis of the tracer is included in the analyte list.

Data Evaluation

The concentration of the leak test tracer compound is determined by the analytical laboratory with other concentration data. Detection of the leak test compound does not automatically indicate that a significant leak occurred. Vapor intrusion guidance for many states provides thresholds for acceptable leaks. If applicable regulatory guidance does not specify otherwise, a leak threshold of 10-percent is typically recommended. Expected surface air concentrations of common tracers (both 1,1-difluorethane and isopropyl alcohol) based on application method are listed below:

Application Method	**Approximate Surface Concentration**	**Target Tracer Concentration***
Rag Method	1,000,000 ug/m^3	<100,000 ug/m^3
Container Method	1,000,000,000 ug/m^3	<100,000,000 ug/m^3

*Tabulated target tracer concentration is based on an acceptable leak threshold of 10-percent. The actual target tracer concentration may vary based on applicable regulatory guidance.
Source: H&P Mobile Geochemistry, 2013. *Evaluation of Leak Check Procedures for Soil Vapor Sampling*.

Using these approximate surface concentrations as a guide, concentrations which exceed the project-specific leak threshold, indicate that sample data are suspect, and the Project Manager should be contacted to determine appropriate corrective action, e.g., data qualification, resampling, repair/replacement of the sample collection point, etc.

D.5 Leak Test to Verify Air Tightness of Sampling Point – Quantitative Tracer

Leak testing to verify the integrity of the sample collection point is required. This section describes a quantitative inert gas tracer test, which is one of the options recommended to meet this objective.

a. Use an air flow rate meter (Dry Cal® or equivalent) to determine the flow rate of the inert gas detector.
    i. Using tubing, connect the inert gas detector probe to the outlet of the flow rate meter. The type of tubing used here is optional; the only requirement is that there is a good fit in order to obtain an accurate flow rate reading. Record the flow rate of the inert gas detector (mL/min).

b. Calibrate the inert gas detector according to the manufacturer's recommendations.
c. If used, install a T-connection. The T-connection, such as that shown in Photograph 17, connects the sample point to both the inert gas detector (which may also be used to double as the purge pump) and the sampling canister, allowing flow from the sample point to be switched from the inert gas detector to the sampling canister without the introduction of ambient air. In order to assemble a stainless-steel T-connector with the parts listed in Section D.2, follow the procedures below:
    i. Cut a 1-foot long section of disposable tubing and attach to the down-flow side of the ball valve. Lock the tubing by closing the $^1/_4$-inch nut to be finger-tight, then turn the nut with a wrench approximately 45 degrees in a clockwise direction. Check to ensure that the tubing is firmly attached to the ball valve.
    ii. If not already attached, attach nuts with ferrules to each side of the $^1/_4$-inch tee. Install a $^1/_4$-inch OD port connector between the tee and the ball valve. Tighten

both nuts approximately 45 degrees in a clockwise direction to lock the tee and the ball valve together.

iii. Install one nut and a port connector to the base of the tee. The connection between the connector and the tee will need a ferrule, but the connection between the connector and the sampling canister will not.

iv. Components can be field screened for leaks by placing the assembly into water and passing air through the components.

v. At the time of sampling, attach the sample tubing to the one remaining open port in the tee. Lock the tubing by closing the $^1/_4$-inch nut to be finger-tight, then turning the nut with a wrench approximately 45 degrees in a clockwise direction.

vi. At the time of sampling, connect the base of the tee with the port connector to the top of the sample collection train.

vii. Install the inert gas containment system using either the plastic wrap method or inverted container method as described below:

D.5.1 Plastic Wrap Method (for smooth interior surfaces only)

a. Wipe down floor with a wet paper towel in the vicinity of the sampling location to ensure a good seal and allow the floor to dry.
b. Allocate an approximately 2-foot by 2-foot section of plastic wrap and push the sample tubing through the center of the plastic wrap. The plastic wrap should form tightly to the tubing.
c. Connect the sample collection train with Teflon® or Teflon®-lined tubing to the vapor point as described in Section 2.2.5 of the SOP.
d. Slide the plastic wrap down the tubing until it reaches the floor.
e. Place the polyethylene tubing from the inert gas source under the plastic wrap. Attach the plastic wrap to the floor with duct tape or equivalent. If necessary, use a small piece of duct tape to secure the plastic wrap seal around the sample tubing. See Photograph 21 for an example layout.

The edges of the plastic and any penetrations through the plastic should be checked with the tracer gas detector for leaks. If any leaks are found, the leaks need to be sealed prior to purging and sampling.

D.5.2 Inverted Container Method

a. Obtain a plastic container, plastic tote, or similar container large enough to cover the sampling point (Photograph 22). If tracer testing of the entire sampling apparatus is desired, the container should be large enough to fit the entire sampling apparatus (including canister) inside (Photograph 23).
b. Modify the container for tracer testing by drilling three holes in the lower end of the container, sized appropriately for commonly sized tubing:

- One hole for the inert gas supply to enter the container (using larger diameter drill bit so tubing can fit through hole):
- One hole for the sample tubing to exit the container (using larger diameter drill bit so tubing can fit through hole):
- One hole to allow the tracer gas meter to quantify the concentration in the atmosphere of the shroud (using smaller diameter drill bit).

Note a larger container may be used such that the sample canister and sample collection train is contained within the container. If so, tracer testing will also detect leaks and short-circuiting from the sample collection apparatus, not just the sample collection point.

c. Wipe down floor with a wet paper towel in the vicinity of the sampling location to ensure a good seal and allow the floor to dry.
d. Attach sample collection train to the vapor point as described in Section 2.2.5 of the SOP. If a small container is used, run the sample tubing through the container.
e. Place the container over the sample point. Wet bentonite paste, weather-stripping, or duct tape may be installed around the rim of the container to help limit air flow and ensure a stable helium-enriched environment around the sample collection point.
f. Set up an inert gas tank and regulator to add the gas to the enclosure.
g. Connect the tubing from the inert gas tank to the container by inserting the tubing through the hole in the lower end of the container.
h. Introduce inert gas into the containment system and record concentration in the shroud. Open the ball valve and purge one tubing volume and begin measuring inert gas concentrations until three purge volumes have been removed. If the tracer concentration detected in the sample tubing is less than or equal to 10 percent (unless a different project-specific value applies) of the concentration of the inert gas in the shroud, the seal is considered competent. If the inert gas is detected in the sample tubing above 10 percent relative to the concentration in the shroud, then the seal around the sampling point is not competent and additional bentonite must be installed prior to sampling. Repeat the leak check procedure until less than or equal to 10 percent of the inert gas is detected. Record the final inert gas concentration in the field book or on a field form. Purging three to five purge volumes while collecting inert gas readings prior to sample collection is ideal.
i. Use the ball valve on the T-connector to redirect flow from the inert gas detector to the sampling canister, or if a T-connector is not used, remove the sample tubing from the inert gas detector and immediately connect the sample collection apparatus. Cover the end of the tubing when changing the tubing over so ambient air does not enter the sample tubing.
j. Complete shut-in leak test described in Section D.3 above if the sample collection train was not enclosed in the tracer containment apparatus (e.g., inverted container) during quantitative tracer testing. Otherwise, proceed with sample collection as described in Section 2.2.5 of the SOP.

06

Equipment Decontamination (Includes SOP for PFAS)

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Authorization Signatures			
		Elizabeth Denly	
Technical Reviewer Cory Yates	Date 4/29/21	Environmental Sector Quality Director Elizabeth Denly	Date 4/29/21

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1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the procedures needed for decontamination of equipment used in the field during environmental investigations (e.g., sediment, soil, groundwater investigations). Other state or federal requirements may be above and beyond the scope of this SOP and will be followed, if applicable. The actual procedures used should be documented and described in the field notes. Preventing or minimizing potential cross-contamination of samples is important for the collection of representative samples, avoiding the possible introduction of sampling error into sample results, and for protecting the health and safety of site personnel.

Removing or neutralizing potential contaminants that may have accumulated on equipment and vehicles ensures protection of personnel, reduces or eliminates potential transfer of contaminants to clean areas, and minimizes the likelihood of sample cross-contamination.

The use of dedicated or disposable sampling equipment (e.g., disposable liners, plastic spoons, plastic or aluminum bowls) should be considered as an alternative to equipment decontamination and the subsequent generation of decontamination fluids.

1.2 Summary of Method

Equipment decontamination is used to remove potential contaminants from a sampling device or piece of field equipment prior to and between the collection of samples. It is also used to limit personnel exposure to residual contamination that may be present on used field equipment.

Contaminants can be physically removed from equipment or deactivated by sterilization or disinfection. Gross contamination of equipment requires physical decontamination, including abrasive and nonabrasive methods. These may include the use of brushes, air and wet blasting, or high-pressure water, followed by a wash/rinse process using appropriate cleaning solutions. A solvent rinse may be required when organic contamination is present, and an acid rinse may be required when metals are parameters of interest. Equipment decontamination procedures can vary depending on the media being sampled and the type of sampling equipment being used. Disposal of decontamination fluids will be handled on a project-specific basis and will be conducted in accordance with the applicable regulations.

1.3 Equipment

The following equipment may be utilized when decontaminating equipment. Project-specific conditions or requirements may warrant the use of additional equipment or deletion of items from this list. For specialized sampling programs involving per- and polyfluoroalkyl substances (PFAS), refer to Attachment B for further details.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)

- Alconox®, Liquinox® or other non-phosphate, concentrated, laboratory-grade soap
- Simple Green® or other nontoxic biodegradable cleaner
- Deionized, distilled, organic-free, or potable water as appropriate as determined by the Project Manager. Water may be supplied by the laboratory or purchased from commercial vendors depending on project requirements.
- Pump sprayer
- Pressure sprayer
- Squeeze bottle filled with hexane (option for organic analyses)
- Squeeze bottle filled with methanol as appropriate (option for organic analyses)
- Squeeze bottle filled with isopropanol as appropriate (option for organic analyses)
- Squeeze bottle filled with 10 percent nitric acid (option for metals analyses and stainless-steel equipment)
- Squeeze bottle filled with 1 percent nitric acid (option for metals analyses)
- Container (squeeze bottle to 5-gallon bucket) filled with appropriate grade water and a non-phosphate, laboratory-grade soap (approximately 1 tablespoon of soap to 5 gallons of water)
- Extra quantities of above listed liquids
- Containers, such as buckets or wash basins (the type and number of containers is dependent on the procedure)
- Scrub brushes
- Small wire brush
- Aluminum foil
- Polyethylene sheeting
- A container for decontamination of pumps and associated tubing

1.4 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel and/or subcontractors shall follow the site-specific HASP. TRC personnel and/or subcontractors will use the appropriate level of PPE as defined in the HASP.

Sampling equipment or materials that have come in contact with chemical contaminants may be handled during implementation of this SOP. Certain decontamination fluids, including solvents and/or acids, are considered hazardous materials, and TRC employees will always handle and store them appropriately. Hazardous substances may be incompatible or may cause dangerous chemical reactions, including the production of heat, violent reactivity, or produce toxic vapors or other byproducts. Some hazardous substances may be incompatible with clothing or equipment and can permeate or degrade protective clothing or equipment. Also, hazardous substances may pose a direct health hazard to workers through inhalation, skin contact, or if a combustible material is exposed to heat/flame. Safety data sheets (SDS) for chemicals handled by TRC personnel should be maintained in a designated location at the project site.

1.5 Cautions and Potential Problems

Special care should be taken when decontaminating equipment used for sampling for PFAS. Please refer to Attachment B for details.

- The use of deionized, distilled, or organic-free water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment, provided that it has been certified by the vendor as analyte-free and/or meets the project-specific requirements.

- Alconox®, Liquinox®, or other non-phosphate, concentrated, laboratory-grade soap may contain trace quantities of perchlorate or 1,4-dioxane.

- Avoid using an excessive amount of soap during decontamination procedures, as this could result in difficulty rinsing the soap residue off of the equipment. Typically, the soap solution is prepared using 1 tablespoon of soap to 5 gallons of water.

- Use sufficient amounts of decontamination fluid (e.g., acid or solvent rinses) so that the fluid flows over the equipment and runs off. Spraying the equipment with a minimal amount of decontamination fluid that does not run off is ineffective.

- Spent decontamination solutions are considered investigation-derived waste (IDW) and must be managed as directed by the site-specific field program. Project and regulatory requirements, chemical compatibility, ambient conditions, and professional judgment should be used to determine the appropriate decontamination process with respect to combining and/or segregating decontamination fluids. Section 3 of this SOP provides more guidance on the disposal procedures.

- Several procedures can be established to minimize the potential for cross-contamination or analytical interference by decontamination fluids. For example:

  - The use of methanol in the decontamination procedure may not be appropriate if methanol is a contaminant of concern.

  - Isopropanol may be used as a substitute for methanol but may not be appropriate when collecting samples for volatile organic compound (VOC) analyses. Residual isopropanol on the equipment may cause substantial interferences in subsequent VOC analyses and may result in unnecessary dilutions and/or false positive results if isopropanol is not removed in subsequent decontamination steps. It should also be noted that the application of isopropanol to hot metal surfaces (e.g., a steam-cleaned split spoon) may cause oxidation of the isopropanol to acetone.

  - If hexane is used in the decontamination procedure, caution should be used to ensure that the hexane is completely volatilized and the equipment is subsequently rinsed when samples are to be analyzed for VOCs and volatile petroleum hydrocarbons (VPH).

Residual hexane on equipment could interfere with the VOC and VPH analyses and may result in unnecessary dilutions and/or false positive results.

- Cover monitoring and sampling equipment with protective material (i.e., aluminum foil, polyethylene sheeting, or Ziploc® bags) to minimize potential re-contamination after decontamination.

- Use dedicated or disposable sampling equipment when appropriate to minimize the need for decontamination. Although disposable sampling tools are encouraged in order to minimize the generation of decontamination fluids, it should be noted that plastic tools may not be appropriate for collection of samples to be analyzed for semi-volatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). Potential phthalate contamination may cause significant interferences in the subsequent analyses and may result in unnecessary dilutions and/or false positive results.

- After decontamination, equipment should be handled only by personnel wearing clean disposable, powder-free, nitrile gloves to prevent recontamination.
- Following decontamination, the equipment should be moved away (preferably upwind) from the decontamination area to prevent recontamination.
- Equipment that is not decontaminated properly may result in potentially high, biased results in field samples. **Note:** Equipment blank collection may be appropriate after decontamination of equipment used to collect highly contaminated samples.

1.6 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers; and
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Refer to the site-specific sampling plan and/or Quality Assurance Project Plan (QAPP), if applicable, for site-specific procedures. Other state or federal requirements may be above and beyond the scope of this SOP and will be followed if applicable. The actual procedures used should be documented and described in the field notes.

2.1 General

Personnel, sample containers, and equipment leaving the contaminated area of a site must be decontaminated. Various decontamination methods will either physically remove contaminants by abrasive and/or washing actions, inactivate contaminants by disinfection or sterilization, or both. Decontamination procedures should be documented in the field book.

2.2 Physical Decontamination Procedures

In many cases, gross contamination can be removed by physical means. The physical decontamination techniques appropriate for equipment decontamination can be grouped into two categories: abrasive methods and nonabrasive methods. In general, heavy equipment decontamination is conducted by drilling and construction subcontractors and not by TRC personnel. However, TRC personnel will typically need to document such decontamination efforts as part of project work. Special care should be taken during decontamination procedures following sampling for PFAS; please refer to Attachment B for details.

ABRASIVE CLEANING METHODS APPROPRIATE FOR DRILLING EQUIPMENT (DRILLING RIGS, ETC.)

Abrasive cleaning methods involve rubbing and wearing away the top layer of the surface containing the contaminant. The following abrasive methods are available but are not commonly used:

- *Mechanical:* Mechanical cleaning methods use metal or nylon brushes. The amount and type of contaminants removed will vary with the hardness of bristles, length of brushing time, and degree of brush contact.

- *Air Blasting:* Air blasting is used for cleaning large equipment, such as bulldozers, drilling rigs, or auger bits. The equipment used in air blasting employs compressed air to force abrasive material through a nozzle at high velocities. The distance between the nozzle and the surface cleaned, as well as the pressure of air, the time of application, and the angle at which the abrasive material strikes the surface, determines cleaning efficiency. Air blasting has several disadvantages, including its inability to control the amount of materials removed, it can aerate contaminants, and it generates large amounts of waste.

- *Wet Blasting:* Wet blasting, also used to clean large equipment, involves use of a suspended fine abrasive delivered by compressed air to the contaminated area. The amount of materials removed can be carefully controlled by using very fine abrasives. One disadvantage of this method is the generation of a large amount of waste.

NONABRASIVE CLEANING METHODS APPROPRIATE FOR FIELD EQUIPMENT (DRILLING AUGERS AND RIGS, ETC.)

Nonabrasive cleaning methods involve forcing the contaminant off a surface with pressure. In general, less of the equipment surface is removed using nonabrasive methods. The following nonabrasive methods are available:

High-pressure Potable Water: This method consists of a high-pressure pump, an operator-controlled directional nozzle, and a high-pressure hose. Flow rates typically range from 20 to 140 liters per minute (approximately 5 to 37 US gallons per minute). This procedure is used the majority of the time and is more appropriate for equipment with painted surfaces.

Ultrahigh-Pressure Potable Water: This system produces a pressurized water jet. The ultrahigh-pressure spray removes tightly adhered surface film. The water velocity ranges from 500 meters per second (m/sec) to 900 m/sec (approximately 1,640 to 2,953 feet per second). Additives can enhance the method. This method is not applicable for hand-held sampling equipment. This procedure is not commonly used but would be appropriate for carbon steel drilling rods and augers.

Steam Cleaning: This method consists of a high-pressure hot water cleaner capable of generating a pressure of at least 2,500 pounds per square inch (psi) and producing hot water and/or steam (at least 200 degrees Fahrenheit), and is typically equipped with a soap compartment. Due to the high temperatures associated with this method, steam cleaning should not be used for polyvinyl chloride (PVC) or plastic equipment.

2.3 Procedure for Sampling Equipment

Sampling equipment, such as split-spoon samplers, shovels, hand augers, trowels, spoons, spatulas, bailers, tethers, dippers, and pumps, will be cleaned using the following procedure. Special care should be taken during decontamination procedures following sampling for PFAS; please refer to Attachment B for details. **Note:** The overall number of containers needed for collection of decontamination fluids may vary depending on chemical compatibilities, project and regulatory requirements, and ultimate disposal methods for these fluids.

1. Lay out sufficient polyethylene sheeting on the ground or floor to allow placement of the necessary number of containers (e.g., plastic wash basins or buckets) and an air-drying area. The number of decontamination steps and designated containers should be determined prior to field sampling based on the site-specific sampling plan. At a minimum, one container should be designated for the detergent wash. A second container should be designated for water rinsing. A third container may be designated for non-water rinsing. If more than one, the non-water rinsate fluids may need to be separated. Non-water rinsate fluids should not be combined with the detergent wash during decontamination. Place the containers on the polyethylene sheeting. The decontamination line should progress from “dirty” to “clean”.

   Note: In instances where acid or solvent rinses are required, additional containers may be needed to manage collection and subsequent disposal of the spent decontamination fluids.

2. Fill the first container with potable water. Add sufficient non-phosphate, concentrated, laboratory-grade soap to cause suds to form. Do not use an excessive amount of the soap (approximately 1 tablespoon of soap to 5 gallons of water) or rinsing the soap residue off the equipment will be difficult.

3. Disassemble the equipment, as appropriate.

4. Brush any visible dirt off sampling equipment into a designated area before getting equipment wet.

5. Using a clean, coarse scrub brush, submerge and wash the sampling equipment in the soap solution in the first container, removing all dirt and/or visible hydrocarbons. Allow excess soap to drain off the equipment into the container when finished.

6. If cleaning a pump that is not completely disassembled, run the submerged pump in the container long enough to allow sufficient contact time with the internal components of the pump.

7. Rinse the equipment with appropriate water over an appropriate container, using a coarse scrub brush or pressure sprayer to aid in the rinse if necessary. If an additional acid or solvent rinse is not required, proceed to Step 10.

8. **If sampling for metals and if required by the project, rinse the equipment with nitric acid over an appropriate container. Consider using a container dedicated to acidic solutions to minimize the volume of liquid that needs to be neutralized later. A 10 percent nitric acid solution is used on stainless steel equipment. A 1 percent nitric acid solution is used on all other equipment. If not required, this step may be omitted.

9. **If sampling for organic parameters and if required by the project, rinse the equipment over an appropriate container using methanol or isopropanol (see Cautions and Potential Problems). If oily, a hexane rinse should follow the methanol/isopropanol rinse, or as an alternative, Simple Green® can be used if approved by the Project Manager. Consider using an appropriate container dedicated to volatile solvents to minimize the volume of liquid that subsequently needs to be managed as IDW. If not required, this step may be omitted.

   Allow the equipment to completely air dry prior to proceeding to the next step.

   **** Steps 8 and 9 are optional and may be used on a site-specific basis. The site-specific sampling plan or QAPP, if available, should be consulted. In the absence of a sampling plan or QAPP, the Project Manager will decide upon the necessity of these steps.**

10. Rinse the equipment over an appropriate container using deionized, distilled or organic-free water after each step. If cleaning a pump that is not completely disassembled, run the submerged pump in the container long enough to allow sufficient contact time with the internal components of the pump.

11. Allow the equipment to completely air dry on a clean surface (e.g., polyethylene sheeting or a clean container) (See*NOTE).

    ***NOTE** that if temperature or humidity conditions preclude air drying equipment, sufficient spares, as applicable and if possible, should be available so that no item of sampling equipment need be used more than once. If an ample amount of spare equipment is not available and the equipment will not completely air dry, additional rinses with deionized, distilled or organic-free water should be used. The inability of equipment to air dry and the usage of additional rinses should be recorded in the field book or on the appropriate form.

12. Reassemble equipment, if necessary, and wrap completely in clean, unused, protective material. Reuse of equipment on the same day without wrapping in protective material is acceptable.
13. Spent decontamination fluids are considered IDW and must be managed as directed by the site-specific field program.
14. Record the decontamination procedure in the field book or on the appropriate form.
15. Decontamination solution and rinse water should be refreshed at regular intervals as appropriate to meet project quality objectives.

2.4 Procedure for Measuring Equipment

Measuring equipment, such as pressure transducers, water level indicators, oil/water interface probes, and soil moisture/pH meters will be cleaned using the following procedure, unless it conflicts with the manufacturer's recommendations. Special care should be taken during decontamination procedures following sampling for PFAS; please refer to Attachment B for details.

1. Fill two clean containers (e.g., plastic wash basins or buckets) with potable water.
2. Add sufficient nonphosphate, concentrated, laboratory-grade soap to one container to form a thin layer of soap suds. If oily residues are apparent, the use of Simple Green® may be required.
3. Brush any visible dirt off measuring equipment before getting the equipment wet.
4. Either spray rinse the device with the soap solution over the first container, or for heavily soiled equipment, immerse the device in the container containing soap and gently agitate. Scrub device if it is soiled. Do not submerse any electrical controls or take-up reels. Submerse only that portion of the device that came in contact with potential contaminants.
5. Immerse the device in the container containing the potable water and gently agitate. Do not submerse any electrical connectors or take-up reels. Submerse only that portion of the device that came in contact with potential contaminants.
6. Spray rinse equipment with deionized, distilled, or organic-free water over the last container used.
7. Allow the equipment to air dry if time allows.
8. Record the decontamination procedure in the field book or on the appropriate form.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for IDW disposal with the Project Manager.

Each project must consider IDW disposal methods and have a plan in place prior to performing field work. Provisions must be in place regarding what will be done with IDW. If IDW must be removed from the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

One type of quality control sample specific to the field decontamination process is the equipment blank. The equipment blank provides information about the effectiveness of the decontamination process employed in the field. An equipment blank can detect contamination that may arise from potentially contaminated equipment or equipment that has not been decontaminated effectively.

Equipment blanks consist of a sample of analyte-free (i.e., deionized, distilled, organic-free) water that is poured over and through a decontaminated sampling device and placed in a clean sample container. Ideally, the reagent water should come from the laboratory and be certified as clean. If the blank water is not certified as clean and/or not supplied by the laboratory performing the analyses, a separate water blank that has not run through the sampling equipment should also be sent to the laboratory for analysis.

Equipment blanks are typically collected for all parameters of interest at a minimum rate of 1 per day per matrix; however, the frequency of equipment blank collection will vary from project to project, depending upon the data quality objectives and/or regulatory requirements, and will be specified in either the site-specific sampling plan or QAPP. Equipment blanks are typically not required if dedicated sampling equipment is used.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All reagents used must be documented in the field book or on the appropriate form. Any deviations from the decontamination procedures specified in the sampling plan or QAPP must be approved by the Quality Assurance Officer and Project Manager and documented in the field book. The lot number and vendor of each reagent used should be documented in the field book. Refer to ECR SOP 001 for field documentation procedures.

Planning for the collection of equipment blank samples can be tracked in the TRC Environmental Data Management System (EDMS). This can ensure the field teams are reminded by the mobile data collection app to collect equipment blank samples per the sampling plan or QAPP. Data quality checks for equipment blank samples can be automatically run by the TRC EDMS and highlight any non-conformities to the QAPP or concentrations detected in the equipment blank samples when data are loaded. Discuss with your EDMS data manager to have this automated report configured for your project site.

6.0 REFERENCES

USEPA. December 1987. *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001.

USEPA. January 1991. *Compendium of ERT Groundwater Sampling Procedures*. OSWER Directive 9360.4-06. PB91-9211275.

USEPA. November 1992. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001. USEPA Office of Solid Waste.

USEPA. January 1999. *Compendium of ERT Groundwater Sampling Procedures*. EPA/540/P-91/007. OSWER Directive 9360.4-06. PB91-921275.

USEPA. June 22, 2020. *Field Equipment Cleaning and Decontamination*. LSASDPROC-205-R4. Region 4. Laboratory Services and Applied Science Division. Athens, Georgia.

7.0 SUSTAINABLE RECOMMENDATIONS

Sustainable practices should be incorporated wherever practical. Items to consider for equipment decontamination are as follows:

- Utilize Alconox® soap when appropriate due to its biodegradable nature;
- Utilize a reusable container such as a carboy for decontamination water;
- Utilize reusable decontamination equipment such as plastic spray bottles, plastic brushes, etc., when appropriate;
- Utilize recycled plastic sheeting to contain decontamination rinsate, if available; and,
- Send decontamination rinsate to a wastewater treatment facility for water reuse/recycling when practical.

8.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
1	DECEMBER 2016	ADDED ATTACHMENT B TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING
3	APRIL 2021	REVIEWED AND REVISED SOP

Attachment A: SOP Fact Sheet

EQUIPMENT DECONTAMINATION

PURPOSE AND OBJECTIVE

Removing or neutralizing potential contaminants that may have accumulated on equipment and vehicles ensures protection of personnel, reduces or eliminates potential transfer of contaminants to clean areas, and minimizes the likelihood of sample cross-contamination. Preventing or minimizing potential cross-contamination of samples is important for the collection of representative samples, avoiding the possible introduction of sampling error into sample results, and for protecting the health and safety of site personnel.

WHAT TO BRING

- Field book
- Appropriate PPE
- Site-specific HASP
- Alconox®, Liquinox® or other nonphosphate, concentrated, laboratory-grade soap
- Simple Green® or other nontoxic biodegradable cleaner
- Deionized, distilled, organic-free water, or potable water as appropriate as determined by the Project Manager
- Pump or pressure sprayer
- Squeeze bottles filled with appropriate decontamination chemicals (e.g., organic solvents, nitric acid)
- Containers, such as buckets or wash basins (type and number is dependent on the procedure)
- Scrub brushes and/or small wire brush
- Aluminum foil
- Polyethylene sheeting
- A container for decontamination of pumps and associated tubing

OFFICE

- Prepare/update the site-specific HASP; make sure the field team is familiar with the latest version.
- Review site-specific sampling plan/QAPP for decontamination procedures and procedures for management of investigation-derived waste (IDW) (e.g., used decontamination solutions).
- Confirm all required decontamination supplies are in stock or order as needed.

ON-SITE

- Verify project HASP including safety data sheets for decontamination chemicals used on site.
- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Establish a designated equipment and personnel decontamination area.
- Provide for the proper collection and management of all IDW.
- Verify that appropriate PPE is worn by all site personnel (including subcontractors) and the work area is safe.

SAMPLING EQUIPMENT DECONTAMINATION - PROCEDURES

Sampling equipment, such as split-spoon samplers, shovels, hand augers, trowels, spoons, spatulas, bailers, tethers, dippers, and pumps, will be cleaned using the following procedure. **A more simplified procedure for decontamination of measuring equipment is presented in the SOP.** Note: The overall number of containers needed for collection of decontamination fluids may vary depending on chemical compatibilities, project and regulatory requirements, and ultimate disposal methods for these fluids.

1. Lay out sufficient polyethylene sheeting on the ground or floor to allow placement of the necessary number of containers (e.g., plastic wash basins or buckets) and an air-drying area. At a minimum, one container should be designated for the detergent wash. A second container should be designated for water rinsing. A third container may be designated for nonwater rinsing. Nonwater rinsate fluids should not be combined with the detergent wash during decontamination. The decontamination line should progress from "dirty" to "clean".
   Note: In instances where acid or solvent rinses are required, additional containers may be needed to manage collection and subsequent disposal of the spent decontamination fluids.
2. Fill the first container with potable water. Add sufficient nonphosphate concentrated laboratory-grade soap to cause suds to form. Do not use excessive amount of the soap (approximately 1 tablespoon of soap to 5 gallons of water) or rinsing the soap residue off the equipment will be difficult.
3. Brush any visible dirt off of the sampling equipment into a designated area before getting equipment wet.
4. Using a clean, coarse scrub brush, submerge and wash the sampling equipment in the soap solution in the first container, removing all dirt and/or visible hydrocarbons.

EQUIPMENT DECONTAMINATION

5. Rinse the equipment with appropriate water over an appropriate container, using a coarse scrub brush or pressure sprayer to aid in the rinse if necessary. If an additional acid or solvent rinse is not required, proceed to Step 8.
6. **If sampling for metals and if required by the project, rinse the equipment with nitric acid over an appropriate container. Consider using a container dedicated to acidic solutions to minimize the volume of liquid that needs to be neutralized later. A 10 percent nitric acid solution is used on stainless steel equipment. A 1 percent nitric acid solution is used on all other equipment. If not required, this step may be omitted.
7. **If sampling for organic parameters and if required by the project, rinse the equipment over an appropriate container using methanol or isopropanol (see Caution and Potential Problems). If oily, a hexane rinse should follow the methanol/isopropanol rinse, or as an alternative, Simple Green® can be used if approved by the Project Manager. Consider using an appropriate container dedicated to volatile solvents to minimize the volume of liquid that subsequently needs to be managed as IDW. If not required, this step may be omitted.
   Allow the equipment to completely air dry prior to proceeding to the next step.
   ** Steps 6 and 7 are optional and may be used on a site-specific basis. The site-specific sampling plan or QAPP, if available, should be consulted. In the absence of a sampling plan or QAPP, the Project Manager will decide upon the necessity of these steps.
8. Rinse the equipment over an appropriate container using deionized, distilled or organic-free water after each step.
9. Allow the equipment to completely air dry on a clean surface (e.g., polyethylene sheeting or a clean container).
   ***NOTE** that if temperature or humidity conditions preclude air drying equipment, sufficient spares, if possible, should be available so that no item of sampling equipment need be used more than once. If an ample amount of spare equipment is not available and the equipment will not completely air dry, additional rinses with deionized, distilled or organic-free water should be used. The inability of equipment to air dry and the usage of additional rinses should be recorded in the field logbook or on the appropriate form.
10. Reassemble equipment, if necessary, and wrap completely in clean, unused, protective material. Reuse of equipment on the same day without wrapping in protective material is acceptable.
11. Spent decontamination fluids are considered IDW and must be managed as directed by the site-specific field program.
12. Decontamination solution and rinse water should be refreshed at regular intervals as appropriate to meet project quality objectives.

INVESTIGATION DERIVED WASTE (IDW) DISPOSAL

Field personnel should review the project work plan and ensure project-specific IDW management documentation and containerization requirements are specified or discussed with the Project Manager before going to the project site.

DATA MANAGEMENT AND RECORDS MANAGEMENT

All reagents used must be documented in the field book or an appropriate field form. Any deviations from the decontamination procedures specified in the work plan, sampling plan or QAPP must be approved by the Quality Assurance Officer and Project Manager and documented in the field book. The lot number and vendor of each reagent used should be documented in the field logbook. Refer to ECR SOP 001 for field documentation procedures.

DOs AND DO NOTs OF EQUIPMENT DECONTAMINATION

DOs:

- DO call the Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them on site work.
- DO manage and collect IDW in accordance with project requirements.
- DO use deionized, distilled or analyte free water that is provided by the laboratory, is certified analyte-free, and/or meets project requirements.
- DO use sufficient amount of decontamination fluids so that the fluid flows over the equipment and runs off.
- DO use new wrapped disposable dedicated sampling equipment when appropriate to minimize the need for decontamination.

DO NOTs:

- DO NOT use an excessive amount of soap during decontamination.
- DO NOT sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc.; call the Project Manager if this issue arises.

Attachment B: SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Equipment Decontamination Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Use only Alconox® or Liquinox® soap; do not use Decon 90. • Use new plastic buckets for wash and rinse water. • Ensure that PFAS-free water is used during the decontamination procedure. • Do not use aluminum foil.
1.5	Always consult the Site-specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to decontamination procedures: • Tyvek® suits should not be worn. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Food and drink should not be allowed within the decontamination area. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only. • Personnel involved with decontamination should wear a new pair of nitrile gloves after each decontamination procedure when handling equipment to avoid re-contamination. Avoid handling unnecessary items with nitrile gloves. • Do not store on or cover equipment with aluminum foil after decontamination. Use of polyethylene sheeting is acceptable. • Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended six washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work.
2.2	• New nylon or metal bristle brushes should be used for mechanical cleaning methods. • If high-pressure water is used, it must be tested prior to use for the presence of PFAS.
2.3	• Ensure that PFAS-free water is used during the last step of the decontamination procedure.
2.4	• Ensure that PFAS-free water is used during the last step of the decontamination procedure.

07

Groundwater Monitoring Well Installation (Includes SOP for PFAS)

Title: **Groundwater Monitoring Well Installation**	Procedure Number: **ECR 007**
	Revision Number: **2**
	Effective Date: **August 2020**

Authorization Signatures

		Elizabeth Denly	
Technical Reviewer James Peronto	Date 8/5/20	Environmental Sector Quality Director Elizabeth Denly	Date 8/5/20

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Attachment B	SOP Fact Sheet

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the construction and installation of groundwater monitoring wells. TRC typically employs a drilling subcontractor to perform the actual construction and installation. The SOP conforms to *A Compendium of Superfund Field Operations Methods* (EPA/540/P-87/001) and American Society for Testing and Materials (ASTM) standard D5092, *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers* (ASTM 2004). A thorough discussion of well design, installation, materials, and potential problems is found in *Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring,* Chapter 10: Design and Installation of Ground-Water Monitoring Wells (Nielsen and Schalla 2006). In general, this SOP conforms to typical practices utilized in the field; project-specific and local or state regulatory requirements should be applied, as needed.

1.1 Scope and Applicability

The objective of a groundwater monitoring well is to provide for the collection of representative groundwater samples and hydrologic data on the target saturated zone. These objectives require that the well be installed and developed (well development is presented in ECR SOP 006) using suitable materials, equipment, and procedures that will best represent the actual hydraulic conditions. Specific monitoring well design and installation procedures depend on project-specific objectives and subsurface conditions. The well construction activity should include consideration of the potential impact on the groundwater quality and measures to rectify that impact to the extent practicable. The following aspects should to be considered prior to well installation:

- Borehole drilling method
- Well construction materials
- Well depth
- Screen length
- Location, thickness, and composition of annular seals
- Well completion and protection requirements

Monitoring well installation will be performed in accordance with the applicable regulatory agency standards and the project-specific work plan. Drilling methods used to pilot the borehole for monitoring well installation will be dependent on the physical nature of the subsurface materials (unconsolidated materials and/or consolidated materials) at the project site.

1.2 Summary of Method

The most common type of monitoring well installations are single-screen, single casing wells designed to monitor one specific interval within the groundwater. Monitoring wells are typically 2 inches (inside) diameter, but may be larger or smaller depending on the project requirements. With direct push technology being used more frequently, 1-inch diameter wells are also frequently used. Monitoring wells most commonly consist of 5 or 10 feet of well screen with an interconnected length of blank well casing that extends to the surface. The annulus between the screen and the formation is filled with a filter pack of appropriately-sized sand depending on the formation material. The annulus between the blank casing and the borehole is filled with an annular seal to the ground surface. A surface completion usually consisting of a traffic-rated well vault or monument that protects the well from damage or unauthorized use is installed at or above the surface.

For more complicated monitoring well installations, such as situations requiring very small screen intervals (such as with fractured rock), open boreholes, or multiple zones of interest, the well design can be modified to suit the application. See Nielsen and Schalla (2006) for additional information on less conventional well installations.

In general, all well materials (other than filter sand, seals, and grout) are typically provided by the manufacturer and are individually plastic-wrapped. If required by the project-specific work plan or at the discretion of the TRC inspector, well materials (other than filter sand, seals, and grout) may be steam-cleaned, rinsed with deionized water, and covered in plastic prior to installation of the well to prevent the introduction of foreign contaminants into the aquifer. Decontamination and bagging can be conducted by the manufacturer, prior to delivery to the site. Furthermore, well construction materials shall be properly stored until use to ensure their good condition and cleanliness.

1.3 Equipment

The following list of equipment may be used during the installation of groundwater monitoring wells. Many of these materials may be supplied by the drilling subcontractor. Specific details on these materials are described in Section 2.2. Site-specific conditions may warrant the use of additional items or deletion of items from the list.

