Memo

SUBJECT
RACER Pontiac North Campus 2026 Fiero Temporary Monitoring Plan

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DEPARTMENT
Environment

COPIES TO
Project File
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PROJECT NUMBER
30321425

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This memorandum describes the approach for temporary monitoring, including groundwater and soil vapor, at the former Fiero properties of the Revitalizing Auto Communities Environmental Response Trust (RACER) Pontiac North Campus properties (Site) located in Pontiac, Michigan (**Figure 1**). The Fiero Temporary Monitoring Plan (2026 FTMP) supplements the Pontiac North Campus Site Groundwater Monitoring Plan (GMP) 2025 Modification (Arcadis 2026). The objectives of the FTMP are to collect data semi-annually to further evaluate the stability of the chlorinated volatile organic compounds (cVOCs) in groundwater and soil vapor at the Fiero properties.

Based on the 2025 sampling results, which have been presented in USEPA monthly meetings, it is recommended to continue monitoring select monitoring wells within the source area, along the plume core, downgradient near the property boundary, and off-site, on a semi-annual frequency. The proposed monitoring locations are presented in **Figure 2**, and monitoring frequency and analytical parameters are summarized and illustrated in **Table 1**. No changes in groundwater sampling locations from the 2025 FTMP, presented in Appendix F of the *2024 Fiero Temporary Groundwater Monitoring Plan Summary* (Arcadis 2025), are recommended at this time. As has previously been the case, the 2026 FTMP will be completed in parallel with the Pontiac North Campus Site GMP (Arcadis 2026).

Groundwater Sampling

Groundwater gauging and sampling methodology of the 2026 FTMP will be consistent with the USEPA approved 2023 Revised Fiero Temporary Monitoring Plan (Arcadis 2023), which utilizes the USEPA Low-Stress (or Low-Flow) Purging and Sampling Procedure (USEPA 2017). All samples will be submitted to Merit Laboratories Inc. of East Lansing, Michigan for laboratory analysis of cVOCs via USEPA Method 8260. The laboratory standard operating procedure (SOP) for the USEPA Method 8260 analysis of cVOCs is included in **Attachment 1**.

Soil Vapor Sampling

In addition to groundwater monitoring, soil vapor will be sampled from the existing soil vapor monitoring probes (SVMPs) on a semi-annual frequency. It should be noted that SVMPs SV-07-24 and SV-08-24, installed in 2024, were approved by USEPA to move from quarterly sampling to semi-annual sampling frequency, via email transmittal on August 26, 2025. The methodology of the 2026 FTMP will be consistent with the 2023 Revised Fiero Temporary Monitoring Plan (Arcadis 2023). Samples will be analyzed by Eurofins AirToxics for Fiero site-

specific cVOCs in accordance with USEPA Method TO-15. The laboratory SOP for the USEPA Method TO-15 analysis of cVOCs is included in **Attachment 1**.

Laboratory Analytical Methods

Groundwater samples will be analyzed for cVOCs by the project laboratory Method 8260C for groundwater and TO-15 for soil gas. Relevant laboratory SOPs (**Attachment 1**) and Arcadis Technical Guidance Instructions (TGIs) (**Attachment 2**) are summarized in **Table 1** below.

Table 1: Index of Standard Operating Procedures (SOP) and Technical Guidance Instructions (TGI)

Laboratory SOP	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry Method SW-846 8260C/ EPA 624.1 (includes USEPA Method SW8260 SIM)
	Volatile Organic Compounds by Gas Chromatography/ Mass Spectrometry Method TO-15
Arcadis TGI	Manual Water-Level and NAPL Monitoring
	Low Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
	Sub-Slab and Soil Vapor Sampling Using Whole Air Canisters
	Groundwater and Soil Sampling Equipment Decontamination

Quality Assurance/Quality Control Procedures

Field Quality Assurance / Quality Control

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

- Field duplicate samples for groundwater and soil gas will be collected at a minimum frequency of 1 per 10 or fewer investigative samples. Field duplicate samples will be analyzed to assess the precision of the field sample collection procedures.
- Sufficient sample volume will be provided to the laboratory (as necessary) for matrix spike and spike duplicate (MS/MSD) analyses for groundwater. The data from MS/MSD analyses provides an indication of the precision and accuracy of the analytical method relative to the sample matrix. Samples for MS/MSD analysis will be designated at a minimum frequency of 1 per 20 or fewer samples.

Groundwater samples will be collected in laboratory supplied bottles and soil gas samples will be collected in laboratory provided SUMMA® canisters, packed in laboratory supplied shipping containers, and transported in accordance with the laboratory container, preservation, shipping, and packaging requirements.

Laboratory Quality Assurance / Quality Control

Laboratory QA/QC requirements for the analysis of groundwater and soil gas samples include analyzing method blanks, initial calibration verification standards, continuing calibration verification standards, MS/MSD samples, and Laboratory Control Samples (LCS). The analysis frequency for these QA/QC samples is identified in the applicable laboratory SOP provided in **Attachment 1**. The acceptance criteria for these QC checks will be consistent with the analytical methods and laboratory SOP.

Laboratory Report Deliverables

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

1. Case Narrative:
   a. Date of issuance
   b. Project name and number
   c. Any deviations from intended analytical strategy
   d. Condition of samples "as received"
   e. Discussion of whether sample holding times were met
   f. Discussion of technical problems or other observations that may have created analytical difficulties
   g. Discussion of any laboratory quality control checks that failed to meet project criteria
2. Chemistry Data Package
   a. Dates of sample collection, receipt, preparation, and analysis
   b. Cross-reference of laboratory to project sample identification numbers
   c. Description of data qualifiers used
   d. Methods of sample preparation and analysis
   e. Sample results in tabular format
   f. Method blank data, surrogate data, LCS data, duplicate sample data, MS/MSD data,
   g. Fully executed chain-of-custody document

Data Review and Validation

Upon receipt of the final Level II data packages from the project laboratories a Tier II data review and validation will be completed. The data review will evaluate the final analytical results, holding time period compliance, equipment blank sample data, field duplicate sample data, method blank data, LCS data, laboratory duplicate data, surrogate compound spike data, and MS/MSD sample data. Data will be reviewed in accordance with the USEPA National Functional Guidelines for Organic Superfund Methods Data Review, EPA 540-R-20-005, November 2020 (with reference to the historical USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, OSWER 9240.1-05A-P, October 1999 as appropriate), and USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review, EPA 542-R-20-006, November 2020.

Schedule and Reporting

This FTMP will be executed for 2026 at which time an assessment will be completed to evaluate appropriate changes or modifications for 2027. After each event for 2026, the data results will be communicated to USEPA during regularly scheduled meetings. Following completion of the 2026 FTMP a summary report will be provided to USEPA within 90 days of receipt of the results of the second sampling event and will include:

- Written summary of field activities
- Figures and tables summarizing the analytical results
- Groundwater elevation contour maps for the semi-annual gauging events
- cVOC trend graphs and a summary of Mann-Kendall stability analysis for wells with exceedances of Residential Site Specific Volatilization to Indoor Air Criteria (SSVIAC). The Mann-Kendall analysis can be utilized when the following criteria are met:

    - Include data collected after 2017, when sampling frequency increased and following a spike in concentrations observed at certain monitoring wells due to deteriorating concrete slab conditions
    - At least 5 data samples collected after 2017
    - Of the samples collected after 2017, at least 50% of the samples have detections
- Based on the above criteria for Mann-Kendall, some wells do not have sufficient data to perform the Mann-Kendall analysis. For those wells a concentration over time graph will be developed.

The first 2026 FTMP semi-annual event is planned for March of 2026.

References

Arcadis 2023. 2023 Revised Fiero Temporary Monitoring Plan, RACER Trust Pontiac North Campus. April 4.

Arcadis 2025. 2024 Fiero Temporary Groundwater Monitoring Plan Summary, RACER Trust Pontiac North Campus. August 8.

Arcadis 2026. Groundwater Monitoring Plan (2025 Modification). RACER Trust Pontiac North Campus. February 6.

U.S. Environmental Protection Agency (USEPA; Region I). 2017. Low-Stress (Low-Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells – Revision 4. July 30, 1996; Revised September 19, 2017.

Enclosures

Figure 1 – Site Layout Map

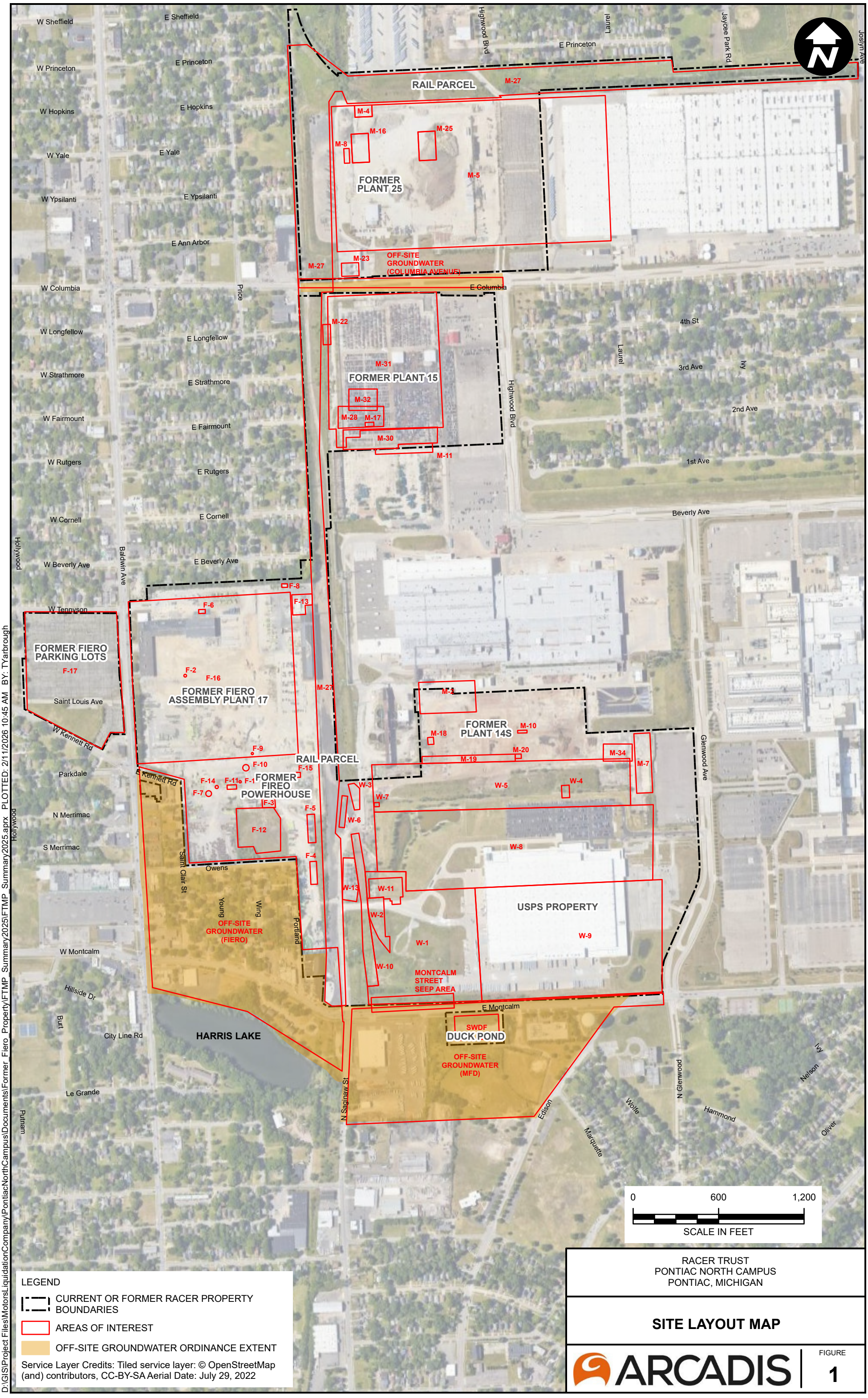
Figure 2 – 2026 Fiero Temporary Monitoring Plan Locations

Table 1 – 2026 Fiero Temporary Monitoring Plan Summary

Attachment 1 – Laboratory Standard Operating Procedures

Attachment 2 – Arcadis Technical Guidance Instructions

Figures



RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

SITE LAYOUT MAP

ARCADIS

FIGURE
1

D:\GIS\Project Files\MotorsLiquidationCompany\PontiacNorthCampus\Documents\Former_Fiero_Property\FTMP_Summary2025\FTMP_Summary2025.aprx PLOTTED: 2/11/2026 10:45 AM BY: TYarbrough

Service Layer Credits: Tiled service layer: © OpenStreetMap (and) contributors, CC-BY-SA
Google Earth Pro Aerial Dated March 19, 2021

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MWF2
MWF8-01
PZF17-01
PZF17-02
PZF17-03
PZF17-04
PZF17-05
MWF16-17
MWF16-05
MWF16-12
MW-09-22
MWF16-18
MWF16-06
MWF16-20
MWF16-24
MWF16-26
TW-12-22
MWF16-19
MWF16-16
MWF16-22
MW-14-22
MW-13-22
MW-16-22
MW-15-22
MWF16-07
MWF16-15
MWF7-03
MW-11-22
MWF16-25
MWF16-23
MWF7-02
MWOS-08
MWOS-09R
UNKNOWN-01
MW-06-20
MWF15-01
SV-01-21
SV-02-21
MW-08-21
SV-06-21
SV-05-21
MWOS-10
SV-04-21
SV-03-21
MW-07-20
MW-05-18
SV-07-24
SV-08-24
MWF12-01R
MWF12-02R
MW-02-17

Holywood
W Tennyson
W Mansfield
Saint Louis Ave
W Kennett Rd
Baldwin Ave
Parkdale
E Kennett Rd
N Merrimac
S Merrimac
Saint Clair St
Owens
Wing

N

LEGEND

- EXISTING MONITORING WELL
- SOIL VAPOR MONITORING POINT
- SEMI-ANNUAL GAUGING ONLY
- SEMI-ANNUAL SAMPLING
- NOT INCLUDED IN 2025 FIERO MONITORING PLAN
- APPROXIMATE GROUNDWATER ORDINANCE EXTENT
- CURRENT OR FORMER RACER PROPERTY

0 200 400
SCALE IN FEET

RACER TRUST
PONTIAC NORTH CAMPUS
PONTIAC, MICHIGAN

2025 TEMPORARY MONITORING PLAN LOCATIONS

ARCADIS

FIGURE
2

Table

Table 1
2026 Fiero Temporary Groundwater Monitoring Plan Summary
RACER Trust Pontiac North, Pontiac, Michigan

Well	Gauging	VOCs	Primary Function
MW-02-17	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-05-18	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-06-20	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-07-20	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-08-21	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-09-22	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core
MW-11-22	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MW-13-22	NM	NM	Not monitored, no longer need performance monitoring of the ZVI barrier
MW-14-22	NM	NM	Not monitored, no longer need performance monitoring of the ZVI barrier
MW-15-22	NM	NM	Not monitored, no longer need performance monitoring of the ZVI barrier
MW-16-22	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core
MWF12-01R	SA	NM	Gauging only to assist with GW elevation contour
MWF12-02R	SA	NM	Gauging only to assist with GW elevation contour
MWF15-01	SA	SA	Monitoring well to monitor area of historic elevated soil concentrations
MWF16-05	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core
MWF16-06	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume source area
MWF16-07	SA	SA	Delineation well to monitor and define the southern plume boundary
MWF16-12	SA	SA	Delineation well to monitor and define the upgradient plume boundary
MWF16-15	SA	SA	Delineation well to monitor and define the plume boundary
MWF16-16	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core
MWF16-17	SA	SA	Delineation well to monitor and define the plume northern boundary
MWF16-18	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core

Table 1
2026 Fiero Temporary Groundwater Monitoring Plan Summary
RACER Trust Pontiac North, Pontiac, Michigan

Well	Gauging	VOCs	Primary Function
MWF16-19	NM	NM	Well damaged as part of new construction. To be properly abandoned. Plume boundary well understood.
MWF16-20	NM	NM	Well damaged as part of new construction. To be properly abandoned. Plume boundary well understood.
MWF16-22	SA	SA	Monitoring well to monitor the concentration and stability of the CVOC plume core
MWF16-23	SA	SA	SW perimeter well to monitor for downgradient migration of CVOC impacts
MWF16-24	SA	NM	Gauging only to assist with GW elevation contour
MWF16-25	SA	SA	Perimeter well to monitor for migration of CVOC impacts
MWF16-26	SA	SA	Perimeter well to monitor for migration of CVOC impacts
MWF2	SA	NM	Gauging only to assist with GW elevation contour
MWF7-02	SA	SA	Monitoring well to monitor the concentration and migration of the CVOC plume core
MWF7-03	SA	NM	Gauging only to assist with GW elevation contour
MWF8-01	SA	NM	Gauging only to assist with GW elevation contour
MWOS-08	SA	SA	Offsite well to monitor for downgradient migration of CVOC impacts
MWOS-09R	SA	SA	Offsite well to monitor for downgradient migration of CVOC impacts
MWOS-10	SA	SA	Offsite well to monitor for downgradient migration of CVOC impacts
PZF17-02	SA	NM	Gauging only to assist with GW elevation contour
PZF17-04	SA	NM	Gauging only to assist with GW elevation contour
PZF17-05	SA	NM	Gauging only to assist with GW elevation contour
TW-12-22	SA	SA	Monitoring well to monitor the concentration and migration of the CVOC plume core
Unknown-01	SA	SA	Delineation well to monitor and define the plume boundary
SV-01-21	NM	SA	SW perimeter - soil vapor monitoring
SV-02-21	NM	SA	SW perimeter - soil vapor monitoring
SV-03-21	NM	SA	SW perimeter - soil vapor monitoring

Table 1
2026 Fiero Temporary Groundwater Monitoring Plan Summary
RACER Trust Pontiac North, Pontiac, Michigan

Well	Gauging	VOCs	Primary Function
SV-04-21	NM	SA	SW perimeter - soil vapor monitoring
SV-05-21	NM	SA	SW perimeter - soil vapor monitoring
SV-06-21	NM	SA	SW perimeter - soil vapor monitoring
SV-07-24	NM	SA	SW perimeter - soil vapor monitoring
SV-08-24	NM	SA	SW perimeter - soil vapor monitoring

Notes:
SV locations will be monitored for soil vapor only
Q = Quarterly
SA = Semi-annual (1Q and 3Q)
NM = Not Monitored

Attachment 1

Laboratory Standard Operating Procedures

STANDARD OPERATING PROCEDURE

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

APPROVALS:

Barbara Ball

03/22/2024

QA Officer Date

Mayra Mushaly

03/22/2024

Technical Director Date

Number	Description of Change	Date
001-011	Previous revisions not documented	
0012	Updated to comply with DoD QSM and ISO 17025 standards.	6/9/11
013	Updated to method 8260C	9/4/13
014	Updated to comply with DoD QSM 5.0 standards.	04/01/16
015	Updated to comply with DoD QSM 5.1 standards.	01/17/18
016	NY NELAC Audit Finding	03/13/19
017	DOD Audit Corrective Action	09/29/2020
018	2020 Internal Audit revisions	02/16/2021
019	NY NELAC Audit Finding	05/25/2022
020	Emergency SOP Amendment Form	03/08/2023
021	2023 Internal Audit revisions	03/22/2024
022		

1.0 SCOPE AND APPLICATION

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

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

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

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

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

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

2.0 SUMMARY OF THE METHOD

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

Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. Identification of target analytes is accomplished by comparing their mass spectra

with the electron impact spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five point (or more) calibration curve.

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

3.0 INTERFERENCES

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

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

4.0 APPARATUS AND MATERIALS

Gas chromatograph/mass spectrometer system

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

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

Purge-and-trap device.

Microsyringes - 10 to 500-µL.

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

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

pH paper.

5.0 REAGENTS

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

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

Stock standard solutions.

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

Internal standard solutions - The internal standards used are pentafluorobenzene, 1,4-difluorobenzene, chlorobenzene-d_5, and 1,4-dichlorobenzene-d_4 (see Table 2). Internal standards are used at a working concentration of 50 mg/L and are added to samples, spikes, blanks, and calibration standards at a uniform concentration of 50 µg/L (i.e. 10µL per 5000µL purge volume). For SIM (selective ion monitoring) analysis, internal standards of 1-4-Dioxane-d8, 1,2-Dibromoethane-D4, and 1,2-Dibromo-3-chloropropane-C3 is used, but with concentrations at 50 ppb for 1,4-Dioxane and 1,2-Dibromoethane-D4, and 1,2-Dibromo-3-chloropropane-C3 for 0.4 ppb (µg/L).

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

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

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

- Matrix spiking mixes for individual analytes are created at 100 mg/L and spiked into samples at 50 µg/L (*i.e.* 2.50µL per 5000µL purge volume).
- For SIM (selective ion monitoring) analysis, compounds of interest are spiked at concentrations of 0.1 ppb (µg/L).
- For 1-Dioxane, compounds of interest are spiked at concentrations of 50 ppb (µg/L).

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

6.0 SAMPLE HANDLING AND PRESERVATION

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

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

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

7.0 PROCEDURE

Sample introduction.

- Direct injection - This method of introduction is used only rarely, generally when the compounds of interest exhibit poor purging efficiency. Quantitation in this case, if required, is generally subject to external standard calibration procedures (*cf*. Method 8000).
- Purge-and-trap - This is generally used for sample introduction for both soil and water samples. All samples, standards, spikes, and blanks are introduced into the GC/MS system in an identical manner (see Merit SOP# ORL-005).

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

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

Initial calibration.

- Each GC/MS system must be hardware-tuned to meet the criteria in Table 4 for 4-bromofluorobenzene. Analysis does not begin until these criteria are met.
    - In the absence of any other manipulations, evaluate the mass spectrum of the peak apex or the scan immediately preceding or following from the total ion chromatogram for the BFB peak. This is the default approach used.
    - If the above evaluation is adversely affected by ion peak asymmetry, average the three highest intensity scans of the peak or average the mass spectrum ranging from the 10% initial peak intensity to the tailing 10% peak intensity level from the total ion chromatogram for the BFB peak.
    - If the above evaluation is adversely affected by background contamination, perform a background subtraction with a spectrum within 20 scans of the BFB peak which does not represent a target compound. Use of this procedure may be indicative of failing MS performance. The MS source should be cleaned and re-tuned.
    - The BFB mass intensity criteria in Table 4 are used as tuning acceptance criteria.