- Appropriate level of personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Weighted tape measure appropriate to the depth of well
- Well screens with appropriately sized slot openings
- Well casings/risers
- Well end caps
- Centralizers
- Graded sand for filter pack (appropriate for formation and screen slot size)
- Fine-grained sand (for use between filter pack and annular seal)
- Bentonite pellets or granules/chips
- Powdered bentonite
- Type I Portland cement
- Redi-Mix concrete
- Protective surface casing (for aboveground or “stick-up” wells)
- Lockable well cover
- Steel manhole/curb box (for flush-mounted wells)
- Equipment decontamination supplies

1.4 Definitions

Annulus/annular space	The space between the well casing/screen and the borehole wall.
Annular seal	An interval of low-permeability material placed above the filter pack designed to inhibit the flow of water into or through the annulus.
Bentonite	A naturally occurring deposit of volcanic ash that has partially weathered to form an absorbent swelling clay, consisting mostly of montmorillonite.
Bridge(-ing)	An obstruction within the annulus that may prevent circulation or complete installation of annular materials.
Casing – pipe (well casing)	Rigid pipe constructed in threaded or welded sections installed to temporarily or permanently counteract caving of the borehole or to isolate an interval to be monitored.
Casing - protective	A section of larger diameter pipe placed over the uppermost end of a monitoring well riser or casing to provide structural protection to the well and restrict unauthorized access.
Caving (sloughing)	The inflow or collapse of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength, or a detached section of consolidated material is dislodged into the borehole.
Cement (Portland cement)	A mixture of calcareous, argillaceous, or other silica-, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce a hardened material when mixed with water. Type I Portland cement as classified by ASTM C150 Standard Specification for Portland Cement is a general purpose cement most commonly used for monitoring wells when the special properties (e.g., sulfate resistance, high early strength, low heat of hydration) specified for other types are not required.
Centralizer	A device that assists in centering the riser pipe and screen in the borehole or casing.
Filter pack (gravel pack; sand pack)	An annular material composed of clean silica sand or sand and gravel of selected grain size and gradation that is placed in the annulus between the screened interval and the borehole wall in a well for the purpose of retaining and stabilizing the formation material.

Flush-threaded	Casing or riser that is threaded and sized in such a manner that the inside and outside diameters are maintained between sections and joints.
Grout	A low-permeability material placed in the annulus between the well casing or riser and the borehole wall (typical well construction), or between the riser and casing, to maintain the alignment of the casing and riser and to prevent movement of groundwater or surface water into the annular space.
Riser	Sections of blank pipe that connect to the well screen and extend to or above the ground surface.
Tamping device	A heavy object attached to a measuring tape, rope or wire used to slip inside the annular space to ensure annular materials are properly placed per the designed depth criteria and to prevent bridging.
Tremie pipe	A tube or string of piping used to convey filter pack and annular seal materials from the ground surface to fill the annulus.
Vented end cap	A covering device that slips over or into the top of the well riser with a hole drilled in it to allow continuous equilibration of the potentiometric surface with the atmospheric pressure.
Well screen	Pipe (typically polyvinyl chloride [PVC] or stainless steel) used to retain the formation or filter pack materials outside of the well. The pipe has openings/slots of a uniform width, orientation, and spacing.

1.5 Health & Safety Considerations

Drilling operations can create a hazardous environment. The potential for injury is fairly high around a drill rig. Level D PPE, including a hardhat, gloves, steel-toed safety shoes, and safety glasses, must be worn at a minimum. Hearing protection is also standard for drilling personnel. Tyvek clothing is recommended when mixing grout. Most well installations are performed with the assistance of the hoist on the drill rig mast as the downhole drill pipe or augers are removed when the well materials are placed. Therefore, TRC personnel must be mindful of the same hazards that apply during drilling. TRC staff should only approach the drill rig if necessary to monitor the breathing zone, confirm depths of materials, or confer with the driller. Before approaching the drill rig, direct eye contact should be made with the driller so they are aware of your presence. The following safety requirements should be adhered to while performing drilling activities:

- The drill rig should not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig should not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

- Serious injuries have occurred while the driller removes casing using a cable and winch. The winch should only be used to move augers or piping – NOT to pull casing, piping or augers from the ground. Use of the drill string is the safest means to pull casing, auger, or piping as the well materials are placed.

- Exposure to potential contaminants can occur from vapors coming from the open boring and from contaminated groundwater being forced out of the boring when grouting.

- While the exposure duration is very low, the dusts from well sand, bentonite, and cement can harm the lungs. Workers should avoid the dust produced when placing the well materials.

- Cement is highly caustic and can irritate the skin. Chemical-resistant gloves should be worn if contact with cement is necessary.

- The bags of sand, cement, and bentonite typically do not require a knife to cut them open. A dull instrument, such as a screwdriver, is sufficient.

- Cutting PVC well casing or screen should be conducted using a PVC cutting tool or hacksaw.

1.6 Cautions and Potential Problems

Well installation is typically conducted by the drilling subcontractor. TRC personnel serve to observe and document the installation and to serve as quality control that the well is installed according to the project specifications. The following cautions or problems may be associated with well installation

- Wells are often specified to be installed as “water table” wells with the screen designed to intersect the top of the water table. The difficulty arises in being able to determine if the water surface as measured in the open borehole will remain the same once the well is installed.

- It is also common that “water table” conditions do not exist due to a confining layer or fractured rock environments. In such cases, the well screen is placed in the producing formation or fracture, and the screen may not intersect the potentiometric surface.

- A well screen should never be placed such that the screen straddles a confining unit, thus connecting two separate aquifer units.

- Flush-mount well constructions require appropriate design to account for vehicular traffic and potential water infiltration into the surface completion among other things. In general, wells with flush-mount completions should not be located in low-lying areas or drainage paths where water influx can be a recurring problem. Appropriate design should consider a drainage layer of sand or gravel with a weep hole so water that accumulates in the vault can drain.

- Aquifer or other pressure conditions at some locations may warrant consideration of a vent hole in the well cap. For flush-mount well completions, a vent hole can provide a means for ambient surface water to enter the well if the if the completion is not designed properly.

Careful consideration should be given to well completion design, including vented well caps, depending on the circumstances at the location.

- If installing wells for per- and poly-fluoroalkyl substances (PFAS) sampling, and PFAS are a potential surface soil contaminant of concern, assume the surface soil is contaminated with PFAS and remove the top six inches and transfer to drums prior to installing the wells. Keep all site surface soil in one drum, if feasible. It is important to minimize PFAS at the surface from getting into the well during construction. Area of soil removal should be the same as the protective concrete apron for the well.

1.7 *Personnel Qualifications*

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Monitoring well installation is typically conducted by a subcontractor experienced in such installations following completion of a soil boring. A qualified TRC representative provides oversight and documentation that the well is properly installed. Subcontractor personnel should not be on the site without a TRC representative being present unless specific prior approval has been given by TRC. The TRC representative should prepare a Monitoring Well Installation Form (Attachment A) that documents the well completion details.

2.1 *Preparation*

Prior to the initiation of field work, the Project Manager or field technical lead (site manager) will secure the services of a qualified drilling contractor. A contract between TRC and the drilling contractor should be executed before mobilization. At a minimum, the drilling contractor must meet the following requirements:

- have the appropriate licenses, registrations and/or certifications for drilling and monitoring well installation in the state in which the work is being conducted,
- have the proper equipment in good operating condition and free of leaks (fuel, hydraulic fluid, lubricants, and similar compounds) available to perform the type of well installation required, and
- have experienced personnel who are OSHA-trained to work on hazardous waste sites.

Before the start of field tasks, the TRC field representative is responsible for coordinating the following items with the drilling subcontractor personnel:

- familiarizing the subcontractor with the objectives of the investigation,

- providing and reviewing a copy of the project-specific work plan with the subcontractor,
- providing and reviewing a copy of the project HASP with the subcontractor,
- determining overhead hazards including power lines, buildings, trees and verifying local/city regulatory requirements if tree roots will be damaged, and
- performing a daily health and safety review with the subcontractor.

Compliance with state and federal requirements is required prior to the installation of monitoring wells. TRC is responsible for ensuring that all required permits have been obtained prior to the start of work. If state regulations require the driller to obtain drilling permits and/or utility clearance approvals, TRC personnel must review the documentation prior to the start of work. This documentation may include, but is not limited to, the following:

- notification and approval to drill/install a monitoring well (access agreement),
- registration or notification of the well installation,
- permit for water withdrawals,
- well abandonment when the project is completed, and
- applicable dig-safe permits or approvals (utility clearance).

Copies of any permits and notification forms must be provided to TRC.

2.2 Materials

Unless approved in writing by TRC, no lubricants or glue shall be used in any manner that could possibly contaminate samples, boreholes, or monitoring wells. The following provides a detailed description of the key features of well installation and how their proper selection and use is necessary to complete an effective groundwater monitoring well.

2.2.1 Well Screens

Monitoring well screens most commonly consist of two-inch diameter, flush-threaded, Schedule 40, PVC, machine-cut, slotted, wire wrap and/or V-wire screen. Up to two-inch or smaller diameter PVC is often used for wells installed using direct-push drilling methods. Four-inch diameter (and larger) wells are most typically used to accommodate larger pumps for groundwater and/or non-aqueous phase liquid (NAPL) recovery – but may also be used for groundwater monitoring. The screen slot size should be selected to retain a minimum of 90% of the filter pack material (see below). The most commonly used slot size is 0.010-inch (0.25 mm) slot openings.

In wells installed at depths greater than 100 feet, Schedule 80 PVC well screens can be used to minimize narrowing of the slots from the increased weight of the riser string. Note that the inside diameter of Schedule 80 riser pipe is slightly smaller than Schedule 40. That difference may cause difficulty when inserting some downhole monitoring equipment or instrumentation.

PVC screens can be adversely affected (typically by weakening or swelling) by concentrations of organic solvents that exceed 25% of the solubility limit. If such subsurface contaminant conditions are possible, the type and concentration of solvent should be researched in more detail prior to well installation. Stainless steel is also a common choice for well screens, but under certain conditions, metals (including iron, nickel, lead, and chromium) have been known to leach from stainless steel screens; in addition, stainless steel screens are costly. Other materials or sizes may be specified in the project-specific work plan as required by site conditions or local regulations. Manufactured prepacked well screens are commercially available and generally consist of a standard, slotted Schedule 40 PVC well screen pipe (typically 0.5 to 2.0 inch diameter) wrapped in a stainless steel mesh filled with filter sand (typically 20-40 grade silica sand). Additional finer sand pack is commonly added directly above the installed prepack as a grout barrier. Since the sand is packed around the slotted PVC before the well screen is installed, using prepacked screens guarantees that sand will be located directly adjacent to and uniformly around the well screen. Prepacked well screens are typically installed by direct push drilling techniques. The use of prepacked well screens generally makes well installation quicker and more efficient than traditional methods. However, their use for permanent groundwater wells for chemical groundwater quality monitoring should first be verified to determine consistency with project-specific and state regulatory requirements.

2.2.2 Riser and End Caps

Monitoring well riser and end caps will consist of appropriately sized, flush-threaded material compatible with the well screen. Other materials or sizes may be specified in the project-specific work plan as required by site conditions or local regulations. The top cap should be vented to allow the passage of air, unless the well is to be installed at or below the ground surface (i.e., “flush mount well”). In that case, the top of the well should be sealed with an expansion cap/plug or a protective watertight manhole provided to prevent the inflow of storm water runoff into the well.

2.2.3 Filter Pack

A filter pack (also known as “sand pack” or “gravel pack”) will be required in any formation other than coarse sand and gravels containing less than 10% fines (silts and clays) by weight. In such formations (i.e. well-to-moderately sorted sands and gravels), a filter pack may not be necessary and the formation can be allowed to collapse around the screen; however, most regulatory guidance requires a filter pack be constructed. The purpose of the filter pack is to inhibit transport of fine-grained formation material into the well screen and stabilize the formation so as to avoid excessive caving/sloughing during installation and development. The introduction of coarser material than the natural formation also results in increasing the effective diameter of the well.

The filter pack material shall be composed of washed, graded, commercially-produced silica sand. Based upon field estimates of grain size distribution of the screened aquifer materials, a sand pack should be selected. A detailed discussion of filter pack determination is found in Nielsen and Schalla (2006). ASTM Standard D5092, *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers* (ASTM 2004), may also be consulted for further guidance on specifications for sand packs for various conditions. If grain size information is not known for the formation, several sand packs should be available during well construction based upon known or presumed geological information for the site. The most common choice of filter pack sand is 20-40 mesh for 0.010-inch screen slots.

One to two feet of clean, fine sand can be used (required in some states) as a buffer between the annular seal and the filter pack to provide added protection that grout invasion into the filter pack and/or the well screen will not occur. This layer is sometimes referred to as the “secondary filter pack.” The sand should be well sorted quartz sand; 40-60 mesh sand is typically used for this purpose.

2.2.4 Annular Seal

An annular seal, typically a minimum of 2 feet thick, is placed above the filter pack and screen to inhibit the boring from serving as a pathway for the vertical movement of water. Without an annular seal, the wellbore annulus can serve to transport contaminants between geologic units (for example, from unconfined to confined aquifer or from the vadose zone to the groundwater). The annular seal will consist of bentonite pellets, chips, granules, or slurry (produced from powdered bentonite). Bentonite swells rapidly when in contact with water. Coated bentonite pellets are preferable in situations where the bentonite must travel through a water column greater than 30 feet, because uncoated pellets may expand and bridge the annulus above the desired depth. Larger bentonite chips may also be used since they also swell at a slower rate than pellets and granules. The selection of the form of bentonite will depend upon the location of the top of the filter pack relative to the water table. If the seal is placed in the vadose zone, the seal will be hydrated with potable water. The volume of water necessary to hydrate the bentonite chips or pellets is dependent on the pellet size, volume of pellets used, and manufacturer's requirements. Granular bentonite is the best choice in situations where the seal is placed in the vadose zone – particularly in arid climates. Other forms of bentonite require longer contact times with water to form an adequate seal. Note that if the seal may be exposed to NAPL, it can shrink and crack. In addition, in situations with total dissolved solids (TDS) concentrations >5,000 parts per million (ppm) or chloride concentrations >8,000 ppm, bentonite will not swell; in these situations, neat cement should be considered as an alternative seal.

2.2.5 Grout

In certain wells, the annular space above the bentonite seal to the ground surface may be grouted with a mixture of 95% Portland cement or equivalent, and 5% bentonite grout, mixed with potable water to the specifications of the concrete manufacturer. This equates to 6 gallons of water added to each 94-pound sack of Type I Portland cement with 3- to 8% powdered bentonite added to improve the workability of the slurry. Bentonite should be prehydrated before adding to the cement to limit clumping. Note that bentonite does not swell considerably when mixed with cement. Grout is generally mixed in a container or barrel using pumps and may include an electric paddle or rotating vane blender.

Note: Grout mixtures may vary based on applicable regulatory requirements or site-specific subsurface conditions.

2.2.6 Surface Protective Casing

The primary purpose of a protective surface completion is to prevent surface water runoff from entering the well, and to prevent unauthorized access to the well. There are two types of protective casings used for surface completions of monitoring wells: (1) the above ground completion and (2) the below ground or flush-mount manhole-type completion, which is typically used in high traffic or public areas where the well could be damaged by equipment or is deemed unsightly.

Above-Ground Completion

An above-grade surface completion (i.e., a well monument) consists of rigid surface casing (typically galvanized or steel coated with rust-proofing or anodized aluminum). The inside diameter of the casing should be at least 2 inches larger than the well casing and be long enough to extend 2.5 to 3 feet above and below the ground surface. The casing is set in the annular seal and/or the surface seal that consists of either concrete (in warm to moderate climates) or bentonite (in cold climates). Bollards are often used around the aboveground surface casing to prevent vehicular damage.

The surface casing shall have a cap with provision for a lock that cannot be easily removed and leave at least 3 to 6 inches of clearance between the top of the well casing and the cap. The base of the casing, at the point where it shall extend above the concrete pad, should have a small weep hole drilled through the casing to prevent the build-up of precipitation or ice between the steel casing and well riser.

Flush-Mount Completion

Flush-mount well completions are generally selected or may be required in areas where vehicular traffic or equipment operation is an important consideration and an above-ground completion may not be a viable option. Depending on the expected activity in the area of the flush-mount completion and the existing surface conditions, the strength and durability of the completion will need to be designed appropriately. An appropriate completion may not be noticed, but a poor completion will generate negative comments with increasing wear and tear. In general, flush-mount completions should be located away from local low areas that drain or accumulate water, if at all possible.

Well completions flush with the pavement or ground surface may be accomplished by various means including the use of well can cylinders or elaborate vaults, and sufficient concrete to stabilize the structure within its surroundings. Regardless of the surface completion, the interior of the flush-mount completion should include the following characteristics: 1) rubber gasket to provide a cover seal; 2) locking capability for well security; 3) drainage management; and 4) sufficient interior space to accommodate any equipment (e.g., dedicated pump) that may be placed in the well.

Flush-mount well completions should provide a minimum of 2 inches of annular space around the outside of the well (i.e., a 6-inch diameter vault for a 2-inch well). The protective steel “skirt” should extent at least 1 foot below the top of the well vault. As most flush-mount wells are installed in paved areas, the concrete used to set the well vault should be compatible with the bearing capacity of the existing pavement. Depending on location considerations, the well completion may be sloped slightly away from the well or completed truly flush with the surroundings. The inside of the manhole annulus should be filled with a drainage layer of sand or gravel with a weep hole so water that accumulates in the vault will drain.

2.3 Monitoring Well Installation

Boreholes to be completed as monitoring wells will be advanced and logged in accordance with ECR SOP 005 (Visual-Manual Procedure for Soil Description and Identification). Equipment used to advance the boring and install the monitoring well will be decontaminated prior to the start of the boring.

All downhole well construction materials (with the exception of the protective casing) should be clean prior to use at the site. In general, all well materials (other than filter sand, seals, and grout) are typically provided individually plastic-wrapped by the manufacturer. If required by the project-specific work plan or at the discretion of the TRC inspector, well materials (other than filter sand, seals, and grout) may be steam-cleaned, rinsed with deionized water, and covered in plastic prior to installation of the well to prevent the introduction of foreign contaminants into the aquifer. Decontamination and bagging can also be conducted by the manufacturer, prior to delivery to the site. Furthermore, well construction materials shall be properly stored until use to ensure their good condition and cleanliness.

2.3.1 Procedures

Monitoring wells will be installed by the drilling subcontractor under the direction of a qualified TRC geologist, environmental scientist, or engineer. Monitoring wells will be installed using the following general procedures which may be dependent on the site-specific requirements.

1. Prior to mobilizing to the site, the construction details of the well to be installed will be provided to the driller, including well identifiers, locations of wells, boring diameter, well materials, screen slot size, screen lengths/depths, riser length, well depths, filter pack materials and depths, annular seal, grouting requirements, and well surface completion requirements.

2. All well materials shall be inspected to ensure that they are new and clean prior to installation.

3. Sections of screen and riser will be threaded together and lowered into the borehole to the predetermined depth. It is preferable to keep the drilling string or temporary casing in the hole while well materials are placed and slowly remove them as the well materials are installed. Centralizers may be used on the well riser in deeper wells to ensure proper well placement within the center of the borehole. Centralizers should not be placed within the location of the annular seal. Once the well is completed, the well cap should have a hole drilled in the top for venting, if possible.

4. The selected well packing materials will be introduced into the annulus in a manner so as to ensure an adequate well pack and seal. Approximately 0.5 to 1.0 foot of filter pack may be placed at the base of the boring to establish a stable base for the well materials. The thickness of each layer of well materials placed in the annulus will be measured with a weighted measurement tape and recorded to the nearest 0.10 foot. The weighted tape may also act as a tamping device to reduce bridging. Augers or casing will be removed sequentially during sand pack installation and the well will remain at the desired depth during auger or casing withdrawal.

   The primary filter pack may be placed using a rigid tremie pipe to minimize the potential for sand bridging in the annulus. The primary filter pack should extend at least 2 feet above the top of the well screened interval. One to 2 feet of fine sand as the secondary filter pack can then be placed above the primary filter pack (if required). However, the height of the filter pack may differ from that specified here due to shallow well depth limitations and project-specific work plan requirements. The secondary filter pack should not extend into a different aquifer unit as the primary filter pack. The depth of each interval of filter pack and volume of material used must be recorded on the Monitoring Well Installation Form and/or the field book.

5. The annular bentonite seal installation technique will vary with the depth of the water table. The appropriate type of bentonite will be selected to suit the objectives of the installation program. The bentonite should be poured slowly into the annular space to minimize

bridging, with periodic tamping. The volume of the annular space should be calculated and compared to the volume of bentonite used as a check to make sure bridging in the annular space has not occurred. If a tremie pipe is used for installation of the annular seal, either coated pellets or slurry should be used because bridging may occur as the bentonite swells. The preferred method of annular seal placement is by using the drilling rods or augers as a conductor casing, except in deep or difficult wells. The annular seal typically ranges from 1 to 5 feet in thickness. Annular seals in wells installed above the water table will be hydrated typically with 10 to 20 gallons (added in 5-gallon increments) of water and allowed to swell prior to the emplacement of a cement-bentonite grout mixture (if the well is to be grouted). In arid or highly permeable formations, the bentonite pellets should be allowed to swell for 1 hour. The high TDS concentration of cement grout does not act to hydrate bentonite, so it is important to allow the bentonite to hydrate fully in water. The level and volume of material(s) used for the annular seal are then recorded on the Monitoring Well Installation Form and/or the field book.

6. Once the annular seal is sufficiently hydrated, a cement-bentonite grout (or other type depending on local regulation) is placed to fill the remaining annulus of the boring. Depending on the depth of the well and water table, the grout may be tremied into the desired location from the bottom up. A side-discharge tremie is preferred so as to not disturb the annular seal. The tremie can remain near the bottom until grouting is completed. Grout requires 8 to 48 hours to set, but it does not become rigid like cement. The grout mixture (percentage of cement to bentonite) will be recorded and will be in accordance with the project-specific work plan or recommended guidance and Section 2.2.5 of this SOP. The grout will be pumped into the boring around the well materials to the surface. If necessary, after solidification of the grout and settling occurs, the grout may need to be topped off with additional grout mixture. The need for additional grout will be based on the intended surface completion for the well. The composition and volume of material(s) used for the grout are then recorded on the Monitoring Well Installation Form and/or the field book.

7. For wells finished above-grade, the protective casing may be cemented in place as described in Section 2.2.6 or completed with grout and bentonite in areas subject to frost heave. The protective casing should be in a plumb position and installed with at least half of the casing below ground and below the frost line (3- to 5 feet below ground surface). The protective casing should have a granular material placed in the base and a weep hole drilled through the casing to allow drainage of water that accumulates in the protective casing. Once completed, the well will be locked and typically allowed to settle for a minimum of 24 hours prior to well development. After well installation, development of a well should occur as soon as reasonably possible to enable representative sampling within the parameters of the project schedule. Some regulatory agencies require minimum timeframes for the newly-installed well materials, such as the bentonite seal or grout column, to cure before initiating well development (e.g., 24 or 48 hours).

   In some instances, a concrete pad is often constructed around wells to provide a working surface and more significant protective surface seal; this concrete pad is required by law in some states. These pads should be a minimum of 4 inches in thickness and are typically a minimum of 2 feet by 2 feet. It is recommended that the concrete pad extend 4 to 6 inches below the ground surface within six inches of the borehole. In areas of traffic or periodic mowing, three or four guard posts ("bumper guards" or bollards) may be positioned around the well to protect the well from equipment. The ground or pad around the well head should be sloped away from the well to promote drainage away from the surface completion. The guard posts consist of 3- to 4-inch diameter steel pipes set 3 to 4 feet outside the concrete pad. The pipes are set at least 3 feet in the ground and are filled with concrete. The well "stickup" and the guard posts should be painted a bright color (typically "safety yellow") for visibility. The type and details of the surface completion should be sketched, photographed or otherwise recorded on the Monitoring Well Installation Form and/or the field book.

8. Depending on the location of the well, flush-mounted utility boxes (i.e., well vaults or manholes) or above-ground, steel, protective casings with locking caps will be used to complete the well. Flush-mount wells should be located outside of areas that accumulate ponded water or areas of runoff, if at all possible, to minimize the potential for well damage by freeze/thaw conditions or for surface water to flow into the completed well.

   The well top should extend a minimum of 4 inches from the bottom of the cement or grout base with sufficient distance to the vault cover to accommodate any equipment (e.g., dedicated pump) that may be placed in the well. The well vault should also include a rubber gasket to make it water tight and is typically tightened with lug bolts.

   Flush-mount well vaults should provide a minimum of 2 inches of free space around the outside of the well (i.e., a 6-inch diameter vault for a 2-inch well). The protective, steel "skirt" should extent at least 1 foot below the top of the well vault. The vault will be sealed in concrete or cement grout that extends 4 to 6 inches away from the vault and extends a minimum of 1 foot below the frost depth. As most flush-mount wells are installed in paved areas, the concrete used to set the well vault should be compatible with the bearing capacity of the existing pavement. The vault should be set slightly higher than the existing grade and the concrete sloped (1- to 2% slope) away from the manhole to promote drainage away from the well. In cold-weather areas where snow removal occurs, the well may have to be set flush with the pavement to avoid damage. The inside of the manhole annulus should be filled with a drainage layer of sand or gravel with a weep hole, so water that accumulates in the vault will drain. Below-grade wells should be fitted with a locking, water-tight friction cap or expandable plug because below-grade wells often fill with water.

9. The wells should be permanently marked with the well identification number either on the cover or an appropriate place (i.e., in concrete pad) that will not be easily damaged and/or vandalized. Keyed-alike weatherproof brass padlocks should be installed on each well casing.

10. The manufacturer, type, weight, and number of bags or other containers of each type of well sand, cement, bentonite, and any other grout materials should be counted and documented on the Monitoring Well Installation Form and/or the field book as a means of determining if the amount used is consistent with the information obtained by the drilling subcontractor.

11. All information concerning well installation details will be recorded on a Monitoring Well Installation Form (examples provided in Attachment A).

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

There are minimal wastes other than general refuse and PPE that is generated during well installation. Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following quality assurance/quality control procedures apply:

- Check well construction materials to ensure these materials conform with the project-specific work plan and project specifications.
- Operate field instruments according to the manufacturers' manuals.
- Calibrate field instruments at the proper frequency, if utilized.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record well installation measurements on field forms or in a field book. See Attachment A for an example of a Monitoring Well Installation Form.

The following additional information should be recorded in the field book and/or Monitoring Well Installation Form:

- Well/piezometer or monitoring point identification number
- Well permit number (if applicable)
- Date of well installation
- Type of drilling method used and model number of rig
- Ground surface elevation (if known)
- Diameter and depth of borehole
- Depth of well bottom
- Depth of top and bottom of screened interval
- Depth of top and bottom of filter pack
- Depth of top and bottom of secondary filter pack (if used)
- Depth of top and bottom of annular seal
- Depth of top and bottom of grout seal
- Type, diameter, length, and screen slot size of well screen
- Type, diameter and length of riser
- Type, diameter, and length of casing (if used)
- Type, gradation, and volume/mass of filter pack
- Type and volume/mass of secondary filter pack (if used)
- Method used for filter pack placement

- Well lock type (i.e., padlock) and key number
- Type and volume of bentonite or other material used for annular seal
- Method used for annular seal placement
- Type, volume, and mix percentages of grout used
- Method used for grout placement
- Source of water used
- Type and length of protective casing
- Type and dimensions of well vault
- Type, number and array of protective posts (if used)
- Type and dimensions of surface completion/seal
- Measurement of "stickup" above or below ground
- Initial depth to groundwater
- Other pertinent observations
- Measurement equipment used
- Decontamination procedures used

6.0 REFERENCES

ASTM. 2004. *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers*, ASTM Standard D 5092, ASTM, West Conshohocken, PA 2004, pp. 20.

EPA. 1987. *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, US EPA. August 1987.

Nielsen, D.M. and Ronald Schalla. 2006. *Design and Installation of Ground-Water Monitoring Wells*. In Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring. Second Edition. David M. Nielsen ed. CRC Press. Boca Raton, FL. pp. 339 – 805.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	JANUARY 2014	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING
2	AUGUST 2020	MODIFICATIONS WHEN SAMPLING FOR PFAS

ATTACHMENT A
EXAMPLE MONITORING WELL INSTALLATION FORMS

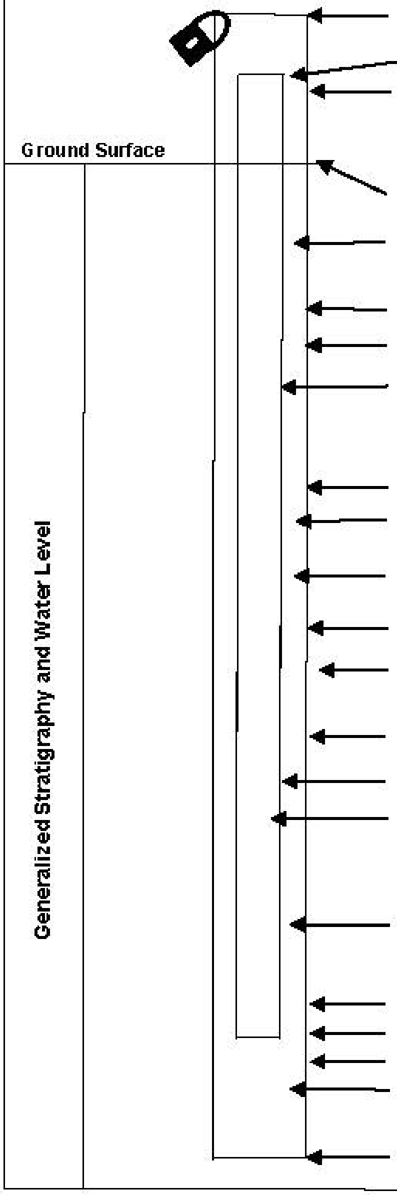
Monitoring Well Construction Summary

Well ID.

Project: ____________ **No.:** ____________
Client: ____________ **Date Completed:** ____________
Location: ____________
Boring Contractor: ____________ **Method:** ____________
TRC Geologist: ____________

Depth to Ground Water: ____________
Development Date: ____________
Development Method: ____________
Notes:

Height/Depth ( ) **Elevation ( )**



Top of protective casing: ____________ ____________
Top of riser pipe: ____________ ____________
I.D. of protective casing: ____________
Type of protective casing: ____________

Ground Surface Elevation: ____________ ____________
Type/thickness of surface seal: ____________

Bottom of protective casing ____________ ____________
Borehole diameter: ____________
Riser pipe I.D.: ____________
Type of riser pipe: ____________

Top of grout: ____________ ____________
Type of grout/backfill: ____________
Method of grout/backfill: ____________

Top of seal: ____________ ____________
Type and thickness of seal: ____________

Top of filter pack: ____________ ____________
Elevation/Depth top of screen: ____________ ____________
Type of screen: ____________
Slot size: ____________
I.D. of screen: ____________
Type of filter/sand pack: ____________

Bottom of screen: ____________ ____________
Bottom of well: ____________ ____________
Bottom of filter pack: ____________ ____________
Type of backfill below monitoring well: ____________

Bottom of borehole: ____________ ____________

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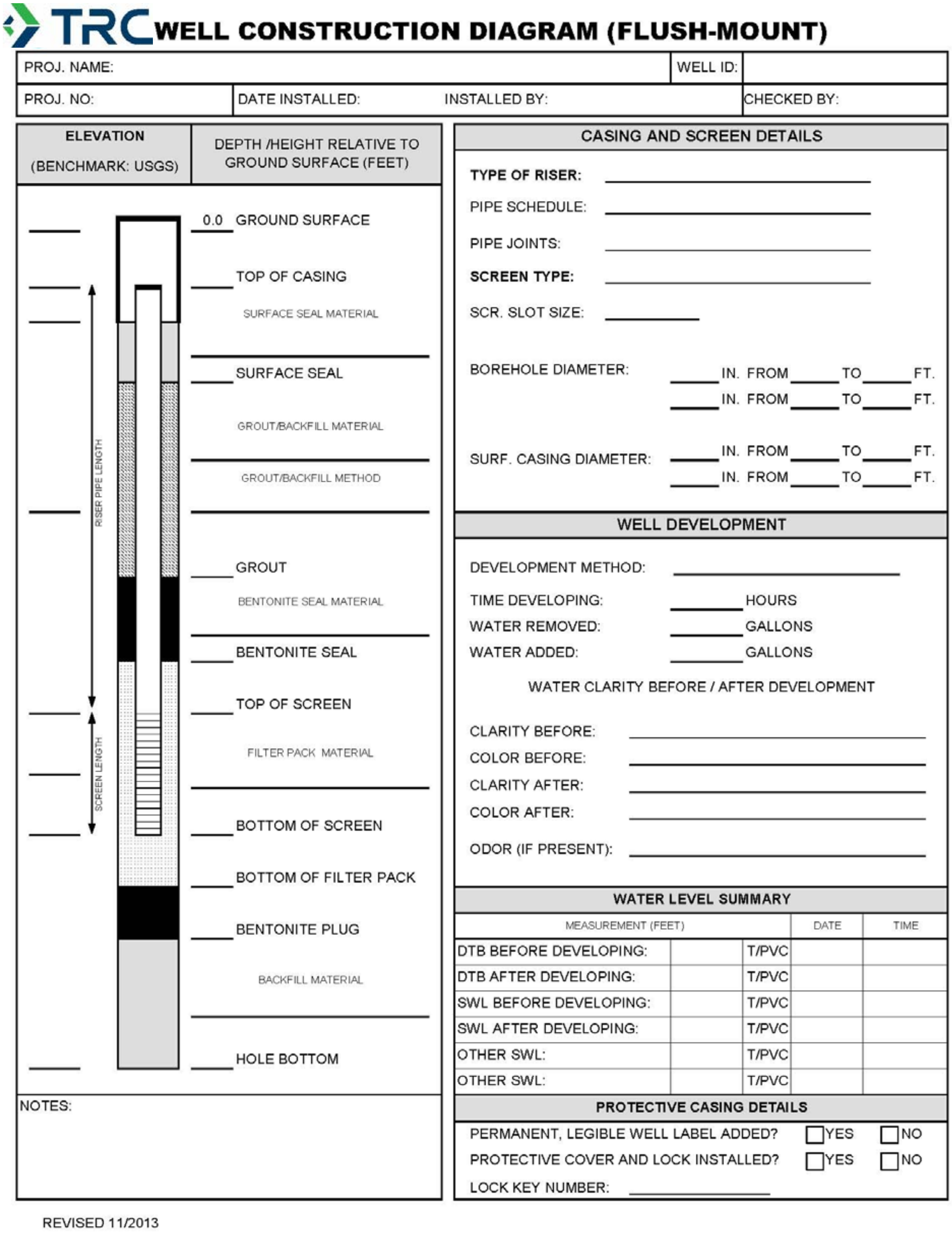


TRC WELL CONSTRUCTION DIAGRAM (FLUSH-MOUNT)

PROJ. NAME: ____ WELL ID: ____

PROJ. NO: ____ DATE INSTALLED: ____ INSTALLED BY: ____ CHECKED BY: ____

ELEVATION (BENCHMARK: USGS)	DEPTH /HEIGHT RELATIVE TO GROUND SURFACE (FEET)
____	0.0 GROUND SURFACE
____	____ TOP OF CASING
____	SURFACE SEAL MATERIAL ____
	____ SURFACE SEAL
	GROUT/BACKFILL MATERIAL ____
____	GROUT/BACKFILL METHOD ____
	____ GROUT
	BENTONITE SEAL MATERIAL ____
	____ BENTONITE SEAL
____	____ TOP OF SCREEN
____	FILTER PACK MATERIAL ____
____	____ BOTTOM OF SCREEN
	____ BOTTOM OF FILTER PACK
	____ BENTONITE PLUG
	BACKFILL MATERIAL ____
____	____ HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____

PIPE SCHEDULE: ____

PIPE JOINTS: ____

SCREEN TYPE: ____

SCR. SLOT SIZE: ____

BOREHOLE DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

SURF. CASING DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____

TIME DEVELOPING: ____ HOURS

WATER REMOVED: ____ GALLONS

WATER ADDED: ____ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____

COLOR BEFORE: ____

CLARITY AFTER: ____

COLOR AFTER: ____

ODOR (IF PRESENT): ____

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWL BEFORE DEVELOPING:		T/PVC		
SWL AFTER DEVELOPING:		T/PVC		
OTHER SWL:		T/PVC		
OTHER SWL:		T/PVC		

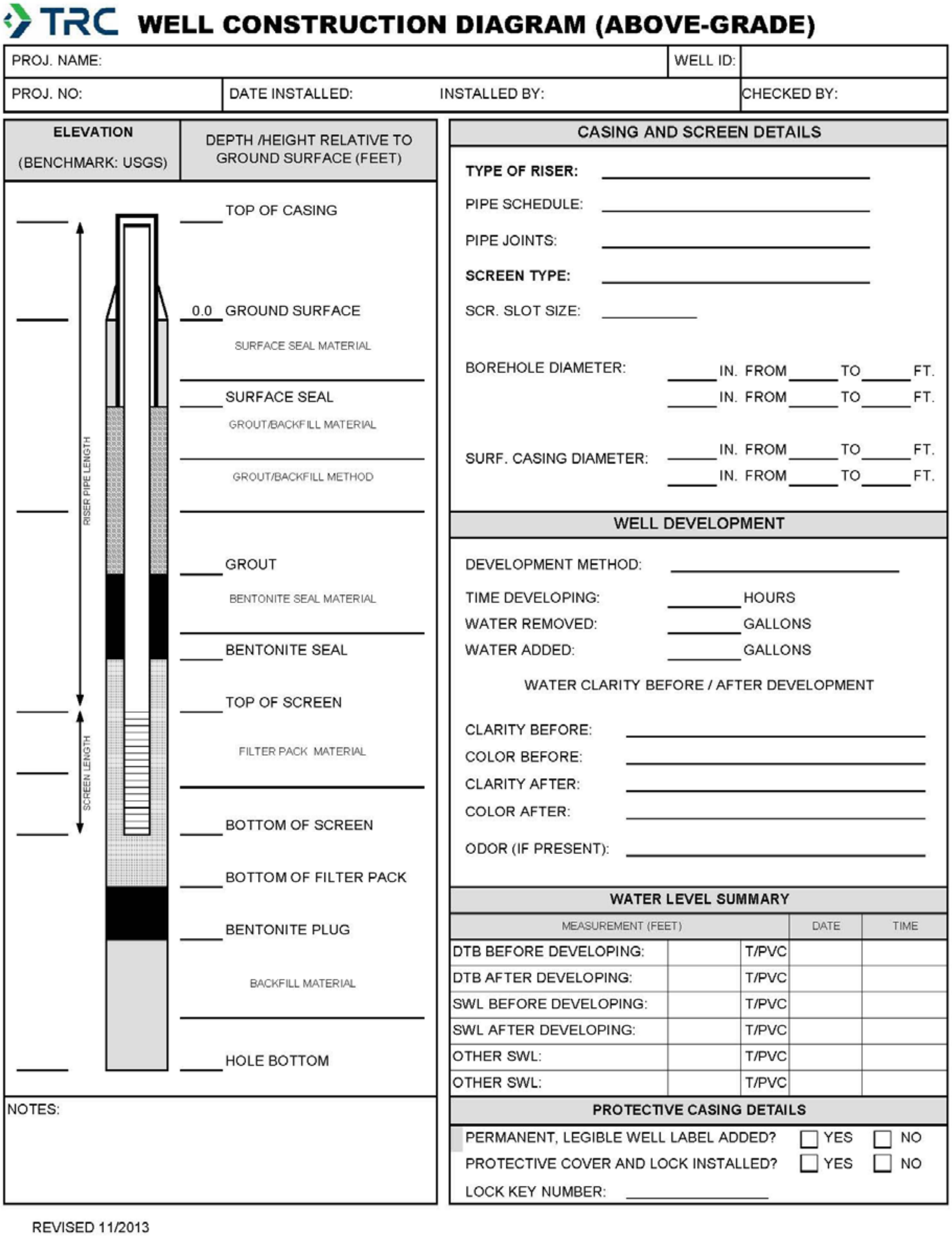
PROTECTIVE CASING DETAILS

PERMANENT, LEGIBLE WELL LABEL ADDED? ☐YES ☐NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐YES ☐NO

LOCK KEY NUMBER: ____

REVISED 11/2013



WELL CONSTRUCTION DIAGRAM (ABOVE-GRADE)