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

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

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

♦ Response Factor Criteria

- It is recommended that a minimum response factor for the most common target analytes as noted in Table 2b, be demonstrated for each individual calibration level as a means to ensure that these compounds are behaving as expected. In addition, meeting the minimum response factor criteria for the lowest calibration level is important in demonstrating the desired sensitivity. Due to the large number of compounds that may be analyzed, some compounds will fail to meet this criteria. In particular, poor performers such as ketones and 1,2-dibromo-3-chloropropane are likely to fail this criteria but have been demonstrated to perform adequately overall.

- If the minimum response factors are not met, the system must be evaluated, and corrective action must be taken before sample analysis begins. Possible problems include standard mixture degradation, contamination in the purge-and-trap system, excessively high or low purge flow rates, and active sites in the column or chromatographic system. Replacing the calibration standards, clipping and/or replacing the column will likely solve this problem.

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

- Linearity of target analytes - If the %RSD of any target analytes is 20% or less, then the relative response factor may be assumed to be constant over the calibration range, and the average relative response factor may be used for quantitation.
    - Refer to SW-846 Method 8000 if a least-squares regression is used to determine a linear or quadratic fit to the calibration data. Quadratic polynomials are generally fit through the origin in order to prevent the symptomatic aphysical prediction of high concentrations at very low responses. The coefficient of determination for any regression fit should be ≥0.99. In addition, 6 calibration data points are required for a calibration fit with 3 free parameters, while 5 are required for a calibration fit with 1 or 2 free parameters.
    - When the RSD exceeds 20%, the plotting and visual inspection of a calibration curve can be a useful diagnostic tool. The inspection may indicate analytical problems, including errors in standard preparation, the presence of active sites in the chromatographic system, analytes that exhibit poor chromatographic behavior, *etc*.
    - The method of linear regression analysis has the potential for a significant bias to the lower portion of a calibration curve, while the relative percent difference and the quadratic methods of calibration do not have this potential bias. When calculating the calibration curves using the linear regression model, a minimum quantitation check on the viability of the lowest calibration point should be performed by re-fitting the response from the low concentration calibration standard back into the curve. The recalculated concentration of the low calibration point should be within 30% of the standard's true concentration. Other recovery criteria may be applicable depending on the project's data quality objectives. For analytes which do not meet the minimum quantitation calibration re-fitting criteria reporting those analytes as estimated when the concentration is at or near the lowest calibration point may be appropriate.
    - The initial calibration curve should be verified immediately after performing the standard analyses using a second source standard at a concentration near the midpoint of the calibration range. The acceptance limits are 70-130% or project specific. Analytes that fail this criteria are considered estimated values.
    - The quality of the calibration fit for any particular compound is communicated to the data user via the Quality Control report for a given batch of samples. The calibration summary report includes: the concentration and RF for each standard in the calibration curve, the type of calibration fit, the calibration fit parameters (*i.e*. average RF or

regression coefficients), and the appropriate calibration quality metric (*i.e*. %RSD or COD).

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

calibration, then corrective action must be taken prior to the analysis of samples. In cases where compounds fail, they may still be reported as non-detects if it can be demonstrated that there was adequate sensitivity to detect the compound at the applicable quantitation limit. For situations when a failed compound is present, the concentration is an estimated value. Drift is defined as the normalized deviation of the measured from the spike value of a target component: $\%D = \left|C - C_{spike}\right| / C_{spike}$.

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

GC/MS analysis of samples.

- Samples are screened at a diluted state via GC/MS whenever possible prior to analysis within a 12-hour QC batch. This can identify potentially low surrogate recoveries, high target compound concentrations, non-target matrix interferences. This will minimize contamination of the GC/MS system from unexpectedly high concentrations of organic compounds.
- Samples are introduced into the GC/MS system by loading the 40ml zero headspace vial onto the autosampler which draws 5ml of sample and adds internal standards and surrogate standards to achieve a 5ug/L concentration.

  For SIM analysis, internal and surrogate standards are spiked at 0.4μg/L, except 1,4-Dioxane which is spiked at 50 μg/L.
- If the concentration for any quantitation ion exceeds the initial calibration range of the GC/MS system, the sample extract should be diluted and reanalyzed. In any event, a result based on an extrapolation of calibration curve beyond the working range is flagged on the analytical report.
- The Extracted Ion Current Profile (EICP) area for all of the internal standards in all spikes, blanks, and samples is monitored relative to the most recent calibration verification standard. Changes by more than a factor of two (*i.e.* 50% to 200%) can indicate adverse matrix effects (in the case of an isolated sample) or degrading MS performance (in the case of a systematic low bias). A single-sample matrix effect is documented either via screening or re-analysis and is noted on the analytical report (see Table 5a and 5b). Similarly, the retention times for all of the internal standards in all spikes, blanks, and samples is monitored relative to the most recent calibration verification standard. The change in retention time for any internal standard by more

than 30 seconds of the most recent calibration verification standard is indicative of the same potential problems listed above and should be flagged/corrected as appropriate.

Qualitative analysis.

- The qualitative identification of compounds determined by this method is based on retention time and on comparison of the sample mass spectrum, after background correction, with characteristic ions in a reference mass spectrum. The reference mass spectrum must be generated by the laboratory using the conditions of this method. The characteristic ions from the reference mass spectrum are given in Figures 1a and 1b. Compounds are identified when the following criteria are met.
    - Initial selection of a target compound peak is performed by the Chemstation data system search routine. The search is based on the presence of a target chromatographic peak containing ions specific for the target compound at a compound specific retention time.
    - The RRT of the sample component is within ± 0.06 RRT units of the RRT of the standard component. This is accomplished using retention time extraction windows within the Chemstation data system.
    - The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum. (Example: For an ion with an abundance of 50% in the reference spectrum, the corresponding abundance in a sample spectrum can range between 20% and 80%.)
    - Structural isomers that produce very similar mass spectra are identified as individual isomers if they have sufficiently different GC retention times. Sufficient GC resolution is achieved if the height of the valley between two isomer peaks is less than 25% of the sum of the two peak heights. Otherwise, structural isomers are identified as isomeric pairs.
    - Identification is hampered when sample components are not resolved chromatographically and produce mass spectra containing ions contributed by more than one analyte. When gas chromatographic peaks obviously represent more than one sample component (*i.e.*, a broadened peak with shoulder(s) or a valley between two or more maxima), appropriate selection of analyte spectra and background spectra is important.
    - Examination of extracted ion current profiles of appropriate ions can aid in the selection of spectra and in qualitative identification of compounds. When analytes coelute (*i.e.*, only one chromatographic peak is apparent), the identification criteria may be met, but

each analyte spectrum will contain extraneous ions contributed by the coeluting compound.

- In the two previous cases, analyst expertise as well as knowledge of site history may be important in accepting/rejecting the identification of a compound. In the event of continued uncertainty, the analyst should preferentially make a conservative judgment and accept an identified hit, allowing the potential for a false positive.

♦ For samples containing components not associated with the calibration standards, a library search may be made for the purpose of tentative identification. The necessity to perform this type of identification will be determined by the purpose of the analyses being conducted. Only after visual comparison of sample spectra with the nearest library searches may the analyst assign a tentative identification. Guidelines for tentative identification are:

- Relative intensities of major ions in the reference spectrum (ions > 10% of the most abundant ion) should be present in the sample spectrum.
- The relative intensities of the major ions should agree within ± 20%.
- Molecular ions present in the reference spectrum should be present in the sample spectrum.
- Ions present in the sample spectrum but not in the reference spectrum should be reviewed for possible background contamination or presence of coeluting compounds.
- Ions present in the reference spectrum but not in the sample spectrum should be reviewed for possible subtraction from the sample spectrum because of background contamination or coeluting peaks. Data system library reduction programs can sometimes create these discrepancies.

Quantitative analysis.

♦ Once a compound has been identified, the quantitation of that compound will be based on the integrated abundance of the primary characteristic ion from the EICP.

♦ The curve fit applied in the initial calibration is the same as that used to compute the concentration of a target analyte in a sample. All curve fits are evaluated by the data system and are of the form: $A_s/A_i = k_0 + k_1[C_s/C_i] + k_2[C_s/C_i]^2$. Here A_s and A_i are the areas of the target and internal standard, C_s and C_i are the concentrations of the target and internal standard, and k_i is the i^{th}-order regression coefficient. Note that for a mean RF fit to the calibration data, $k_1 \equiv$ <RF>, while k_0, $k_2 \equiv 0$.

- The concentration of any non-target analytes identified in the sample may be estimated by assuming a mean RF of 1 and by using the tentatively identified compound (TIC) areas for the nearest internal standard and target compound. The resulting concentration should be reported indicating: (1) that the value is an estimate, and (2) which internal standard was used to determine concentration. Use the nearest internal standard free of interferences.
- Structural isomers that produce very similar mass spectra should be quantitated as individual isomers if they have sufficiently different GC retention times. Otherwise, structural isomers are quantitated as isomeric pairs (such as p- and m-xylene).

8.0 QUALITY CONTROL

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

9.0 METHOD PERFORMANCE

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

10.0 EQUIPMENT MAINTENANCE AND TROUBLESHOOTING

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

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

11.0 SAFETY

Eye protection and gloves must be worn while performing the analyses. Every laboratory area has eyewash, emergency shower, and fire extinguisher. The metals lab also has dust masks available for use with dust samples. The air system throughout the laboratory area is on a 100% fresh air exchange system,

this system exchanges 100% the air in the laboratory area with air from outside 6 times per hour and 30 times per hour when the emergency purge button is hit.

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

a. Methanol may react violently with acids, acid chlorides, acid anhydrides, oxidizing agents, reducing agents and alkali metals. Protect from moisture. Highly flammable.
b. Hydrochloric acid is corrosive. Extreme heat or contact with metals can release flammable hydrogen gas, stable under ordinary conditions of use and storage, and incompatible with many substances and highly reactive with strong bases, metals, metal oxides, hydroxides, amines, carbonates, cyanides, sulfides, sulfites, and formaldehyde.

12.0 WASTE DISPOSAL AND POLLUTION PREVENTION

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

13.0 DEFINITIONS

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

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

An Initial Calibration Blank (ICB) is also analyzed before samples to confirm that the deionized water (DI H2O) used for standards, blanks, and dilutions are free from contamination. An ICB for soil samples also includes organic free sand and/or methanol used for standard and QC preparation, as well as sample dilutions and volume adjustments; the control sand and methanol must also be documented as free from contamination.

A Calibration Check Verification standard (CCV) is analyzed at the beginning of each sequence (following the BFB injection) shift and every 12 hour shift thereafter. A CCV is made up from the same standards used

for calibration and is used to ensure that the calibration and retention times are stable.

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

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

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

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

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

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

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

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

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

14.0 REFERENCES

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

Department of Defense, Quality Systems Manual for Environmental Laboratories (DoD QSM), DoD Environmental Data Quality Workgroup, Department of Navy, Lead Service, Version 5.4, 2021

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

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

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

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

EPA Method 624.1, December 2016

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

Compound List Report Ravnica

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

PK#		Compound Name	QIon	Exp_RT	Rel_RT	Cal	#Qual	A/H	ID
1	I	PENTAFLUOROBENZENE (I)	168	4.04	1.000	A	2	A	B
2	S	1,2-DICHLOROETHANE-D4 (S)	65	4.19	1.039	A	2	A	B
3		1,1,2-Trichloro-1,2,2-trifluor	101	2.63	0.651	A	2	A	B
4		Diethyl ether (*)	74	2.41	0.596	A	2	A	B
5		Acetone (*)	43	2.66	0.660	A	2	A	B
6		Methyl iodide (iodomethane) (*	142	2.70	0.669	A	2	A	B
7		Carbon disulfide (*)	76	2.76	0.684	A	2	A	B
8		Methyl Acetate	43	2.91	0.721	A	2	A	B
9		tert-Methyl butyl ether (MTBE)	73	3.17	0.784	A	3	A	B
10		Acrylonitrile (*)	53	3.15	0.780	A	2	A	B
11		2-Butanone (MEK) (*)	43	3.77	0.935	A	2	A	B
12		Dichlorodifluoromethane	85	1.26	0.311	QO	2	A	B
13		Chloromethane (SPCC)	50	1.34	0.332	A	2	A	B
14		Vinyl Chloride (CCC)	62	1.47	0.365	A	2	A	B
15		Bromomethane	94	1.75	0.432	A	2	A	B
16		Chloroethane	64	1.85	0.458	A	3	A	B
17		Acrolein	56	2.52	0.623	A	2	A	B
18		Trichlorofluoromethane	101	2.17	0.538	A	3	A	B
19		1,1-Dichloroethene (CCC/MS)	61	2.58	0.639	A	3	A	B
20		Methylene Chloride	84	2.97	0.736	A	3	A	B
21		trans-1,2-Dichloroethene	61	3.16	0.782	A	3	A	B
22		Hexane	57	3.33	0.825	A	2	A	B
23		Vinyl Acetate	43	3.32	0.823	A	2	A	B
24		1,1-Dichloroethane (SPCC)	63	3.42	0.848	A	2	A	B
25		cis-1,2-Dichloroethene	96	3.76	0.932	A	2	A	B
26		2,2-Dichloropropane	77	3.76	0.932	A	2	A	B
27		Tetrahydrofuran	42	3.92	0.970	A	2	A	B
28		Chloroform (CCC)	83	3.94	0.975	A	2	A	B
29		Bromochloromethane	130	3.90	0.965	A	3	A	B
30		1,1,1-Trichloroethane	97	4.04	1.000	A	2	A	B
31		1,1-Dichloropropene	75	4.11	1.018	A	2	A	B
32		Cyclohexane	42	4.06	1.005	A	3	A	B
33	I	1,4-DIFLUOROBENZENE (I)	114	4.40	1.000	A	2	A	B
34	S	TOLUENE-D8 (S)	98	5.11	1.160	A	2	A	B
35		4-Methyl-2-pentanone (MIBK) (*	58	5.04	1.145	A	3	A	B
36		2-Hexanone (*)	58	5.43	1.232	A	3	A	B
37		2-chloroethylvinyl ether	63	4.90	1.113	A	2	A	B
38		Carbon Tetrachloride	117	4.12	0.936	A	2	A	B
39		Benzene (MS)	78	4.22	0.958	A	2	A	B
40		1,2-Dichloroethane	62	4.23	0.961	A	3	A	B
41	M	Trichloroethene (MS)	95	4.53	1.030	A	3	A	B
42		1,2-Dichloropropane (CCC)	63	4.64	1.055	A	2	A	B
43		Bromodichloromethane	83	4.77	1.083	A	3	A	B
44		Methyl Cyclohexane	55	4.63	1.051	A	3	A	B
45		Dibromomethane	174	4.71	1.069	A	3	A	B
46		cis-1,3-Dichloropropene	75	4.98	1.131	A	2	A	B
47	M	Toluene (CCC/MS)	91	5.14	1.167	A	2	A	B
48		trans-1,3-Dichloropropene	75	5.23	1.188	A	2	A	B

49	1,1,2-Trichloroethane	83	5.32	1.208	A	3	A	B
50	Tetrachloroethene	166	5.39	1.225	A	2	A	B
51 I	CHLOROBENZENE-D5 (I)	82	5.78	1.000	A	2	A	B
52 S	4-BROMOFLUOROBENZENE (S)	174	6.33	1.095	A	2	A	B
53	1,3-Dichloropropane	76	5.40	0.935	A	2	A	B
54	trans-1,4-Dichloro-2-butene	53	6.41	1.109	QO	3	A	B
55	Dibromochloromethane	129	5.51	0.954	A	2	A	B
56	1,2-Dibromoethane	107	5.57	0.965	A	2	A	B
57 M	Chlorobenzene (SPCC/MS)	112	5.79	1.003	A	2	A	B
58	1,1,1,2-Tetrachloroethane	131	5.83	1.009	A	3	A	B
59	Ethylbenzene (CCC)	91	5.84	1.010	A	2	A	B
60	p,m-Xylene	106	5.89	1.019	A	2	A	B
61	o-Xylene	91	6.08	1.052	A	2	A	B
62	Styrene	104	6.08	1.053	A	2	A	B
63	Isopropylbenzene	105	6.24	1.081	A	2	A	B
64	Bromoform (SPCC)	173	6.18	1.070	A	2	A	B
65	1,1,2,2-Tetrachloroethane (SPC	83	6.38	1.104	A	3	A	B
66	1,2,3-Trichloropropane	110	6.41	1.110	A	3	A	B
67	n-Propylbenzene	91	6.44	1.114	A	2	A	B
68	Bromobenzene	156	6.41	1.109	A	2	A	B
69	1,3,5-Trimethylbenzene	120	6.52	1.128	A	2	A	B
70	2-Chlorotoluene	91	6.49	1.123	A	2	A	B
71	4-Chlorotoluene	126	6.54	1.132	A	2	A	B
72	tert-Butylbenzene	91	6.67	1.155	A	2	A	B
73	1,2,4-Trimethylbenzene	120	6.70	1.160	A	2	A	B
74 I	1,4-DICHLOROBENZENE-D4 (I)	152	6.88	1.000	A	2	A	B
75	sec-Butylbenzene	105	6.78	0.986	A	2	A	B
76	p-Isopropyltoluene	119	6.84	0.995	A	2	A	B
77	1,3-Dichlorobenzene	146	6.85	0.995	A	2	A	B
78	1,4-Dichlorobenzene	146	6.89	1.002	A	2	A	B
79	1,2-Dichlorobenzene	146	7.07	1.028	A	2	A	B
80	1,2,3-Trimethylbenzene	105	6.90	1.004	A	2	A	B
81	n-Butylbenzene	91	7.04	1.024	A	2	A	B
82	Hexachloroethane	201	7.19	1.046	A	2	A	B
83	1,2-Dibromo-3-Chloropropane	157	7.44	1.082	A	3	A	B
84	1,2,4-Trichlorobenzene	182	7.84	1.140	A	3	A	B
85	Hexachlorobutadiene	225	7.92	1.151	A	3	A	B
86	1,2,3-Trichlorobenzene	180	8.09	1.176	A	3	A	B
87	Naphthalene	128	7.97	1.159	A	3	A	B
88	2-Methylnaphthalene	142	8.52	1.239	A	2	A	B

Cal A = Average L = Linear LO = Linear w/origin Q = Quad QO = Quad w/origin
#Qual = number of qualifiers
A/H = Area or Height
ID R = R.T. B = R.T. & Q Q = Qvalue L = Largest A = All

WR201119.M Fri Dec 18 09:41:56 2020

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

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

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

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

Key

ISD: Internal Standard Compound

SSD: Surrogate Standard Compound

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

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

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

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

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

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

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

Table 4. BFB Tune Evaluation Criteria

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

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

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

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

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

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

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify.	Flagging is not appropriate.	No samples shall be analyzed without a valid tune.
Initial calibration (ICAL) for all analytes (including surrogates)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	Each analyte must meet one of the three options below: Option 1: RSD for each analyte ≤ 15%; Option 2: linear least squares regression for each analyte: r2 ≥ 0.99; Option 3: non-linear least squares regression (quadratic) for each analyte: r2 ≥ 0.99.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. No samples shall be analyzed until ICAL has passed. If the specific version of a method requires additional evaluation (e.g., RFs or low calibration standard analysis and recovery criteria) these additional requirements must also be met.
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Calculated for each analyte and surrogate.
Evaluation of Relative Retention Times (RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	NA.	After maintenance is performed which may affect retention times, RRTs may be updated based on the daily CCV. RRTs shall be compared with the most recently updated RRTs.
Initial	Once after	All reported	Correct problem.	Flagging is not	No samples shall be analyzed

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Calibration Verification (ICV)	each ICAL, analysis of a second source prior to sample analysis	analytes within ± 20% of true value.	Rerun ICV. If that fails, repeat ICAL.	appropriate.	until calibration has been verified with a second source.
Continuing calibration verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last acceptable CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g, average RFs) these additional requirements must also be met.
Internal standards (IS)	Every field sample, standard, and QC sample.	Retention time ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is	If corrective action fails in field samples, data must be qualified and explained in the case narrative. Apply Q-flag	NA

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

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

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

DoD Appendix C LCS Limits
Method 8260 Solid Matrix

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

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

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

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

DoD Appendix C LCS Limits
Method 8260 Water Matrix

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

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

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

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

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

LCS Limits
EPA 624.1 Water Matrix

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

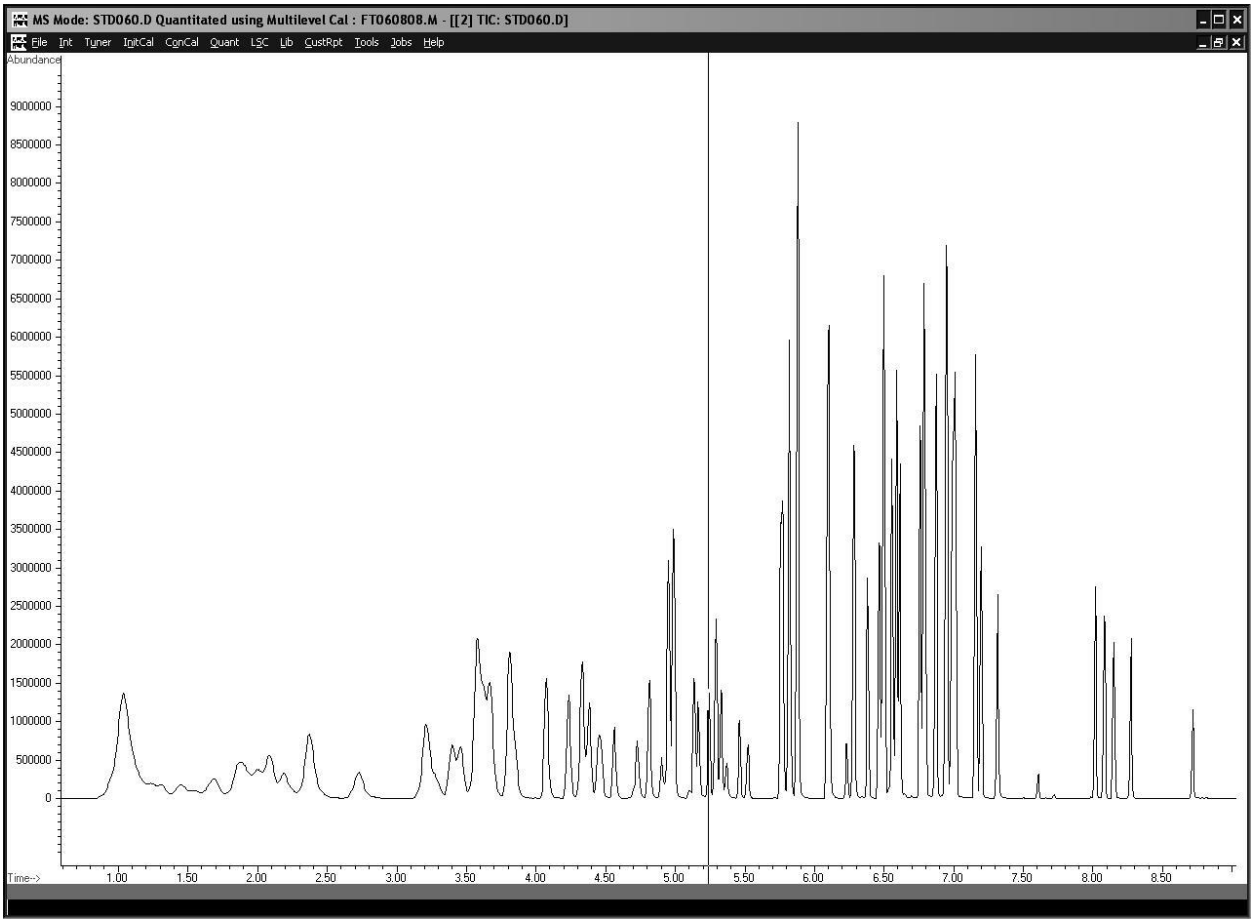
10061-02-6	trans-1,3-Dichloropropene	50	150
79-01-6	Trichloroethene	65	135
75-69-4	Trichlorofluoromethane [Freon-11]	50	150
75-01-4	Vinyl chloride	5	195

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

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

†: Results based on recovery data from 2020.