PROJ. NAME:		WELL ID:	
PROJ. NO:	DATE INSTALLED:	INSTALLED BY:	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH /HEIGHT RELATIVE TO GROUND SURFACE (FEET)
____	____ TOP OF CASING
____	0.0 GROUND SURFACE
	SURFACE SEAL MATERIAL ________
	____ SURFACE SEAL
	GROUT/BACKFILL MATERIAL ________
____	GROUT/BACKFILL METHOD ________
	____ GROUT
	BENTONITE SEAL MATERIAL ________
	____ BENTONITE SEAL
____	____ TOP OF SCREEN
____	FILTER PACK MATERIAL ________
____	____ BOTTOM OF SCREEN
	____ BOTTOM OF FILTER PACK
	____ BENTONITE PLUG
	BACKFILL MATERIAL ________
____	____ HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____________

PIPE SCHEDULE: ____________

PIPE JOINTS: ____________

SCREEN TYPE: ____________

SCR. SLOT SIZE: ________

BOREHOLE DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

SURF. CASING DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____________

TIME DEVELOPING: ____ HOURS

WATER REMOVED: ____ GALLONS

WATER ADDED: ____ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____________

COLOR BEFORE: ____________

CLARITY AFTER: ____________

COLOR AFTER: ____________

ODOR (IF PRESENT): ____________

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWL BEFORE DEVELOPING:		T/PVC		
SWL AFTER DEVELOPING:		T/PVC		
OTHER SWL:		T/PVC		
OTHER SWL:		T/PVC		

PROTECTIVE CASING DETAILS

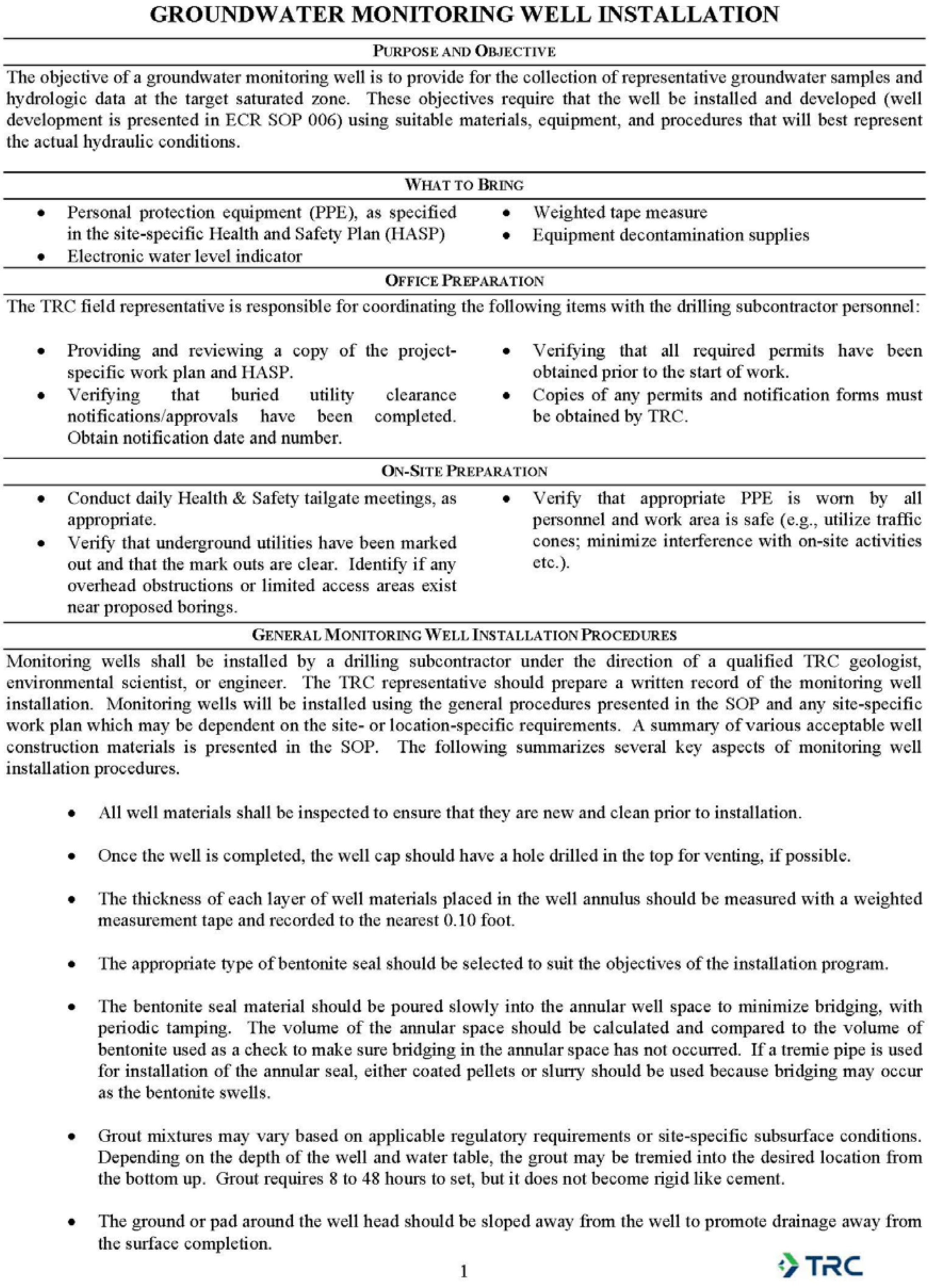
PERMANENT, LEGIBLE WELL LABEL ADDED? ☐ YES ☐ NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐ YES ☐ NO

LOCK KEY NUMBER: ________

REVISED 11/2013

ATTACHMENT B
SOP FACT SHEET



GROUNDWATER MONITORING WELL INSTALLATION

PURPOSE AND OBJECTIVE

The objective of a groundwater monitoring well is to provide for the collection of representative groundwater samples and hydrologic data at the target saturated zone. These objectives require that the well be installed and developed (well development is presented in ECR SOP 006) using suitable materials, equipment, and procedures that will best represent the actual hydraulic conditions.

WHAT TO BRING

- Personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Weighted tape measure
- Equipment decontamination supplies

OFFICE PREPARATION

The TRC field representative is responsible for coordinating the following items with the drilling subcontractor personnel:

- Providing and reviewing a copy of the project-specific work plan and HASP.
- Verifying that buried utility clearance notifications/approvals have been completed. Obtain notification date and number.
- Verifying that all required permits have been obtained prior to the start of work.
- Copies of any permits and notification forms must be obtained by TRC.

ON-SITE PREPARATION

- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Verify that underground utilities have been marked out and that the mark outs are clear. Identify if any overhead obstructions or limited access areas exist near proposed borings.
- Verify that appropriate PPE is worn by all personnel and work area is safe (e.g., utilize traffic cones; minimize interference with on-site activities etc.).

GENERAL MONITORING WELL INSTALLATION PROCEDURES

Monitoring wells shall be installed by a drilling subcontractor under the direction of a qualified TRC geologist, environmental scientist, or engineer. The TRC representative should prepare a written record of the monitoring well installation. Monitoring wells will be installed using the general procedures presented in the SOP and any site-specific work plan which may be dependent on the site- or location-specific requirements. A summary of various acceptable well construction materials is presented in the SOP. The following summarizes several key aspects of monitoring well installation procedures.

- All well materials shall be inspected to ensure that they are new and clean prior to installation.

- Once the well is completed, the well cap should have a hole drilled in the top for venting, if possible.

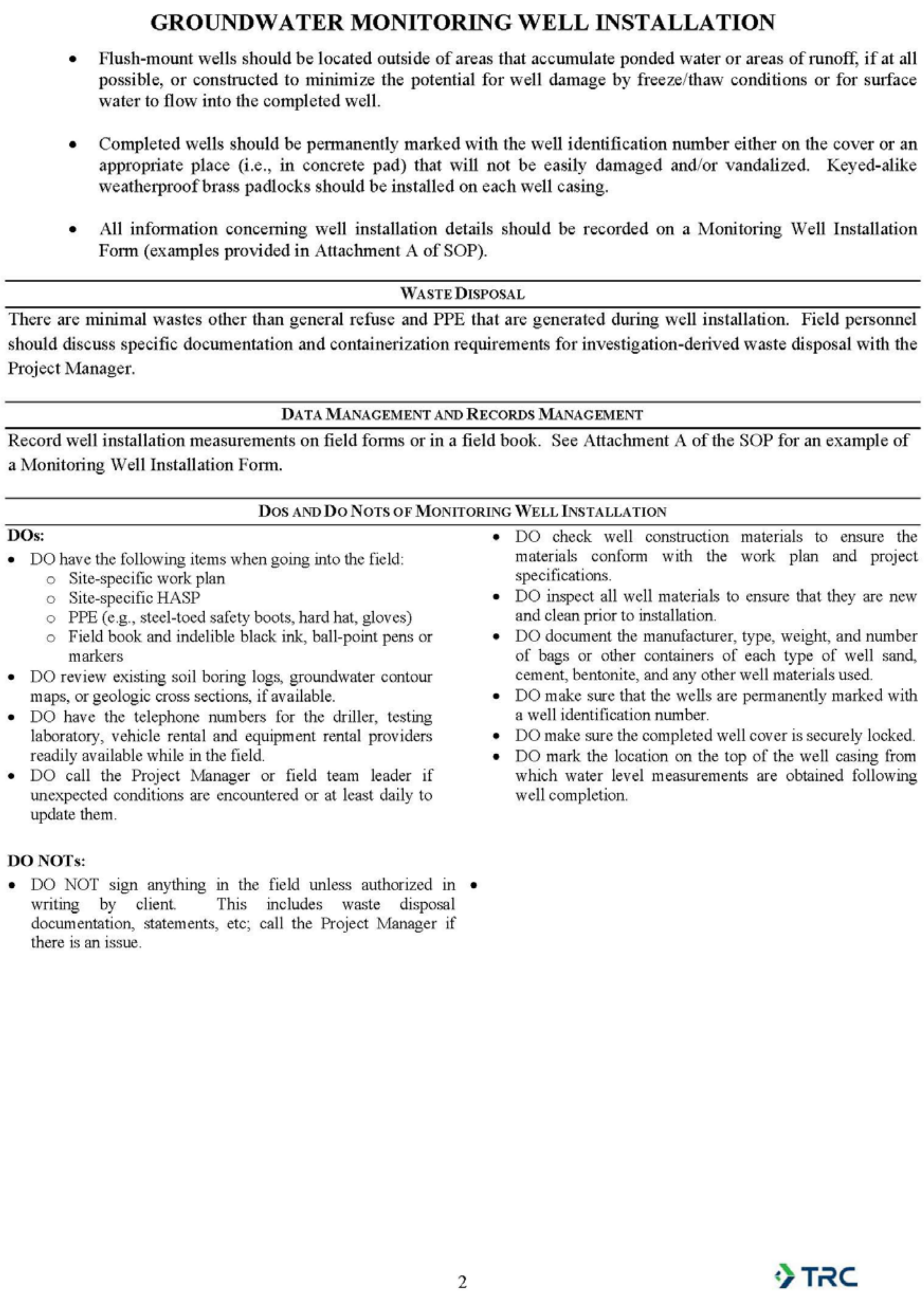
- The thickness of each layer of well materials placed in the well annulus should be measured with a weighted measurement tape and recorded to the nearest 0.10 foot.

- The appropriate type of bentonite seal should be selected to suit the objectives of the installation program.

- The bentonite seal material should be poured slowly into the annular well space to minimize bridging, with periodic tamping. The volume of the annular space should be calculated and compared to the volume of bentonite used as a check to make sure bridging in the annular space has not occurred. If a tremie pipe is used for installation of the annular seal, either coated pellets or slurry should be used because bridging may occur as the bentonite swells.

- Grout mixtures may vary based on applicable regulatory requirements or site-specific subsurface conditions. Depending on the depth of the well and water table, the grout may be tremied into the desired location from the bottom up. Grout requires 8 to 48 hours to set, but it does not become rigid like cement.

- The ground or pad around the well head should be sloped away from the well to promote drainage away from the surface completion.



GROUNDWATER MONITORING WELL INSTALLATION

- Flush-mount wells should be located outside of areas that accumulate ponded water or areas of runoff, if at all possible, or constructed to minimize the potential for well damage by freeze/thaw conditions or for surface water to flow into the completed well.

- Completed wells should be permanently marked with the well identification number either on the cover or an appropriate place (i.e., in concrete pad) that will not be easily damaged and/or vandalized. Keyed-alike weatherproof brass padlocks should be installed on each well casing.

- All information concerning well installation details should be recorded on a Monitoring Well Installation Form (examples provided in Attachment A of SOP).

WASTE DISPOSAL

There are minimal wastes other than general refuse and PPE that are generated during well installation. Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

DATA MANAGEMENT AND RECORDS MANAGEMENT

Record well installation measurements on field forms or in a field book. See Attachment A of the SOP for an example of a Monitoring Well Installation Form.

DOS AND DO NOTS OF MONITORING WELL INSTALLATION

DOs:

- DO have the following items when going into the field:
  - Site-specific work plan
  - Site-specific HASP
  - PPE (e.g., steel-toed safety boots, hard hat, gloves)
  - Field book and indelible black ink, ball-point pens or markers
- DO review existing soil boring logs, groundwater contour maps, or geologic cross sections, if available.
- DO have the telephone numbers for the driller, testing laboratory, vehicle rental and equipment rental providers readily available while in the field.
- DO call the Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them.
- DO check well construction materials to ensure the materials conform with the work plan and project specifications.
- DO inspect all well materials to ensure that they are new and clean prior to installation.
- DO document the manufacturer, type, weight, and number of bags or other containers of each type of well sand, cement, bentonite, and any other well materials used.
- DO make sure that the wells are permanently marked with a well identification number.
- DO make sure the completed well cover is securely locked.
- DO mark the location on the top of the well casing from which water level measurements are obtained following well completion.

DO NOTs:

- DO NOT sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc; call the Project Manager if there is an issue.

08

Well Development (Includes SOP for PFAS)

Title: **Well Development**	Procedure Number: **ECR 006**
	Revision Number: **2**
	Effective Date: **January 2020**

Authorization Signatures

		Elizabeth Denly	
Technical Reviewer	Date	Environmental Sector Quality Director	Date
James Peronto	1/1/20	Elizabeth Denly	1/1/20

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ATTACHMENTS

Attachment A	Example Well Development Form
Attachment B	SOP Fact Sheet
Attachment C	SOP Modifications for PFAS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for the development of wells. Well development is completed to (1) evacuate any water added during the drilling of wells, (2) establish a good hydraulic connection between the well and the surrounding water-bearing zone, (3) settle the sand pack and formation following the disruptive drilling and installation activities, (4) alleviate clogging, smearing or compaction of formation materials at the borehole wall due to the drilling process, and (5) remove fine particles (e.g., silt or clay) from the water column and sand pack in order to obtain groundwater samples that are representative of the water-bearing zone in which the well is installed and/or enhance groundwater extraction and injection rates. Well development typically occurs for all newly installed wells and can also be implemented to refurbish an older well where significant silt/sediment build-up has occurred, as may be observed when the measured depth to bottom of a well is notably shallower than the recorded constructed depth to bottom.

1.2 Summary of Method

Proper well development includes initial and ongoing water-level and water quality measurements, implementation of the development method, management of the development wastes, equipment decontamination, and documentation. First, the well should be opened and initial measurements (e.g., headspace air monitoring readings, depth to water, total depth of the well) are collected and recorded. The well is developed using the method selected for each project based on the lithology, site conditions, and objectives and requirements of the project. Development of the well continues until the water is visually clear and free of sediments (e.g., turbidity <10 nephelometric turbidity units [NTU]), until a minimum number of well volumes has been evacuated (depending on regulatory requirements) or until water quality parameters such as pH, temperature, and specific conductivity stabilize, depending on project requirements. All purge water is containerized for proper characterization and disposal at an appropriate facility unless prior approval to discharge to land surface has been obtained from appropriate sources (e.g., governing regulatory agency). Final measurements (e.g., depth to water, total depth of the well, total water removed) are recorded in the field book or on the Well Development Form (Attachment A). Equipment is decontaminated, as appropriate, prior to use in the next well.

After well installation, development of a well should occur as soon as reasonably possible to enable representative sampling within the parameters of the project schedule. Some regulatory agencies require minimum timeframes for the newly-installed well materials, such as the bentonite seal or grout column, to cure before initiating well development (e.g., 24 or 48 hours). In addition, more vigorous well development methods (e.g., surging) may require a relatively longer setup time before development. If a less vigorous method (e.g., bailing) is being used, development may be initiated shortly after installation when grout is not used in well installation or if the sealant is above the water table. Regardless, the method used for development should not interfere with the setting of the well seal, which should be considered in preparing the work plan.

Well development also provides an opportunity to collect data that can be used to estimate the hydraulic conductivity (permeability) of the screened water-bearing formation. These estimates can be used to estimate groundwater flow velocities, and are often needed to project the extent of plume migration, estimate monitored natural attenuation rates, and other investigative tasks. Estimates of hydraulic conductivity and aquifer transmissivity can be derived from a measure of a well's specific capacity; i.e., flow rate divided by water-level drawdown (expressed in gallons per minute per foot [gpm/ft] of drawdown). The data needed to estimate specific capacity are the flow rate (purge rate during development, measured with a flow meter or a 5-gallon bucket and stopwatch), the static (pre-pumping) depth to water, and the pumping depth to water. The duration of pumping when the pumping depth to water is measured should also be noted.

Several development methods may be used depending on site conditions and project requirements. There are several regulatory agency guidance documents (e.g., USGS, 1997) as well as ASTM standards available for reference. If possible, select a development method that avoids introduction of air, foreign water, or chemicals to the aquifer during development. A few development methods are outlined in Section 2.0. For specialized well development programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment C for further details.

1.3 Equipment

The following list of equipment may be utilized during the development of wells. Site-specific conditions may warrant the use of additional items or deletion of items from this list.

- Appropriate level of personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Oil/water interface probe
- Extra batteries for water level/interface probe
- Field book and forms
- Well keys
- Socket wrench
- Centrifugal or submersible pump and tubing/hosing
- Water quality meter (including parameters such as pH, temperature, specific conductivity, oxidation-reduction potential (ORP) and dissolved oxygen (DO)
- Flow-through cell
- Turbidity meter
- Plastic beaker, jar, or disposable plastic cups
- Bailer and cord
- Large-capacity DOT-approved containers (if required)
- Five-gallon buckets
- Surge block
- Bulk supply of deionized/organic-free water
- Well construction diagrams and previous well development data (if available)
- Equipment decontamination supplies

1.4 Definitions

Bailer	A cylindrical device suspended from a rope or cable, which is used to remove water, non-aqueous phase liquid (NAPL), sediment or other materials from a well or open borehole. Usually equipped with some type of check valve at the base to allow water, NAPL, and/or sediment to enter the bailer and be retained as it is lifted to the surface.
Dense Non-aqueous Phase Liquid (DNAPL)	Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.
Depth To Water (DTW)	The distance to the groundwater surface from an established measuring point.
Light Non-aqueous Phase Liquid (LNAPL)	Separate-phase product that is less dense than water and, therefore, floats on the surface of the water.
Monitoring Well	A well made from a polyvinyl chloride (PVC) pipe, or other appropriate material, with slotted screen installed across or within a saturated zone. A monitoring well is typically constructed with a PVC or stainless steel pipe in unconsolidated deposits and with steel casing in bedrock.
Non-aqueous Phase Liquid (NAPL)	Petroleum or other fluid that is immiscible in water and tends to remain as a separate liquid in the subsurface.
Piezometer	A well made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Separate-phase Product	A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column.
Low-permeability Formation	A geologic formation that has very slow recharge and discharge rates due to small pore spaces in the formation material. A clay formation is considered to have low permeability and a very slow recharge rate compared to a more permeable formation, such as sand or gravel.
Surge Block	A disc-shaped or cylindrical device that closely fits the well casing interior and is operated like a plunger below the water table to force water in and out of the well as a well development tool.

Total Depth of Well	Distance from the measuring point to the bottom of the well.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

When present, special care should be taken to avoid contact with contaminated groundwater, LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards (special care should be taken when sampling for PFAS. Please refer to Attachment C for details).

1.6 Cautions and Potential Problems

The following cautions or problems may be associated with well development:

- The observed presence of NAPL may warrant alternative goals and objectives for the well other than immediate development. The Project Manager should be contacted for direction on how to proceed.
- Low-yielding wells (e.g., at clay-bedrock interface, tight bedrock formations, etc.) may produce insufficient water to achieve optimal development including parameter stabilization.
- High-yielding wells (e.g., in coarse sand and gravel aquifers) may require the removal of large quantities of water to approach optimal development.
- Long well screens and/or larger diameter wells may require more time and effort to ensure adequate development of the entire interval depending on the development method employed.
- Development of wells should occur from the least-contaminated well to the most-contaminated well, if known.
- Overpumping is not as vigorous as surging and jetting and is probably the most desirable method for the development of new wells. The possibility of disturbing the filter pack is greatest with jetting well development methods, which are generally reserved for redevelopment of clogged extraction or injection wells. Surging or jetting may be preferred methods for supply, recovery, or injection wells (if constructed with metal screens) to achieve higher well efficiencies.
- The introduction of external water or air by jetting may alter the chemistry of the aquifer.
- Surging with compressed air may produce “air locking” in the water-bearing zone, preventing water from flowing into the well.
- Exercise caution with the use of surge blocks in PVC screen and pipe as the well could be damaged.
- Small (2-inch nominal diameter) submersible pumps that will fit in 2-inch diameter well casings are especially susceptible to becoming lodged (stuck) if used in well development applications.
- Prior to sampling a well, sufficient time should be allowed for equilibration with the formation after development. Refer to the governing regulatory agency for guidance regarding the required/recommended time interval between well development and sampling.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Well development will be completed on wells after the grout, annular seals, and protective casings are deemed sufficiently stable (i.e., 24 to 48 hours after installation) for the development method being utilized and/or after required regulatory agency timeframe requirements. Development may be performed immediately after well installation if grout is not used during well installation or if the sealant (i.e., bentonite seal) is above the water table, in accordance with the regulatory requirements. Various well development methods, including surging, pumping, hand bailing, and jetting, are summarized below, followed by step-by-step well development procedures.

2.1 Well Development Methods

Surging Method

Surge and Pump: To increase the effectiveness of well development, the well can be surged and then pumped. Surging may be accomplished in several ways, but essentially water is rapidly forced into and out of a well in a wash and backwash action. One method of surging is to simply turn the pump on for a few minutes and then turn it off for a few minutes. Surging can also be accomplished with a surge block, which is a piston-like device attached to the end of a drill rod or pipe. The block is plunged up and down along the screened interval, similar to a piston in a cylinder, to flush water in and out of the well. Periods of surging are typically followed by a period of water extraction to remove the sediment brought into the well. Surge blocks are best utilized for wells screened in lithologies of medium to high porosities and hydraulic conductivities. Exercise caution with the use of surge blocks in PVC screens which can be damaged by tight-fitting surge blocks.

A surge block method is used alternately with either a bailer or pump, so that materials that have been agitated and loosened by the surging action are removed. The cycle of surging-pumping/bailing is repeated until satisfactory development is achieved.

The surge block, usually attached and operated by a drill rig, is lowered to the top of the well screen and then operated in a surging action with a typical stroke of about three feet. The surging action is usually initiated at the top of the well screen and gradually worked downward through the screened interval so that sand or silt loosened by the surging action cannot cascade down on top of the surge block and prevent removal from the well. The surge block is removed at regular intervals and the fine material that has been loosened is removed by a bailer or pump.

Surging is initially gentle and the energy of the action is gradually increased during the development process. By controlling the speed, length and stroke of the surge block, the surging activity can range from very rigorous to very gentle.

Pumping Method

Pumping develops a well by creating a surging action as a result of variable flow rates. An electric submersible pump or compressed air-operated air displacement pump is installed into the well. The rate of flow is varied at levels adjacent to the well screen.

Overpumping: A simple method of well development is overpumping, where water is simply pumped from the well at a high rate.

Many pumps can also be used to surge a well, employing a similar method as with the surge block. While either off or running, the pump may be plunged up and down along the screened interval, in effect flushing water and sediment in and out of the well and adjacent filter pack.

Hand Bailing Method

Surge and Bail: Instead of a surge block, a bailer can be used in a similar manner since the diameter of the bailer is commonly slightly smaller than the diameter of the well. A water-filled bailer can be plunged up and down, followed by periods of bailing out sediment suspended in the water column. The impact of the bailer as it strikes the surface of the water produces an outward surge of water through the well construction and into the formation. This action tends to break sediment bridges that may have formed during well installation. Movement of water back into the well suspends fine sediments into the water column, which are removed with the bailer.

Bailers are good well development tools for wells screened in low-permeable formations. Deep wells or large purge volume wells should not be developed with bailers, as development with a bailer would be very labor intensive.

Jetting Method

Another method of development is high-velocity hydraulic jetting. Using a specialized jetting tool, jets of water are directed horizontally at the sides of the well from inside the well to loosen fine-grained material and drilling mud residue from the formation. The loosened material is flushed into the well and can be removed through concurrent pumping or by bailing. Caution should be used when using a jetting method of development as there is the possibility of disturbing the well filter pack. For product recovery, a jetting method of development can push product away from the well and can delay or completely prevent product from coming back into the well.

2.2 General Procedures for Well Development

1. The project plan will be consulted regarding any project-specific well development requirements.

2. Consult the well completion diagram and boring log to determine the well construction (well diameter, depth and length of screen), soil core vapor screening results, lithology of the screened interval, and depth to water.

3. If potable water was introduced into the water-bearing zone during well installation, the estimated amount of water lost to the formation during the drilling process should be removed during well development to ensure connection with formation water during the development process.

4. Select the appropriate method and equipment to implement development of the well. Ensure any non-dedicated equipment is clean and decontaminated prior to use and also in between wells. The development equipment should be the appropriate length to reach the entire length of the well screen. The method should be capable of evacuating the development water to the surface and into containers if required.

5. Measure the static DTW and total depth of the well using ECR SOP 004, and determine the amount of standing water in the well (well volume). Record the DTW and calculate the water column volume of the well.

   To calculate the volume of water in the well, the following equation (Equation 1) is used:

   Well Volume (V) = $\pi r^2 h (cf)$
   where:
   π = pi (3.14)
   r = radius of well in feet (ft)
   h = height of the water column in ft. [This may be determined by subtracting the DTW from the total depth of the well as measured from the same reference point.]
   cf = conversion factor in gallons per cubic foot (gal/ft^3) = 7.48 gal/ft^3.

   The volume in gallons/linear foot (gal/ft) for common size wells are as follows:

Well Diameter (inches)	Volume (gal/ft)	Volume in Liters
2	0.1631	0.6174
3	0.3670	1.389
4	0.6524	2.470
6	1.4680	5.557

   If the volumes for the common size wells above are utilized, Equation 1 is modified as follows:

   Well volume = (h)(f)
   where:
   h = height of the water column (feet)
   f = the volume in gal/ft

6. Using the appropriate length of dedicated or decontaminated hosing/tubing and the selected pumping apparatus, insert the equipment into the well.

7. Initiate water removal from the well and record the initial water quality measurements including pH, temperature, specific conductivity, DO, ORP and turbidity (as required by project specifications) in the field book or on the Well Development Form. Record any odors, water color/clarity, changes in air monitoring results or other observations in the field book or on the Well Development Form.

8. Optional step to estimate the permeability of the formation: Estimate flow rate of extracted water, in gallons per minute (gpm). The flow rate can be measured with a 5-gallon bucket and stop watch, or timed transfer to any vessel which can be measured. Measure DTW in the well during pumping to derive an estimate of water-level drawdown. Calculate the approximate specific capacity (gpm/ft of drawdown). Tracking the improvement of specific capacity can provide a direct measure of the effectiveness of well development and can determine when development is no longer providing improvement.

9. In general, well development should proceed until the following criteria are met (note: certain regulatory agencies may have more stringent well development requirements):

   a. Water can enter as readily as hydraulic conditions allow.

   b. A representative sample can be collected.

      - In general, representative conditions can be assumed when the water is visibly clear of sediments (e.g., turbidity <10 NTU).
      - In addition to clear water, a further criterion for completed well development is that the other water quality parameters mentioned above stabilize to within 10 percent between readings over one well volume. During well development, pH, specific conductivity, DO, ORP, temperature and turbidity can additionally be monitored to establish natural conditions and evaluate whether the well has been completely developed.

   c. The duration, along with any measured water quality parameters (e.g. pH, temperature, specific conductivity, DO, ORP and turbidity) should be recorded on the Well Development Form.

      In some instances, collection of a sample with a turbidity of 10 NTU or less is difficult or unattainable. If a well does not provide a sediment-free sample, development can stop when all of the following conditions are met:

      - Several procedures have been tried,
      - Proper well construction has been verified,
      - Turbidity has stabilized within 10 percent over three successive well volumes, and
      - Specific conductivity and pH have stabilized over at least three successive well volumes.
        (It should be noted that pH, temperature, and specific conductivity may not stabilize if water quality has been degraded).

   d. The sediment thickness remaining in the well is less than 1 percent of the screen length or less than 0.1 foot for screens equal to or less than 10 feet.

   e. A minimum of three times the standing water volume in the well (to include the well screen, casing, plus saturated annulus, assuming 30 percent annular porosity) should be removed. If water was added as part of the well installation and development, attempts should be made to recover the volume of water added, plus the three well volumes.

10. Measure the total depth of the well, to determine the amount, if any, of sand/silt removed during development of the well.

11. Note the final water quality parameters in the field book or on the Well Development Form. The time between well development and sampling will depend on project objectives and regulatory requirements.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following Quality Assurance/Quality Control procedures apply:

- Operate field instruments according to the manufacturers' manuals.
- Calibrate field instruments at the proper frequency.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

- Record well development measurements on field forms or in a field book. See Attachment A for an example of a Well Development Form.
- The following additional information should be recorded on the field form or in a field book:
    - Well/piezometer or monitoring point identification number
    - Well/piezometer or monitoring point location (sketch of the sample point or reference to a location figure)
    - Date of well installation
    - Date(s) and time of well development
    - Static DTW before and after development
    - Quantity of water removed and initial and completion times
    - Quantity and source of water added to well to facilitate development, if applicable
    - Type and capacity of pump or bailer used
    - Description of well development techniques
    - Visual or sensory description (e.g., odors, product, etc.)
    - Time and date measurements were taken
    - Personnel performing the task
    - Weather conditions during task
    - Other pertinent observations
    - Measurement equipment used
    - Calibration procedures used
    - Decontamination procedures used

6.0 REFERENCES

U.S. EPA *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001. December 1987.

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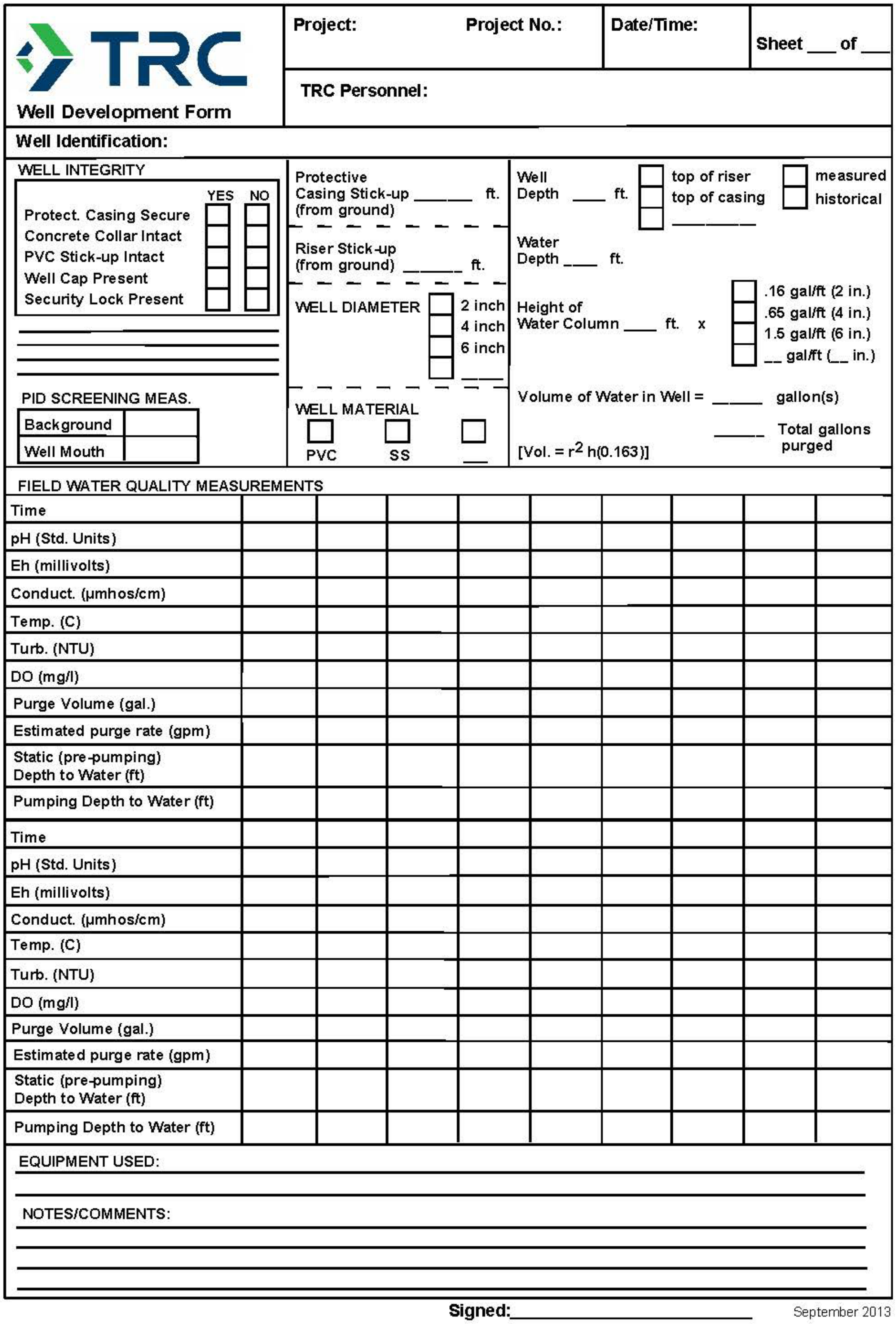
7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	OCTOBER 2013	NOT APPLICABLE
1	AUGUST 2017	ADDED ATTACHMENT C TO ACCOMMODATE MODIFICATIONS REQUIRED WHEN DEVELOPING WELLS WHICH WILL BE SAMPLED FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING

ATTACHMENT A

EXAMPLE WELL DEVELOPMENT FORM



Well Development Form

Project: **Project No.:** **Date/Time:** **Sheet ___ of ___**

TRC Personnel:

Well Identification:

WELL INTEGRITY

	YES	NO
Protect. Casing Secure	☐	☐
Concrete Collar Intact	☐	☐
PVC Stick-up Intact	☐	☐
Well Cap Present	☐	☐
Security Lock Present	☐	☐

Protective Casing Stick-up (from ground) ______ ft.

Riser Stick-up (from ground) ______ ft.

WELL DIAMETER ☐ 2 inch ☐ 4 inch ☐ 6 inch ☐ ____

Well Depth ____ ft. ☐ top of riser ☐ top of casing ☐ ________ ☐ measured ☐ historical

Water Depth ____ ft.

Height of Water Column ____ ft. x ☐ .16 gal/ft (2 in.) ☐ .65 gal/ft (4 in.) ☐ 1.5 gal/ft (6 in.) ☐ __ gal/ft (__ in.)

PID SCREENING MEAS.

Background	
Well Mouth	

WELL MATERIAL ☐ PVC ☐ SS ☐ __

Volume of Water in Well = _____ gallon(s)

_____ Total gallons purged

[Vol. = r^2 h(0.163)]

FIELD WATER QUALITY MEASUREMENTS

Time									
pH (Std. Units)									
Eh (millivolts)									
Conduct. (µmhos/cm)									
Temp. (C)									
Turb. (NTU)									
DO (mg/l)									
Purge Volume (gal.)									
Estimated purge rate (gpm)									
Static (pre-pumping) Depth to Water (ft)									
Pumping Depth to Water (ft)									
Time									
pH (Std. Units)									
Eh (millivolts)									
Conduct. (µmhos/cm)									
Temp. (C)									
Turb. (NTU)									
DO (mg/l)									
Purge Volume (gal.)									
Estimated purge rate (gpm)									
Static (pre-pumping) Depth to Water (ft)									
Pumping Depth to Water (ft)									

EQUIPMENT USED:

NOTES/COMMENTS:

Signed:________________________

September 2013

ATTACHMENT B

SOP FACT SHEET

WELL DEVELOPMENT

PURPOSE AND OBJECTIVE

Well development is completed to (1) evacuate any water added during the drilling of wells, (2) establish a good hydraulic connection between the well and the surrounding water-bearing zone, (3) settle the sand pack and formation following the disruptive drilling and installation activities, (4) alleviate clogging, smearing or compaction of formation materials at the borehole wall due to the drilling process, and (5) remove fine particles (e.g., silt or clay) from the water column and sand pack in order to obtain groundwater samples that are representative of the water-bearing zone in which the well is installed and/or enhance groundwater extraction and injection rates. State and federal requirements may be above and beyond the scope of this SOP and should be followed, if applicable.