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



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

ANALYTICAL METHODS

Section 9.0

Method: EPA Method TO-14A/TO-15 Volatile Organic Compounds (Standard/QUAD)			
Laboratory SOP #: 6	Revision #: 50	Effective Date: May 28, 2024	Methods Manual Summary

Description: This method involves full scan gas chromatograph/mass spectrometer (GC/MS) analysis of whole air samples collected in evacuated stainless steel canisters. Samples are analyzed for volatile organic compounds (VOCs) using EPA Method TO-14A/TO-15 protocols. An aliquot of up to 0.5 liters of air is withdrawn from the canister utilizing a volumetric loop or mass flow controller. This volume is loaded onto a hydrophobic multibed sorbent trap to remove water and carbon dioxide and to concentrate the vapor sample. The focused sample is then flash-heated to sweep adsorbed VOCs onto a secondary trap for further concentration and/or directly onto a GC/MS for separation and detection.

Eurofins Environment Testing Northern California, LLC maintains a suite of TO-14A/TO-15 methods, each optimized to efficiently meet the data objectives for a wide range of targeted concentration ranges. The methods, their reporting limits, and typical applications are summarized in the table below. This method summary describes TO-14A/TO-15 full scan (Standard or QUAD).

Eurofins Environment Testing Northern California, LLC Method	**Base Reporting Limits**	**Typical Application**
TO-14A/TO-15 Full Scan (5&20)	5 – 20 ppbv	Soil gas and ppmv range vapor matrices
TO-14A/TO-15 Full Scan (Standard or QUAD)	0.5 – 5.0 ppbv	Ambient air, soil gas, and ppbv level vapor matrices
TO-14A/TO-15 Full Scan (Low-level)	0.1 – 1.0 ppbv	Indoor and outdoor air
TO-14A/TO-15 SIM	0.01 – 0.5 ppbv	Indoor and outdoor air

Certain compounds are not included in Eurofins Environment Testing Northern California, LLC's standard target analyte list. These compounds are communicated at the time of client proposal request. Unless otherwise directed, Eurofins Environment Testing Northern California, LLC reports these non-routine compounds with partial validation. Validation may include a 3-point calibration with the lowest concentration defining the reporting limit, no second source verification analyzed, and no method detection limit study performed unless previous arrangements have been made. In addition, stability of the non-standard compound during sample storage is not validated. Full validation may be available upon request.

Eurofins Environment Testing Northern California, LLC takes no modifications of technical significance to Method TO-15 for the "QUAD" configurations. Since Eurofins Environment Testing Northern California, LLC applies TO-15 methodology to all Summa canisters regardless of whether TO-14A or TO-15 is specified by the project, the laboratory has

established modifications to method TO-14A as detailed in Table 1. Please note that Methods TO-14A and TO-15 were validated for specially treated canisters. As such, the use of Tedlar bags for sample collection is outside the scope of the method and not recommended for ambient or indoor air samples. It is the responsibility of the data user to determine the usability of TO-14A and TO-15 results generated from Tedlar bags.

Table 1. Summary of TO-14A Method Modifications

Requirement	TO-14A	Laboratory Modifications
Sample Drying System	Nafion Drier	Multibed hydrophobic sorbent.
Blank acceptance criteria	≤ 0.2 ppbv	≤ RL
BFB ion abundance criteria	Ion abundance criteria listed in Table 4 of TO-14A	Follow abundance criteria listed in TO-15.
BFB absolute abundance criteria	Within 10% when comparing to the previous daily BFB	CCV internal standard area counts are compared to ICAL; corrective action when recovery is less than 60%.
Initial Calibration	≤ 30% RSD for listed 39 VOCs	Follow TO-15 requirements of ≤ 30% RSD with 2 of Laboratory's 62 standard compounds allowed out to ≤ 40% RSD

The standard target analyte list, reporting limit (RL) also referred to as Limit of Quantitation, QC criteria, and QC summary can be found in Tables 2 through 6.

Table 2 is the standard list of accredited compounds (except where noted), reporting limits and QC acceptance criteria. Each project may be customized as needed. Additional compounds and different reporting limits may be obtainable and/or achieved upon request.

Table 2. Method TO-14A/TO-15 Analyte List (QUAD)

Analyte	RL/LOQ (ppbv)	QC Acceptance Criteria			
		ICAL (%RSD)	CCV (%R)	ICV/LCS (%R)	Precision Limits (Max. RPD)
1,1,2,2-Tetrachloroethane	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,1,2-Trichloroethane	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,1-Dichloroethane	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,1-Dichloroethene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,2,4-Trichlorobenzene	2.0	≤ 30%	70 – 130	70 – 130	± 25
1,2,4-Trimethylbenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,2-Dibromoethane (EDB)	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,2-Dichlorobenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,2-Dichloroethane	0.5	≤ 30%	70 – 130	70 – 130	± 25

Analyte	RL/LOQ (ppbv)	QC Acceptance Criteria			
		ICAL (%RSD)	CCV (%R)	ICV/LCS (%R)	Precision Limits (Max. RPD)
1,2-Dichloropropane	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,3,5-Trimethylbenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,3-Dichlorobenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,4-Dichlorobenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Benzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Bromomethane	1.0	≤ 30%	70 – 130	70 – 130	± 25
Carbon Tetrachloride	0.5	≤ 30%	70 – 130	70 – 130	± 25
Chlorobenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Chloroethane	2.0	≤ 30%	70 – 130	70 – 130	± 25
Chloroform	0.5	≤ 30%	70 – 130	70 – 130	± 25
Chloromethane	5.0	≤ 30%	70 – 130	70 – 130	± 25
Chlorotoluene (Benzyl Chloride)	0.5	≤ 30%	70 – 130	70 – 130	± 25
cis-1,2-Dichloroethene	0.5	≤ 30%	70 – 130	70 – 130	± 25
cis-1,3-Dichloropropene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Dichloromethane (Methylene Chloride)	1.0	≤ 30%	70 – 130	70 – 130	± 25
Ethylbenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Freon 11 (Trichlorofluoromethane)	0.5	≤ 30%	70 – 130	70 – 130	± 25
Freon 113 (Trichlorotrifluoroethane)	0.5	≤ 30%	70 – 130	70 – 130	± 25
Freon 114	0.5	≤ 30%	70 – 130	70 – 130	± 25
Freon 12 (Dichlorodifluoromethane)	0.5	≤ 30%	70 – 130	70 – 130	± 25
Hexachlorobutadiene	2.0	≤ 30%	70 – 130	70 – 130	± 25
m,p-Xylene	1.0	≤ 30%	70 – 130	70 – 130	± 25
Methyl Chloroform (1,1,1-Trichloroethane)	0.5	≤ 30%	70 – 130	70 – 130	± 25
o-Xylene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Styrene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Tetrachloroethene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Toluene	1.0	≤ 30%	70 – 130	70 – 130	± 25
trans-1,3-Dichloropropene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Trichloroethene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Vinyl Chloride	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,3-Butadiene	0.5	≤ 30%	70 – 130	70 – 130	± 25
1,4-Dioxane	1.0	≤ 30%	70 – 130	70 – 130	± 25

Analyte	RL/LOQ (ppbv)	QC Acceptance Criteria			
		ICAL (%RSD)	CCV (%R)	ICV/LCS (%R)	Precision Limits (Max. RPD)
2-Butanone (Methyl Ethyl Ketone)	2.0	≤ 30%	70 – 130	70 – 130	± 25
2-Hexanone	2.0	≤ 30%	70 – 130	70 – 130	± 25
4-Ethyltoluene	0.5	≤ 30%	70 – 130	70 – 130	± 25
4-Methyl-2-Pentanone (MIBK)	0.5	≤ 30%	70 – 130	70 – 130	± 25
Acetone	5.0	≤ 30%	70 – 130	70 – 130	± 25
Bromodichloromethane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Bromoform	0.5	≤ 30%	70 – 130	70 – 130	± 25
Carbon Disulfide	2.0	≤ 30%	70 – 130	70 – 130	± 25
Cyclohexane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Dibromochloromethane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Ethanol	5.0	≤ 30%	70 – 130	70 – 130	± 25
Heptane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Hexane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Isopropanol	2.0	≤ 30%	70 – 130	70 – 130	± 25
Methyl t-Butyl Ether (MTBE)	2.0	≤ 30%	70 – 130	70 – 130	± 25
Tetrahydrofuran	0.5	≤ 30%	70 – 130	70 – 130	± 25
trans-1,2-Dichloroethene	0.5	≤ 30%	70 – 130	70 – 130	± 25
2,2,4-Trimethylpentane	0.5	≤ 30%	70 – 130	70 – 130	± 25
Cumene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Propylbenzene	0.5	≤ 30%	70 – 130	70 – 130	± 25
3-Chloropropene	0.5	≤ 30%	70 – 130	70 – 130	± 25
Naphthalene*	1.0	≤40%	60 – 140	60 – 140	± 25
TPH (Gasoline) **	50	1-Point Calibration	N/A	ICV only; 60 – 140	± 25
NMOC (Hexane/Heptane)**	10	1-Point Calibration	N/A	NA	± 25

*Due to its low vapor pressure, Naphthalene may exceed TO-15 performance requirements. The wider QC limits reflect typical performance. Although Naphthalene is not on Eurofins Environment Testing Northern California, LLC's "standard" TO-15 list, it is commonly requested and included in Table 2.

**TPH and NMOC are not on Eurofins Environment Testing Northern California, LLC's "standard" TO-15 list, but are included in Table 2 due to common requests. These are semi-quantitative non-accredited parameters.

Table 3 is the list of non-standard NELAP accredited Method TO-15 compounds that may be requested.