WHAT TO BRING

- Field book or field forms
- Well keys, socket wrench, and device to remove standing water from flush-mount manholes.
- Water level meter and extra batteries
- Water quality meters, including turbidity meter
- Decontaminated pump, control box, power source (i.e., battery, generator, etc.)
- Tubing
- Bailer and cord
- Surge block
- Equipment decontamination supplies
- Indelible marking pens or markers
- Means of containerizing purge water

OFFICE

- Prepare/update the HASP; make sure the field team is familiar with the latest version.
- Review the work plan with the Project Manager and/or the field lead.
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure, test equipment and make sure it is in proper working order.

ON-SITE

- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities, pedestrian traffic etc.)
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.

GENERAL DEVELOPMENT PROCEDURES

- Well development will be completed on wells after the grout, annular seals, and protective casings are deemed sufficiently stable (i.e., 24 to 48 hours after installation) for the development method being utilized and/or after required regulatory agency timeframe requirements.
- Measure the static water level and total depth of the well using ECR SOP 004, and determine the amount of standing water in the well (well volume). Calculate volume of water in one well volume.
- Using the appropriate length of dedicated or decontaminated hosing/tubing and the selected pumping apparatus, insert the equipment into the well.
- Initiate water removal from the well and record the initial field water quality measurements including pH, temperature, conductivity, DO, ORP and turbidity (as required by project specifications) in the field book or on the Well Development Form. Record any odors, water color/clarity, changes in air monitoring results or other observations in the field book or on the Well Development Form.
- Well development procedures may include surging, overpumping, bailing, and jetting.
- Continue well development procedures until criteria have been met (e.g., turbidity <10 NTU, stabilization of water quality parameters, sediment thickness remaining in well is less than 1 percent of screen length) and a minimum of three times the standing water volume in the well has been removed.

WATER DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

ATTACHMENT C

SOP MODIFICATIONS FOR PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when developing wells where PFAS may be sampled. The following table highlights the required modifications to this SOP when sampling for PFAS.

Well Development Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® or low density polyethylene (LDPE)[1] during well development. This includes bailers, tubing, bailer cord/wire, waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. • High density polyethylene (HDPE) or silicone tubing should be used in lieu of Teflon® or Teflon®-lined tubing. • Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-It Notes during sample handling or mobilization/demobilization. • Do not use potable water for decontamination. Use deionized, distilled or organic-free water. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to procedures: • Tyvek® suits should not be worn during well development prior to conducting PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. PFAS-free rain gear (ponchos and umbrellas) that could be used during sampling can be purchased at IKEA stores. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (*e.g.*, Gatorade®) may be consumed in the staging area only. • Personnel involved with well development should wear powderless nitrile gloves at all times while handling tubing or equipment. Avoid handling unnecessary items with powderless nitrile gloves. A new pair of gloves must be donned prior to developing each well.

Well Development Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
	• Wash hands with Alconox® or Liquinox® and deionized water after leaving vehicle before setting up at a well development location.
1.6	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work. • Avoid using sunscreens or insect repellants that are not natural or chemical free.

Notes:

[1] – PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces and, in the case of LDPE tubing, to allow for less turbulent flow along the surface of the tubing.

09
Test Pit Installation

Title: **Test Pit Investigations**	Procedure Number: **ECR 012**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures			
		Elizabeth Denly	
Technical Reviewer James Peronto	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for completing and logging test pits during field investigations at hazardous and non-hazardous waste sites.

1.2 Summary of Method

The objective of a test pit investigation is to observe and document subsurface conditions in an area of interest to the project. This SOP presents typical test pit logging procedures; however, implementation may vary based upon project-specific needs.

Typically, heavy equipment (e.g., excavator or backhoe) is utilized to remove soil or material in designated cuts or layers, creating a rectangular surface area test pit. The test pit is usually a narrow excavation (relative to its width) made below ground surface. The total depth and width of the test pit vary based on project objectives. Personnel gather various data from the test pit without entering the excavation, unless appropriate engineering/safety controls are implemented. The test pit is then properly backfilled and closed. Closure may include replacement of excavated soils, installation of appropriately characterized backfill, compaction, and restoration of surface conditions (e.g., paving) based on site-specific conditions and work plan-specific requirements.

A test pit investigation is typically conducted for the following reasons:

- Documenting and observing subsurface conditions and lithology;
- Confirming depth to bedrock;
- Obtaining sidewall or excavation floor soil/material samples;
- Identifying the vertical and horizontal extent of soil contamination or non-native fill material below ground surface;
- Conducting percolation tests;
- Conducting soil density tests;
- Identifying preferential pathways below ground surface;
- Investigating historical structures (e.g., suspect or former underground storage tanks); and
- Investigating anomalous results of geophysical surveys completed at the surface.

1.3 Equipment

The following list of equipment includes the items that may be used by TRC personnel during the excavation of test pits. Subcontractor personnel typically provide and operate all excavation and other construction-related equipment. Project-specific conditions or requirements may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Test pit sampling plan
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags

- Caution or danger flagging tape
- Measuring tape with weight (0.1-foot increments)
- Pocket penetrometer
- Applicable air monitoring equipment, such as photoionization detector (PID) or flame ionization detector (FID), as specified in the HASP
- Field book
- Test pit log sheets
- Camera
- Calculator
- Polyethylene sheeting (may be provided by contractor)
- Sample container labels
- Chain-of-custody (COC) forms (TRC or laboratory, as appropriate)
- See soil sampling supplies from ECR SOP 003, Soil Sampling
- See soil description supplies from ECR SOP 005, Visual-Manual Procedure for Soil Description and Identification
- See equipment decontamination supplies from ECR SOP 010, Equipment Decontamination
- Indelible marking pens or markers
- Organic absorbent (e.g., Slikwik®, ground corn cob, sawdust)
- Sample coolers
- Ice (for sample storage/preservation)
- Zip-loc® plastic bags (for ice and COC forms)
- Survey equipment and/or global positioning system (GPS) and/or other means of establishing test pit and/or sample locations

1.4 Definitions

Spoils Pile	(a.k.a. stockpile): Soil or other material removed from an excavation and temporarily stored on site during an investigation.
Swing Radius	The area that can be reached as a piece of earth-moving equipment (e.g., excavator) swings its extension arm and bucket around 360 degrees as the base remains stationary.
Test Pit	A typically shallow excavation performed to observe and document subsurface conditions in an area of interest.

1.5 Health & Safety Considerations

Any test pit can present physical dangers, such as difficult entry and exit; slip, trip, and fall hazards; and the possibility of cave-ins, which could trap and suffocate workers. At contaminated sites, chemical hazards may also cause low-lying areas, such as a test pit, to collect high-density gases and vapors.

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Specifically, test pits require additional safety precautions that are related to heavy equipment operation, excavation safety, and hazardous atmospheres. These safety precautions should be listed within the site-specific HASP and comply with Occupational Safety and Health Administration (OSHA) guidance on trenching and excavations (29 CFR Part 1926 Subpart P). TRC personnel must read and understand the site-specific HASP prior to implementing this SOP.

General Test Pit Safety Rules:

- Keep heavy equipment away from test pit edges.
- Identify other sources that might affect test pit stability.
- Keep excavated soil (spoils) and other materials at least 2 feet from test pit edges.
- Conduct a utility clearance before digging.
- Test for atmospheric hazards, such as low oxygen, hazardous fumes, and toxic gases when >4 feet deep.
- Inspect test pits at the start of each shift.
- Inspect test pits following a rainstorm or other water intrusion event.
- Do not work under suspended or raised loads and materials.
- Inspect test pits after any occurrence that could have changed conditions in the test pit.
- Ensure that personnel wear high-visibility or other suitable clothing when exposed to vehicular traffic.
- Maintain eye contact with the excavator operator so that they know where you are at all times. If you want to approach the excavator or test pit, signal the operator first and ensure the equipment is stopped before you approach.
- Watch for tell-tale signs of instability in the test pit (e.g., cracks, sloughing, inflow of water). Do not approach the crest of the pit if instability is perceived. Also note that soil can and will fail beneath asphalt, so take extra care when excavating through paved surfaces.
- Mark the location of the test pit with orange cones or flagging to alert others of the presence of the test pit.
- Backfill the test pit as soon as possible once the investigation is done. Do not allow the test pit to remain open.

Refer to ECR SOP 003, Soil Sampling for details on health and safety issues related to soil sampling.

1.6 Cautions and Potential Problems

The following is a list of problems that may arise during a test pit investigation:

- Cave-in (Sidewall Collapse)

The primary hazard during test pit completion is injury from a cave-in. Evaluation of soil physical properties is important and should be conducted as much as practical before test-pitting commences (e.g., through analysis of available soil maps or previously installed boreholes) and as much as practical while the test pit advances in depth to determine appropriate sloping, benching, and shoring in order to mitigate potential sidewall cave-in. Field personnel can fall into the test pit by standing too close to the edge of the excavation during the cave-in. Essential personnel should stand a minimum of 2 feet from the edge of the test pit and should not stand between the spoils pile and the edge of the test pit.

At no time will TRC personnel enter a test pit that is ≥4 feet deep to gather data, unless appropriate engineering/safety controls are implemented. Test pits that are ≥4 feet deep require provision of safe access and egress, such as ladders, steps, or ramps, to all workers. Such devices must be located within 25 feet of all workers. Test pits ≥5 feet deep require the use of a protective system, unless the excavation is made entirely in stable rock. **At no time will TRC personnel enter an unprotected test pit that is ≥5 feet deep or a test pit in which water has accumulated.**

- <u>Communication</u>

Due to the excessive noise emitted from heavy machinery (e.g., backhoe/excavator, water truck, etc.), it is advised that the use of hand signals be established between TRC personnel and the equipment operator/subcontractors before conducting any equipment movement or operation. Furthermore, TRC personnel need to maintain eye contact with the equipment operator(s) and awareness of equipment movement, and remain outside of the equipment swing radius and/or outrigger radius at all times during operation. At no time will TRC personnel be allowed to work under raised loads or equipment (e.g., buckets, booms, outriggers, cables, shackles, steel plates, etc.).

Additionally, personnel should wear Department of Transportation (DOT)-approved safety vests or other suitable garments with reflective/high-visibility materials. When test-pitting activities need to take place adjacent to or within public roadways, it may be necessary to arrange for a designated, trained flag person with signs and barricades.

- <u>Airborne contaminants and particulates</u>

During test pit investigations, hazardous soil vapor and/or particulate matter may become airborne. Appropriate dust and vapor suppression controls shall be implemented during excavation and material placement. Consult the site-specific HASP and local regulatory agency requirements for air monitoring and respiratory requirements. Consult the site-specific work plan and/or Project Manager to determine whether any in-field notifications to nearby property owners may be required.

- <u>Collection of soil samples</u>

Due to safety precautions, direct collection of soil samples from the sidewalls and floor of the test pit may not be possible. Therefore, soil sampling activities during the test pit investigation often may employ unique soil sample collection methodologies. Typically, this requires the use of the backhoe or excavator bucket for retrieval of the samples from the desired location. Care should be exercised during sample collection from the equipment bucket due to the presence of heavy machinery. It is advised that TRC personnel ensure the sample material does not become disturbed while the bucket is being lifted to the ground surface from the test pit prior to sample collection. Avoid collecting a sample that was in direct contact with the backhoe bucket or other machinery. Further discussion of these methodologies is presented below in Section 2.0.

- Potentially hazardous buried objects/materials

Watch carefully for buried objects/materials, especially materials that may pose a safety hazard. If buried containers potentially containing liquids (e.g., drums, carboys, or tanks) are encountered, cease excavation and notify the Project Manager.

- Utilities

The first step in any site excavation/test-pitting program is to notify the public utility locating service for the respective city or state. Advance notifications must be given in accordance with public locating service requirements (e.g., 72 hours in advance). Prior to notification, areas requested to be surveyed and marked by the utility locating service must be clearly identified/marked in the field by TRC in accordance with any pre mark-out requirements (e.g., correct spray paint color [white] and appropriate words [e.g., Dig Safe, Call Before You Dig (CBYD)]). The call to the utility locating service will set in motion the mark-out process, whereby documented underground utilities are marked, if any exist. For test pit programs on private properties in urban settings or locations having prior development, third-party utility locating services must be hired to locate and mark buried utilities not located in public right-of-ways that are marked out by public utility locating services.

Nonetheless, as noted below, caution should be exercised during any excavation in case utilities at the location were not identified and marked. Notify the utility locating services early in the design phase to aid in siting test pits to avoid known utilities in advance and to help minimize potential in-field adjustments. Note that another follow-up utility locating service notification may then be required prior to test pit excavation activities depending upon the advance notification requirements (e.g., no more than 10 days in advance). Take note of overhead utilities and work clear of them to avoid electric shock, injury, and property damage. Overhead power lines are a major concern and must be avoided or de-energized. Even without direct contact, electricity can arc from the power lines to another object.

Before beginning the test pit excavation, walk the site and identify potential locations for investigation and utilities. Do not just rely on the utility locating service and their associated mark-out. Actively look for evidence of underground services (e.g., service boxes, plugs, exposed pipes, trenches, etc.), locate the test pits accordingly, and remain cognizant of utilities during the performance of the work. If there is evidence of a potential buried utility with no visible mark-out, the location should be avoided until surveyed by a third-party utility locating service or the suspect buried utility is confirmed absent or deactivated by other means.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- OSHA 8-hour Health and Safety Training for HAZWOPER supervisors
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

It is strongly advised that TRC coordinate with the test pit contractor prior to on-site mobilization to ensure the chosen equipment will meet the test pit depth requirements.

The following procedures should be used during the implementation of test pit investigation activities. Always refer to the site-specific work plan and/or scope of work for any site-specific sampling procedures. Procedures may vary depending on the activities being performed, type of equipment used, excavation requirements, sampling strategy and contaminants present at the site. Site-specific conditions may warrant the use of air monitoring, PPE and access restrictions; these will be defined in the site-specific HASP.

2.1 Preparation

The following items should be considered during preparation of test pit activity.

- The scope of the investigation, objectives, potential contaminants, spoils pile segregation, soil management plan, and HASP (as applicable) should be reviewed with all subcontractor personnel prior to initiation of the test pit investigation.
- All intended hand signals to be used during the excavation should be reviewed and understood between the TRC personnel directing the operation and the equipment operator(s).
- Prior to penetrating the ground surface, TRC personnel shall ensure that proper utility clearances have been performed by the appropriate responsible party(s). No work shall commence if the proper utility clearance has not been authorized.
- Typically, one individual will be designated to direct the operator; make observations and complete a written field log; conduct work area, excavation or continuous air monitoring; and be responsible for record-keeping, photography, sample collection, storage and documentation. Alternately, two personnel can perform these tasks depending on the objective, complexity and duration of the test pit investigation.
- It is a good practice to also photo document the site conditions prior to excavation activities.
- All safety monitoring equipment (e.g., PID, dust meter) will be operational and pre-calibrated prior to the first test pit. Refer to the equipment manufacturer documentation for proper calibration procedures.
- Specific provisions for segregation and stockpiling of waste materials that might be encountered/excavated should also be taken into account in the site-specific work plan (see Section 3.0 below).

2.2 Test Pit Investigation

1. The location and estimated total depth(s) of the test pit(s) should be identified in the site-specific work plan.

2. If subsurface utility line locations were identified at or nearby the location prior to test-pitting, then TRC personnel should inform the excavation equipment operator/subcontractor of the locations and instruct them to excavate with extreme caution. If there is a suspect or known buried utility at the location where the test pit is to be completed and the test pit location cannot be moved, the utility should first be deactivated, if possible. In addition, excavation using an excavator bucket at the location should be minimized or avoided until the

utility is uncovered and located by hand digging with a shovel. In most instances, it may be prudent to have a utility representative on site to help identify underground utilities at or in close proximity to planned test pit locations, especially if assistance is required to more accurately locate and/or deactivate the utility.

3. If required, erosion controls (e.g., silt socks, silt fencing, hay bales) will be installed around the test pit to prevent surface runoff from contaminating adjacent surface soils. Initiate the excavation in appropriate lifts as directed in the site-specific work plan. Record observations as the test pit is advanced. Test pits are typically advanced in a linear fashion and are rectangular in shape.

    - Excavated soil/material should be placed an appropriate distance away from the edge of the test pit to minimize potential collapse of a sidewall; for safety purposes excavated soil/material should never be placed closer than 2 feet from the edge of the test pit.
    - If contamination is anticipated or encountered, TRC personnel should have the contractor position polyethylene sheeting (at least 6 mil) next to the test pit on which to place excavated soils to prevent cross-contamination of adjacent surface soils, pavement or otherwise covered surface. For safety reasons, TRC personnel observing spoil piles should not stand between the stockpiled soil/material and the test pit.
    - Excavation activities and observations should be recorded in the field book or on a Test Pit Log, which is provided in Attachment A.

4. The rationale for soil sample collection locations and methods within the test pit, if any, should be pre-determined in the site-specific work plan. In many cases, soil/material will be brought to the surface in the equipment bucket for soil/material sampling. When this is performed, the TRC field personnel typically direct the equipment operator to the desired sidewall or excavation floor location to collect the sample using the equipment bucket. Once the equipment bucket is lifted to the ground surface, TRC personnel shall instruct the operator to place the bucket on the ground surface and turn off the equipment motor.

    - It may be advisable to remove the upper surface (approximately 3 to 6 inches or more) of recovered materials to obtain undisturbed material from the equipment bucket (as opposed to the materials from the sidewall that were exposed to the atmosphere while the test pit was being advanced).
    - It is further advised that TRC personnel ensure the sample material does not become disturbed while the bucket is being lifted to the ground surface from the test pit prior to sample collection.
    - Avoid collecting a sample that was in direct contact with the backhoe bucket or other machinery.
    - Soil samples collected for volatile organic compound (VOC) analysis should be collected prior to completing a stratigraphic description in order to minimize the time the test pit sidewall or floor is exposed to the atmosphere and volatilization. Soil samples for other chemical analyses should be collected as soon as possible upon exhumation in order to minimize the time soil samples are exposed to the atmosphere.
    - See ECR SOP 003, Soil Sampling for specific soil sampling techniques.

5. Typical observations and sample collection information documented in the field is presented in Section 5.0. Such information is typically documented in a Test Pit Log or the field book. Example Test Pit Logs are provided in Attachment A.

2.3 Closure of the Test Pit

1. Backfill and return the excavated area to match the original grade. TRC personnel should instruct the operator/subcontractor to backfill the excavated soil/material at approximately the same depth within the test pit that they were removed. Instruct the operator/subcontractor to compact the backfilled soil in lifts and to not leave surface depressions, holes, debris or other trip hazards at completion. Refer to the site-specific work plan, if applicable, for potential alternate closure requirements (e.g., compaction requirements, flowable fill) and whether excavated spoils observed to have signs of potential contamination (e.g., staining, odors, PID readings) should not be used for backfill.

2. Stake, label, flag and/or collect GPS coordinates or distance measurements to nearby physical reference points of the test pit center and pertinent features for future reference, reporting and/or surveying.

3. If segregation of contaminated soil and/or wastes has occurred, the disposition of these materials should be in accordance with the site-specific work plan. This will result in a deficit of fill material. Fill material utilized to replace this deficit must be in accordance with the site-specific work plan.

4. As specified in the site-specific work plan, return the surface conditions to pre-excavation conditions (e.g., loaming, seeding, mulching, paving) if required.

5. As specified in the site-specific work plan, erosion and sedimentation structures utilized must remain in place until the surface area has been stabilized (e.g., seed germination and plant growth to maturity, pavement replaced).

6. Documentation of site conditions upon demobilization from the site should be noted in the field book. High visibility fencing, barricades, and/or caution tape are mandatory for any excavation left unattended or open overnight. Photographs of the area are also recommended prior to field staff departure.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum or roll-off bin, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of specific field quality control (QC) samples will be specified in the project-specific planning documents and may include one or more of the following samples: equipment blank, trip blank, field duplicate, and matrix spike/matrix spike duplicates (MS/MSDs). Refer to ECR SOP 003, Soil Sampling for quality assurance (QA)/QC procedures associated with soil sample collection.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record the general sample collection information, such as location, identification, and date/time in the field book or on a Test Pit Log (See Attachment A for examples). Unless prescribed in the site-specific work plan or if different from the site-specific work plan, typical field documentation recorded on a Test Pit Log or in the field book includes the following information:

- Name of TRC and subcontractor personnel;
- Weather during test pit activity;
- Field screening results of soil and ambient conditions (e.g., VOCs, dust) in accordance with the site-specific work plan and HASP, as applicable;
- Visual signs of contamination, staining, petroleum or other odors, buried containers, or potential migration pathways;
- The depth and lateral position in the test pit of any subsurface samples collected (laboratory or geotechnical);
- GPS coordinates (X and Y) of the test pit location and coordinate system, if known,
- Ground surface or top of pit elevation of test pit; if known;
- Type of equipment used for excavation of test pit;
- The soil lithology - the depth to observed soil layers and the soil composition per ECR SOP 005, Visual-Manual Procedure for Soil Description and Identification;
- The depth to the groundwater table, if encountered;
- The presence of any immiscible (floating) layers or sheens in groundwater;
- Any aqueous samples that were collected and how aqueous samples were collected;
- Sample identification number(s);
- Field duplicate location;
- Sample location (description or sketch of the sample point);
- Sample depth interval(s);
- The dimensions of the test pit at completion;
- Distance measurements of test pit location to nearby physical reference points; and
- Photographs of the test pit sidewalls and bottom and any observed features of interest should be taken and recorded in the field book or on a Test Pit Log. Be certain to note the date, time, orientation of the photo and the direction that the photographer was facing (e.g., Photo #1 taken facing North). Be mindful of light conditions, such that inner test pit characteristics are not hidden or poorly visible in the final photographs.

Affix a properly completed label to each sample container.

All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the record management procedures specified in the site-specific work plan must be approved by the Project Manager and documented in the field book.

6.0 REFERENCES

A Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

ECR SOP 003, *Soil Sampling*, Revision 1, January 2020.

ECR SOP 005, *Visual-Manual Procedure for Soil Description and Identification*, Revision 1, January 2020.

ECR SOP 010, *Equipment Decontamination*, Revision 1, January 2020.

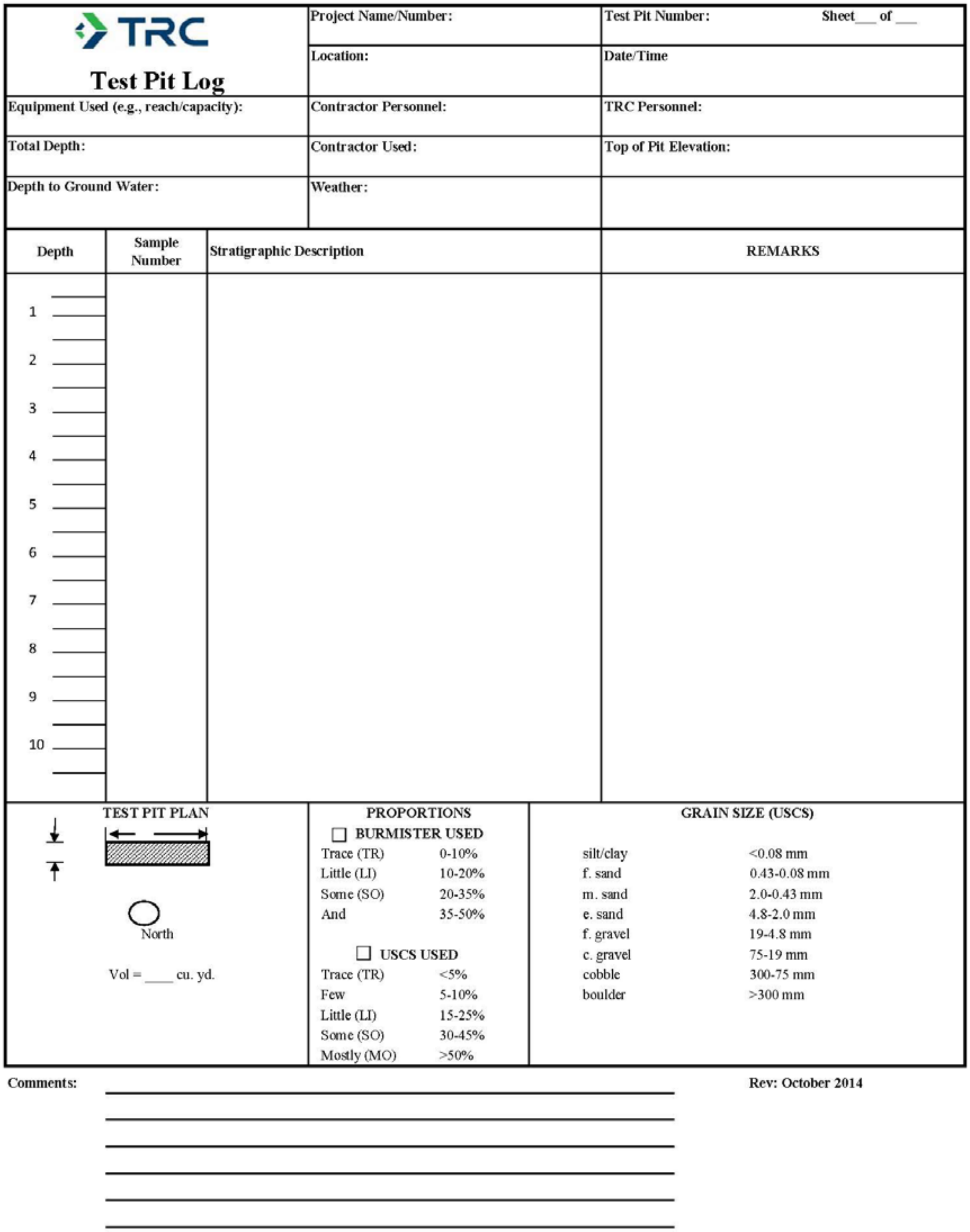
US Department of Labor, Occupational Safety and Health Administration, 29 CFR Part 1926.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	NOVEMBER 2014	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Attachment A

Example Test Pit Logs



TRC **Test Pit Log**	**Project Name/Number:**	**Test Pit Number:** **Sheet___ of ___**
	Location:	**Date/Time**
Equipment Used (e.g., reach/capacity):	**Contractor Personnel:**	**TRC Personnel:**
Total Depth:	**Contractor Used:**	**Top of Pit Elevation:**
Depth to Ground Water:	**Weather:**	

Depth	Sample Number	Stratigraphic Description	REMARKS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

TEST PIT PLAN

North

Vol = ____ cu. yd.

PROPORTIONS

☐ **BURMISTER USED**

Trace (TR)	0-10%
Little (LI)	10-20%
Some (SO)	20-35%
And	35-50%

☐ **USCS USED**

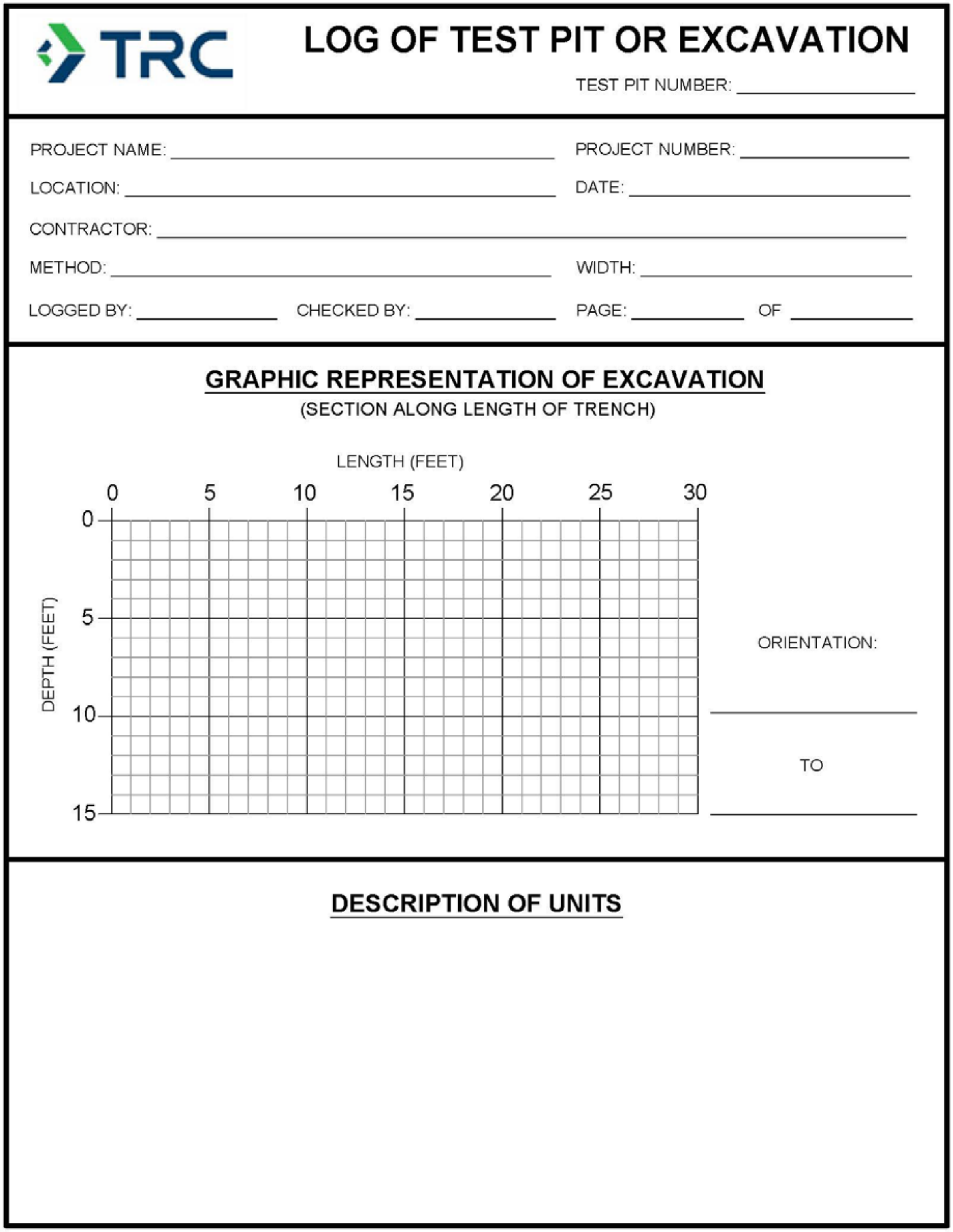
Trace (TR)	<5%
Few	5-10%
Little (LI)	15-25%
Some (SO)	30-45%
Mostly (MO)	>50%

GRAIN SIZE (USCS)

silt/clay	<0.08 mm
f. sand	0.43-0.08 mm
m. sand	2.0-0.43 mm
c. sand	4.8-2.0 mm
f. gravel	19-4.8 mm
c. gravel	75-19 mm
cobble	300-75 mm
boulder	>300 mm

Comments:

Rev: October 2014



LOG OF TEST PIT OR EXCAVATION

TEST PIT NUMBER: ____________

PROJECT NAME: ____________ PROJECT NUMBER: ____________

LOCATION: ____________ DATE: ____________

CONTRACTOR: ____________

METHOD: ____________ WIDTH: ____________

LOGGED BY: ____________ CHECKED BY: ____________ PAGE: ________ OF ________

GRAPHIC REPRESENTATION OF EXCAVATION

(SECTION ALONG LENGTH OF TRENCH)

ORIENTATION: ____________

TO ____________

DESCRIPTION OF UNITS

Attachment B

SOP Fact Sheet

TEST PIT INVESTIGATIONS

PURPOSE AND OBJECTIVE

The objective of completing test pits is to observe and document subsurface conditions in an area of interest to the project.

Typically, heavy equipment (e.g., excavator or backhoe) is utilized to remove soil in designated lifts creating a test pit. This test pit is usually a narrow excavation (relative to its width) made below ground surface. Personnel gather various data from the test pit without entering the excavation unless appropriate engineering/safety controls are implemented. The test pit is then properly backfilled and closed.

The field team is responsible for the accurate and uniform collection of soil samples and for completing consistent, accurate, and uniform lithologic descriptions.

WHAT TO BRING

- Field book
- Test pit log sheets
- Map/site plan
- Indelible marking pens or markers
- Personal protective equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags
- Caution tape
- Measuring tape with weight (0.1 foot increments)
- Applicable air monitoring equipment (per the HASP)
- Camera
- Polyethylene sheeting (unless supplied by contractor)
- Sample container labels
- Chain of custody (COC) forms
- Soil sampling supplies
- Equipment decontamination supplies
- Sample coolers
- Ice (for sample storage/preservation)
- Zip-loc® plastic bags (for ice and COCs)
- Trash bag
- Survey equipment and/or GPS (means of establishing sample locations)

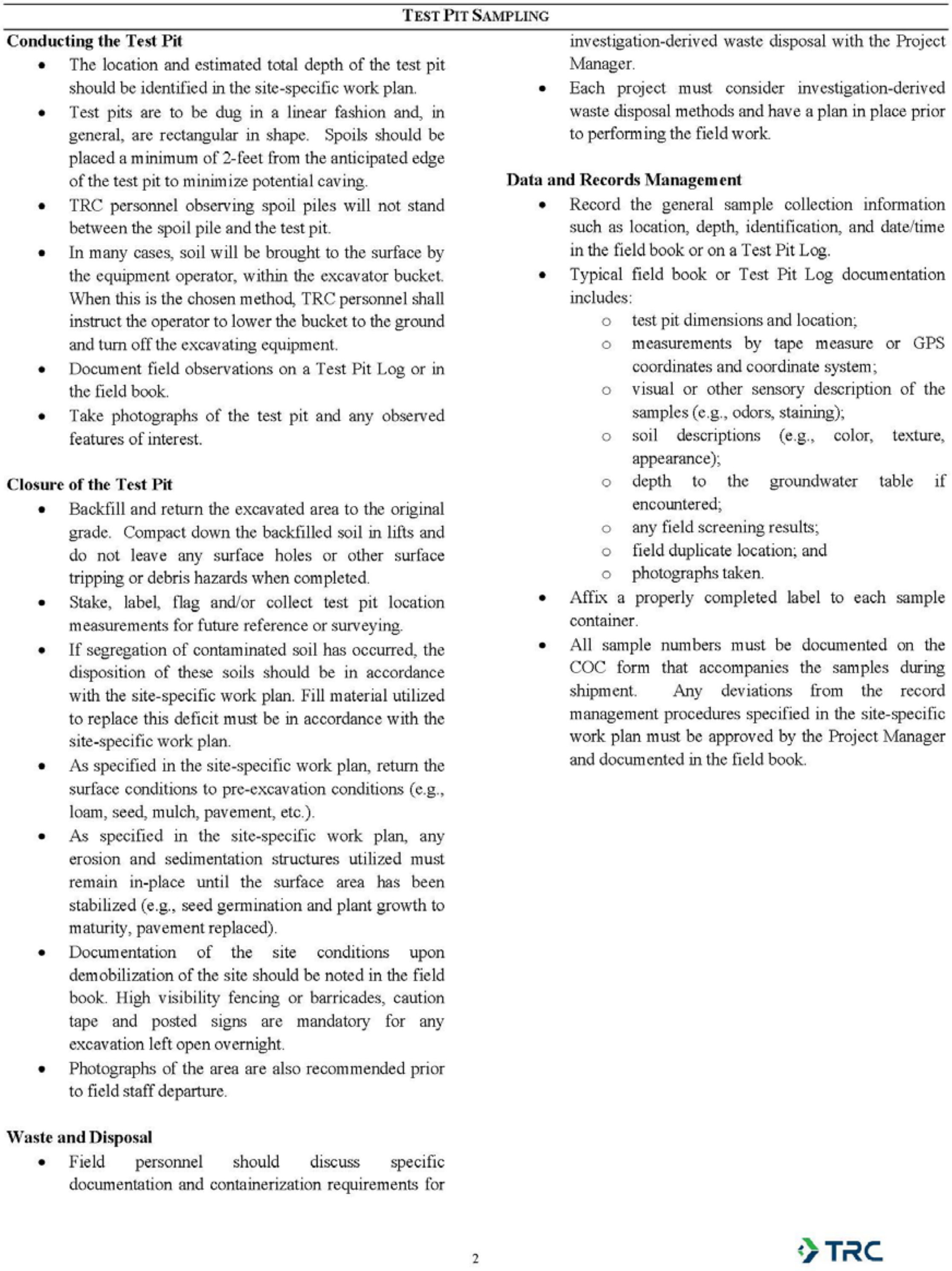
OFFICE

- Prepare/update the project HASP; make sure the field team and field contractors have been provided the latest version.
- Review project-specific work plan for sampling and analytical procedures.
- Verify with the contractor that proper utility clearances/mark-outs have been completed at planned test pit locations.
- Determine if private utility survey/mark out is required for private property not included in public utility clearance.
- Discuss the objectives for the sampling program with the Project Manager and/or the field team leader.
- Discuss test pit order, sample collection method, designation, analytical parameters, turn-around times, laboratory, etc.
- Discuss field decontamination procedures and collection of investigation derived wastes.
- Review spoils pile segregation and stockpiling.
- Notify contractor of any heavy equipment decontamination responsibilities (e.g., power washer, drums, kiddie pool).
- Confirm that all necessary sampling and monitoring equipment is available in-house or has been ordered.
- Review sample bottle order for accuracy and completeness and submit to laboratory.

ON-SITE

- Verify that underground utilities have been marked out and that the mark-outs are clear. Sketch and photograph mark out buried utility locations.
- Identify if any overhead utilities, obstructions or limited access areas exist near proposed test pits and contact the Project Manager if any proposed locations need to be moved.
- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Establish a designated heavy equipment decontamination area, as needed.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities and pedestrian traffic, etc.)
- All intended hand signals to be used during the excavation should be reviewed and understood between the TRC personnel directing the operation and the equipment operator(s).
- Calibrate any field monitoring equipment.

1



TEST PIT SAMPLING

Conducting the Test Pit

- The location and estimated total depth of the test pit should be identified in the site-specific work plan.
- Test pits are to be dug in a linear fashion and, in general, are rectangular in shape. Spoils should be placed a minimum of 2-feet from the anticipated edge of the test pit to minimize potential caving.
- TRC personnel observing spoil piles will not stand between the spoil pile and the test pit.
- In many cases, soil will be brought to the surface by the equipment operator, within the excavator bucket. When this is the chosen method, TRC personnel shall instruct the operator to lower the bucket to the ground and turn off the excavating equipment.
- Document field observations on a Test Pit Log or in the field book.
- Take photographs of the test pit and any observed features of interest.

Closure of the Test Pit

- Backfill and return the excavated area to the original grade. Compact down the backfilled soil in lifts and do not leave any surface holes or other surface tripping or debris hazards when completed.
- Stake, label, flag and/or collect test pit location measurements for future reference or surveying.
- If segregation of contaminated soil has occurred, the disposition of these soils should be in accordance with the site-specific work plan. Fill material utilized to replace this deficit must be in accordance with the site-specific work plan.
- As specified in the site-specific work plan, return the surface conditions to pre-excavation conditions (e.g., loam, seed, mulch, pavement, etc.).
- As specified in the site-specific work plan, any erosion and sedimentation structures utilized must remain in-place until the surface area has been stabilized (e.g., seed germination and plant growth to maturity, pavement replaced).
- Documentation of the site conditions upon demobilization of the site should be noted in the field book. High visibility fencing or barricades, caution tape and posted signs are mandatory for any excavation left open overnight.
- Photographs of the area are also recommended prior to field staff departure.

Waste and Disposal

- Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.
- Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work.

Data and Records Management

- Record the general sample collection information such as location, depth, identification, and date/time in the field book or on a Test Pit Log.
- Typical field book or Test Pit Log documentation includes:
    - test pit dimensions and location;
    - measurements by tape measure or GPS coordinates and coordinate system;
    - visual or other sensory description of the samples (e.g., odors, staining);
    - soil descriptions (e.g., color, texture, appearance);
    - depth to the groundwater table if encountered;
    - any field screening results;
    - field duplicate location; and
    - photographs taken.
- Affix a properly completed label to each sample container.
- All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the record management procedures specified in the site-specific work plan must be approved by the Project Manager and documented in the field book.

2

10
Slug Test Procedures

Title: **Slug Test Procedures**	Procedure Number: **ECR 029**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Jeff Hansen		David Hay	
Jeff Hansen Principal Author	Date 1/1/20	David Hay Contributing Author	Date 1/1/20
Nidal		Elizabeth Denly	
Nidal Rabah Technical Reviewer	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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1.0 INTRODUCTION

1.1 Scope and Applicability

The objective of this Standard Operating Procedure (SOP) is to specify the methodologies and techniques for performing slug tests to estimate local aquifer properties. The parameters obtained from a slug test analysis represent the saturated medium in the immediate vicinity of the well screen due to the limited volume of the displaced groundwater and the heterogeneity of geologic media.

1.2 Summary of Method

Slug tests are performed by near-instantaneous raising or lowering the water level in a well, then measuring the change in water level with time as it rebounds to the static water level. The most common and preferred method for initiating a slug test is to rapidly introduce or remove a solid object to/from the well. In low permeability media, it is possible to measure the change in water level using an electronic water level indicator. However, it is preferable to use a pressure transducer and a data logger during slug tests for frequent water level measurements, particularly during the early part of the test when the rate of water level rebound is greatest. These early time data are essential for differentiating filter pack drainage effects from aquifer response (*i.e.*, groundwater flow from or to the aquifer), which is required to calculate hydraulic conductivity.

Recorded measurements of transient water level rebound are analyzed for aquifer parameters using analytical solutions that account for well geometry (*i.e.*, well casing radius, borehole radius, and length of screen or open borehole), hydrogeologic boundary conditions (*e.g.*, aquitard thickness for leaky aquifers and block thickness/diameter in bedrock aquifers), and other hydrogeologic information (*e.g.*, water level displacement, initial static water column height, depth to the top of the screen below the top of the aquifer, and aquifer thickness). The solutions vary depending on the type of aquifer (confined or unconfined), boundary conditions, partial or full aquifer penetration, and the potential occurrence of wellbore skin and inertial effects. *The Design, Performance, and Analysis of Slug Tests* (Butler, 1998) is an essential reference for project managers, field personnel, and data analysts.

1.3 Equipment

The following equipment is generally needed for performing slug tests:

- Well keys and/or gate box key
- Hand tools, including socket set and safety knife
- Three- to five-inch long bolt to hang slug from the well head
- Health and safety monitoring equipment – consult health and safety plan (HASP)
- Trash bags
- Buckets (5-gallon capacity)
- Electronic water level meter and/or oil/water interface probe
- Gauge/Vented transducer and data logger. If a non-vented (absolute pressure) transducer is used, a barometer should be deployed during testing to assess barometric pressure effects.

Applying barometric pressure corrections prior to data analysis is especially important for slow rebounding water levels in low permeability media.

- Polyvinyl chloride (PVC) slugs (two different displacement volumes varying by a factor of two or more), or, for very high hydraulic conductivity media, an air-tight pneumatic well-head apparatus with compressed air or nitrogen gas supply, regulator, and appropriate fittings. Pneumatic well-head apparatus configurations may vary by manufacturer. The user should check with the manufacturer to determine specific types and diameters of fittings needed to connect the compressed gas supply to the well-head apparatus and to secure the apparatus to the well casing.
- If slug test is conducted by water removal
  - A bailer or a pump (and hoses, pipes, or tubes with necessary fittings)
  - Containers and check valves and gages
- Compressed air or nitrogen
- Duct tape
- 1/8-inch nylon rope or similar
- Polyethylene sheeting
- Laptop computer or tablet with appropriate software for downloading data
- Site documents: HASP, Field Sampling Plan (FSP), SOP, site plan, access agreements, etc.
- Test well construction data including diameter, depth, screen interval, etc.
- Field logbook, pen, permanent marker, data sheets, etc.
- Personal Protective Equipment (PPE) - see site-specific HASP
- Air monitoring equipment as required by the HASP (*e.g.*, photoionization detector (PID), flame ionization detector (FID), multi-gas meter, dust meter, etc.)
- Traffic control/warning equipment (cone, tape, etc.)
- Decontamination equipment (*e.g.*, Alconox®, Liquinox®, or equivalent, distilled water, paper towels, spray bottles, and brushes, as needed).

1.4 Definitions

Falling Head Test – A slug test which rapidly raises the water level in a well, followed by recording the transient water levels and times since initiation of the test until the level rebounds to or closely approaches the static water level.

Hydraulic Conductivity – A property of porous or fractured media that defines the rate of fluid flow through the media. In the English System of measurement, the typical units of hydraulic conductivity are gallons per day per square foot (gal/day/ft^2), or feet per day (ft/day). In the International System (SI), the units are meters per day (m/day) or centimeters per second (cm/sec).

Rising Head Test – A slug test which rapidly lowers the water level in a well, followed by recording the transient water levels and times since initiation of the test until the level rebounds to or closely approaches the static water level.

Slug – A solid object, volume of water, or pressurized air or nitrogen that induces a sudden change of head in a well. The change in water level may be induced by adding a known volume of water to a well (usually with a drop tube) or removing water using a bailer or pump, although techniques involving addition or removal of water should be avoided (Butler, 1998).

When a solid object is used to initiate the water level displacement, a slug is commonly a cylindrical object that can be submerged in the well water or withdrawn from the water to generate the displacement. The advantage of using a solid slug is the capability of properly conducting slug testing by performing a series of alternating rising and falling head tests. The solid slug is commonly constructed with an appropriate diameter and length of PVC pipe that is filled with clean sand and securely capped and sealed at both ends. An eye bolt is fastened to the top of the slug for attaching cotton twine or a rope (nylon or polypropylene) to enable lowering or raising the slug in the well. Natural fiber ropes may be treated with oil and should not be used. A slug should have the capability of generating an initial displacement of the water column in the test well ranging between 0.5 foot and 3 feet, depending upon the permeability of the medium (Cunningham, 2010). Water level displacements at the lower end of this range are preferable in low permeability media to minimize the rebound time, especially for conducting multiple tests in a well and testing multiple wells. Displacements toward the upper end of the range are generally better suited for higher permeability media, in which the rebound time is faster.

Well Skin – A finite thickness zone of altered natural permeability near the wellbore, which is classified as positive or negative according to whether the skin has lower or higher permeability than the natural medium. In the case of a positive skin, the medium near the wellbore has a decreased permeability, which may be the product of many factors, including drilling mud infiltration, fine sediments distributed along the borehole wall during drilling, or mineral precipitation. A negative skin occurs when the permeability immediately adjacent to the wellbore is enhanced by processes such as washing out natural fractures or solution cavities near the wellbore, hydraulic fracturing, or acid treatment during well development or rehabilitation.

2.0 PERSONNEL QUALIFICATIONS

Since this SOP will be implemented at sites or in work areas that may entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers and 8-hour annual HAZWOPER refresher training.
- OSHA 10-hour Construction Industry Outreach Training.
- Site-specific safety training.

2.1 *Health & Safety Considerations*

TRC personnel will be on site when implementing this SOP. TRC personnel will use appropriate PPE. The Project Manager, Office Safety Coordinator (OSC), TRC ECR Safety Manager, or TRC National Safety Director can address questions or safety concerns. Project-specific safety considerations should be documented in the project-specific work plan (or equivalent).

If the HASP indicates that groundwater in the wells may contain measurable levels of volatile organic compounds (VOCs), the wellheads should be screened using a PID or FID to assess the VOC vapor level and identify the necessary procedures. If monitoring results indicate elevated VOC concentrations in the well, the level of PPE may need to be increased in accordance with the HASP. Contact with non-aqueous phase liquid (NAPL), if present, should be avoided.

For safety and avoidance of error associated with fatigue, a work shift should be no longer than 12 hours. A minimum break time of 8 hours following a work shift is recommended.

3.0 PLANNING FOR SLUG TESTING

The planning stage for slug testing includes compiling well construction data (*i.e.*, well diameter, borehole diameter, screen length, total well depth) and hydrogeologic information (water levels and a description of the media screened by the wells). These data will be used to select and/or implement the appropriate equipment, including the transducer, the slug type and size, and the rope length for a solid slug. An initial estimate of the magnitude of hydraulic conductivity will assist in the choice of slug type and size based on expected duration of rebound and number of wells.

Information on well development and the age of the well should be reviewed to determine if additional development is warranted prior to testing. Well development is typically minimal at monitoring wells (Butler, 1998). If new wells are being installed, consider designing them to minimize the thickness of the filter pack annulus to limit filter pack drainage and the length of screen for efficiency of well development.

3.1 Cautions & Potential Problems

(a) Slug tests in wells constructed with 1) large annulus filter packs relative to the radius of the well casing and 2) filter packs extending several feet above the top of the well screen may produce water level rebound data that are significantly compromised by filter pack drainage. Careful evaluation of slug test data generated from these wells should be performed by a hydrogeologist or engineer experienced in slug test analysis to determine if the resulting aquifer parameters are consistent with the geologic medium.

(b) Transducers are rated for a range of pressures. When using a transducer, verify that the transducer is rated for the pressure head that will be encountered in the well during the test. For example, a transducer rated at 30 psi would be appropriate for use at depths of up to 69 feet below the static water level ([2.31 feet of water column/1 psi] * 30 psi = 69 feet). Note that when conducting slug tests, transducers need not be installed at depths greater than 10 feet below the base of the slug when fully immersed. Therefore, transducers rated for pressures of 10 to 20 psi are adequate.

(c) Prior to initiating the test, the transducer should be set a minimum of one foot above the bottom of the well, and the transducer cable shall be secured at the top of the well to prevent vertical movement of the transducer during the test. The transducer must also be located sufficiently below the bottom of the fully immersed solid slug, several feet if possible, to avoid producing dynamic pressure effects in the data.

(d) When using transducers and data loggers, data should be collected at an appropriate rate. A rapid rate is important in high permeability media, where water level rebound is rapid and filter pack drainage must be distinguished from aquifer discharge during data analysis.

(e) Solid slugs should have a diameter that does not impede the flow of water along the slug or into or out of the well.

(f) If a solid slug is used to initiate a test, ensure there is sufficient space for the slug and the transducer cable to avoid disturbing the transducer during insertion or withdrawal of the slug.

(g) Although not a recommended method of slug testing, if rising head tests are performed with a bailer, the bailer should be completely removed from the well.

(h) In order to obtain accurate aquifer parameters, wells must be adequately developed to remove drilling debris along the borehole wall and drilling additives (if used) that may form a low permeability "skin". In wells screened across the water table, some development of the unsaturated filter pack is desirable to ensure that aquifer response data collected during falling head tests are representative of the aquifer. In cases where the extent of well development is questionable, redevelopment of the well prior to slug testing should be considered.[1]

(i) A minimum of three slug tests should be performed at each well. The magnitude of the initial displacement should be varied by at least a factor of two, and the first and last tests of the series should have the same initial displacement. The direction of slug-induced flow should be varied during the series of tests to identify a skin-related directional dependence. The flow direction in the majority of tests should be from the medium into the well (rising head test). Flow from the well into the medium (falling head test) can lead to a progressive decrease in near-well hydraulic conductivity as a result of mobilized fine material being lodged deeper into the medium. Data from slug tests with two different slug sizes and different flow directions can be used to assess the occurrence of a well skin.

(j) A good approach to slug testing is to initiate the series of tests with a rising head test. Slowly submerge the slug, then wait for the water level to return to static. Perform at least the following tests: the initial rising head test, followed by a falling head test, and finishing with a rising head test.

(k) An ideal test series consists of the initial rising head test followed by a pair of falling head and rising head tests with a larger slug and finishing with a pair of falling and rising head tests with the smaller slug.

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[1] It may be appropriate to perform slug tests on a well before redevelopment to assess the need for redevelopment. For example, if a change in hydraulic conductivity from baseline conditions is suspected, that would be related to injection of remedial amendments.

4.0 PROCEDURES FOR SLUG TESTING

4.1 Slug Tests Using Solid Slugs and Bailers

The following procedure is recommended for slug testing:

(a) Prior to conducting slug tests, the expected initial water level displacement (H_0*) in the well should be calculated for each slug and recorded on a field form or in a field book. Water level displacement by solid slugs and bailers is calculated with the following equations:

$$V_s = p * r_s^2 * h_s = V_{sw} = p * r_c^2 * h_c$$

or

$$h_c = (r_s^2 * h_s)/r_c^2 = H_0*$$

Where:

V_s = volume of the slug (L^3),
p = 3.1416,
r_s = radius of the slug (L),
h_s = length of the slug (L),
V_{sw} = volume of water displaced by the slug (L3),
r_c = radius of the casing/screen (L), and
h_c = water level displacement in casing/screen (L).

The actual water level displacement (H_0) is less than H_0* because the slug does not displace the water in the casing/screen instantaneously, and drainage from the filter pack begins before the slug is completely withdrawn (rising head test), or some of the displaced water enters the unsaturated filter pack before the slug is fully submerged (falling head test). H_0* can be bounded at the lower end by accounting for the filter pack porosity and assuming no flow to or from the medium:

$$V_{sw} = p * r_s^2 * h_s = p * r_c^2 * H_{0L*} + (p * r_w^2 * H_{0L*} - p * r_c^2 * H_{0L*}) * f_{fp},$$

or

$$H_{0L*} = r_s^2 * h_s / [r_c^2 + f_{fp} * (r_w^2 - r_c^2)]$$

Where:

H_{0L*} = minimum expected initial water level displacement (L),
r_w = radius of the well (L),
f_{fp} = porosity of the filter pack.

H_0 typically exceeds H_{0L*}, unless the slug is raised or lowered very slowly, which would invalidate the test.

(b) Open the well.

(c) Perform headspace screening of the well in accordance with the requirements of the work plan and/or HASP.

(d) Don a clean pair of nitrile gloves and measure the static water level using a decontaminated electronic water level meter. If NAPL occurs at the site, verify the absence of NAPL in the well using an oil/water interface probe. Do not conduct a slug test in a well containing NAPL.

(e) If the well was capped with an expansion plug and was not vented, wait for water level stabilization. For the purpose of slug testing, consider stabilization attained when the water level does not vary by more than 0.1 foot over a period of 15 minutes for granular media and a period of 1 hour for fine-grained media.

(f) Record the well designation and location, static water level, and the date and time of the observation in the field logbook.

(g) Determine the depth of deployment of a pressure-sensitive transducer/data logger, which should be a minimum of one foot off the bottom of the well. With the intended depth of deployment from the top of the well casing, measure the corresponding length of transducer cable from the transducer using a tape, and mark the cable where it will be secured at the top of casing. This procedure ensures the initial head of water above the transducer (depth of transducer minus depth of static water level) is known for analysis of the data.

(h) Secure the transducer cable at the wellhead to prevent the transducer from sliding down the well during the slug test.

(i) Confirm the static water level in the well using the electronic water level meter.

(j) Program the data logger/transducer in accordance with the manufacturer's instructions. When using In-Situ® data loggers, the data type should be "water level", the reference should be the top of casing (static water level = depth to water from top of casing), and the time scale (frequency of data collection) may be logarithmic or linear. The data collection frequency should be set to logarithmic for tests in sand and gravel. For tests in fine-grained sediments, a reduced frequency of data collection may be appropriate. The frequency of data collection should be determined with concurrence of the Project Manager/hydrogeologist prior to entering the field. When programming the data logger for each test, the input data must include the well designation, the type of test being performed (*i.e.*, RH – rising head or FH – falling head), and a numeric value corresponding to the sequence of the test for multiple tests on a well.

(k) After programming the data logger/transducer, verify that the water level (head) and/or pressure (2.31 feet/psi) read by the transducer is consistent with the length of the water column above the transducer determined in (g). Most data loggers generate real time water level/head and/or pressure data for viewing on a computer. Consult the manufacturer's instrument manual for the transducer data logger being used.

(l) Raise the transducer by a minimum of six inches measured along the cable with a tape to verify on the computer that the transducer registered the change in head or pressure within the error limits of the transducer. If the change was accurately recorded by the transducer, proceed to step (n) below.

(m) If the change is not accurate within the error limits of the transducer, remove the transducer from service and repeat steps (g) through (l) with a backup transducer.

(n) When performing tests in areas where potential background variations in water level affect the data (*i.e.*, tidal, river stage, or anthropogenic influence), monitor the aquifer with the pressure transducer for an appropriate duration before beginning the test and after complete rebound to determine potential ambient water level trends and adjustments to the data prior to analysis. Pre- and post-test monitoring may also be necessary for tests in a low hydraulic conductivity medium, requiring long rebound periods in which barometric pressure affects water levels.

(o) To perform a rising head test with a slug or a bailer, the slug/bailer is slowly lowered into the well until submerged just below the water surface. Prior to lowering the slug or bailer in the well, the necessary length of the rope attached to the slug/bailer must be measured according to the depth to water and marked to ensure that the top of the slug/bailer will be no more than 6 inches below the static water level. If a solid slug will be used with the intent of conducting a subsequent falling head test, the rope must also be marked so that the bottom of the slug will be no more than 1 foot above the static water level prior to lowering the slug.

(p) Before pulling the slug for the initial rising head test, measure the depth to water to ensure the level has returned to static. Activate the data logger/transducer and in a smooth, rapid motion, withdraw the slug/bailer from the well. Monitor water level rebound using the data logger. When the water level has rebounded (*i.e.*, the difference between the water level and the static water level is less than 5% of the initial displacement), stop the data logger and save the data for the first test.

(q) Before introducing a solid slug for the subsequent falling head test, be sure that the transducer/data logger has been re-programmed with the appropriate information. If a longer slug is used for the falling head test, measure the rope and slug length to mark the rope so that the bottom of the slug will be no more than 1 foot above the static water level prior to lowering the slug. Activate the data logger and lower the slug below the static water level in a smooth, rapid motion to the mark on the rope for complete submergence that was measured for the rising head test. In anticipation of suspending the solid slug, a good practice to avoid disturbing the water during rebound is to affix a 3- to 5-inch long bolt to the rope, depending on casing diameter, at the mark of complete submergence prior to lowering the slug. Monitor water level rebound.

(r) Note that for test initiation, the slugs/bailers should be withdrawn and introduced (solid slug) as quickly as practicable without disturbing the transducer and generating oscillations of the water in the well. Splashing with introduction of the solid slug can be avoided by first slowly lowering the slug a known distance to within a couple of inches of the water, then rapidly lowering it. Good skills in test initiation are acquired through practice, and the necessary rapidity is different for low permeability and high permeability media.

(s) Prior to performing each repeat slug test, measure the water level using the water level meter, record the water level, date, and time of the observation in the field logbook, and re-program the transducer in accordance with (j). Also, record the type of test (RH or FH) and sequence number of the test in the field notebook.

4.2 Pneumatic Slug Tests

Pneumatic slug tests should be considered, if the medium is anticipated to be highly permeable. The pneumatic approach can only be applied to wells with screens that are fully submerged because the procedure requires pressurizing the air column or developing a vacuum in a sealed well. Pressurization is accomplished with compressed air or nitrogen gas, which depresses the water level. A rising head test is initiated, after the air column is rapidly depressurized. Applying a vacuum to the air column raises the water level, and breaking the vacuum initiates a falling head test. Alternatively, a pair of falling- and rising-head tests can be performed in tandem, if both the pressurization (falling-head) and depressurization (rising-head) are conducted very rapidly with respect to the response of the water level.

The pressure required to perform a successful test is not more than 1 to 2 psi. Pneumatic pressurization slug tests should only be performed on wells with screens submerged at least 3.5 feet below the static water level. Otherwise, the pressurization must be carefully performed and monitored to avoid depressing the water level below the top of the well screen. Typical pneumatic displacements range from 10 to 100 cm (0.33 to 3.3 ft), corresponding to 0.14 to 1.4 psi. However, Zurbuchen et al. (2002) present data suggesting the displacement in high permeability media should be limited to 0.87 to 1.5 ft (0.38 to 0.65 psi). Procedures for conducting pneumatic pressurization slug tests are outlined below. Similar steps are applicable to pneumatic vacuum tests. Consult Butler (1998) for additional information and precautions in performing pneumatic slug tests.

a) Perform steps (b) through (n) as described in Section 4.1.

b) Using the static water level (L_s) and well completion log, calculate the length of water column (L_w) from the static water level to the top of the well screen using the following equation:

$$L_w = D_{ws} - L_s$$

Where: D_{ws} = Depth to top of well screen below ground surface (feet);

Note: Static water level must be in feet below ground surface. Measurements made from the top of casing must be adjusted, as appropriate, if the casing is above or below ground surface.

c) Calculate the maximum theoretical pressure (P_{max}) that can be applied during pressurization of the well casing at which the water level is depressed to the top of the well screen:

$$P_{max} = L_w/2.3067 \text{ ft/psi.}$$

The actual air or gas pressure applied to the casing should be less than P_{max}. An applied air pressure of P_{max} less approximately 0.25 to 0.5 psi should maintain the water level between approximately 0.5 and 1 foot above the top of the screen.

d) Verify that the transducer is at least 2 feet below the depth of the intended depressed water level.

e) Attach the pneumatic well-head apparatus to the well casing.

f) Connect the pressurized air or gas supply to the pneumatic well-head apparatus and verify that the bleeder valve on the assembly is closed.

g) Program the data logger and record the hydraulic head or pressure measured with the transducer in a field book or on an appropriate field form. Be sure the data collection frequency is programed to logarithmic.

h) Slowly pressurize the well casing, and check for leaks along the joint between the well-head apparatus and the well casing using a solution of Alconox® and distilled water (or equivalent). As necessary, tighten or re-seat the well-head apparatus, and repeat this step until leaks are eliminated.

i) After leaks are eliminated, pressurize the well to the planned pressure. Record the applied pressure in the field log book or on the appropriate field form.

j) When the transducer has the same reading as the initial reading prior to pressurization, activate the data logger and release the pressure by opening the pressure-release valve on the pneumatic well-head apparatus.

k) After the water level has rebounded, save the test data and re-program the data logger for the next test.

l) After this initial pressurization procedure for a rising head test, a pair of falling- and rising-head tests could be performed in tandem, if the water level response is monitored during pressurization as well as after the pressure is released. The pressurization (falling-head) and depressurization (rising-head) must be conducted very rapidly with respect to the response of the water level. The falling-head test terminates when the pressure in the well reaches equilibrium (the transducer has the same reading as the initial reading prior to pressurization).

m) Multiple tests should be performed at different displacements in accordance with recommendations in Section 3.1.

5.0 DECONTAMINATION

Reusable equipment, including water level meters, measuring tapes, transducers, and slugs will be thoroughly decontaminated using a solution of Alconox™ and/or Liquinox™ followed by a rinse with distilled water prior to and following uses at different wells to avoid cross-contamination.

Equipment that cannot be readily decontaminated (*e.g.,* slugs that are heavily contaminated) will be discarded after each use and managed as investigation-derived waste (IDW).

6.0 INVESTIGATION-DERIVED WASTE DISPOSAL

IDW generated during slug tests includes expendable equipment (*i.e.*, unusable slugs, rope, and PPE) and decontamination residuals and supplies. These materials will be managed as IDW in accordance with the project FSP.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Upon completing each test, the data should be reviewed on a field laptop computer. For wells exhibiting a moderate to high rate of rebound, a plot of the water level rebound versus time should exhibit an asymptotic trend. Wells exhibiting a low rate of rebound will typically exhibit a linear response, unless monitoring is continued for an extended duration. Deviations from this response pattern may indicate problems, and the test may be repeated when the water level has rebounded to static conditions.

It is good practice to perform multiple (*e.g.,* 2 to 3 rising and 2 falling head) tests in each well with two different water level displacements (*i.e.*, using two different slug sizes) to assess the validity of the hydraulic conductivity estimates (*i.e.*, not affected by poor well development).

8.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

At the end of each day, or more frequently as necessary, data will be downloaded to a laptop computer and emailed to the data manager for retention in the project file pending analysis. The data should also be saved to a flash drive to prevent inadvertent data loss.

The field logbook should be used to record the following information, at a minimum:

- Weather conditions at the time of testing;
- The make, model, pressure rating, accuracy rating, and serial number of the pressure transducer used to record water level data;
- Well designation and location;
- The static depth to water and total depth of the tested well;
- The depth of the transducer in the tested well below its measurement point;
- Reference point from which all measurements are made;
- The type of test (RH or FH);
- The expected displacement, or the pneumatic pressure and displacement; and
- Time that the test is started and stopped.

Any deviations from the record management procedures specified in the FSP or Quality Assurance Project Plan, if applicable, must be approved by the QA Officer and Project Manager and documented in the field logbook.

9.0 REFERENCES

Butler, J.J., 1998. *The Design, Performance, and Analysis of Slug Tests.* Lewis Publishers, Boca Raton, Florida.

Cunningham, W.L., 2010. *Conducting an Instantaneous Change in Head (Slug) Test with a Mechanical Slug and Submersible Pressure Transducer*, United States Geological Survey.

Zurbuchen, B.R., V.A. Zlotnik, and J.J. Butler, 2002. *Dynamic interpretation of slug tests in highly permeable aquifers*. Water Resources Research, v. 38, no. 3, p. 7-1 to 7-18.

10.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	FEBRUARY 2019	NOT APPLICABLE.
1	JANUARY 2020	TRC RE-BRANDING

Appendix B
Health and Safety Plan

Risk Analysis (RA)

1. General Information

Business Unit	☒ **Environmental Consulting, Construction, or Remediation**		
Client Name:	Detroit Axle Ferndale	Project #:	495430.0000.0000
Project Name:	Former Hayes Lemmerz (Detroit Axle)	Project Manager:	Kelly Cratsenburg
Street Address:	1600 West 8 Mile Road	City, State, ZIP	Ferndale, MI, 48167
Prepared By:	Renee Whitlock	Date:	8/22/2022
Approved By:	Kelly C. Cratsenburg (PM) **Kelly Cratsenburg**	Approved By:	Colin Daining (HSC) **Colin Daining**
Date:	August 31, 2022	Date:	August 31, 2022

Proposed Dates(s) of Work: August 2022 to August 2023

Proposed Scope of Work On Site:

- Utility Clearance
- Test pitting/Pot holing
- Soil boring advancement
- Monitoring well installation
- Soil vapor monitoring point installation
- Soil, groundwater, and soil vapor sampling

TRC Role(s) On Site:

☐ TRC Staff Will Not Be On Site (RA is for subcontractor information only)

☐ Resident Project Representative (e.g., RPR, “Observe and Document”)

☐ Construction Manager (e.g., CM, Managing/General Contractor)

☐ Representative for Client (e.g., “Agent for Owner”)

☒ General On-site Consulting/Engineering Services

☒ Other:

☒ Soil Sampling
☒ Groundwater Sampling
☒ Remedial Excavation Oversight
☐ Solid Waste Sampling
☐ Surface Water Sampling
☐ Phase I Site Walk
☐ Liquid Waste Sampling
☐ Wastewater Sampling
☒ Utility clearance oversight

	Major Project Tasks	TRC Task	Subcontractor Task	Minimum PPE Level Required see HSP for details (suggested levels for Subcontractor work)
1.	Utility Clearance	☐	☒	☐ N/A ☒ D ☐ C ☐ B ☐ A
2.	Soil boring Advancement	☐	☒	☐ N/A ☒ D ☐ C ☐ B ☐ A
3.	Monitoring well installation	☐	☒	☐ N/A ☒ D ☐ C ☐ B ☐ A
4.	Soil, groundwater, and soil vapor sampling	☒	☒	☐ N/A ☒ D ☐ C ☐ B ☐ A
5.	Test Pitting/Pot Holing	☐	☒	☐ N/A ☒ D ☐ C ☐ B ☐ A
6.		☐	☐	☐ N/A ☒ D ☐ C ☐ B ☐ A
7.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
8.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
9.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
10.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
11.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
12.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
13.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
14.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
15.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
16.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
17.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
18.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
19.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
20.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
21.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
22.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
23.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
24.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
25.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
26.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
27.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
28.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
29.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A
30.		☐	☐	☐ N/A ☐ D ☐ C ☐ B ☐ A

2. Contingency Planning

Local Emergency Resources	
Ambulance: 911	Emergency Room: 911
Police: 911	Fire Department: 911
USEPA Contact: ☐ N/A ☐ Specify:	Poison Control Center: 1.800.222.1222 ☐ Specify:
Other (client services offered, etc.):	

Site Resources			
Drinking Water Supply	☒ TRC	☒ Subcontractor	☐ Client
Wash Water Supply	☐ TRC	☐ Subcontractor	☐ Client
Telephone – Land Line		☐ Subcontractor	☒ Client
Telephone – Cellular	☒ TRC	☒ Subcontractor	
First Aid Kit	☒ TRC	☒ Subcontractor	
Fire Extinguisher	☒ TRC	☒ Subcontractor	☐ Client
Emergency Shower	☐ TRC	☐ Subcontractor	☐ Client
Eye Wash	☒ TRC	☐ Subcontractor	☐ Client
Other:	☐ TRC	☐ Subcontractor	☐ Client

Emergency Contacts	
TRC Technical Contact:	Kelly Cratsenburg 734.412.5424 (cell) Brian Yelen 734.585.7835 (cell) Henry Schnaidt 734.646.5328 (cell)
TRC Project Manager (PM):	Kelly Cratsenburg 734.412.5424 (cell)

Emergency Contacts	
TRC National Safety Director (Mike Glenn): TRC Safety Manager (Tim Johnson): ▪ Confined Space Permits ▪ Air Monitoring Plans ▪ Scaffolding Permits ▪ Demolition Plan Approval	Mike Glenn 949.727.7347 (office) 949.697.7418 (cell) Tim Johnson 949.727.7363 (office) 925.260.9491 (cell)
Radiation Safety Officer (RSO):	George Shereda 608.250.0812 (cell) 734.748.9332 (home - emergency only)
TRC Health & Safety Coordinator (HSC): ▪ Excavation Permits ▪ Hot Work Permits ▪ Lockout/Tagout Permits ▪ Traffic Control Plan Approval ▪ Lighting Plan Approval	Colin Daining 734.904.3311 (cell)
TRC Field Contact:	Brian Yelen 734.585.7835 (cell) Henry Schnaidt 734.646.5328 Jake Krenz 734.585.7836
Contractor Contact:	Karen Donnelly (Terra Probe) 734.854.7703
Client Contact:	Michael Brennan 313.235.0349 (office) 734.560.9271 (cell) michael.brennan@dteenergy.com

Emergency Route (provide detailed directions and/or attach a map):

The emergency route should be driven at least once before fieldwork begins, to verify that the planned route is feasible. Hospitals or clinics identified for emergency medical care should also be contacted, to verify that emergency care is provided at that location. Verify the exact location of the medical facility during this call.

Hospital:	Ascension Providence Hospital Southfield Campus 16001 W Nine Mile Road Southfield, MI, 48075	Other:

Emergency Procedures:

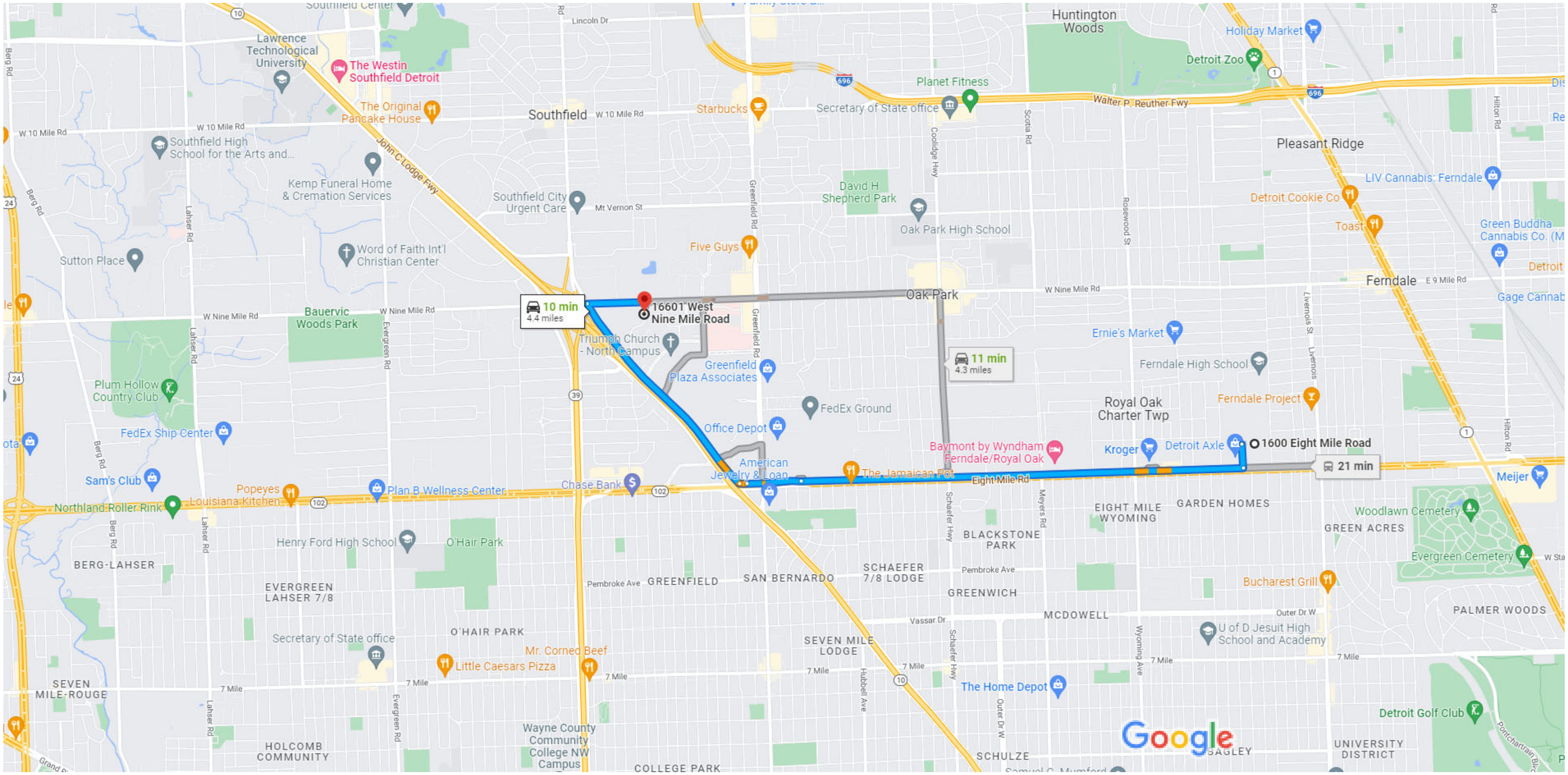
If an emergency develops at the site, the first responder should take the following course of action:

- Notify the proper emergency services for assistance.
- Notify other personnel at the site.
- As soon as possible, contact the TRC Safety Manager to inform them of the incident.
- Prepare a summary report of the incident for the client representative as required.

Google Maps

1600 Eight Mile Rd, Ferndale, MI 48220 to 16601 W Nine Mile Rd, Southfield, MI 48075

Drive 4.4 miles, 10 min



Map data ©2022 Google 2000 ft

1600 Eight Mile Rd
Ferndale, MI 48220

↑ 1. Head south toward Eight Mile Rd W

⚠ Partial restricted usage road

0.1 mi

↱ 2. Turn right onto M-102 W/Eight Mile Rd W

ⓘ Pass by Dollar Tree (on the right in 0.4 mi)

2.4 mi

↗ 3. Use the right 2 lanes to turn slightly right onto 8 Mile Service Rd

0.3 mi

↱ 4. Keep right to continue toward M-10 Service Drive NB/Northwestern Hwy Service Rd

223 ft

↱ 5. Turn right onto M-10 Service Drive NB/Northwestern Hwy Service Rd

ⓘ Continue to follow M-10 Service Drive NB

1.3 mi

↱ 6. Turn right onto W Nine Mile Rd

ⓘ Destination will be on the right

0.3 mi

16601 W Nine Mile Rd
Southfield, MI 48075

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Emergency Equipment Required On Site:

☒ First Aid Kit

☒ Emergency Eye Wash

☐ Emergency Shower

☒ Fire Extinguisher

☐ Spill Control Media

☐ Other:

Investigation of Near Miss Incident and Initial Report of Incident/Exposure:

TRC employees are required to report any incident, near miss, or injury, as soon as possible, by contacting the following:

☒ TRC National Safety Director –

- Mike Glenn (949.697.7418 cell)
- or Office H&S Coordinator or
- TRC Safety Manager –Tim Johnson (925.260.9491 cell)

☒ Notify supervisor

☒ Notify project manager

☐ Notify client
(name):
(phone number)

☐ Complete client report:

The incident report submittal operator will obtain the necessary information from the employee and enter the information into the H&S incident database. All appropriate H&S, HR, and legal staff will be notified and will follow up as necessary.