Table 3. Method TO-15 Additional Analyte List (QUAD)

Analyte	RL/LOQ (ppbv)	QA Acceptance Criteria			
		ICAL (%RSD)	CCV (%R)	ICV/LCS (%R)	Precision Limits (Max. RPD)
1,1,1,2-Tetrachloroethane	0.5	≤30%	70 – 130	70 – 130	± 25
1,2,3-Trichloropropane	0.5	≤30%	70 – 130	70 – 130	± 25
1,2-Dibromo-3-chloropropane	2.0	≤30%	70 – 130	70 – 130	± 25
1,3-Dichloropropane	0.5	≤30%	70 – 130	70 – 130	± 25
2-Chlorotoluene	2.0	≤30%	70 – 130	70 – 130	± 25
Acrylonitrile	0.5	≤30%	70 – 130	70 – 130	± 25
alpha-methyl-styrene	2.0	≤30%	70 – 130	70 – 130	± 25
4-Isopropyltoluene (p-Cymene)	2.0	≤30%	70 – 130	70 – 130	± 25
Bromobenzene	2.0	≤30%	70 – 130	70 – 130	± 25
Butane	2.0	≤30%	70 – 130	70 – 130	± 25
Butyl Benzene	0.5	≤30%	70 – 130	70 – 130	± 25
Dibromomethane	0.5	≤30%	70 – 130	70 – 130	± 25
Ethyl Acetate	2.0	≤30%	70 – 130	70 – 130	± 25
Freon 21 (Dichlorofluoromethane)	2.0	≤30%	70 – 130	70 – 130	± 25
Freon 22 (Chlorodifluoromethane)	2.0	≤30%	70 – 130	70 – 130	± 25
Isobutane	2.0	≤30%	70 – 130	70 – 130	± 25
Isopentane	2.0	≤30%	70 – 130	70 – 130	± 25
Methyl Methacrylate	2.0	≤30%	70 – 130	70 – 130	± 25
Methylcyclohexane	2.0	≤30%	70 – 130	70 – 130	± 25
Nonane	2.0	≤30%	70 – 130	70 – 130	± 25
n-Pentane	2.0	≤30%	70 – 130	70 – 130	± 25
Propylene	2.0	≤30%	70 – 130	70 – 130	± 25
Octane	2.0	≤30%	70 – 130	70 – 130	± 25
sec-Butylbenzene	0.5	≤30%	70 – 130	70 – 130	± 25
tert-Butyl Alcohol	2.0	≤30%	70 – 130	70 – 130	± 25
tert-Butyl Benzene	2.0	≤30%	70 – 130	70 – 130	± 25
Vinyl Acetate	2.0	≤30%	70 – 130	70 – 130	± 25
Vinyl Bromide	0.5	≤30%	70 – 130	70 – 130	± 25

Table 4. Internal Standards

Analyte	Accuracy (% R)
Bromochloromethane	60 – 140
1,4-Difluorobenzene	60 – 140
Chlorobenzene-d_5	60 – 140

Table 5. Surrogates

Analyte	Accuracy (% R)
1,2-Dichloroethane-d_4	70 – 130
Toluene-d_8	70 – 130
4-Bromofluorobenzene	70 – 130

Table 6. Summary of Calibration and QC Procedures for Methods TO-14A/TO-15

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action
Tuning Criteria	Every 24 hours	TO-15 ion abundance criteria	Correct problem then repeat tune.
Minimum 5-Point Initial Calibration (ICAL)	Prior to sample analysis	% RSD ≤ 30 with 2 compounds allowed out to ≤ 40% RSD	Correct problem then repeat Initial Calibration curve.
Initial Calibration Verification and Laboratory Control Sample (ICV and LCS)	After each Initial Calibration curve, and daily prior to sample analysis	Recoveries for 85% of "Standard" compounds must be 70–130%. No recovery may be < 50%. ICV evaluated on a full list basis at the time of calibration. If specified by the project, in-house generated control limits may be used.	Check the system and reanalyze the standard. Re-prepare the standard if necessary to determine the source of error. Re-calibrate the instrument if the primary standard is found to be in error.
Continuing Calibration Verification (CCV) for Standard compounds	At the start of each analytical clock after the tune check	70–130%	Compounds exceeding this criterion and associated data will be flagged and narrated with the exception of high bias associated with non-detects. If more than two compounds from the standard list recover outside of 70–130% or > 10% of VOCs if short list is used (20 compounds or less), corrective action will be taken. If any compound exceeds 60–140%, samples are not analyzed unless data meets project needs. Check the system and reanalyze the standard. Re-prepare the standard if necessary. Re-calibrate the instrument if the criteria cannot be met.
Laboratory Blank	After analysis of standards and prior to sample analysis, or when contamination is present.	Results less than the laboratory reporting limit	Inspect the system and re-analyze the blank. "B"-flag data for common contaminants.

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action
Internal Standard (IS)	As each standard, blank, and sample is being loaded	Retention time (RT) for blanks and samples must be within ±0.33 min of the RT in the CCV and within ±40% of the area counts of the daily CCV internal standards.	**For blanks:** Inspect the system and reanalyze the blank. **For samples:** Re-analyze the sample. If the ISs are within limits in the re-analysis, report the second analysis. If ISs are out-of-limits a second time, dilute the sample until ISs are within acceptance limits and narrate.
Surrogates	As each standard, blank, and sample is being loaded	70–130% If specified by the project, in-house generated control limits may be used.	**For blanks:** Inspect the system and reanalyze the blank. **For samples:** Re-analyze the sample unless obvious matrix interference is documented. If the %Rs are within limits in the re-analysis, report the second analysis. If %Rs are out-of-limits a second time, report data from first analysis and narrate.
Laboratory Duplicates – Laboratory Control Sample Duplicates (LCSD)	One per analytical batch	RPD ≤25%	Narrate exceedances. If more than 5% of compound list is outside criteria or if compound has >40%RPD, investigate the cause and perform maintenance as required. If instrument maintenance is required, calibrate as needed.

Attachment 2

Arcadis Technical Guidance Instructions

TGI - Manual Water-Level and NAPL Monitoring

Rev: 5.1

Rev Date: April 28, 2025

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
0	0	October 11, 2018	All	Updated and re-written as TGI	Marc Killingstad Everett H. Fortner III
1	1	May 8, 2020	All	Updated and added NAPL gauging	Marc Killingstad Everett H. Fortner III Andy Pennington
2	2	April 5, 2022	All	Formatting and Revisions	Martha Wulftange
3	3	December 22, 2022	11	Data Management	Martha Wulftange
4	4	March 1, 2023	All	Annual review completed by SME. Document Revision Number and Document Date Updated.	Everett H. Fortner III
5	4	March 8, 2024	All	Annual review completed by SME. Document Revision Number and Document Date Updated.	Everett H. Fortner III
6	5.1	April 28, 2025	All	Annual review completed by SME. Typographical error fixes and reference updates	Colleen O. Barton

Approval Signatures

Prepared by: 

4/28/2025

Colleen O. Barton, PG (Preparer)

Date

Reviewed by: 

4/28/2025

Marc Killingstad, PE (Subject Matter Expert)

Date

1 Introduction

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

2 Intended Use and Responsibilities

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

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

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

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

3 Scope and Application

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

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

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

4 Personnel Qualifications

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

5 Equipment List

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

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

6 Cautions

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

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

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

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

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

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

7 Health and Safety Considerations

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

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

8 Procedure

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

Calibration Procedures

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

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

Water-Level Measurement Procedures

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

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

- The top of the monitoring well will be cleaned with a clean rag to prevent loose particulate matter from falling into the well.
- Perform a well inspection (note that a well inspection form may be required to be filled out along with a photo to document the conditions).
- Place clean plastic sheeting on the ground next to the well.
- Unlock and/or open the monitoring well cover while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps – see Section 7).
- Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading (if applicable and requirement for the site).
- Allow the water-level in the well to equilibrate with atmospheric pressure for a few minutes (check previous field forms or field books for equilibration time, if noted).
- Locate the measuring reference point that correlates to the survey point on the well casing. If one is not found, make a reference point by notching the highest and/or north point on the inner casing (or outer if an inner casing is not present) or mark with a permanent mark. All downhole measurements will be taken from the reference point. Document any changes or new reference point addition.
- Measure to the nearest 0.01 foot and record the height of the inner well casing and outer protective casing to ground level (note that some well pads are raised and are not at true ground surface).
- Lower the indicator probe into the center of the well until contact with the water surface is indicated by either an audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. Use and install a tape guide (available from some manufacturers) to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does rub on the inner or outer casing which could fray and damage the tape.
- If an oil-water interface probe is being used to measure depth and thickness of NAPL, lower the interface probe into the center of the well until a contact with the NAPL surface is indicated by either audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. To gauge the water level in a well which contains LNAPL (LNAPL-water interface), advance the interface probe past the LNAPL-water interface until the probe produces a solid audible alarm indicating water. While slowly retrieving the probe upward, the equipment will produce a different tone when the LNAPL-water interface is reached (typically this is a multiple alarm sound or flashing light). This level should represent the depth to water. The depth indicating the bottom of the water column and top of DNAPL layer, if any, is indicated by the multiple alarm signal or flashing light emitted by the interface probe.
- Hold the tape at the measuring point and repeat the measurement two more times.
- Read and record measurement to the nearest 0.01 foot. Check the measurement with previous measurements, if available, and note any anomalies/discrepancies; if significant, contact the project staff.

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

Total Depth Measurement Procedures

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

Initial Decontamination

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

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

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

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

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

Notes:

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

9 Waste Management

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

10 Data Recording and Management

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

Field personnel will complete all applicable field forms for each test (see attached forms and FieldNow® available forms). Forms will include recommended data file naming protocol per the field implementation plan. Data that has been collected must be transmitted at the end of the day (notes/forms/data file). The files must be transmitted to the appropriate project directory (via direct transfer or email to data manager). Work completed that day and any relevant observations noted during the daily activities as well as copies of the data mentioned above should be summarized and provided in an email. The appropriate team member will review the data for accuracy and provide feedback. Field equipment calibration, decontamination activities, and waste management activities will be recorded in the field notebook, appropriate field form, or daily log.

Refer to the Quality Procedure Data Management, QP 4.09, for additional information on data management.

11 Quality Assurance

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

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

12 References

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

U.S. Environmental Protection Agency, 2025. *FSBPROC-105-R6 Operating Procedure, Groundwater Level and Well Depth Measurement.* April 17.

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TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev: 3

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 12, 2018	All	Updated and re-written as TGI with new branding and content	Marc Killingstad
	1	May 8, 2020	Pages 5, 10-11	Added clarification/details for equipment requirements and procedure steps based on USEPA guidance	Marc Killingstad
	2	April 5, 2022	All	Updated to new branding template and minor edits	Marc Killingstad
	3	April 5, 2023	All	Annual review completed by SME. Document version number and document date updated.	Marc Killingstad

Approval Signatures

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	Xuan Xu (Preparer)	Date
Reviewed by:		4/5/2023
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

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

2 Intended Use and Responsibilities

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

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

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

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

3 Scope and Application

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

construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

4 Personnel Qualifications

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

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

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

5 Equipment List

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

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

  - YSI 6-Series Multi-Parameter Instrument
  - Horiba U-22 Multi-Parameter Instrument.
  - Hydrolab Series 3 or Series 4a Multiprobe and Display.

  NOTE: *Transparent, small volume flow-through-cells (e.g., 250 milliliters or less) are preferred as they allow for easy detection of air bubbles and sediment buildup in the cell, which can interfere with the monitoring instrument probes. A small volume cell also allows for quick turnover of water in the cell between measurements of the indicator field parameters. It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.*

- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment from contact with potential sources of contamination.
- Decontamination equipment
  - Non-phosphate laboratory soap (Alconox or equivalent), brushes, and clean buckets, and/or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the present items are clean
  - Distilled or de-ionized water for equipment decontamination
- Indelible ink pen
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Sampling pump, which may consist of one or more of the following:
  - Submersible pump (e.g., Grundfos Redi-Flo 2)
  - Peristaltic pump (e.g., ISCO Model 150)
  - Bladder pump (e.g., Marschalk System 1, QED Micropurge, Geotech)
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery
  - Submersible pumps such as Grundfos require a pump controller to run the pump
  - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N_2 or CO_2 gas cylinders)
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used
  - For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will be used through the pump apparatus
  - Teflon® will not be used when sampling for per- and polyfluoroalkyl substances (PFAS)
- Graduated cylinder and stopwatch or other device to measure time to determine pumping rate
- Appropriate water sample containers (supplied by the laboratory)
- Appropriate blanks (trip blank supplied by the laboratory)
- Sample labels and Chain-of-Custody forms (COC)
- 0.45-micron disposable filters (if field filtering is required)

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

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

6 Cautions

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

Weather

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

Cross-Contamination

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

Pumps

- Preferred methods of extracting groundwater are adjustable rate, submersible pumps - such as centrifugal pumps or bladder pumps – constructed of stainless steel or polytetrafluoroethylene (PTFE, i.e., Teflon®). However, *PTFE will not be used when sampling for per- and polyfluoroalkyl substances (PFAS). PTFE could contain PFAS*.

- When using a bladder pump for collecting VOCs and dissolved gases, “best practice” is to set-up the pump to deliver sufficient water to fill a 40 mL VOC vial.
- The use of peristaltic pumps will be based on the type of data to be collected. *Because the use a peristaltic pump can result in de-gassing of VOC and / or dissolved gases from groundwater, a different type of pump will be considered if these compounds are of concern.*
- *Manual or motor driven inertial pumping devices are not recommended because they cause greater disturbance during purging and pumping than regular pumps and are less easily controlled. This could cause a higher degree of data variability.*

Tubing

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

General Precautions

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

7 Health and Safety Considerations

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

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

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

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

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

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

8 Procedure

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

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

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

   a. For submersible and non-dedicated bladder pumps, decontaminate the pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new bladder and attachment of an air-line, sample discharge line, and safety cable prior to placement in the well. Attach the air-line tubing to the air-port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Take care not to reverse the air and discharge tubing lines during bladder pump setup, as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of pump (if present, depending on pump model used). Slowly lower the pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Avoid twisting

and tangling of safety cable, tubing, and electrical lines while lowering the pump into the well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well, as this could lead to unintended contamination.

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

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

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

9. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the multi-parameter water-quality sonde and make sure to record equipment/instrument identification (manufacturer and model number).

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

11. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified) and adjust the pumping rate to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement): the water level should stabilize, however, this is not always possible.

12. If the well diameter is of sufficient size, measure the water level every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping.

13. Maintain a steady flow rate to the extent practicable and do not break pump suction or cause entrainment of air in the sample.

14. Record pumping rate adjustments and depths to water.

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

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

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

maintained, the well may be pumped until the drawdown is at a level slightly higher than top of the well screen.

15. After water levels have stabilized and a sufficient volume has been purged (see note below), continue pumping and begin monitoring field indicator parameters using a multi-parameter water-quality sonde coupled with a flow-through-cell.

    NOTE: *The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.*

16. Use the flow to measure all indicator field parameters, except for turbidity, every 3 to 5 minutes (or after each volume of the flow-through cell has been purged or other appropriate interval); turbidity samples will be collected before the flow-through-cell using the T-valve and a clean container such as a glass beaker.

17. Record field indicator parameters on the groundwater sampling log.

18. The well is considered stabilized and ready for sample collection when three consecutive readings are within the following limits:

    - **Turbidity** within ± 10% for values greater than 5 nephelometric turbidity units [NTUs] or if three turbidity values are less than 5 NTUs, consider the values stabilized
    - **Dissolved Oxygen (DO)** within ± 10% for values greater than 0.5 mg/L or if three DO values are less than 0.5 mg/L, consider the values stabilized
    - **Specific Conductance** within ± 3%
    - **Temperature** within ± 3%
    - **pH** within ± 0.1 unit
    - **Oxidation/Reduction Potential (ORP)** within ±10 millivolts (mV)

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

    NOTE: *While achieving turbidity levels less than 5 NTU and a stable drawdown of less than 0.3 feet is desirable, sample collection may still take place provided the indicator field parameter criteria in this procedure are met.*

19. If the parameters have stabilized but turbidity remains relatively high (e.g., greater than 50 NTUs), the pump flow rate may be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If groundwater turbidity has been minimized (i.e., consecutive readings within ± 10%) and the values for all other parameters have stabilized, the well may be sampled; however, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.

20. If after one (1) hour of purging indicator field parameters have not stabilized, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.

    In general, three potential options are available if stabilization criteria are not met:

    a. Continue purging until stabilization is achieved.

    b. Discontinue purging, do not collect any samples, and record in field logbook/on the sampling form that stabilization could not be achieved (documentation must describe attempts to achieve stabilization).

c. Discontinue purging, collect samples, and provide full explanation of attempts to achieve stabilization. There is a risk that the analytical data obtained under these conditions, particularly metals and hydrophobic organic analytes, may reflect a sampling bias and, as a result, the data may not meet the data quality objectives of the sampling event.

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

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

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

Oxygen Solubility in Fresh Water

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

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

21. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container.
22. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container.
    a. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell will be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection.
    b. Under no circumstances will analytical samples be collected from the discharge of the flow- through cell.
    c. If an in-line ‘T’ and valve are used, the valve needs to be removed as well.

d. Samples will be collected in the following order: VOCs, total organic carbon (TOC), semi- volatile organic compounds (SVOCs), metals and cyanide, and others (or other order as defined in the site-specific FIP/work plan).
e. When the container is full, tightly screw on the cap.

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

9 Waste Management

Materials generated during groundwater sampling activities, including disposable equipment and excess purge water, will be stored on site in appropriately labeled containers and disposed of properly. Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage*, the procedures identified in the

FIP or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field logbook.

10 Data Recording and Management

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

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

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

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

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

11 Quality Assurance

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

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

- One duplicate for every 10 samples
- One laboratory matrix/matrix spike sample for every 20 samples
- In addition to the quality control samples to be collected in accordance with this TGI, the following quality control procedures will be observed in the field:
- Collect samples from monitoring wells, in order of increasing concentration, to the extent known based on review of historical site information if available
- Equipment blanks will include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well)
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled

- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures—calibrate instruments at the beginning of each day, verify the calibration at the end of each day, and record all calibration activities in the field notebook
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well following the procedure for equipment decontamination

12 References

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

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

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

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

13 Attachments

Attachment A – Low Flow Sampling Field Form

Attachment A

Low-Flow Sampling Field Form

GROUNDWATER SAMPLING FORM

Project No. _____ Well ID _____ Date _____

Project Name/Location _____ Weather _____

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

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

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

Pump On/Off _____ Centrifugal _____ Submersible _____ Other _____

Sample Time: _____ Volume Purged _____

Purge Start _____ Gallons Purged _____ Sample ID _____ Sampled by _____

Purge End _____ Replicate/Code No. _____

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

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

Constituents Sampled	Container	Number	Preservative

Comments _____

Well Casing Volumes

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

Well Information

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

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

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

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TGI - Sub-Slab Vapor and Soil Vapor Sampling Using Whole Air Canisters

Rev: 3

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
1	1	9/18/2016	All	Updated Rev0	Mitch Wacksman
2	2	8/4/2023	All	Updated Rev1	Sarah Jonker Christina Weaver Robert Uppencamp
3	3	7/22/2025	All	Complete re-write to all sections.	Sarah Jonker Margaret Bartee

Approval Signatures

Prepared by:		7/22/2025
	Sarah Jonker	Date
Reviewed by:		7/22/2025
	Margaret Bartee	Date

1 Introduction

This Technical Guidance Instruction (TGI) provides the methods and procedures for collecting whole air samples via USEPA Method TO-15 from sub-slab vapor or exterior soil vapor using whole air stainless-steel canisters. It is advisable to consult with a vapor intrusion subject matter expert (SME) when planning and executing the procedures detailed in this TGI.

2 Intended Use and Responsibilities

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

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

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

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

3 Scope and Application

This Technical Guidance Instruction (TGI) has been updated to reflect United States Environmental Protection Agency (USEPA) criteria (USEPA 2015) and best practices.

This document describes the procedures for collecting exterior soil vapor or sub-slab soil vapor (herein referred to as "soil vapor") samples using whole air stainless-steel canisters for the analysis of volatile organic compounds (VOCs) by USEPA Method TO-15 (TO-15). This document assumes a sample port (either sub-slab port or exterior soil vapor probe) has already been installed. This document covers the above ground assembly and sampling methods.

Separate TGIs are available in the TGI library for the installation of sub-slab ports and exterior soil vapor probes. Sampling is typically able to commence a minimum of 2 hours after installation of a sub-slab port (VaporPin®) and a minimum of 24 hours after installation of a soil vapor probe. Confirm equilibration times with the project's regulatory jurisdiction.

Method TO-15 typically uses a 1-liter, 3-liter, or 6-liter stainless-steel canisters to collect a whole air sample. The whole air sample is then analyzed for VOCs using a quadrupole or ion-trap gas chromatograph/mass spectrometer (GS/MS) system to provide typical compound detection limits of 0.5 parts per billion volume (ppbv).

The following sections list the necessary equipment, materials, and detailed instructions for collecting soil vapor samples for VOC analysis.

4 Personnel Qualifications

Arcadis field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, Department of Transportation (DOT)/International Air Transport Association HazMat #1, site-specific training, first-aid, and cardiopulmonary resuscitation (CPR), as needed. Arcadis field sampling personnel will be well versed in the relevant technical guidance instructions (TGIs) and possess the required skills and experience necessary to successfully complete the desired field work. Arcadis personnel responsible for leading soil vapor sample collection activities must have previous soil vapor sampling experience.

5 Equipment List

The equipment required for soil vapor sample collection is presented below. All stainless-steel supplies must be cleaned/decontaminated prior to use.

5.1 Laboratory

- 1, 3, or 6-liter whole air stainless-steel canisters. Order either batch certified canisters or individually certified canisters as required by the project. Order at least one extra whole air stainless-steel canister per 20 samples to account for a potential loss of vacuum malfunction in shipping, if feasible. A 1-liter whole air stainless-steel canister is typical for soil vapor sampling and will achieve most reporting limit requirements. Confirm the applicable screening levels for the project will be met by the laboratory reporting limits.
- Flow controllers must be ordered for each whole air stainless-steel canister ordered. Flow controllers will come with in-line particulate filters and vacuum gauges. Flow controllers are pre-calibrated to specified sample duration (e.g., 5, 10, or 30 minutes) or flow rate (e.g., between 80-200 milliliters per minute [mL/min]). Confirm with the laboratory that the flow controller comes with a particulate filter and vacuum gauge.
- Order a stainless-steel duplicate tee as needed. Projects typically require 1 duplicate per 10 samples or 20 samples. Confirm the project QA/QC requirements.