Note: Pursuant to TRC's "Drug and Alcohol-Free Workplace" policy (TRC Academy Course #900013753), TRC may require employees or subcontractors to be tested upon reasonable suspicion, following accidents or incidents during work activities, or during travel to or from a project site. Client policies may be more stringent in regard to procedures following an accident. Project managers must be aware of these and inform employees and subcontractors of any additional requirements.

3. Site Classification

	Identification of Potential Hazards	Yes	No	Site Type[(1)]
1.	Is the work a Phase I ESA (i.e., supervised plant walk-through, etc.)	☐	☒	1
2.	Is the work being performed solely by a subcontractor (i.e., TRC not on site)	☐	☒	1
3.	Is the work just a supervised inspection for process evaluation, other inspections, meetings, records review, or a tour?	☐	☒	1
4.*	Is the work completely absent of any chemical, physical, biological, or radiological hazards which would require a site specific health and safety plan?	☐	☒	1
5.	Does the work include any mandatory client H&S requirements?	☐	☒	1, 2, or 3
6.	Does the project include on-site work other than office type areas?	☒	☐	2 or 3
7.	Does the proposed work scope involve any of the following?	☒	☐	
	▪ Known and controlled chemical or biological hazards	☒	☐	2
	▪ Unprotected work at elevation (fall protection required)	☐	☒	2
	▪ Invasive activities (i.e., Phase II ESA, UST Removal, sampling, etc.)	☒	☐	2 or 3
	▪ Exposure to ionizing radiation (i.e., using nuclear gauges, etc.)	☐	☒	2 or 3
	▪ Open excavations/trenches (competent person may be required on site)	☒	☐	2 or 3
	▪ Confined space entry (permit may be required)	☐	☒	2 or 3
	▪ The use of scaffolding (qualified inspections are required)	☐	☒	2 or 3
	▪ Heavy equipment	☒	☐	2 or 3
	▪ Facility maintenance (O&M, piping, electrical, lockout/tagout, etc.)	☐	☒	2 or 3
	▪ Underground utilities may be encountered	☒	☐	2 or 3
	▪ Overhead utilities may be encountered	☒	☐	2 or 3
	▪ Stack testing	☐	☒	2 or 3
	▪ Geotechnical drilling	☐	☒	2 or 3
	▪ Demolition Activities with known or suspected contamination	☐	☒	2 or 3
	▪ Unknown or uncontrolled chemical or biological hazards	☒	☐	3
	▪ Known and uncontrolled chemical or biological hazards	☒	☐	3
	▪ Waste sampling	☐	☒	3
	▪ Construction activities with known or suspected contamination	☐	☒	3
	▪ Remedial activities (RCRA, CERCLA, EnviroBlend®, Oxigent, etc.)	☐	☒	3
8.	Is the work regulated by 29 CFR 1910.120 (OSHA) or 30 CFR (MSHA)?	☐	☒	3
9.	Is the work regulated by NPL, CERCLA, RCRA, TSD, or SARA?	☐	☒	3

1. (1) Denotes typical site level (based on activities).

Site Type Designation:

☐ **Type 1** Known and controlled hazards associated with consulting/engineering services

☐ **Type 2** Known and controlled hazards, but with invasive, hazardous activities and/or civil/mechanical construction related services, or sampling

☒ **Type 3** Unknown and/or uncontrolled hazards associated with corrective action clean-up, and/or remediation of hazardous substances

4. Site Characterization

Client Requirement(s)[1]:	☒ None ☐ Site Orientation ☐ H&S Orientation ☐ Permits or Other Requirements (specify and attach, if available):
Site Information:	☒ Map/Diagram (attach) ☐ Map/Diagram Unavailable ☒ Inactive Site ☐ Active Site (specify below)
General Environmental Concerns:	☒ Contaminated Water ☐ Wastewater ☐ Dust ☒ Contaminated Soil ☐ Solid Waste ☐ Noise ☐ Contaminated Air ☐ Waterways ☐ Other:
Site Security/Access Control:	☐ None ☒ On Site ☐ Other (explain):
Amenities Available for Work:	☒ None ☐ Waste Storage ☐ Restrooms ☐ Tools/Equipment Storage ☐ Office/Trailer Space ☐ Supplies Storage
Utilities Available For Work:	☒ None ☐ As Listed:
Medical Services Available:	☒ None On Site ☐ As Listed:
Facility Alarms/Signals:	☒ None ☐ As Listed:
Traffic/Parking/Railway Issues:	☒ None ☐ As Listed (On-Site/Off-Site):
☐ Permits Required (specify)[2]:	☐ TRC: ☐ Local: ☐ State: ☐ Federal: ☐ Other: ☒ N/A
☒ Utility Locate Service(s):	☐ On Site ☐ Client ☒ Sub-contractor utility locating ☐ Off Site ☐ Diggers Hotline ☒ One Call ☐ Julie, Inc. ☐ N/A

[1] If relying on the client for any specific hazard identification and control, implemented control and effectiveness should be documented prior to beginning any work activities. This is recommended for all field projects.

[2] Permit examples: Utilities (electrical, water, gas, etc.); Excavations; Explosives; Cranes; Burning; Fuel storage; Traffic control; Hoists; Cutting; Welding; Demolition; Confined space; Restricted access areas; etc.

Detailed Physical Description of Site/Facility: ☒ Map/Diagram Attached

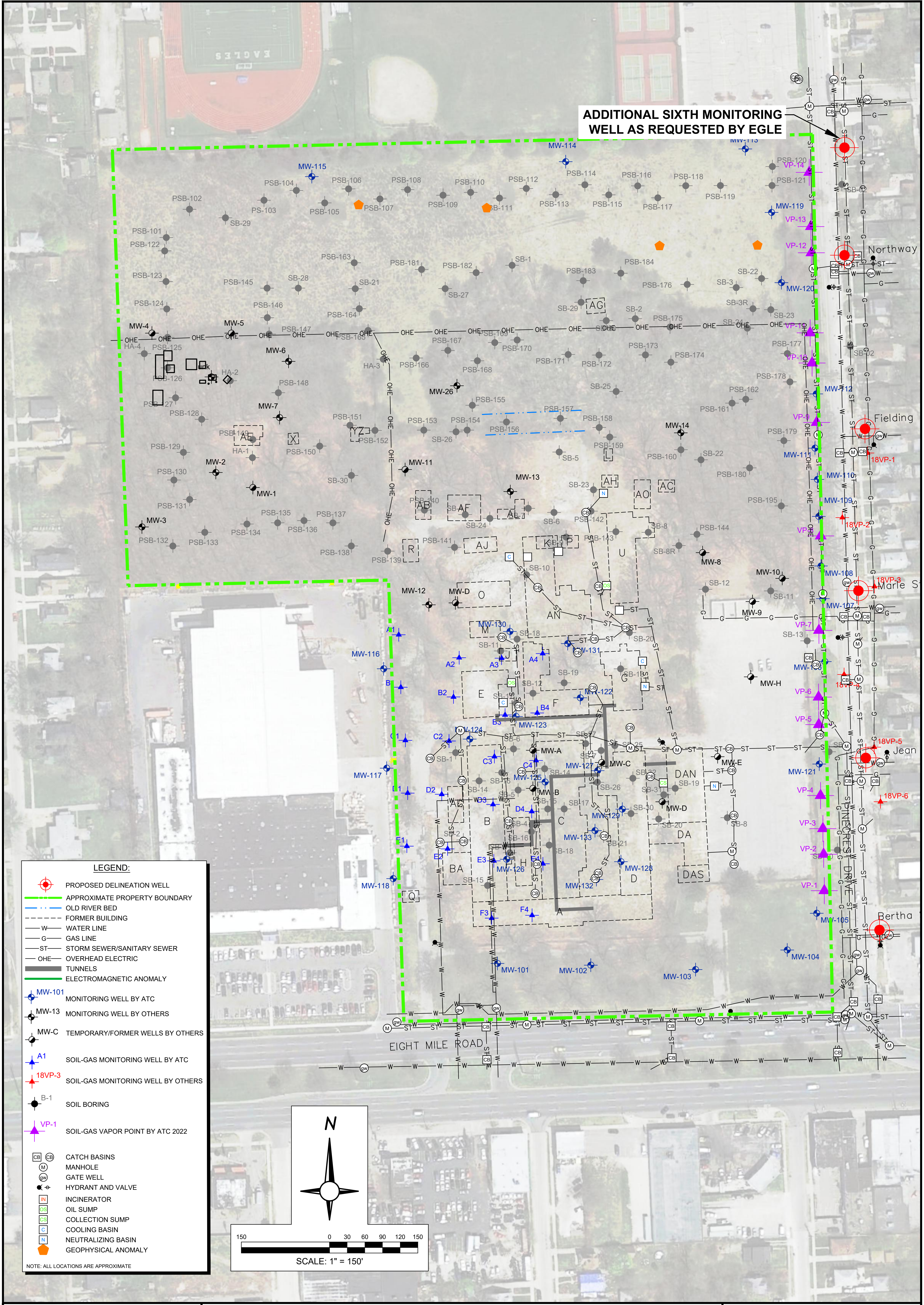
Site Activities/Current Operations: ☒ None ☐ As Specified:

Other Concurrent Site Activities, Work, and/or Other Adjacent Hazards or Concerns:

☒ None As Specified:

☐ Schools ☐ Daycare ☐ Hospital ☐ Airport

☐ Residential ☐ Offices ☐ Shopping ☐ Other:



LEGEND:

- PROPOSED DELINEATION WELL
- APPROXIMATE PROPERTY BOUNDARY
- OLD RIVER BED
- FORMER BUILDING
- —W— WATER LINE
- —G— GAS LINE
- —ST— STORM SEWER/SANITARY SEWER
- —OHE— OVERHEAD ELECTRIC
- TUNNELS
- ELECTROMAGNETIC ANOMALY
- MW-101 MONITORING WELL BY ATC
- MW-13 MONITORING WELL BY OTHERS
- MW-C TEMPORARY/FORMER WELLS BY OTHERS
- A1 SOIL-GAS MONITORING WELL BY ATC
- 18VP-3 SOIL-GAS MONITORING WELL BY OTHERS
- B-1 SOIL BORING
- VP-1 SOIL-GAS VAPOR POINT BY ATC 2022
- CB CB CATCH BASINS
- M MANHOLE
- gw GATE WELL
- HYDRANT AND VALVE
- IN INCINERATOR
- OS OIL SUMP
- CS COLLECTION SUMP
- C COOLING BASIN
- N NEUTRALIZING BASIN
- GEOPHYSICAL ANOMALY

NOTE: ALL LOCATIONS ARE APPROXIMATE

TRC
1540 Eisenhower Place
Ann Arbor, MI 48108
Phone: 734.971.7080
www.trcsolutions.com

PROJECT:

**DETROIT AXLE FERNDALE
FORMER HAYES LEMMERZ SITE
WEST EIGHT MILE ROAD
FERNDALE, MI**

TITLE:

EASTERN BOUNDARY WORK PLAN- PROPOSED LOCATIONS

WORKING COPY

DRAWN BY:	E.ALEXANDER
CHECKED BY:	K. CRATSENBERG
APPROVED BY:	---
DATE:	AUGUST 2022
PROJ. NO.:	495430.0000.0000
FILE:	495530-EB WP PL.dwg

FIGURE 1

"TYPE 3" Site Acknowledgment Statement (if applicable):

As an employee of TRC, I have reviewed the Risk Analysis (RA). I hereby acknowledge that I have received the RA, and that I agree that the work area is a "**Type 3**" site that does not require a detailed Health & Safety Plan (HSP). If during work activities there are additional hazards identified, I will communicate those to the Project Manager (PM) and the Health & Safety Coordinator (HSC), and an updated RA will be prepared.

Signatures of TRC Site Personnel:

Signature	Date

5. Hazard Evaluation

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Aluminum		S		Inh, Con		Admin., PPE & Site Control	NA	0	NA	NA	N.D.		TWA-15 mg/m^3 (total), 5 mg/m^3 (respirator)
Arsenic	1910.1018	S, L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	Ca (5 mg/m^3)		Ca (5 mg/m^3)
Beryllium		S		Inh, Con		Admin., PPE & Site Control	NA	0	NA	NA	Ca (4 5 mg/m^3		TWA-0.002 mg/m^3, C 0.005 mg/m^3 0.025 mg/m^3 (30-min max peak
Cadium		S, F		Inh ,Ing		Admin., PPE & Site Control	NA	0	NA	NA	Ca (9 mg/m^3)		TWA-0.005 mg/m^3
Chromium		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	250 mg/m^3		TWA-1.0 mg/m^3
Cobalt		S, F		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	20 mg/m^3		TWA-0.1 mg/m^3
Copper		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	100 mg/m^3		TWA-1.0 mg/m^3
Lead	1910.1025	S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	100 mg/m^3		TWA-0.05 mg/m^3
Managanese		S		Inh, Con		Admin., PPE & Site Control	NA	0	NA	NA	500 mg/m^3		C 5 mg/m^3
Mercury		S		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	0.0012	NA	NA	10 mg/m^3		C 0.1 mg/m^3

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Nickel		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	10 mg/m^3		TWA-1.0 mg/m^3
Selenium		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	1.0 mg/m^3		TWA-0.2 mg/m^3
Silver		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	10 mg/m^3		TWA-0.01 mg/m^3
Tin		S, F		Inh, Con		Admin., PPE & Site Control	NA	0	NA	NA	100 mg/m^3		TWA-2.0 mg/m^3
Titanium		S		Inh, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Zinc		S		Inh, Abs, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
PCB (Chlorodiphenyl) Aroclor 1242		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	0.001	NA	NA	Ca (5 mg/m^3)		TWA 1 mg/m^3 [skin]
PCB (Chlorodiphenyl) Aroclor 1254		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	0.00006	NA	NA	Ca (5 mg/m^3)		TWA 0.5 mg/m^3 [skin]
Asorbic Acid													
Hydrochloric Acid		Aq		Inh, Ing, Con		Admin., PPE & Site Control	12.74	40.5 atm	NA	NA	50 ppm		7 mg/m^3
Methanol		L, G, Vp, F		Inh, Abs, Ing, Con		Admin., PPE & Site Control	10.84	96	6	36	6,000 ppm		TWA 200 ppm
Nitric Acid		Aq		Inh, Ing, Con		Admin., PPE & Site Control	11.95	48	NA	NA	25 ppm		2 ppm (5 mg/m^3)
Sodium Hydroxide		S, L		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	10 mg/m^3		TWA 2 mg/m^3

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Sodium Sulfate													
Zinc Acetate													
Acenaphthene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	--	--	NA	NA	NA
Acenaphthylene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	--	--	NA	0.2 mgm^3	TWA 0.2 mg/m^3
Anthracene		S		Inh, Con		Admin., PPE & Site Control	NA	NA	0.6	NA	Ca (80 mg/m3)		TWA 0.2 mg/m^3
Benzo(a)pyrene		S		Inh, Con		Admin., PPE & Site Control	NA	NA	NA	NA	Ca (80 mg/m3)	NA	TWA 0.2 mg/m^3
Benzo(b)fluoranthene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA		TWA 0.2 mg/m^3
Benzo(g,h,i)perylene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Benzo[a]anthracene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Benzo[k]fluoranthene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Chrysene		S		Inh, Con		Admin., PPE & Site Control	NA	NA	NA	NA	Ca (80 mg/m3)	0.2 mg/m^3 TWA	TWA 0.2 mg/m^3
Dibenz(a,h)anthracene		S		Ing, Con		Admin., PPE & Site Control	NA	NA	NA	flourene sds	NA	NA	NA
Fluoranthene		S		Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Fluorene		S		Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Indeno[1,2,3-cd] pyrene		S		Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	NA	NA	NA
Naphthalene		S		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.12	0.08	0.9	5.9	250 ppm	NA	TWA 100 ppm (50 mg/m3)
Phenanthrene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	Ca (80 mg/m3)	NA	TWA 0.2 mg/m3
Pyrene		S		Inh, Ing, Con		Admin., PPE & Site Control	NA	NA	NA	NA	Ca (80 mg/m3)	NA	TWA 0.2 mg/m3
1,1,1-Trichloroethane (Methyl Chloroform)		L		Inh, Ing, Con		Admin., PPE & Site Control	11	100	7.5	12.5	700 ppm		TWA 350 ppm (1,900 mg/m^3)
1,1,2,2-Tetrachloroethane		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11.1	5	NA	NA	Ca (100 ppm)		TWA 5 ppm (35 mg/m^3) [skin]
1,1,2-Trichloroethane		S, L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11	19	6	15.5	Ca (100 ppm)		TWA 10 ppm (45 mg/m^3) [skin]
1,1-Dichloroethane		L		Inh, Ing, Con		Admin., PPE & Site Control	11.06	182	5.4	11.4	3,000 ppm		TWA 100 ppm (400 mg/m^3)
1,1-Dichloroethene		L		Inh, Ing, Con		Admin., PPE & Site Control	9.65	180-265	5.6	12.8	1,000 ppm		TWA 200 ppm (790 mg/m^3)
1,2,4-Trichlorobenzene		S, L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	1	2.5	6.6	N.D.		None
1,2-Dibromo-3-chloropropane	1910.1044	L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	0.8	?	?	CA (N.D.)		TWA 0.001 ppm

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
1,2-Dibromoethane		S, L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	9.45	12	NA	NA	Ca (100 ppm)		TWA 20 ppm, C 30 ppm, 50 ppm [5-min max peak]
1,2-Dichlorobenzene		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	9.06	1	2.2	9.2	200 ppm		C 50 ppm (300 mg/m^3)
1,2-Dichloroethane		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11.05	64	6.2	16	Ca (50 ppm)		TWA 50 ppm, C 100 ppm, 200 ppm [5-min max peak]
1,2-Dichloropropane		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	10.87	40	3.4	14.5	Ca (400 ppm)		TWA 75 ppm (350 mg/m^3)
1,3-Dichlorobenzene													
1,4-Dichlorobenzene		S		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.98	1.3	?	2.5	Ca (400 ppm)		TWA 75 ppm (450 mg/m^3)
1,4-Dioxane		S and L		Inh, Abs, Ing, Con	N	Admin., PPE & Site Control	9.13	29	2	22	Ca (500 pm)	NA	OSHA PEL TWA -360 mg/m^3 (skin)
2-Butanone		L		Inh, Ing, Con		Admin., PPE & Site Control	9.54	78	1.4	11.4	3,000 ppm		TWA 200 ppm (590 mg/m^3)
2-Hexanone		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	9.34	11	?	8	1,600 ppm		TWA 100 ppm (410 mg/m^3)
4-Methyl-2-pentanone (Methyl isobutyl ketone)		L		Inh, Ing, Con		Admin., PPE & Site Control	9.3	16	1.2	8	500 ppm		TWA 100 ppm (410 mg/m^3)
Acetone		L		Inh, Ing, Con		Admin., PPE & Site Control	9.69	180	2.5	12.8	2,500 ppm (10% LEL)		TWA 1,000 ppm (2,400 mg/m^3)

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Benzene	1910.1028	L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	9.24	75	1.2	7.8	Ca (500 ppm)		TWA 1 ppm, ST 5 ppm
Bromodichloromethane													
Bromoform		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	10.48	5	NA	NA	850 ppm		TWA 0.5 ppm (5 mg/m^3) [skin]
Bromomethane		L, G		Inh, Abs (liquid), Con (liquid		Admin., PPE & Site Control	10.54	1.9 atm	10	16	Ca (250 ppm)		C 20 ppm (80 mg/m^3) [skin]
Carbon disulfide		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	10.08	297	1.3	50	500 ppm		TWA 20 ppm C 30 ppm 100 ppm (30-min max peak)
Carbon tetrachloride		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11.47	91	NA	NA	Ca (200 ppm)		TWA 10 ppm C 25 ppm, 200 ppm (5-min max peak in any 4 hours)
Chlorobenzene		L		Inh, Ing, Con		Admin., PPE & Site Control	9.07	9	1.3	9.6	1,000 ppm		TWA 75 ppm (350 mg/m^3)
Chloroethane		L, G		Inh, Abs (liquid), Ing (liquid), Con		Admin., PPE & Site Control	10.97	1,000	3.8	15.4	3,800 (10% LEL)		TWA 1,000 ppm (2,600 mg/m^3)
Chloroform		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11.42	160	NA	NA	Ca (500 ppm)		C 50 ppm (240 mg/m^3)
Chloromethane (Methyl Chloride)		G		Inh, Con (liquid)		Admin., PPE & Site Control	11.28	5.0 atm	8.1	17.4	Ca (2,000 ppm)		TWA 100 ppm C 200 ppm, 300 ppm (5-min max peak in any 3 hours)

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
cis-1, 2 Dichloroethene		S, Aq, Vap	N.D.	Inh, Ing	N	Admin., PPE & Site Control	11.05	64	6.2	16	Ca (50ppm)		50ppm TWA, 100ppm CEILING, 200ppm;
cis-1,3-Dichloropropene		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	28	5.3	14.5	Ca (N.D.)		none
Dibromochloromethane													
Dichlorodifluoromethane		L, G		Inh, Con (liquid)		Admin., PPE & Site Control	11.75	5.7 atm	NA	NA	15,000 ppm		TWA 1,000 ppm (4,950 mg/m^3)
Ethylbenzene		L		Inh, Ing, Con		Admin., PPE & Site Control	8.76	7	0.8	6.7	800 (10% LEL)		TWA 100ppm (435 mg/m^3)
Isopropylbenzene (Cumene)		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.75	8	6.5	0.9	900 (10% LEL)		TWA 50 ppm (245 mg/m^3) [skin]
Methyl tert-butyl ether (MTBE)													
Methylene chloride	1910.1052	L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	11.32	350	13	23	Ca (2,300 ppm)		TWA 25 ppm, ST 125 ppm
m-Xylene		L, Aq		Inh, Abs, Ing, Con		Admin., PPE & Site Control	NA	0.03	NA	NA	None		N.D.
o-Xylene		L, Aq		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.56	7	0.9	6.7	900 ppm		TWA 100 ppm
p-Xylene		L, Aq		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.44	9	1.1	7	900 ppm		TWA 100 ppm

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Styrene		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.4	5	0.9	6.8	700 ppm		TWA 100 ppm C 200 ppm, 600 ppm (5-min max peak in any 3 hours)
Tetrachloroethene (PCE)	OAC 3745-300-08 (C)	Aq, Vap	N.D	Inh, Ing, Abs	N	Admin., PPE & Site Control	9.32	14 mmHg (20˚C)	N/A	N/A	150 ppm	NA	TWA 100 ppm C 200 ppm (for 5 minutes in any 3-hour period); maximum 300 ppm
Toluene		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	8.82	21	1.1	7.1	500 ppm		TWA 200 ppm C 300 ppm, 500 ppm (10-min max peak)
trans-1,2-Dichloroethene													
trans-1,3-Dichloropropene		L		Inh, Abs, Ing, Con		Admin., PPE & Site Control	?	28	5.3	14.5	Ca (N.D.)		None
Trichloroethylene (TCE)		S, Aq, Vap	N.D	Inh, Ing	N	Admin., PPE & Site Control	9.45	58	8	10.5	Ca (1000 ppm)	NA	100ppm TWA, 200ppm CEILING, 300ppm 5-minute MAX PEAK IN ANY 2Hrs
Trichlorofluoromethane		L, G		Inh, Ing, Con		Admin., PPE & Site Control	11.77	690	NA	NA	2,000 ppm		TWA 1,000 ppm (5,600 mg/m^3)
Vinyl Chloride	OAC 3745-300-08 (C)	S; Aq	N.D	Inh, Ing, Abs, Con, Ext	N	Admin., PPE & Site Control	9.99	3.3	3.6	33	Ca [N.D.]		TWA 1 ppm C 5 ppm [15-minute]

Risk Analysis (RA)

Potential Chemical, Biological, or Radiological Hazards

Complete (1) Substance Name (be specific)	Specific Applicable OSHA Standard (if any)	Physical State (2) (S, L, G, Aq, Vap, F, P)	Max. (3) Conc. Level Per Physical State	Potential Routes of Exposure (4) (Inh, Ing, Abs, Con, Ext)	Warning Properties (G, P, N)	General (5) Control Measures (Eng., Admin., PPE)	IP (6) (eV)	VP(6) (mm HG)	LEL(6) (%)	UEL(6) (%)	IDLH (7)	ACGIH TLV (C, ST, TWA) (8) (R) or (T) (9)	OSHA PEL (C, ST, TWA) (8) (R) or (T) (9)
Asbestos	1910:1001, 1926.1101	S		Inh, Ing, Con		Admin., PPE & Site Control	NA	0	NA	NA	Ca (N.D.)		
Bis (2-ethylhexyl) phthalate		L		Inh, Ing, Abs, Con, Ext		Eng or PPE	NLV	NLV	NLV	ND	ND	ND	
Dibenzofuran		L		Inh, Ing, Abs, Con, Ext		Eng or PPE	NLV	NLV	NLV	ND	ND	ND	
Di-n-Butyl phthalate		L		Inh, Ing, Abs, Con, Ext		Eng or PPE	0.000 27	NLV	NLV	ND	ND	ND	
Dense, non-aqueous free product		L		Inh, Ing, Abs, Con, Ext		Eng or PPE	ND	ND	ND	ND	ND	ND	
Trimethylbenzenes (1,2,4- and 1,3,5-)		L		Inh, Ing, Abs, Con, Ext		Eng or PPE	2	0.8	6.6	ND	25 ppm	25 ppm	
PFAS	NA	L	Unknown	Ing. Con	N	PPE	NA	NA	NA	NA	NA	NA	NA

(1) Use OSHA regulated name, not elemental forms. If available, attach MSDS. Identify any sample preservative or O&M chemicals or subcontractor chemicals in this table also.
(2) S = Solids, L = Liquid, G = Gas, Aq = Aqueous, Vap = Vapor, F = Fume, P = Airborne Particulate
(3) If available, attach laboratory results or summary tables.
(4) Inh = Inhalation Hazard, Ing = Ingestion Hazard, Abs = Absorption Hazard, Con = Contact Hazard, Ext = External Exposure Hazard
(5) See the following sections for detailed control measures: personal protection equipment (PPE), Air Monitoring (Admin), or Site Control (Admin and Eng.).
(6) IP = Ionization Potential, VP = Vapor Pressure, LEL = Lower Explosive Limit, UEL = Upper Explosive Limit, N/A = Not Applicable, N.D. = Not Determined
(7) IDLH = Immediately Dangerous to Life and Health. NEVER enter IDLH conditions on site without proper respiratory protection.
(8) C = Ceiling Value, ST = Short-Term Exposure Limit, TWA = Time-Weighted Average, None Est. = None Established
(9) R = Respirable Limit, T = Total Limit
(10) Warning Properties: Good (G), Poor (P), None (N)

5. Hazard Evaluation (continued)

Site Specific Physical Hazards

Hazard	Specific Control Measure
Buried Debris	Buried debris and contamination may be encountered during test pitting/pot holing and other subsurface investigations. If debris and/or unexpected contamination is encountered, stop work, and contact the project manager to complete a risk assessment and proper PPE prior to proceeding with the work.
Small Tree limb and shrub cutting by contractor	Be sure personnel are clear of cutting activities and avoid cutting above head level. Subcontractor will wear Level D projection (includes chaps for chainsaw operation) for grubbing and clearing associated with their H&S requirements.
Uneven Terrain	Terrain in the wooded area of the Site may be uneven and may be covered with downed trees and branches. Walk slowly in area. Haul small loads to and from destination. Be aware of surroundings and be sure work area is level before completing work.

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Aboveground Storage Tanks (AST)	Be aware of any above ground storage tanks and the type of material being stored in them. Be aware of the potential of spills, fires, explosions, etc., while working near the tanks. Stay clear of tanks whenever possible and be aware of any equipment operators near the tank(s).
☒	Animals (dogs, etc.)	Be aware of any animals on site or adjacent to the site. Appropriate care should be taken if any feral (wild) animals are encountered.
☒	Battery (Lead Acid Type)	Be sure to store batteries upright, within a container, and inspect for damage prior to use to avoid battery acid leaks. If a leak exists, provide ventilation, wear safety glasses and nitrile gloves when handling the battery and during cleanup. Have clean wash water nearby when using lead acid batteries in the field.
☐	Blasting/Explosives	TRC personnel shall not handle any explosive devices or materials. TRC personnel should understand the blasting procedures being used by the subcontractor, and all of the associated health & safety precautions. The subcontractor shall handle, store, and use the explosives in accordance with 29 CFR 1926.900, Subpart H and U.
☐	Boat or Barge	A boat or barge should be used that is adequately stable for the type of activity conducted. The boat or barge should have all of the appropriate and current licensing and registrations required by the applicable regulatory agencies. All applicable laws and regulations will be followed when launching the boat or barge, and when navigating to and from the work site. Personal floatation devices should always be worn while navigating the boat or barge. The boat <u>must be equipped</u> with the following approved United States Coast Guard (USCG) safety equipment: ▪ A Type I, II, or III personal flotation device (PFD) for every person aboard (should be worn while navigating) The following equipment is <u>recommended</u>: ▪ A Type IV throwable PFD ▪ Audible distress signal device (air horn, whistle) ▪ Fire extinguisher (if engine-propelled) ▪ Auxiliary propulsion (spare paddles, trolling motor) ▪ Bow and stern lines ▪ Anchor and anchor line ▪ First aid kit ▪ Visual distress signal device(s) (flares, dyes) ▪ Additional PFDs Be familiar with local weather and tidal characteristics. Do not conduct sampling from a boat/barge when threatening weather is imminent, or poor visibility exists. Sampling from a boat is prohibited in water containing substances likely to cause injury upon short-term or prolonged contact. Sampling from a boat is prohibited when the temperature of the water is high or low enough to cause injury upon short-term or prolonged exposure. Avoid sampling from a boat when unsafe water turbulence (waves) exists.

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
		Avoid standing in a boat. Always use the buddy system when sampling from a boat or barge; on person should be on shore with visual contact of the barge and should be able to summon emergency assistance if needed Be familiar with local weather and tidal characteristics. Work on a boat or barge will not be performed when threatening or severe weather is impending or present.
☒	Briars or Thistles	Be aware of any briars or thistles on site. Wear appropriate clothing and gloves. Avoid contact with briars or thistles whenever possible.
☐	Business Traffic	Be aware of traffic patterns associated with local businesses near the work site. Allow traffic to enter and exit the businesses in such a manner to avoid creating traffic hazards, back-ups, delays, or potential accident situations.
☐	Cement Dust	Stay clear of mixing operations and avoid contact with or breathing of the dust.
☐	Chain Saws	Stay clear of any chain saw operations. Subcontractor is responsible for the safe use of chain saws on site.
☐	Cleaning Agents	Use caution of applying cleaning agent to equipment. Use gloves, safety glasses, splash shields, and protective clothing as needed.
☐	Client Activities	Be aware of client activities at or adjacent to the site. Work activities should be coordinated with other site activities to avoid conflicts.
☐	Cold Stress	Work schedules may be modified when temperatures are below 20° F as measured by the wind chill factor. Take frequent breaks to warm up. Drink plenty of fluids. Wear appropriate clothing, and monitor for cold stress symptoms (frostbite, hypothermia, etc.).
☐	Compressed Air or Gas Cylinders	Compressed air or gas cylinders should be clearly marked, and they should be stored, transported, and secured in an approved manner.
☐	Compressed Air/Gas or Pressurized Liquids Hoses, Lines & Fittings	Compressed air or gas, or pressurized liquid lines or hoses should be inspected at least daily, or in the event a leak develops, or if a line or hose is run over or crimped.
☐	Concrete/Masonry/ Foundations	No construction loads shall be placed on a concrete structure or portion of a concrete structure unless a person who is qualified in structural design has determined that the structure or portion of the structure is capable of supporting the loads. All protruding reinforcing steel, onto and into which employees could fall, shall be guarded to eliminate the hazard of impalement. No employee shall be permitted to work under concrete buckets while buckets are being elevated or lowered into position. To the extent practical, elevated concrete buckets shall be routed so that no employee, or the fewest number of employees, are exposed to the hazards associated with falling concrete buckets. A limited access zone shall be established whenever a masonry wall is being constructed. All masonry walls over eight feet in height shall be adequately braced to prevent overturning and to prevent collapse unless the wall is adequately supported so that it will not overturn or collapse. The bracing shall remain in place until permanent supporting elements of the structure are in place.

Risk Analysis (RA)

Other Common Physical Hazards
(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Confined Spaces (tanks, vaults, vessels, trenches, manholes, some excavations, etc.)	The scope of this project does not entail entry into confined spaces. Confined spaces will not be entered unless a confined space entry permit has been completed, signed, and approved, and all participating personnel are trained in confined space entry procedures, including safety, and rescue procedures. Real and potential hazards of confined space are not addressed by this hazard assessment, and health and safety plan.
☒	Cutting Tools	All utility knives with manually retracting blades (including "pocketknives" and other "collapsible, open-blade cutting tools") are not permitted on any TRC jobsite. Activities which include the need to have a sharp cutting tool will be evaluated to determine the proper tool. The proper tools need to be supplied at the job site and be used at all times in substitution for any tool with a fixed open blade knife edge. TRC employees who have fixed open blade knife tools in their offices, work vehicles, or other work-related locations should keep them at home. Subcontractors may keep them in their work vehicles providing they are not used for TRC work. (See TRC's Fixed Open Blade Knife Policy, April 2013). Stay clear of contractors' cutting tools, especially saws and torches. Be aware that cutting operations could create other hazards, such as falling objects, or shifting materials, etc. Safety glasses should be worn while using cutting tools. Spark-proof tools should be used when working in areas of potential explosive or flammable conditions.
☐	Demolition Activities	Stay clear of walls, ceilings, roofs, etc., as they are being demolished.
☐	Demolition Debris	Demolition material should only be handled by appropriate equipment because of sharp points, edges, etc. Demolition material may also pose a trip hazard, fall, or puncture hazard, so avoid walking or climbing on debris piles, etc.
☐	Drums	If drums are used on-site, they should be clearly labeled with the name of the contents. Drums should only be handled with the appropriate equipment. Drums discovered during excavations, etc., shall not be opened or moved until appropriate identification can be performed. At a minimum, Level B protection is required for sampling any unlabeled drums discovered during remediation procedures.
☒	Dust/Particulates (PNOR)(Particulates Not Otherwise Regulated) (OSHA PEL = 15 mg./m^3, total) (OSHA PEL = 5 mg./m^3, respirable)	For general dust, work should be performed up-wind if possible. If conditions warrant it, monitoring should be done with a PM-10. Monitoring should occur at least 3 times per day, and every time re-entering the site. Readings should be taken downwind from the work area or inside the equipment as indicated by the conditions on site. If the OSHA PEL is exceeded, or is likely to be exceeded, engineering or administrative controls should be used, or a dust respirator must be worn. For hazardous dusts, a detailed air monitoring plan and a respiratory protection plan should be developed for the site activities.
☐	Elevated Work	For any construction work activities elevated 6 feet or more, or other non-construction activities elevated 4 feet or more, fall protection must be provided. Caution should be taken on catwalks and ladders because of potential slippery conditions, or the potential for footwear to catch on the surfaces.
☒	Energized Sources (electrical equipment or hookups, lines, etc.,) (Lockout/Tagout)	Contractors for all electrical activities, and any facility equipment with moving parts should follow proper lock-out/tag-out procedures, and only properly trained employees will perform the work. Employees will not perform any lock-out/tag-out activities unless personnel are properly trained in lockout/tagout procedures. Heed any caution signs or labels.
☒	Equipment Exhaust	Equipment exhaust should be ventilated away from the work area while drilling inside structures. Industrial fans can be used to move exhaust out of the area.

Risk Analysis (RA)

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☒	Ergonomic Issues (job hazard analysis)	Ergonomic hazards will be addressed on a site-specific basis once mobilization to the field has occurred. Workstations will be evaluated on an individual basis.
☐	Evening Work	If work is performed during the evening hours, work shall be limited by the availability and the quality of artificial lighting. Care should also be taken to avoid slip, trip, and fall hazards that are not as easy to identify during low light conditions.
☒	Excavations	Stay clear of excavation walls. TRC personnel will not enter an excavation, in accordance with 1926 Sub Part P. Subcontractor must provide a competent person on site, if one is required by the planned activities. Side cuts should conform to 1926 Subpart P requirements, or shoring should be used. All open excavations should be secured using traffic cones, barrier tape, or barricade signs stating, “Do Not Enter Excavations,” especially if left open overnight.
☐	Explosives	Be aware of potential explosive materials and how to identify them. No smoking is allowed on-site or near where potential explosive materials may be present.
☐	Facility Conveyors (product or waste lines)	Stay clear of facility conveyors, product process lines, and waste disposal lines. Be aware of any client specific health and safety requirements to work in these areas.
☐	Facility Equipment/ Machinery	Be aware of active and moving client equipment on site.
☐	Facility Piping - above ground	Stay clear of above ground pipes. Client is responsible to identify all applicable aboveground facility pipes prior to any work activities in the area. Pipes can be overhead hazards, or trip hazards. Pipes can be hazardous because of the material flowing through them, such as steam, natural gas, toxic chemicals, etc. Some pipes are also coated with hazardous material such as asbestos.
☐	Facility Piping - below ground	Client is responsible to identify all applicable underground facility pipe locations prior to any subsurface activities.
☐	Fall Hazard	Proper tie-off, harnesses, railings, etc. should be used when performing work on ladders, scaffolding, man-lifts, or on the roof of buildings, etc. Stay clear of the edges of pits, trenches, quarries, etc.
☐	Falling Objects	Be aware of any potential falling objects or materials on site. Stay clear of any areas identified as potential falling object areas.
☒	Fences	Be aware of fences in disrepair that may be trip hazards or may have materials that could cause punctures or cuts. Use caution when crossing over or under fences.
☒	Field Equipment	If field equipment is heavy or awkward to carry, get assistance or use carts to help move around the site.
☒	Field Vehicle	TRC personnel shall follow all applicable state and federal traffic laws while traveling to and from the site, and while working on the site. In particular the following laws should be followed: speed limits, parking restrictions, use of wipers and lights during precipitation events, limiting cell phone use, etc. It is the responsibility of the driver to verify that all safety equipment on the vehicle is working properly before they drive the vehicle. In particular the following items should be checked: tire pressure, tire tread, windshield wipers, windshield washer, headlights, taillights, brake lights, spare tire, fire extinguisher, first aid kit, etc.
☐	Fire Hazards	Eliminate sources of ignition in work areas that have ignitable materials. Provide an ABC fire extinguisher in close proximity to the support zone.
☐	Flooded Areas	Do not drive through flooded areas or standing water. Do not wade into moving water, or water deeper than 2 feet without adequate assistance.
☒	Flying Debris/ Eye Injuries	Be aware of any flying debris on site and wear protective eyewear when necessary.

Risk Analysis (RA)

Other Common Physical Hazards
(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Forklifts	Be aware of forklift patterns and stay clear of those routes.
☒	Hand Tools	Use only the appropriate tool for the task at hand. Use the tool(s) as designed, described, and intended by the manufacturer.
☒	Heat Stress	The work schedule may be modified if the ambient temperature is more than 80°F. Take breaks as necessary, and drink plenty of fluids. If necessary, wear sunscreen and sunglasses on bright days. Monitor site personnel for signs of heat stress symptoms (heat rash, heat cramps, heat exhaustion, or heat stroke).
☒	Heavy Equipment	Contractor is responsible for safe operation of equipment. All mobile heavy equipment must have a functioning backup alarm, and operators must comply with equipment manufacturer's instructions. Maintain proper distance and remain in line of sight of operator and out of reach of equipment. Isolate equipment swings, if possible. Make eye contact with the equipment operator before approaching the equipment. Understand and review hand signals, and wear orange safety vest, if necessary.
☒	Heavy Lifting	Use proper lifting procedures and equipment when handling heavy objects such as drums, manhole covers, tank covers, etc.
☐	High Pressure Gas Lines, etc.	Be aware of high-pressure gas lines and follow approved safety precautions when working with or around the lines.
☐	Highway Traffic	Traffic control within the right-of-way will be in accordance with the MDOT "Work Zone Safety – Guidelines for Construction, Maintenance, and Utility Operations" procedures. Work may be restricted within specific lanes during peak traffic times. Verify peak traffic times, and review planned activities with the MDOT, so that appropriate lane closures can be coordinated.
☒	Housekeeping	All field vehicles, job trailers, and field offices will be properly cleaned and organized to prevent cluttered work and storage areas.
☐	Hunters/Firing Range, etc.	Be aware of surrounding activities that may involve hunting, firearms, etc. that may not be in your immediate area, but could be create an unsafe work environment.
☐	Ice (thin)	When project activities include either crossing ice or working directly on the ice, a detailed plan should be developed that will be used to continually evaluate the ice conditions, and to determine when work should be terminated due to unsafe conditions. All staff working on the ice will wear an appropriate and approved personal floatation device. Other emergency equipment such as ropes, a throwable floatation device, a means to warm a wet and cold worker, etc. must be available. A buddy system should also be used for this type of work, such that one person is always on shore or at least on previously determined safe ice.
☒	Insects (ticks, bees, spiders, etc.)	Site workers with known allergies to insect bites should carry their own medication. In case of emergencies, inform fellow workers of any severe allergies. Use insect repellant as necessary, and as specifically allowed on site. If possible, wear long-sleeved shirts and pants. If appropriate, check for ticks at the end of each day. Have other appropriate first aid supplies handy for bites.
☒	Irate Neighbors	Be aware of the potential for irate neighbors or outsiders that may interfere with work activities, or that may potentially damage equipment or on-site materials, etc.
☐	Ladders	Ladders should only be used if they are in good condition, conform to OSHA requirements, and if they will be used in an appropriate manner. Be especially cautious of slipping on ladders when the ladder or footwear is wet or dirty.

Risk Analysis (RA)

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Landfill Gas (Methane, CO_2, Hydrogen Sulfide)	Avoid breathing gas, especially in low oxygen areas (simple asphyxiant). Potentially flammable and explosive, so keep ignition sources away from gas. Explosive conditions of LEL >5% in a work area should be ventilated as soon as possible, or the area should be evacuated.
☐	Leachate (Municipal Solid Waste - MSW)	MSW leachate may contain hazardous biological substances, so avoid physical contact with leachate and, if possible, stay up-wind. If contact is made with leachate, wash affected areas thoroughly with soap and water. If boots, contact leachate they should be thoroughly washed with soap and water also.
☐	Lead	Wear gloves when in contact with lead contaminated soil, etc. Thoroughly wash hands and arms when daily work is completed.
☒	Long Hours/Fatigue	Long work hours can lead to fatigue, and fatigue can lead to the physical inability to perform the work in a safe manner, or travel to, or from, a work site in a safe manner. If long work hours are scheduled, or if the scheduled work takes longer than planned, field staff should determine if fatigue is, or will be, an issue. Field staff should evaluate whether they are able to complete the work in a safe manner, or whether they are able to travel in a safe manner. If fatigue is an issue, appropriate breaks should be planned or taken, including overnight stays when necessary.
☐	Material Handling	Move containers and heavy material only with the proper equipment, and secure them to prevent dropping, falling, or loss of control during transport. Stay clear of material handling operations, especially near slopes. Do not stand down the slope from equipment, supplies or materials being moved above on the slope, or being deployed onto the slope.
☐	Material Storage	Stored material may be a falling hazard, or a crush hazard. Do not stand adjacent to materials stacked up, such as pipes, geosynthetic rolls, etc., or in the area of deployment.
☐	Methane Gas (Landfill Gas)	Explosive conditions (5% LEL) will be ventilated, if encountered, prior to working in an area. Methane is a simple asphyxiant.
☐	Mine or Quarry	No work shall be performed within 15 feet (or other designated client setback, whichever is greatest) of the mine or quarry walls. Be aware of the potential for falling rocks or slope failures.
☐	Municipal Solid Waste (MSW)	MSW may contain hazardous biological substances, so avoid physical contact, and if possible, stay up-wind. Wear appropriate PPE, such as gloves, safety shoes, and safety glasses. Wash hands, arms, and face after working near MSW. Reusable PPE and equipment should be thoroughly decontaminated after exposure to MSW. MSW may also contain sharp objects with the potential to puncture PPE.
☐	Natural Gas	Natural gas is flammable and explosive. Keep ignition sources away from gas sources. Use spark proof tools when working with gas lines, etc.
☒	Noise	Hearing protection must be worn when noise levels exceed 85 dBA in the work area. If you need to raise your voice to be heard at the work site, then hearing protection should be worn. Hearing protection will be worn near drill rigs.
☒	Overhead Hazards	Pay attention to overhead equipment, piping, and structures. A hard hat must be worn at all times when overhead hazards are present on site.
☒	Pedestrian Traffic (public, client, workers)	Be aware of pedestrian traffic patterns and, route traffic around the exclusion zone(s), as necessary, to avoid distractions and the potential for exposures or accidents. Use appropriate barricades and caution tape to mark work areas.
☒	Poisonous Plants	Be able to identify any local poisonous plants and avoid them if possible or wear protective clothing as necessary. When removing potentially exposed clothing or PPE, the clothing or PPE should be carefully and thoroughly washed or decontaminated.

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Portable Heaters	Be aware of portable heater locations and stay a safe distance from them.
☐	Power Washing Equipment	Stay clear of the power washing nozzles and equipment.
☐	Propane Tanks	Be aware of propane tank locations, and any gas lines leading to or from the tanks.
☐	Radiation (ionizing)	Exposure to ionizing radiation can be controlled by one of three methods. Time, distance, or shielding. Limit your time near the radioactive source. Keep your distance from the radioactive source. Shield yourself from the radioactive source with appropriate shielding material. If the radioactive source(s) are from TRC equipment, the TRC employee using the equipment needs required training to use the equipment and must be monitored using a dosimeter badge.
☐	Rock Blasting	Contractor is responsible for following safe blasting protocol. Heed all contractor warnings at time of blasting and stay well clear until safe to return to area, as indicated by the contractor.
☒	Sample Preservative Chemicals	Wear safety glasses and nitrile gloves when adding preservative chemicals to sample bottles or vials. Have clean wash water nearby.
☐	Scaffolding	Stay clear of scaffolding. Be aware of the OSHA safety requirements for using constructing and scaffolding.
☒	Severe Weather	Work may be suspended if dangerous weather conditions (lightening, tornadoes, high winds, heavy rain, freezing rain, etc.) occur. Be aware of changing weather conditions and be prepared to take shelter as necessary. Potential shelters should be identified prior to beginning work.
☒	Sharp Objects	Wear appropriate gloves when handling sharp objects or use appropriate equipment to move objects.
☒	Slippery Ground/Surfaces	Exercise caution, especially on slopes, field trailer floors and stairs, after a precipitation event. Use slip resistant boots or implement surface preparations to eliminate the slippery nature of the surface prior to accessing the area. Spill control measures and general housekeeping should be utilized to help prevent slipping on wet floors, wet pavement, and general work areas.
☒	Slips, Trips, and Falls	Maintain clear walkways for work areas.
☒	Snakes	Be aware of the potential for snakes in the area and wear snake boots, snake chaps, gaiters, or leggings as needed.
☐	Steam Cleaning Equipment	Stay clear of the steam cleaning nozzles and equipment.
☐	Steel Erection	All materials, equipment, and tools, which are not in use while aloft, shall be secured against accidental displacement. The controlling contractor shall bar other construction processes below steel erection unless overhead protection for the employees below is provided. Employees engaged in steel erection activities on a walking/working surfaces with an unprotected side or edge more than 15 feet above a lower level shall be protected from fall hazards by guardrail systems, safety net systems, personal fall arrest systems, positioning device systems or fall restraint systems.
☐	Steep Slopes or Banks	Pay attention to footing and walking. Stay a safe distance from unstable or extremely steep slopes. Wear appropriate footwear. Be aware of potential slope or bank failures. Heavy equipment should not be operated on or near unstable slopes or banks.

Risk Analysis (RA)

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Strong Nuisance Odors	Strong odors should be ventilated before entering a work area, or a respirator shall be worn as needed.
☒	Sunburn	For extended periods of time outdoors on sunny days, sunglasses, long-sleeved shirts and long pants should be worn to help prevent sunburn and eye problems. Wear sunscreen as appropriate for the project.
☐	Surface Water	Working next to or on, bodies of water shall be done using the buddy system. Staff shall wear USCG-approved personal floatation devices when on or adjacent to bodies of water.
☒	Terrain	Uneven or steep terrain can cause hazardous conditions for walking and transporting equipment around the site. Site personnel should use caution when working on uneven surfaces, and they should avoid working down-slope from heavy equipment, or materials being moved or stored.
☒	Traffic (client, contractors, public, semi-trucks, forklifts, etc.)	Obey all posted speed limits. Park in designated areas only. Be aware of traffic patterns on site, and during access to the site. Use orange traffic cones and barrier warning tape, as needed, or if within 25 feet of the right-of-way. TRC personnel must wear orange safety vests when working in or near traffic areas.
☐	Trains/Railroad Tracks	Be aware of any train activities on the site, entering or leaving the site, or immediately adjacent to the site. Do not walk between the rails or on the railroad ties. When driving, stop at all railroad crossings, even if they are unmarked, and look in both directions before proceeding across the tracks.
☐	Transporting Hazardous Materials	TRC personnel who transport hazardous materials shall have the required DOT training prior to transporting materials, and will comply with all applicable DOT regulations and requirements for labeling, packaging, etc.
☐	Tree Cutting	Stay clear of tree cutting activities.
☐	Trenching	TRC personnel will not enter trenches not in accordance with 1926 Sub Part P. Be aware that some trenching conditions may result in a confined space condition.
☒	Trip Hazards (wires, cords, hoses, debris, corn stubble, uneven surfaces, etc.)	Temporary wires, cords, hoses, etc., should be properly located, marked, and protected to help prevent tripping and disruption to work activities. Trip hazards are particularly a problem early in the morning, late in the day, or under other poor lighting conditions.
☐	Underground Storage Tanks (USTs) (Septic Tanks)	If any unknown USTs are encountered, drilling or excavations will be terminated in that location until a new scope of work, Risk Assessment and Health & Safety Plan can be developed.
☒	Uneven Surfaces	Be aware of uneven walking or driving surfaces and exercise caution when moving around the site.
☒	Utilities – Overhead (electrical, telephone, cable TV, etc.)	A subcontractor, the client, or TRC will locate and identify all overhead utilities. The owner or client will be responsible for identifying all applicable overhead utilities, product lines, pipes, and aboveground tanks. A minimum clearance of 20 feet must be maintained between equipment and overhead utility lines.
☒	Utilities – Underground (electric, gas, telephone, water, storm sewer, sanitary sewer, cable TV, etc.).	A subcontractor, the client, or TRC will call Digger's Hotline to locate all underground utilities. The owner or client will be responsible for marking all applicable on-site underground utilities, product lines, pipes, and tanks.
☐	Waterways	Exercise caution near, around, or in waterways. Harnesses should be worn when working in, or within 4 feet of, the waterway, especially when attempting to sample from shore or a boat or barge. All applicable laws and regulations will be followed when navigating a boat or barge to and from a work site.

Other Common Physical Hazards

(modify as needed, but include with all project hazard assessments)

☒	Physical Hazard	General Control Measure
☐	Welding Tools	Stay clear of welding operations, and do not look directly at the welding process without appropriate eyewear and shield.
☐	Michigan Department of Transportation (MDOT) Work	Follow the appropriate MDOT guidelines regarding: ▪ Work Zone Safety – Guidelines for Construction, Maintenance, and Utility Operations ▪ Safety Directives Applicable to Subcontractor's Activities ▪ Foot Protection ▪ Eye Protection ▪ Protective Headgear – Hard Hats ▪ Confined Spaces – IHLR 32.61 ▪ Safety Vest ▪ Personal Safety Equipment Requirements on Railroad Property
☐	MDOT Traffic Control	**Traffic Control**: Traffic control within the right-of-way will be in accordance with the MDOT "Work Zone Safety – Guidelines for Construction, Maintenance, and Utility Operations" procedures. Work may be restricted within specific lanes during peak traffic times. Verify peak traffic times, and review planned activities with the MDOT, so that appropriate lane closures can be coordinated.

1. General Information

Client Name:	Detroit Axle Ferndale	Project #:	495430.0000.0000
Project Name:	Former Hayes Lemmerz (Detroit Axle)	Project Manager:	Kelly Cratsenburg
Prepared By:	Renee Whitlock	Date:	8/18/2022
Approved By:	Kelly C. Cratsenburg (PM) **Kelly Cratsenburg**	Approved By:	Colin Daining (HSC) **Colin Daining**
Date:	August 31, 2022	Date:	August 31, 2022

Proposed Date(s) of TRC Work: August 2022 to August 2023

On-Site Project Team Member	On-Site Project Responsibilities
Henry Schnaidt Brian Yelen Jake Krenz	TRC Site Health and Safety Representative (Supervisor)
NA	Project Engineer
Kelly Cratsenburg	Project Hydrogeologist
Kelly Cratsenburg	Project Technical Coordinator
Henry Schnaidt	Project Scientist
Henry Schnaidt	Observation and Documentation
Henry Schnaidt	Soil Sampling
Henry Schnaidt	Groundwater Sampling

2. (1) Field projects will be audited for H&S compliance if they meet the requirements of the audit program.

Any required construction/demolition activities: ☒ No ☐ Yes If Yes, complete Section 2

2. Construction Tasks: [**work tasks to be performed by TRC staff or TRC subcontractors]**

Civil

☐ Sewer (utility)
☐ Water (utility)
☐ Electric (utility)
☐ Communications (utility)
☐ Siding
☐ Roofing
☐ Drywall
☐ Flooring
☐ Ceilings
☐ Casework
☐ Masonry
☐ Escalator
☐ Steel (erection)
☐ Pre-cast (erection)
☐ Concrete (erection)
☐ Re-bar
☐ Elevator
☐ Fireproofing
☐ Windows
☐ Landscaping
☐ Painting
☐ Insulation
☐ Doors
☐ Finish Concrete

Mechanical

☐ Insulation
☐ Millwright
☐ Fire Protection
☐ Boiler
☐ Industrial Ventilation
☐ Steel Fabrication/Erection

Other

☐ Electrical
☐ Demolition (attach a detailed "**<u>Demolition Plan</u>**")

☐ Others
☐ Others
☐ Others

Estimated Direct-Hire TRC Employees:

Home Office: ☐ Not Applicable ☐ Specify:
Craft Labor: ☐ Not Applicable ☐ Specify:

Craft	Quantity
Craft	Quantity

3. Applicable Safety Standards or Regulations:

☐ Federal OSHA ☒ State OSHA ☐ Owner/Client

Specific Standards:	29 CFR 1910 (OSHA)	29 CFR 1926 (Other Regulations)
☒ Medical Services and First Aid	1910.151	1926.50
☒ Hazard Communication (HAZCOM)	1910.1200	1926.59
☐ Lead Exposure	1910.1025	1926.62
☒ HAZWOPER	1910.120	1926.65
☒ Personal Protective Equipment (PPE)	1910.132-138	1926.95-107
☐ Respiratory Protection	1910.134	1926.103
☐ Ventilation	1910.94	1926.57
☒ Noise Exposure	1910.95	1926.52
☐ Illumination	N/A	1926.56
☒ Fire Protection	1910.157	1926.24 and 150-155
☐ Sanitation	1910.141	1926.51
☐ Materials Handling (rigging, etc.)	1910.176	1926.250-251
☐ Welding/Cutting	1910.251-255	1926.350-354
☐ Lockout/Tagout	1910.147	1926.417
☐ Electrical (flexible cords, etc.)	1910.305	1926.400-449
☐ Scaffolding	1910.28-29	1926.450-454
☐ Fall Protection (elevated work)	1910.23-29, 1910.66-68	1926.104-107; 500-503
☐ Ladders/Stairways	1910.25-27	1926.1050 and 1060
☐ Cranes, Derricks, Hoists, Elevators, etc.	1910.179-181	1926.550-555
☐ Aerial Lifts	1910.66-68	1926.556
☒ Earth Moving Equipment	N/A	1926.602
☐ Powered Industrial Trucks (forklifts)	1910.178	1926.602
☒ Excavations and Trenching	N/A	1926.650-652
☐ Concrete and Masonry	N/A	1926.700-706
☐ Steel Erection	N/A	1926.750-761
☐ Demolition	N/A	1926.850-860
☐ Asbestos	1910.1001	1926.1101
☐ Confined Space Entry	1910.146	1926.21
☐ Commercial Diving	1910.401-441	1926.1071-1092
☒ Compressed Gases	1910.101-105	N/A
☐ Ionizing Radiation	1910.1096	1926.53
☒ Benzene	1910.1028	1926.1128
☐ Cadmium	1910.1027	1926.1127
☒ Tools - Hand and Power	N/A	1926.300-307
☐ Blasting and Using Explosives	N/A	1926.900-914

4. Training Required (* required for all “Type 3” sites; but minimum recommended)

Check “A” if training required for everyone, and check “T” if training required for specific task.

A	T	Subject	Reference	
			29 CFR 1910	29 CFR 1926 or Other
☒	☐	HAZWOPER 40 hour*	1910.120	1926.65
☒	☐	3-Day HAZWOPER Supervised On-Site*	1910.120	1926.65
☒	☐	8-Hour HAZWOPER Refresher*	1910.120	1926.65
☐	☒	8-Hour Supervisor HAZWOPER*	1910.120	1926.65
☒	☐	First Aid, CPR*	1910.151	1926.23,.50
☐	☐	Respiratory Protection	1910.134	1926.103
☐	☐	Confined Space ☐ Permit attached	1910.146	1926.21
☐	☐	Mine Safety (MSHA)	N/A	30 CFR 48.8
☐	☐	Lockout/Tagout ☐ Permit attached	1910.147	1926.417
☐	☐	Bloodborne Pathogens	1910.1030	N/A
☐	☐	Noise Exposure	1910.95	1926.52
☐	☐	Competent Person	N/A	1926.32,.450,.650
☐	☐	Construction Health and Safety OSHA 10-Hour	N/A	1926.21
☐	☐	Demolition	N/A	1926.850
☐	☐	Excavations ☐ Permit attached	N/A	1926.650-652
☐	☐	Electrical Work	1910.332	1926.400-.449
☐	☐	Ladders/Stairways	N/A	1926.1050-1060
☐	☐	Scaffolding	1910.28	1926.450-454
☐	☐	Fall Protection	1910.23-29; 1910.66-68	1926.104,.501
☐	☐	Commercial Diving	1910.410	1926.1071-1092
☐	☐	Hot Work ☐ Permit attached	1910.251-255	1926.350
☐	☐	Lead Awareness	1910.1025	1926.62
☐	☐	Asbestos Awareness	1910.1001	1926.1101
☐	☐	Cadmium	1910.1027	1926.1127
☐	☐	Benzene	1910.1028	1926.1128
☐	☐	Ionizing Radiation	1910.1096	1926.53; 10 CFR 19.12
☐	☐	Troxler or NITON Gauge User	1910.1096	10 CFR 19.12
☐	☐	Radiation Safety Program	1910.1096	10 CFR 20.1101
☐	☐	Hazard Communication (HAZCOM)	1910.1200	1926.59
☐	☐	DOT Hazardous Materials Shipping	1910.1201	49 CFR 172.704

Client-specific training: ☒ Not Applicable ☐ Specify
Site-specific orientation: ☒ Not Applicable ☐ Specify
Competent person: ☒ Not Applicable ☐ Specify
Direct-hire employee training/certification: ☒ Not Applicable ☐ Specify

5. Medical Surveillance

Surveillance Required: * required for all "Type 3" sites; baseline is minimum recommended
** Specify frequency below

		29 CFR 1910	29 CFR 1926 or Other
☒	HAZWOPER Physical - Baseline*	1910.120	1926.65
☒	HAZWOPER Physical – Annual	1910.120	1926.65
☒	HAZWOPER Physical - Biennial*	1910.120	1926.65
☐	OSHA Respiratory Protection Questionnaire	1910.134	1926.103
☐	Respiratory Certification Exam	1910.134	1926.103
☐	Arsenic (urine) **	1910.1018	N/A
☐	Asbestos **	1910.1001	1926.1101
☐	Cadmium (blood) **	1910.1027	1926.1127
☐	Lead/ZPP (blood) **	1910.1025	1926.62
☐	Mercury (blood) **	N/A	N/A
☐	PCB **	N/A	N/A
☐	Vinyl Chloride **	1910.1017	1926.117
☐	Hepatitis B Vaccine (series) **	1910.1030	N/A
☐	Tetanus/Diphtheria	N/A	Stay Current
☐	Stress Test	N/A	Only as requested
☐	Visual Acuity Test	N/A	Only as requested
☐	Hearing Test (Audiometry)	N/A	Only as requested
☐	Pulmonary Function	N/A	Only as requested

Client-specific drug testing[1]: ☒ Not Applicable ☐ Specify
Client-specific medical monitoring[1]: ☒ Not Applicable ☐ Specify
Site-specific medical monitoring: ☒ Not Applicable ☐ Specify
**Frequency of medical monitoring: ☒ Not Applicable ☐ Specify

[1] Client required drug testing or medical monitoring should be coordinated through the CHSM.

Note: TRC has a "Drug and Alcohol-Free Workplace" policy (TRC Academy Course #900013753). TRC may require employees or subcontractors to be tested upon reasonable suspicion, following accidents or incidents during work activities, or during travel to or from a project site. Client policies may be stricter in regard to procedures following an accident. Project managers must be aware of these and inform employees and subcontractors of any additional requirements.

6. Personal Protective Equipment (PPE)

Based on evaluation of potential hazards, the following levels of personal protection have been designated for the applicable work tasks:

Specific TRC Job Task Or Function	Minimum Level Of Protection
TRC Site Visitors—Must be escorted	☒ D
Monitoring well/soil boring/soil vapor monitoring point installation	☒ D ☐ C ☐ B ☐ A
Level D: Safety glasses (ANSI); Safety shoes (ANSI); Hard hat (ANSI); Nitrile gloves; Reflective vest (ANSI); Cut Resistant gloves, hearing protection as needed	
Soil/Groundwater/soil vapor sample collection	☒ D ☐ C ☐ B ☐ A
Level D: Safety glasses (ANSI); Safety shoes (ANSI); Hard hat (ANSI); Nitrile gloves; Reflective vest (ANSI); Cut Resistant gloves	
Surveying, Utility clearing	☒ D ☐ C ☐ B ☐ A
Level D: Safety glasses (ANSI); Safety shoes (ANSI); Hard hat (ANSI); Reflective vest (ANSI)	
Test Pitting/Pot Holing	☒ D ☐ C ☐ B ☐ A
Level D: Safety glasses (ANSI); Safety shoes (ANSI); Hard hat (ANSI); Reflective vest (ANSI)	
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A
	☐ D ☐ C ☐ B ☐ A

Criteria for changing protection levels are as follows:

Evacuation(2) or Protection Level Change(3) Criteria	Approvals Required (1)		
	HSR	HSC	CHSM
Site Evacuation Plan: ☒ Not Applicable ☐ Specify or Attach Plan:			
Change to Level D when: ☒ Not Applicable ☐ Specify	☐		
Change to Level C when: ☒ Not Applicable ☐ Specify	☒	☒	☒
Change to Level B when: ☒ Not Applicable ☐ Specify	☒	☒	☒
Change to Level A when: ☒ Not Applicable ☐ Specify	☒	☒	☒

3. (1) HSR: Health & Safety Supervisor On Site
HSC: Health & Safety Coordinator
CHSM: Corporate Health & Safety Manager
(2) General Recommendations: Evacuate the area when LEL readings are >10% LEL in the atmosphere, or when PID readings are greater
4. than the PEL in the breathing zone.
(3) General Recommendation: To Level C when PID readings are greater than the PEL in the breathing zone. To Level B or A only after detailed evaluation and planning.

Note: Changes to the level of protection shall be made only after the required approvals are obtained. All changes shall be recorded in the field log and reported to the Project Manager as soon as possible. TRC's H&S goal is to avoid using respiratory protection unless it is absolutely necessary or required. Administrative controls or engineering controls should always be considered as a means to reduce potential exposures, before PPE is required or considered.

7. Air Monitoring(1)

The following monitoring instruments shall be used on site to measure airborne contaminant concentrations in either the breathing zone, or as part of the overall site **Air Monitoring Plan** (attach detailed plan):

Monitoring Equipment	Location Of Monitoring	Frequency Of Monitoring	Action Levels
☐ Combustible Gas Indicator	☒ N/A ☐ Monitoring Plan Attached ☐ Confined Space ☐ Specify	☐ Continuously when potential combustible gases or lack of oxygen are suspected. ☐ Specify	5-10% LEL: continue with caution > 10 % LEL: evacuate the area ☐ Specify
☐ O2 Monitor ☐ CO Monitor ☐ H_2S Monitor	☐ N/A ☐ Confined Space ☐ Specify	☐ Continuously when excess oxygen (>22.5%) or lack of oxygen (<19.5%) are suspected. ☐ Specify	< 19.5% Oxygen: evacuate the area; supplied air may be needed > 22.5% Oxygen: evacuate the area; potential fire hazard ☐ Specify
☐ Colorimetric Tubes	☐ N/A ☐ Specify	☐ Periodically during sampling for analytical purposes only	☐ Specify
Type:	☐ Sample Container	☐ Whenever noticeable odor is present	
Type:	☐ Confined Space	☐ Specify	
Type:	☐ Specify		
☒ PID	☐ N/A	☒ Periodically during sampling for analytical purposes only	☐ Specify
Minirae 3000	☐ Sample Container		
Lamp Needed: ☐ 9.8 eV ☒ 10.6 eV ☐ 11.7 eV	☐ Confined Space ☐ Specify	☐ Specify	
Calibration Gas: Isobutylene 100 PPM		☐ Specify	
Correction Factor: **N/A**		☐ Specify	
☐ FID	☐ N/A ☐ Specify	☐ Specify	☐ Specify
☐ Mini-RAM	☐ N/A ☐ Specify	☐ Specify	☐ Specify
☐ Other:	☐ Specify	☐ Specify	☐ Specify
☐ Laboratory Supported	☐ N/A ☐ Specify	☐ Specify	☐ Specify
☐ Personal			
☐ Area			
☐ Perimeter			

5.(1) Whenever air monitoring is required to be performed, a detailed **Air-Monitoring Plan** should be developed and attached to the HSP. The plan should include **Monitoring Locations, Frequency of Readings**, and any **Action Levels** being used to control the work site**.**

8. Site Controls and Work Zones **(describe in detail)**

Facility Alarms or Signals: ☒ Not Applicable ☐ Specify

Work Permits Required: ☒ Not Applicable ☐ Specify

Work Traffic Issues: ☒ Not Applicable ☐ Specify

Parking Issues: ☒ Not Applicable ☐ Specify

Railway Traffic Issues: ☒ Not Applicable ☐ Specify

Support Zone(s):

☒ TRC field vehicle ☐ Job Trailer On Site ☐ Other:

Contamination Reduction Zone(s):

☒ Field vehicle ☐ Facility restroom/utility room ☐ Other:

Exclusion Zone(s):

☒ Area immediately surrounding work area ☐ Other:

Site Entry Procedures:

☒ **Notify Site H&S Representative.**
☒ **Read H&S Plan and sign Acknowledgment Statement**
☐ Check in with the facility contact person ☐ Specify
☐ Check in with facility security guard. ☐ Specify
☒ **Wear proper personal protective equipment.**
☐ Attend facility orientation ☐ Specify
☒ **Conduct daily safety meeting (document).**
☐ Other: ☐ Specify

Decontamination Procedures:

Personnel: (specify)

Example: If severe contamination is expected, or the work was performed in Level A, Level B, or Level C, a specific and detailed decontamination procedure should be written to address the appropriate contamination. If work was performed in Level D or Modified Level D, and minimal contamination is expected, follow standard decontamination procedures, and good personal hygiene. Disposable PPE should be removed, contained, and disposed in an appropriate manner. Prior arrangements should be made if disposal is planned for at the project site. Site workers should plan and stage for wash water and soap at the site, prior to beginning the work. Site workers should wash hands and any exposed skin extremely well with soap and water, prior to leaving the contamination reduction zone, eating, drinking, driving, or leaving the site. Any soiled or contaminated clothing should be removed and handled appropriately, by either washing as soon as possible, or if necessary, disposing. Soiled or contaminated clothing should be carefully bagged prior to disposal or washing, to reduce potential exposure.

Equipment: (specify)

Example: If severe contamination is expected, a specific and detailed decontamination procedure should be written to address the appropriate contamination. Site workers should plan and stage for the appropriate decontamination method at the site, prior to beginning the work. Any contaminated single-use disposable equipment or PPE should be appropriately containerized and disposed as soon as possible in an appropriate manner. Prior arrangements should be made if disposal is planned for at the project site. Contaminated equipment or PPE that will be re-used should be handled and cleaned while wearing the appropriate PPE. Typically, equipment is decontaminated using Alconox soap and de-ionized water. Refer to attachments for PFAS SOPs.

Disposal of Investigation-derived Material:

☐ Leave on site for disposal.

☒ Other: Return soil to boring hole, water to temporary well

Work Limitations (time of day, buddy system, etc.):

☐ Buddy system required for some tasks Specify

☒ Work will be performed during daylight hours only

☐ Work will be performed using artificial light.

Describe or attach a lighting plan:

☒ No eating, drinking, or smoking in contamination reduction zone(s) or exclusion zone(s)

☒ When temperatures are either above 80°F or below 20°F, work schedules may be modified

☐ Other site-specific limitations:

Radiation Safety:

☒ Radiation information is not applicable to this project.

☐ Notify RSO.

☐ Wear dosimeter badge when handling gauge.

☐ Post applicable radiation signs and documents.

☐ Post emergency numbers.

☐ Provide at least two lock systems for overnight storage.

☐ Maintain storage at least 15 feet from full-time workstations.

☐ Block, brace, and securely lock the gauge during “all” transportation.

☐ Limit “public” exposure to gauge while in use.

☐ Provide sketch of gauge storage to RSO.

Acknowledgment Statement:

As an employee of TRC, I have reviewed the Hazard Assessment (HA)/Health & Safety Plan (HSP). I hereby acknowledge that I have received the **required level of training and medical surveillance**, that I am knowledgeable about the contents of this site-specific RA/HSP, and that I will use personal protective equipment (PPE) and follow procedures specified in the HSP.

Signatures of TRC Site Personnel:

Signature	Date

Health and Safety Field Audit Documentation:

If this project has been selected as a field audit candidate, the auditor will review a copy of this RA/HSP and make comments, edits, additions, or deletions on the copy. The audit copy of this document will then be forwarded to the office HSC for review. After review, the HSC will then forward the copy to the Project Manager for review and filing.

____(auditor) Date: ________________________

TRC PROJECT/FIELD SAFETY AUDIT FORM

Project Name: ____________________ Office Location: ____________________

Project Number: ____________________ Date of Audit: ____________________

Check Yes, No or N/A for each item ***For all non-compliant responses, enter description and corrective action(s) on notes page***

	General	Yes	No	N/A	Corrective Action Notes
1	For TRC projects with temporary offices, are OSHA and job-site warning posters posted and are job-site injury records kept?				
2	Are all TRC personnel current on training requirements (i.e., 40-Hour HAZWOPER, 8-Hour Refresher)?				
3	Is training documentation for TRC employees available on site?				
4	Are appropriate TRC personnel current with medical surveillance protocol?				
5	Is at least one TRC employee on site currently trained in CPR and First Aid?				
6	Is there a stocked first aid kit located near/in job trailers?				
7	Are all containers labeled to clearly identify their contents?				
8	Are hot work zones established for hazardous waste operation and enforced?				
9	Are compressed gas cylinders being used on site properly secured?				
10	Are daily, pre-work safety meetings being held?				
	TRC Subcontractors	**Yes**	**No**	**N/A**	**Corrective Action Notes**
11	Were subcontractors qualified for the project by using TRC’s subcontractor H&S Qualification form?				
12	Are subcontractors using appropriate personal protective equipment to protect their employees?				
13	Have all non-TRC employees on site been informed as to possible hazards?				
14	Does the subcontractor have a stocked first aid kit in their job trailer?				
	TRC H&S Plan	**Yes**	**No**	**N/A**	**Corrective Action Notes**
15	Has the H&S plan been reviewed and signed by all on-site TRC personnel?				
16	Are H&S procedures listed in the TRC H&S plan being followed by TRC personnel?				
17	Does the TRC H&S plan address all apparent hazards at this site?				
18	Is the TRC H&S plan specific to the Project operations/TRC project responsibilities?				
19	Is appropriate PPE identified on the TRC H&S plan?				
20	Is the PPE being utilized by TRC personnel as directed in the H&S plan?				
21	Are medical facilities identified on the TRC H&S plan?				

TRC PROJECT/FIELD SAFETY AUDIT FORM

Project Name: ______________________ Office Location: ______________________

Project Number: ______________________ Date of Audit: ______________________

Check Yes, No or N/A for each item ***For all non-compliant responses, enter description and corrective action(s) on notes page***

	Hazard Communication	Yes	No	N/A	Corrective Action Notes
22	Are MSDSs for TRC-supplied materials available?				
23	Are MSDS for subcontractor-supplied materials available?				
24	Have employees received hazard communication training?				
25	Are hazardous substances clearly marked?				
26	Is there an Emergency Response Plan in place in case of unintentional release (i.e., spill kit)?				
	Fire Protection/Prevention	**Yes**	**No**	**N/A**	**Corrective Action Notes**
27	Is fire-fighting equipment available and in proper working condition?				
28	Have TRC personnel been trained in use of fire-fighting equipment?				
29	Are "no smoking" signs posted in appropriate locations?				
	Electrical/Power Tools	**Yes**	**No**	**N/A**	**Corrective Action Notes**
30	Are electrical dangers posted?				
31	Are ground fault circuit interrupters used?				
32	Are terminal/discount/breaker dead front boxes equipped with covers?				
33	Have known underground/overhead utilities been identified and clearly marked?				
34	Are power tools properly grounded or double insulated?				
35	Are mechanical ties and guards in use with power tools?				
36	Is there an appropriate Lockout/Tagout (LOTO) procedure in place?				
	Ladders	**Yes**	**No**	**N/A**	**Corrective Action Notes**
37	Are ladders inspected and properly maintained (e.g., not painted)?				
38	Are ladders properly secured to prevent slipping, sliding, or falling?				
39	Do side rails extend 36 inches above the top of the landing?				
40	Are stepladders fully open when in use?				
41	Are metal ladders being used around electrical equipment?				

TRC PROJECT/FIELD SAFETY AUDIT FORM

Project Name: ______________________ Office Location: ______________________

Project Number: ______________________ Date of Audit: ______________________

Check Yes, No or N/A for each item ***For all non-compliant responses, enter description and corrective action(s) on notes page***

	Scaffolding	Yes	No	N/A	Corrective Action Notes
42	Have employees received training in proper scaffold use?				
43	Is there a competent person on site?				
44	Are all connections secure and scaffold equipment in good working order?				
45	Is scaffold tied into structure when it exceeds 4 times the base width of the scaffold?				
46	Are working areas free of debris, snow, grease, ice?				
47	Are workers protected from falling objects?				
48	Is the scaffold plumb and square with cross-bracing?				
49	Are guard rails, intermediate rails, toe-boards, and end rails in place for scaffolds over 10 ft.?				
	Manholes and Permit-Required Confined Space Entry	**Yes**	**No**	**N/A**	**Corrective Action Notes**
50	Has access and egress been provided?				
51	Has an entry permit been obtained?				
52	Have hazards been properly identified?				
53	Is air monitoring equipment on site, appropriate, calibrated, and in use?				
54	Are areas being ventilated before entry and during occupation?				
55	Have entrant, attendant, and rescue personnel been identified?				
56	Is proper rescue equipment on site? Inspected?				
57	Is appropriate lighting provided?				
	Motorized Vehicles	**Yes**	**No**	**N/A**	**Corrective Action Notes**
58	Have operators received training?				
59	Are brakes, lights, horn, seat belts, backup lights or warning signals intact and functioning?				
60	Are personnel carried in a safe manner?				
61	Are fire extinguishers carried, if appropriate?				

TRC PROJECT/FIELD SAFETY AUDIT FORM

Project Name: ______________________ Office Location: ______________
Project Number: ______________________ Date of Audit: ______________

Check Yes, No or N/A for each item ***For all non-compliant responses, enter description and corrective action(s) on notes page***

	Excavations	Yes	No	N/A	Corrective Action Notes
62	Are excavations inspected daily?				
63	Is there any excavation entry by TRC staff?				
64	Is the competent person overseeing the trenching excavation work on site?				
65	Is shoring, sloping or benching appropriate?				
66	Is access and egress provided for employees working in excavations of 4 feet or greater in depth?				
67	Are materials stored within 2 feet of the excavation?				
68	Is the excavation barricaded?				
69	Have soils been classified (if sloping and benching is used as the protective system for employees)?				
	Water Safety	**Yes**	**No**	**N/A**	**Corrective Action Notes**
70	Are watercraft inspected before use for leaks, damage, etc.?				
71	Is necessary emergency gear (life jackets or rings, fire extinguishers, flares, etc.) available?				
72	Are employees trained on proper safety protocols involving wading and walking in water?				
73	Are employees using the "buddy system" when taking samples in water?				
	Other Items	**Yes**	**No**	**N/A**	**Corrective Action Notes**
74					
75					
76					
77					
78					
80					

HSC Signature: ______________________ **Date:** __________ **PM Signature:** ______________________ **Date:** __________

TRC PROJECT/FIELD SAFETY AUDIT FORM

Notes Page

Item #	Comments And Corrective Actions	Deadline For Correction(S)	Date Complete	Initials

HSC Signature: ______________________ **Date:** __________ **PM Signature:** ______________________ **Date:** __________

DAILY SAFETY MEETING SIGN-IN

Daily Hazard Review Topic:

☐ Animals
☐ Battery
☐ Briars or Thistles
☐ Business Traffic
☐ Cutting Tools
☐ Ergonomic Issues
☐ Field Equipment
☐ Field Vehicle
☐ Fire Hazards
☐ Flying Debris/ Eye Injuries
☐ Hand Tools
☐ Heat Stress
☐ Heavy Equipment
☐ Heavy Lifting
☐ Housekeeping
☐ Insects
☐ Irate Neighbors
☐ Long Hours/Fatigue
☐ Noise
☐ Overhead Hazards
☐ Pedestrian Traffic
☐ Poisonous Plants
☐ Sample Preservative Chemicals
☐ Severe Weather
☐ Sharp Objects
☐ Slippery Ground/Surfaces
☐ Slips, Trips, and Falls
☐ Snakes
☐ Sunburn
☐ Terrain
☐ Traffic
☐ Trip Hazards
☐ Uneven Surfaces
☐ Utilities – Overhead
☐ Utilities – Underground

Acknowledgment Statement:

As an affected employee of TRC, I hereby acknowledge that I have reviewed the contents of this site-specific RA and HASP, and that I will use the applicable personal protective equipment (PPE) and follow the procedures specified in the HASP as it pertains to the scope of the work to be performed today.

Signatures of all onsite TRC Personnel, including Direct-Hires (Required):

Signature	Date

Health & Safety
Direct Reading Instrument Log

Operator: ______________________ **Date:** ____________

Active Operation: ______________________

____

Weather: ______________________

Instrument: ____________ **Miniram:** ____________ **Other:** ____________

Time	Location	Duration	PID	RAM	CO	H_2S	HCN	LEL	02	Comments

Health & Safety
Direct Reading Instrument Log

Time	Location	Duration	PID	RAM	CO	H_2S	HCN	LEL	02	Comments

Operator: ______________________ **SSO:** ______________________

Health & Safety
Authorization to Disclose Health Information

In the event of an incident, this form should be sent with the injured employee to the clinic/hospital where they are being treated. It allows the employee's health information and treatment to be shared with TRC's Worker's Compensation provider Sargent & Associates.

Patient's Name: ____________________________________ Date of Birth: _____________________

1. I authorize the use or disclosure of the above-named individual's health information as described below:

   The following individual or organization is authorized to make the disclosure:

   Any and all healthcare providers that are providing treatment for my **work-related** injury.

2. The type and amount of information to be disclosed is as follows:

   Any and all medical records, hospital records, doctor's office records and notes, diagnostics tests, physical and occupational therapy records, chiropractic records, mental health records, etc. that pertain to my **work-related** injury that occurred on or about ____.

3. This information may be disclosed to and used by the following individual or organization:

   Joanne L. Sargent, R.N.
   CCM, CPUR, CLNC, CWCP, HC Sargent & Associates, Inc.
   20 Chelmsford Street
   Chelmsford, MA 01824
   Phone: 1-978-567-6468
   Fax: 1-978-256-4941

4. I understand that I have the right to revoke this authorization at any time. I understand if I revoke this authorization I must do so in writing and present my written revocation to the Health Information Management Department at Sargent & Associates. I understand that the revocation will not apply to information that has already been released in response to this authorization. Unless otherwise revoked, this authorization will expire at the end of one year.

5. I understand that authorizing the disclosure of this health information is voluntary. I can refuse to sign this authorization. I need not sign this form in order to assure treatment. I understand I may inspect or copy the information to be used or disclosed, as provided in CFR 164.524. I understand that the Health Insurance Portability and Accountability Act (HIPAA – 45 CFR 164.5121[1]) permits health care providers to disclose health information to workers' compensation insurers, State Administrators, employers, and other person or entities involved in workers' compensation systems. If I have questions about the disclosure of my health information, I can contact Joanne Sargent, R.N., at the above telephone number.

Signature____ Date:______________________________

WORKCARE®
Making Health Count

FACT SHEET

EARLY INCIDENT INTERVENTION®

Immediate Access to Medical Advice for Work Related Incidents

(888) 449-7787

INTRODUCTION

WorkCare, Inc. (WorkCare) and TRC have partnered together to promote Incident Intervention®, a resource designed to support company safety goals/targets—while reducing runaway-costs associated with workplace injuries and illnesses.

PURPOSE

Early Incident Intervention provides TRC employees with **IMMEDIATE** telephonic access to WorkCare clinicians at the time of a presumed, non-emergency workplace injury or illness. Clinicians provide expert guidance on the evaluation of symptoms, appropriate first aid, and the need for additional medical evaluation or treatment.

When utilizing this service within the first hour of an incident, known as the "Golden Hour," licensed medical staff can guide the case so that medical evaluation and treatment are rendered appropriately.

> *"…helps the worker traverse the unpredictable terrain of work-related injuries and illness."*

PRINCIPLES OF EARLY INCIDENT INTERVENTION

- Utilizes principles of the "Golden Hour."
- Provides workers immediate clinician support at the time of an incident.
- Focuses on providing the right care, at the right time in the proper setting.

BENEFITS FOR EMPLOYEES

- Instant access to a medically qualified professional for evaluation of symptoms and possible outcomes.
- Professional guidance on appropriate first aid measures and medications.
- Professional advice regarding the need for additional medical evaluation or treatment.

BENEFITS FOR TRC

- Point of contact for emergency and non-emergency medical clinicians.
- Triages the incident to determine risk and urgency, delivering interventions that are consistent with medical guidelines for the specified injury and illness.
- Maintains communication with clinicians to ensure accurate and timely reporting.

The Right Care - The Right Time - The Proper Setting

(888) 449-7787

AUTO INCIDENT REPORT

EMPLOYEE INFORMATION (V-1):

Name: ______________________ Phone: ( ) ______________________

Sector/Practice: ______________________ Office Location: ______________________

Supervisor's Name: ______________________ Supervisor's Phone: ( ) ______________________

Project #: ______________________ Client's Name: ______________________

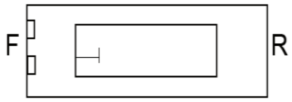
Driver's License #: ______________________ State: ______________________

VEHICLE INFORMATION (V-1):

Year/Make/Model of Vehicle: ______________________

License Plate #: ______________________ Vehicle ID # (VIN): ______________________

Circle Point of Contact:



Was Vehicle Drivable? ☐ Yes ☐ No

Personal: ☐ Yes Rental: ☐ Yes Fleet: ☐ Yes

Rental Company

INCIDENT INFORMATION:

Date of Incident: __________ Time of Incident: ________ A.M. ________ P.M. Photos Taken: ☐ Yes ☐ No

Location of Incident: ______________________ City/State: ______________________

Were The Authorities Contacted? Police: ☐ Yes ☐ No Ambulance: ☐ Yes ☐ No Fire: ☐ Yes ☐ No

Name of Police Dept: ______________ Case #: ______________ Officer Name: ______________

Were Citations Issued? ☐ Yes ☐ No If Yes, To Whom? ______________________

Citation Number: ______________________

Were There Any Witnesses? ☐ Yes ☐ No If Yes, Please Provide Name, Address and Phone Below:

Witness Name: ______________________ Witness Phone: ( ) ______________________

Witness Address: ____

Traffic Conditions (i.e., heavy, light): ______________ Weather Conditions (i.e., dry, wet, ice, fog): ______________

WorkCare Contacted? ☐ Yes ☐ No

TRC Driver Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Front Seat Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Rear Driver Side Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Rear Passenger Side Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Describe Injuries:

____

Describe Damage to Property Other Than Motor Vehicles (i.e., guardrails, mailboxes, etc.):

____

AUTO INCIDENT REPORT

OTHER DRIVER & VEHICLE INFORMATION (V-2):

Driver's Name: ____________________ Driver's Phone: (   ) ____________

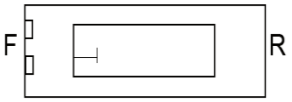
Driver's Address: ____

Owner's Name (If different than driver): ____________ Owner's Phone: (   ) ____________

Owner's Address: ____

Year/Make/Model of Vehicle: ______________ License Plate #: __________ State: ______

Circle Point of Contact:



Was Vehicle Drivable? ☐ Yes ☐ No

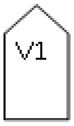
Insurance Company Name: ____________________ Policy Number: ____________________

Insurance Company Phone: (   ) ____________ Number of Passengers in Vehicle: __________

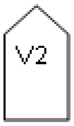
List Persons Injured: ____

Were Any Other Vehicles Involved in Incident? ☐ Yes ☐ No If yes, provide details below:

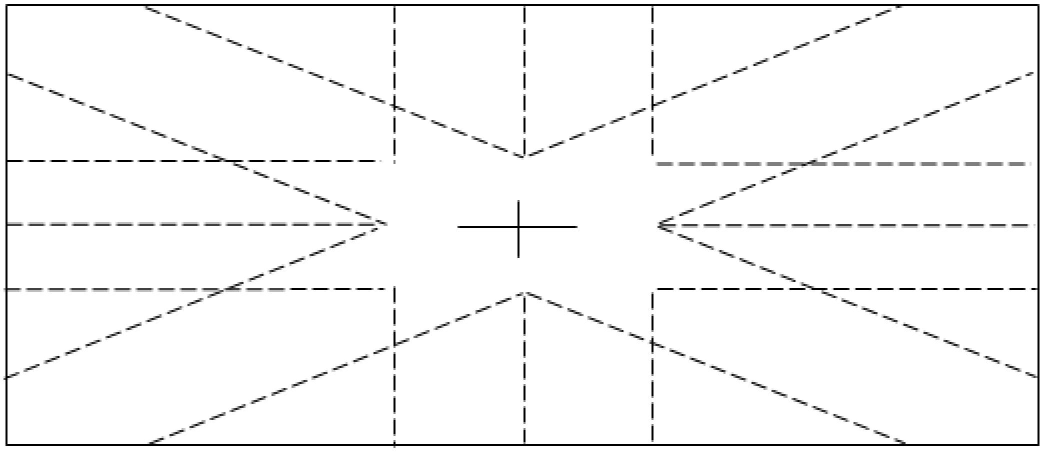
PLEASE DESCRIBE THE INCIDENT AND COMPLETE THE DIAGRAM BELOW. Be sure to indicate as many details as possible (i.e., How many lanes in each direction; Were there any turn lanes; What kind of traffic controls were there – light, stop sign, yield sign, Positions of vehicles on impact).

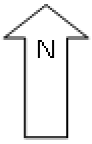


V-1 TRC Vehicle



V-2 Other Vehicle





Completed By: ______________________________ Signature: ____________________

INCIDENT NOTIFICATION REPORT

(To be completed immediately after an Injury, Illness, Incident or Significant Near Miss by Employee's Supervisor and Employee involved)

Incident Category

☐ Injury/Illness ☐ Near Miss/Loss ☐ Property Damage ☐ Other

1 Incident Location: ____________________

2 Project #: ____________________

3 Client: ____________________

4 Date Incident Occurred: ____________________ Time: __________

5 Date Incident Reported: Time:

TRC Employee Information

6 Name: ____________________ Phone: __________

7 Office: ____________________ Address: __________

8 Supervisor Name: ____________________ Phone: __________

9 Title or Occupation: ____________________

10 Sector/Practice:

Incident Description

11 Task Performed/Description of Incident:

____

12 Conditions at the Time of Incident (weather, lighting, etc.):

____

13 Description of Property Damage:

Employee Injury or Illness Description

14 Describe the Injury or Illness:

____

15 First Aid/Medical Treatment Administered:

____

16 Was WorkCare Contacted? ☐ Yes ☐ No

17 Name of Doctor's Office, Clinic or Hospital: ____________________

18 Address: Phone:

INCIDENT NOTIFICATION REPORT

(To be completed immediately after an Injury, Illness, Incident or Significant Near Miss by Employee's Supervisor and Employee involved)

Subcontractor Involvement

19 Was a subcontractor involved? ☐ Yes ☐ No

20 Name of Company: ______________________________

21 Address: ______________________________

22 Contact Name: ____________________ Phone: __________

23 Description of the Incident:

Witness Information

24 Were there witnesses to the incident? ☐ Yes ☐ No

	Name(s)	Address(es)	Number(s)
25			

Immediate Corrective Actions

26 Describe the Immediate Corrective Actions Taken:

Client Notification

27 Is there a client incident notification requirement? ☐ Yes ☐ No

28 Contact Name ______________________________

29 Date of Notification: ____________________ Time: __________

30 Notification Method:

Supervisor: ______________ Signature: ____________________ Date: __________

Employee: Signature: Date:

A “Safe Catch” is a potential hazard or incident that has not resulted in any personal injury. Unsafe working conditions, unsafe employee behaviors, improper use of equipment or use of malfunctioning equipment have the potential to cause work related injuries. It is everyone’s responsibility to report and/or correct these potential incidents immediately. Please complete this form as a means to report these “Good Catch” situations and submit to your local OSC Representative and Mike Glenn, VP/National Safety Director.

Complete ALL field entries:

Employee Name:		Date:	
Location:		Office:	
Project Number:		Practice:	

Conditions

Please check all appropriate conditions:

☐ Unsafe Act	☐ Unsafe Condition	☐ Unsafe Equipment	☐ Unsafe Use of Equipment

Description of Incident or Potential Hazard:

Task Performed at Time of Incident:

Causes (Primary and Contributing):

Corrective Action(s) Taken (remove the hazard, replace, repair, or retrain):

Employee Signature:		Date Completed:	

Our Mission: To reduce the frequency of incidents by applying local lessons learned globally.

If you have any questions about this report or would like additional information, please reference Compliance Program CP019 TRC Incident Response and Lessons Learned Program, located on TRCNET or contact Mike Glenn, VP/National Safety Director at mglenn@trcsolutions.com.

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® or low density polyethylene (LDPE)[1] during sample handling or mobilization/demobilization. This includes bailers, tubing, bladders, bailer cord/wire, waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. High density polyethylene (HDPE) or silicone tubing should be used in lieu of Teflon® or Teflon®-lined tubing. • Passive diffusion bags (PDBs) should not be used due to the presence of LDPE material in PDBs. • Blue Ice® (chemical ice packs) must not be used to cool samples or be used in sample coolers. Regular ice in Ziploc® bags can be used. • Do not use LDPE or glass sample containers or containers with Teflon-lined lids. HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. • Do not use aluminum foil. • Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-It Notes during sample handling or mobilization/demobilization. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to field preparation during PFAS sampling: • Tyvek® suits should not be worn during PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
	• Personnel involved with sample collection and handling should wear nitrile gloves at all times while collecting and handling samples or sampling equipment. Avoid handling unnecessary items with nitrile gloves. A new pair of gloves must be donned prior to collecting each sample. • Wash hands with Alconox or Liquinox and deionized water after leaving vehicle before setting up to sample a well.
1.6.1	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering on the day of sampling. • Avoid using sunscreens or insect repellants that are not natural or chemical free.
1.6.2	• Consider collecting samples for total suspended solids which will become important for fate and transport and treatment considerations. Floc accumulates high concentrations of PFAS and specifically some of the longer-chain PFAS; when this floc settles out, concentrations can decrease by an order of magnitude. • Low-flow sampling is preferred for PFAS sampling. Bailers should be avoided due to the potential for PFAS to accumulate at the air/water interface. If bailers need to be used, purging of at least one well volume should be performed to remove static surface conditions. • If sampling for parameters other than PFAS, perform PFAS sampling first. Schedule PFAS sampling at the beginning of the work day to avoid other sources of contamination.
2.0	• Monitoring wells should always be sampled from the lowest contamination to the highest contamination, when possible. In source areas, if deep wells are anticipated to be less contaminated, the deep wells should be sampled prior to sampling the shallow wells to avoid cross-contamination from sampling equipment.
2.2.5	Tubing used to purge and sample groundwater for PFAS must not be LDPE or Teflon®. HDPE and silicone are acceptable.
2.3 and 2.3.3	LDPE and/or glass containers should not be used for sampling. Teflon®-lined caps should also not be used during sample collection. Instead, HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable.
2.4	Due to LDPE material in PDBs, PDBs cannot be used for PFAS sampling.
2.5 (e)	Avoid using waterproof labels for sample bottles. The use of paper labels covered with clear tape or placed in Ziploc® bags to avoid moisture on the sample label is acceptable.
2.5 (f)	Samples for PFAS analysis must be shipped at <10°C. Standard coolers are acceptable. Keep high-concentration PFAS samples in separate coolers from low-concentration PFAS samples.

Notes:

[1] – PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces and, in the case of LDPE tubing, to allow for less turbulent flow along the surface of the tubing.

Appendix C
Field Forms

PAGE _______ OF _______

TRC

PROJECT NAME: ______________________

PROJECT NUMBER: ______________________

PROJECT MANAGER: ______________________

SITE LOCATION: ______________________

____

DATES OF FIELDWORK: ____________ TO ____________

PURPOSE OF FIELDWORK: ______________________

____

____

____

____

WORK PERFORMED BY: ______________________

____

____

____

____

SIGNED DATE

CHECKED BY DATE

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TRC

GENERAL NOTES

PROJECT NAME:	DATE:	TIME ARRIVED:
PROJECT NUMBER:	AUTHOR:	TIME LEFT:

WEATHER
TEMPERATURE: __________ °F WIND: __________ MPH VISIBILITY: ____________________
WORK / SAMPLING PERFORMED

PROBLEMS ENCOUNTERED	CORRECTIVE ACTION TAKEN

COMMUNICATION		
NAME	REPRESENTING	SUBJECT / COMMENTS

INVESTIGATION DERIVED WASTE SUMMARY		
WASTE MATRIX	QUANTITY	COMMENTS

SIGNED DATE

CHECKED BY DATE

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PAGE _______ OF _______

TRC

EQUIPMENT SUMMARY

PROJECT NAME:	SAMPLER NAME:
PROJECT NO.:	

WATER LEVEL MEASUREMENTS COLLECTED WITH:

NAME AND MODEL OF INSTRUMENT	SERIAL NUMBER (IF APPLICABLE)

PRODUCT LEVEL MEASUREMENTS COLLECTED WITH:

NA	
NAME AND MODEL OF INSTRUMENT	SERIAL NUMBER (IF APPLICABLE)

DEPTH TO BOTTOM OF WELL MEASUREMENTS COLLECTED WITH:

NA	
NAME AND MODEL OF INSTRUMENT	SERIAL NUMBER (IF APPLICABLE)

PURGING METHOD

NAME AND MODEL OF PUMP OR TYPE OF BAILER	SERIAL NUMBER (IF APPLICABLE)

SAMPLING METHOD

NAME AND MODEL OF PUMP OR TYPE OF BAILER	SERIAL NUMBER (IF APPLICABLE)
NAME AND MODEL OF FILTERATION DEVICE	FILTER TYPE AND SIZE

☐ LOW-FLOW SAMPLING EVENT

TUBING TYPE

PURGE WATER DISPOSAL METHOD

☐ GROUND ☐ DRUM ☐ POTW ☐ POLYTANK ☐ OTHER ____________________

DECONTAMINATION AND FIELD BLANK WATER SOURCE

STORE BOUGHT	STORE BOUGHT
POTABLE WATER SOURCE	DI WATER SOURCE

SIGNED	DATE	CHECKED BY	DATE

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PAGE _______ OF _______

TRC

WATER QUALITY METER CALIBRATION LOG

PROJECT NAME:	MODEL:	SAMPLER:
PROJECT NO.:	SERIAL #: PROJECT	DATE:

PH CALIBRATION CHECK

pH 7	pH 4 / 10	CAL. RANGE	TIME
(LOT #):	**(LOT #):**		
(EXP. DATE):	**(EXP. DATE):**		
POST-CAL. READING / STANDARD	POST-CAL. READING / STANDARD		
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	

ORP CALIBRATION CHECK

CAL. READING	TEMPERATURE	CAL. RANGE	TIME
(LOT #):	(°CELSIUS)		
(EXP. DATE):			
POST-CAL. READING / STANDARD			
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

TURBIDITY CALIBRATION CHECK

CALIBRATION READING (NTU)		CAL. RANGE	TIME
(LOT #):	**(LOT #):**		
(EXP. DATE):	**(EXP. DATE):**		
POST-CAL. READING / STANDARD	POST-CAL. READING / STANDARD		
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	

NOTES

SPECIFIC CONDUCTIVITY CALIBRATION CHECK

CAL. READING	TEMPERATURE	CAL. RANGE	TIME
(LOT #):			
(EXP. DATE):	(°CELSIUS)		
POST-CAL. READING / STANDARD			
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

D.O. CALIBRATION CHECK

CAL. READING	TEMPERATURE	CAL. RANGE	TIME
	(°CELSIUS)		
POST-CAL. READING /SATURATED AIR			
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

COMMENTS

☐ **AUTOCAL SOLUTION**	☐ **STANDARD SOLUTION (S)**
(LOT #):	LIST LOT NUMBERS AND EXPIRATION DATES UNDER CALIBRATION CHECK
(EXP. DATE):	
CALIBRATED PARAMETERS	**CALIBRATION RANGES (1)**
☐ pH	pH: +/- 0.2 S.U.
☐ COND	COND: +/- 1% OF CAL. STANDARD
☐ ORP	ORP: +/- 25 mV
☐ D.O.	D.O.: VARIES
☐ TURB	TURB: +/- 5% OF CAL. STANDARD
☐ ______________	(1) CALIBRATION RANGES ARE SPECIFIC TO THE MODEL OF THE WATER QUALITY METER
☐ ______________	

PROBLEMS ENCOUNTERED	**CORRECTIVE ACTIONS**

SIGNED ______________________________ DATE

CHECKED BY ______________________________ DATE

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PID FIELD CALIBRATION LOG

PROJECT NAME:	0	MODEL:	
PROJECT NUMBER.:	0.00	LAMP VOLTAGE:	
SAMPLER NAME:	0	SERIAL NO.:	

PID CALIBRATION CHECK

	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:
BATTERY CHECK	☐	☐	☐	☐	☐
ZERO GAS	/	/	/	/	/
SPAN GAS	/	/	/	/	/
AUDIBLE FAN MOTOR CHECK	☐	☐	☐	☐	☐
RESPONSE CHECK	☐	☐	☐	☐	☐

NOTES

PROBLEMS ENCOUNTERED	CORRECTIVE ACTION

SIGNED DATE

CHECKED DATE

REVISED 04/2019

PAGE _______ OF _______

WATER LEVEL DATA

PROJECT NAME:	DATE:
PROJECT NUMBER:	AUTHOR:

WELL LOCATION	TIME	REFERENCE	DEPTH TO WATER (FEET)	DEPTH TO BOTTOM (FEET)	DEPTH TO PRODUCT (FEET)	WATER ELEVATION

ALL WATER LEVELS MUST INCLUDE REFERENCE POINT AND TAPE CORRECTION FACTOR
(E.G., 1.1 + 0.00 T/PVC).

SIGNED DATE

CHECKED DATE

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PAGE _______ OF _______

TRC

WATER SAMPLE LOG

PROJECT NAME: 0	PREPARED		CHECKED	
PROJECT NUMBER: 0.00	BY: 0	DATE:	BY:	DATE:

SAMPLE ID:	WELL DIAMETER: ☐ 2" ☐ 4" ☐ 6" ☐ OTHER ____________
WELL MATERIAL: ☐ PVC ☐ SS ☐ IRON ☐ GALVANIZED STEEL	☐ OTHER ____________
SAMPLE TYPE: ☐ GW ☐ WW ☐ SW ☐ DI ☐ LEACHATE	☐ OTHER ____________

PURGING TIME: DATE:	SAMPLE TIME: DATE:
PURGE METHOD: ☐ PUMP ☐ BAILER ____________	PH: ________ SU CONDUCTIVITY: ________ umhos/cm ORP: ________ mV DO: ________ mg/L
DEPTH TO WATER: ________ T/ PVC	TURBIDITY: ________ NTU
DEPTH TO BOTTOM ________ T/ PVC	☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY
WELL VOLUME: ________ ☐ LITERS ☐ GALLONS	TEMPERATURE: ________ °C OTHER: ____________
VOLUME REMOVED ________ ☐ LITERS ☐ GALLONS	COLOR: ________ ODOR: ____________
COLOR: ____________ ODOR: ________	FILTRATE (0.45 um) ☐ YES ☐ NO
TURBIDITY	FILTRATE COLOR: ________ FILTRATE ODOR: ________
☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY	QC SAMPLE: ☐ MS/MSD ☐ DUP- ________
DISPOSAL METHOD ☐ GROUND ☐ DRUM ☐ OTHER	COMMENTS:

TIME	PURGE RATE (ML/MIN)	PH (SU)	CONDUCTIVITY (umhos/cm)	ORP (mV)	D.O. (mg/L)	TURBIDITY (NTU)	TEMPERATURE (°C)	WATER LEVEL (FEET)	CUMULATIVE PURGE VOLUME (GAL OR L)
									INITIAL

NOTE: STABILIZATION TEST IS COMPLETE WHEN 3 SUCCESSIVE READINGS ARE WITHIN THE FOLLOWING LIMITS:

pH: +/- **0.1** COND.: +/- **10 %** ORP: +/- **10 %** D.O.: +/- **10 %** TURB: +/- **10 %** or </= **5** TEMP.: +/- **0.5°C**

BOTTLES FILLED	PRESERVATIVE CODES A - NONE B - HNO3 C - H2SO4 D - NaOH E - HCL F - _______								
NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N

SHIPPING METHOD: ____________	DATE SHIPPED: ____________	AIRBILL NUMBER: ____________
COC NUMBER: ____________	SIGNATURE: ____________	DATE SIGNED: ____________

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WATER SAMPLE LOG

(CONTINUED FROM PREVIOUS PAGE)

PROJECT NAME: 0	PREPARED		CHECKED	
PROJECT NUMBER: 0.00	BY: 0	DATE:	BY:	DATE:

SAMPLE ID:

TIME	PURGE RATE (ML/MIN)	PH (SU)	CONDUCTIVITY (umhos/cm)	ORP (mV)	D.O. (mg/L)	TURBIDITY (NTU)	TEMPERATURE (°C)	WATER LEVEL (FEET)	CUMULATIVE PURGE VOLUME (GAL OR L)

SIGNATURE: ______________________________

DATE SIGNED: ______________________________

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SEDIMENT / SOIL GRAB SAMPLE LOG

PROJECT NAME: 0	PREPARED		CHECKED	
PROJECT NUMBER: 0.00	BY: 0	DATE:	BY:	DATE:

SAMPLE ID:	COLLECTED BY: 0
DATE COLLECTED:	SAMPLE TYPE: ☐ SEDIMENT ☐ SOIL ☐ OTHER ____________
TIME COLLECTED:	QC SAMPLE: ☐ MS/MSD ☐ DUP- ________

SAMPLE LOCATION	SAMPLE COORDINATES
	NORTHING / LATITUDE:
	EASTING / LONGITUDE:

SAMPLE CONTAINERS:

SAMPLE EQUIPMENT:

SAMPLE SCREENING EQUIPMENT: ☐ PID ☐ GAMMA DETECTOR ☐ FID ☐ OTHER ____________ NOTES: ____________

SAMPLE SCREENING RESULTS: ____________ ☐ PPM ☐ OTHER ____________

SAMPLE DESCRIPTION:

ADDITIONAL NOTES:

SHIPPING METHOD: ____________	DATE SHIPPED: ____________	AIRBILL NUMBER: ____________
COC NUMBER: ____________	SIGNATURE: ____________	DATE SIGNED: ____________

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AIR / VAPOR SAMPLE LOG

PROJECT NAME: 0	PREPARED	CHECKED
PROJECT NUMBER: 0.00	BY: 0 DATE:	BY: DATE:

SAMPLE INFORMATION		
SAMPLE TYPE: ☐ COMPOSITE ☐ GRAB	**SAMPLE ID:**	
SAMPLE MEDIA ☐ INDOOR AIR ☐ SOIL VAPOR ☐ SYSTEM PERFORMANCE ☐ OTHER	LOCATION:	LOCATION COORDINATES: N: E:
SAMPLE DURATION:	SAMPLE HEIGHT / (DEPTH):	
SAMPLE CONTAINER TYPE: ☐ SUMMA CANISTER ☐ TEDLAR BAG ☐ OTHER:		
FLOW VALVE ID / SERIAL NUMBER:	CANISTER SERIAL NUMBER:	

READING	TIME	VACUUM (INCHES - Hg / PSIG)	DATE	INITIALS	COMMENTS
INITIAL VACUUM CHECK					
INITIAL FIELD VACUUM					
FINAL FIELD VACUUM					

SAMPLE START TIME:	**SAMPLE STOP TIME:**

NOTES AND OBSERVATIONS

MOTORIZED VEHICLE STORAGE :

MOTORIZED VEHICLE TRAFFIC:

OPERATIONS (e.g., painting, oil recovery):

CLEANERS / SOLVENTS IN USE:

MATERIAL STORAGE (e.g., paint, gasoline):

NOTICEABLE ODORS:

AUDIBLE OR NEARBY HVAC OPERATION:

OTHER:

ADDITIONAL COMMENTS:

SHIPPING METHOD: ____________	DATE SHIPPED: ____________	AIRBILL NUMBER: ____________
COC NUMBER: ____________	SIGNATURE: ____________	DATE SIGNED: ____________

PAGE _______ OF _______

LOG OF SOIL BORING

PROJECT NAME: 0	**SOIL BORING ID:**	
PROJECT NUMBER: 0.00	LOCATION:	SHEET 1 OF
LOGGED BY: 0		SURFACE ELEV.:
PROJECT LOCATION: 0	N: E:	DATE STARTED:
DRILLED BY: TERRAPROBE, INC.	DRILLER NAME:	DATE COMPLETED:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					2.5		
					5.0		
					7.5		
					10.0		
					12.5		
					15.0		
					17.5		
					20.0		

DRILLING METHOD
DRILL RIG
BORING DIAMETER

WATER LEVEL OBSERVATIONS			
FIRST OCCURRENCE:			
DATE	TIME	DEPTH TO WATER	DEPTH TO BOTTOM

SIGNED DATE

CHECKED DATE

REVISED 04/2019

PAGE _______ OF _______

LOG OF SOIL BORING

SHEET	2	OF

PROJECT NAME: 0	**SOIL BORING ID:**

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					22.5		
					25.0		
					27.5		
					30.0		
					32.5		
					35.0		
					37.5		
					40.0		
					42.5		
					45.0		

SIGNED DATE

CHECKED DATE

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LOG OF SOIL BORING

PROJECT NAME: 0		**SOIL BORING ID:**	
PROJECT NUMBER: 0.00		LOCATION:	SHEET 1 OF
LOGGED BY: 0			SURFACE ELEV.:
PROJECT LOCATION: 0		N: E:	DATE STARTED:
DRILLED BY:	DRILLER NAME:		DATE COMPLETED:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					1.0		
					2.0		
					3.0		
					4.0		
					5.0		
					6.0		
					7.0		
					8.0		
					9.0		
					10.0		
					11.0		
					12.0		

DRILLING METHOD
DRILL RIG
BORING DIAMETER

WATER LEVEL OBSERVATIONS

FIRST OCCURRENCE:

DATE	TIME	DEPTH TO WATER	DEPTH TO BOTTOM

SIGNED ____________ DATE ____________

CHECKED ____________ DATE ____________

REVISED 04/2019

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LOG OF SOIL BORING

SHEET 2 OF

PROJECT NAME: 0

SOIL BORING ID:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					13.0		
					14.0		
					15.0		
					16.0		
					17.0		
					18.0		
					19.0		
					20.0		
					21.0		
					22.0		
					23.0		
					24.0		
					25.0		
					26.0		

SIGNED DATE

CHECKED DATE

REVISED 04/2019

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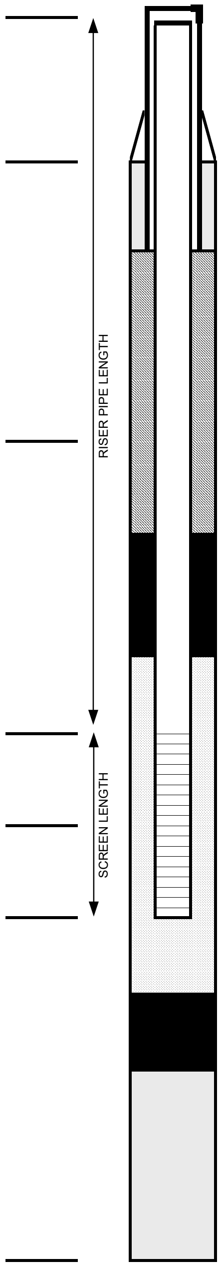
TRC

WELL CONSTRUCTION DIAGRAM

PROJ. NAME: 0		WELL ID:	
PROJ. NO: 0.00	DATE INSTALLED:	INSTALLED BY: 0	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH BELOW OR ABOVE GROUND SURFACE (FEET)



TOP OF CASING

0.0 GROUND SURFACE

CEMENT SURFACE PLUG

GROUT/BACKFILL MATERIAL

GROUT/BACKFILL METHOD

GROUT

BENTONITE SEAL MATERIAL

BENTONITE SEAL

TOP OF SCREEN

FILTER PACK MATERIAL

BOTTOM OF SCREEN

BOTTOM OF FILTER PACK

BENTONITE PLUG

BACKFILL MATERIAL

HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____________________

PIPE SCHEDULE: ____________________

PIPE JOINTS: ____________________

SOLVENT USED? ____________________

SCREEN TYPE: ____________________

SCR. SLOT SIZE: __________

BOREHOLE DIAMETER: _____ IN. FROM _____ TO _____ FT.
_____ IN. FROM _____ TO _____ FT.

SURF. CASING DIAMETER: _____ IN. FROM _____ TO _____ FT.
_____ IN. FROM _____ TO _____ FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____________________

TIME DEVELOPING: ________ HOURS

WATER REMOVED: ________ GALLONS

WATER ADDED: ________ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____________________

COLOR BEFORE: ____________________

CLARITY AFTER: ____________________

COLOR AFTER: ____________________

ODOR (IF PRESENT): ____________________

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWE BEFORE DEVELOPING:		T/PVC		
SWE AFTER DEVELOPING:		T/PVC		
OTHER SWE:		T/PVC		
OTHER SWE:		T/PVC		

PROTECTIVE CASING DETAILS

PERMANENT, LEGIBLE WELL LABEL ADDED? ☐ YES ☐ NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐ YES ☐ NO

LOCK KEY NUMBER: ______________

REVISED 04/2019

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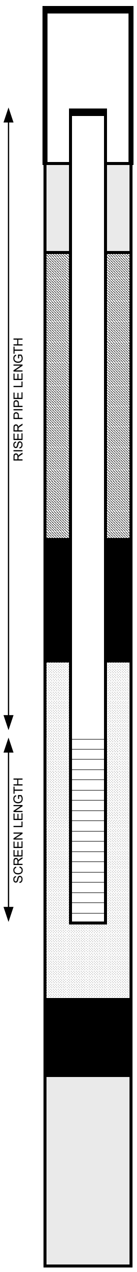
TRC

WELL CONSTRUCTION DIAGRAM

PROJ. NAME: 0		WELL ID:	
PROJ. NO: 0.00	DATE INSTALLED:	INSTALLED BY: 0	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH BELOW OR ABOVE GROUND SURFACE (FEET)
	0.0 GROUND SURFACE
	TOP OF CASING
	CEMENT SURFACE PLUG
	GROUT/BACKFILL MATERIAL
	GROUT/BACKFILL METHOD
	GROUT
	BENTONITE SEAL MATERIAL
	BENTONITE SEAL
	TOP OF SCREEN
	FILTER PACK MATERIAL
	BOTTOM OF SCREEN
	BOTTOM OF FILTER PACK
	BENTONITE PLUG
	BACKFILL MATERIAL
	HOLE BOTTOM



NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____________________

PIPE SCHEDULE: ____________________

PIPE JOINTS: ____________________

SOLVENT USED? ____________________

SCREEN TYPE: ____________________

SCR. SLOT SIZE: __________

BOREHOLE DIAMETER:	____ IN.	FROM ____	TO ____	FT.
	____ IN.	FROM ____	TO ____	FT.
SURF. CASING DIAMETER:	____ IN.	FROM ____	TO ____	FT.
	____ IN.	FROM ____	TO ____	FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____________________

TIME DEVELOPING: ________ HOURS

WATER REMOVED: ________ GALLONS

WATER ADDED: ________ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____________________

COLOR BEFORE: ____________________

CLARITY AFTER: ____________________

COLOR AFTER: ____________________

ODOR (IF PRESENT): ____________________

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWE BEFORE DEVELOPING:		T/PVC		
SWE AFTER DEVELOPING:		T/PVC		
OTHER SWE:		T/PVC		
OTHER SWE:		T/PVC		

PROTECTIVE CASING DETAILS

PERMANENT, LEGIBLE WELL LABEL ADDED? ☐ YES ☐ NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐ YES ☐ NO

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REVISED 04/2019