5.2 Supplies

Soil vapor probes are typically completed with all sample assembly components permanently connected and contained within the manway vault. Purging materials and sampling media are required.

Supplies to build one sub-slab port assembly are listed below. Clean/decontaminate all stainless-steel supplies prior to use. Tubing and ferrules cannot be reused. Stainless-steel supplies should be Swagelok® or Parker A-Lok compatible compression fittings. Supplies can be purchased at companies such as Swagelok® www.swagelok.com, McMaster Carr www.mcmaster.com, or ESP Supply www.shop-esp.com.

Two sub-slab sample assembly types are detailed in Section 8. Materials to build each type of sample assembly are listed below.

Sub-Slab Port Assembly for Vapor Pin™ with Barb Fitting using the Sample Configuration with Purge Isolation

- 1: 1/4-inch stainless-steel valve with compression fittings.
- 6: 1/4-inch stainless-steel compression nuts.
- 6: 1/4-inch stainless-steel front and back compression ferrules.
- 1: 1/4-inch stainless steel union tee. Some labs have flow controllers with a purge port and valve built in. Confirm with the lab flow controller setup (request a diagram or photo). A Luer-Lok™ 3-way valve can be used at the tee fitting as well (single use).
- 36-inches: 1/4-inch outer diameter (OD) Teflon®, Teflon® lined, or Nylaflow tubing.
- 8-inches: 1/4-inch inner diameter (ID) silicone tubing.
- 50 or 60-mL syringe equipped with a three-way Luer-Lok™ valve. Alternately, a low-flow air pump may be used.
- 1-liter Tedlar® bag to collect purge air for the leak detection test, field parameter measurements, and venting outside a structure if working inside.

Sub-Slab Port Assembly for Vapor Pin™ with Barb Fitting using Separate Purge and Sample Configuration

- 1: 1/4-inch stainless-steel ball with compression fittings.
- 3: 1/4-inch stainless-steel compression nuts.
- 3: 1/4-inch stainless-steel front and back compression ferrules.
- 24-inches: 1/4-inch OD Teflon®, Teflon® lined, or Nylaflow tubing.
- 8-inches: 1/4-inch ID silicone tubing.
- 60-mL syringe equipped with a three-way Luer-Lok™ valve. Alternately, a low-flow air pump may be used.
- 1-liter Tedlar® bag to collect purge air for the leak detection test, field parameter measurements, and venting outside a structure if working inside.

5.3 Rental Equipment/Supplies

Appropriate equipment and materials for quality assurance testing are detailed in the respective quality assurance TGIs (i.e., helium leak testing, water dam testing, methane testing).

- Appropriate equipment and materials for quality assurance testing as laid out in the respective quality assurance TGIs (i.e., helium leak testing, water dam testing, methane testing).
- Low-flow air pump with time-elapse clock (GilAir or equivalent) capable of a flow rate between 100 ≤ to ≤ 200 mL/min for purging. This may require a low-flow module. Alternately, a 60-mL syringe with a three-way Luer-Lok™ valve may be used.

- Air pump calibration instrument such as a DryCal® Defender (or equivalent), as needed.
- Photoionization detector (PID) with calibration kit, as needed.
- Multi-gas monitor (LANDTEC® GEM™ 2000 PLUS/5000 or similar) capable of detecting percentage of carbon dioxide, methane, and oxygen with calibration kit, as needed.
- Helium detector (Dielectric MGD-2002 or similar).
- Ultra-high purity (UHP) helium tank with compatible regulator.
- Portable weather meter, as needed. Alternately, weather applications or weather websites can be used.

5.4 Personal Gear and Documents

- Appropriate-sized open-end wrench (typically 9/16-inch and 1/4-inch, #14 spanner for Vapor Pins®).
- 1/4-inch adjustable wrench.
- Channel locking plier with 1.5-inch or larger opening (helium tank manifold and 2-way valves).
- Non-VOC containing modelling clay to mitigate leaks such as Craft Smart Natural Clay (air-dry) or Pepy Plasticine (non-drying). Clay should have no color added and meet ASTM D-4236 standards for required clear labeling (This means they must include general VOCs or harmful ingredients in the label).
- Shroud (plastic bucket, garbage can, plastic bag, plastic drop cloth, laboratory provided helium leak detection kit, etc.).
- Sand filled socks, weighted chain, or equivalent to seal helium shroud when using a plastic bag or drop cloth.
- Chain-of-custody (COC) form(s) – lab supplied preferred.
- Nitrile gloves.
- Work gloves.
- Sample collection log, field notebook/tablet, or current Standard Vapor Intrusion Sampling FieldNow® application.

6 Cautions

The following cautions and field tips should be reviewed and considered prior to installing or collecting a soil vapor sample.

- Sampling personnel should not handle hazardous substances (such as gasoline), permanent marking pens (e.g., Sharpie®), wear/apply fragrances including sunscreens, hand sanitizer, or alcohol-based cleaning products. Do not smoke cigarettes/cigars before and/or during the sampling event.
- Soil vapor sampling equipment and tools should be stored separately from adhesives with VOCs such as duct tape. Field staff should take note of any sanitation stations or recent use of chemicals within proximity of their sample locations.
- Tubing and piping materials commonly used for other types of sampling such as HDPE, LDPE, and PVC should not be used in soil vapor sampling. These materials can either absorb constituents of potential concern present in soil vapor or introduce VOCs via off gassing. Refer to Section 5 for the list of approved soil vapor sampling materials.

- Ensure the flow controller is pre-calibrated to the proper sample collection duration (confirm with laboratory) by checking equipment inventory enclosed with equipment packaging and flow controller tags. Discuss discrepancies with project team prior to final mobilization for sampling. Sample integrity can be compromised if sample collection is extended to the point that the canister reaches atmospheric pressure. Sample integrity is maintained if sample collection is terminated prior to the target duration and a measurable vacuum (e.g., 2 to 10 inches of mercury [in Hg]) remains in the canister when sample collection is terminated.
- The helium detector will function correctly at high relative humidity levels of 50% or greater, but its accuracy and sensitivity may be reduced. In addition, high concentrations of methane can cause false readings. Use a multi-gas monitor to screen purged air during leak check if methane interference is anticipated. Review the TGI for *Administering Helium Tracer Gas Leak Test* for further details on helium leak testing.
- The integrity of the sample train and sample port will be tested in accordance with the project specific requirements. These procedures are contained in their own TGI documents and include helium leak testing, water dam testing, and methane testing.
- When conducting a shut-in test, pull the syringe slowly at a rate no faster than 1 to 2 mL/second (approximately 60 to 120 mL/min, the lower the better) to avoid damage to the flow controller, and stop pulling once you have achieved a vacuum. Most flow controllers are not constructed to withstand vacuum from the outlet side of the device, and therefore, rapid application of strong vacuum from a quick, full pull of a syringe can damage the internal components.
- It is important to record the canister vacuum, start and stop times, and sample identification on a proper field sampling form or current Standard Vapor Intrusion Sampling FieldNow® application. You should observe and record the time/ vacuum at the start, and then again one or two minutes after starting the sample collection. It is a good practice to lightly tap the vacuum gauge with your finger before reading it to make sure the needle is not stuck. If the canister is filling as expected, the sampling rate should match the rate of the flow controller set point. Consult your project manager, risk assessor, or air sampling expert by phone if the canister does not appear to be working properly due to insufficient or rapid pressure changes.
- Ensure that there is still measurable vacuum in the canister after sampling. The target residual vacuum is -5 inches Hg, however the acceptable range is between -2 in Hg and -10 in Hg. Sometimes the gauges sent from labs have off-set errors, or they stick.
- When sampling, carefully consider elevation. If your site is over 2,000 feet above sea level, or the difference in elevation between your site and your lab is more than 2,000 feet, then pressure effects will be significant. If you take samples at a higher elevation, they will contain less air for a given ending vacuum reading. High elevation samples analyzed at low elevation will result in more dilution at the lab, which could affect reporting limits. Conversely, low elevation samples received by a laboratory at high elevation may appear to not have much vacuum left in them. Pressure at sea level is 1 atm which corresponds to 29.92 inches Hg. Enter the sample location (city/town) atmosphere (atm) into the Pressure Conversions Calculator to determine the difference in the corresponding pressure in inches of Hg: http://www.uigi.com/Atmos_pressure.html. For instance, the atmosphere in Denver, Colorado is 0.830 atm which corresponds to 24.83 in Hg. This indicates approximately 5 inches Hg difference from sea level.
- If possible, have equipment shipped two to three days before the scheduled start of the sampling event so that all materials can be checked. Check the vacuum in each canister as soon as they arrive. The preference is a starting vacuum of -28 inches of Hg or more, but some canisters may be used in certain jurisdictions with lower starting vacuum. However, ff the initial vacuum registers less than -25 inches of Hg, then the canister is not appropriate for use and another canister should be used. The initial vacuum required varies by

jurisdiction; confirm with the project regulatory authority and project team prior to sampling. If an analog or digital gauge is available when conducting inventory, ensure the vacuum is similar to the laboratory recorded vacuum on the sample tag. Order replacements, if needed.

- Requesting extra canisters and flow controllers from the laboratory should also be considered to ensure that you have enough equipment on site in case of an equipment failure, especially at remote sites.
- When taking field measurement readings of the soil vapor conditions, it is best practice to collect reading from a Tedlar® bag instead of directly from sample port. This is due to field instruments having a flow rate of greater than 200 ml/min, which can cause partitioning of contaminants during sampling. In addition, for health and safety reasons, when there are elevated concentrations of site contaminants it is best not to purge into the sampler's breathing zone.
- Considering laying out a new trash bag or tarp on the ground next to the sample port to prevent sampling equipment from touching potentially impacted ground (i.e., asphalt parking lot with car oil stains).
- Shallow exterior soil-gas sampling normally should not proceed immediately following a significant rain event. Consult applicable regulations and guidance for recommended wait times following precipitation events before sampling can proceed.
- This TGI is not a substitute for a Work Plan. Staff involved with a soil vapor sampling event must review the Work Plan prior to pre-field planning activities.

7 Health and Safety Considerations

All sampling personnel should review the appropriate health and safety plan (HASP) and job safety analysis (JSA) prior to beginning work to be aware of all potential hazards associated with the job site and the specific task. Field sampling must be carefully performed to minimize the potential for injury and the spread of hazardous substances.

Soil vapor sampling is often done on the ground with workers on their knees. Low stools, knee pads, or a large pad can be used under the entire sample area (i.e., a large, folded box). This will protect the worker's knees. Ensure proper hand protection is worn while working with hand tools during sample train assembly. The metal-on-metal fittings often create small metal splinters, so always use gloves when handling thecanisters, fittings, valves, etc. Do not blow the splinters off towards other workers. Use outer nitrile gloves when handling all sample train components to prevent potential cross contamination.

Methane is encountered at some project sites, especially petroleum sites and in situ remediation sites. Package the canister and flow controller per DOT regulations for return shipment to the laboratory. These regulations can be found at the Transportation Safety Program's Team Site on the Source. The canister does not require preservation with ice or refrigeration during shipment. Refer to TGI – Soil Gas Methane Monitoring for Shipping Determination of Soil Gas Samples if sampling in an area with unknown or known methane conditions. A shipping determination form is required for shipment of any type of samples prior to field mobilization.

8 Procedure

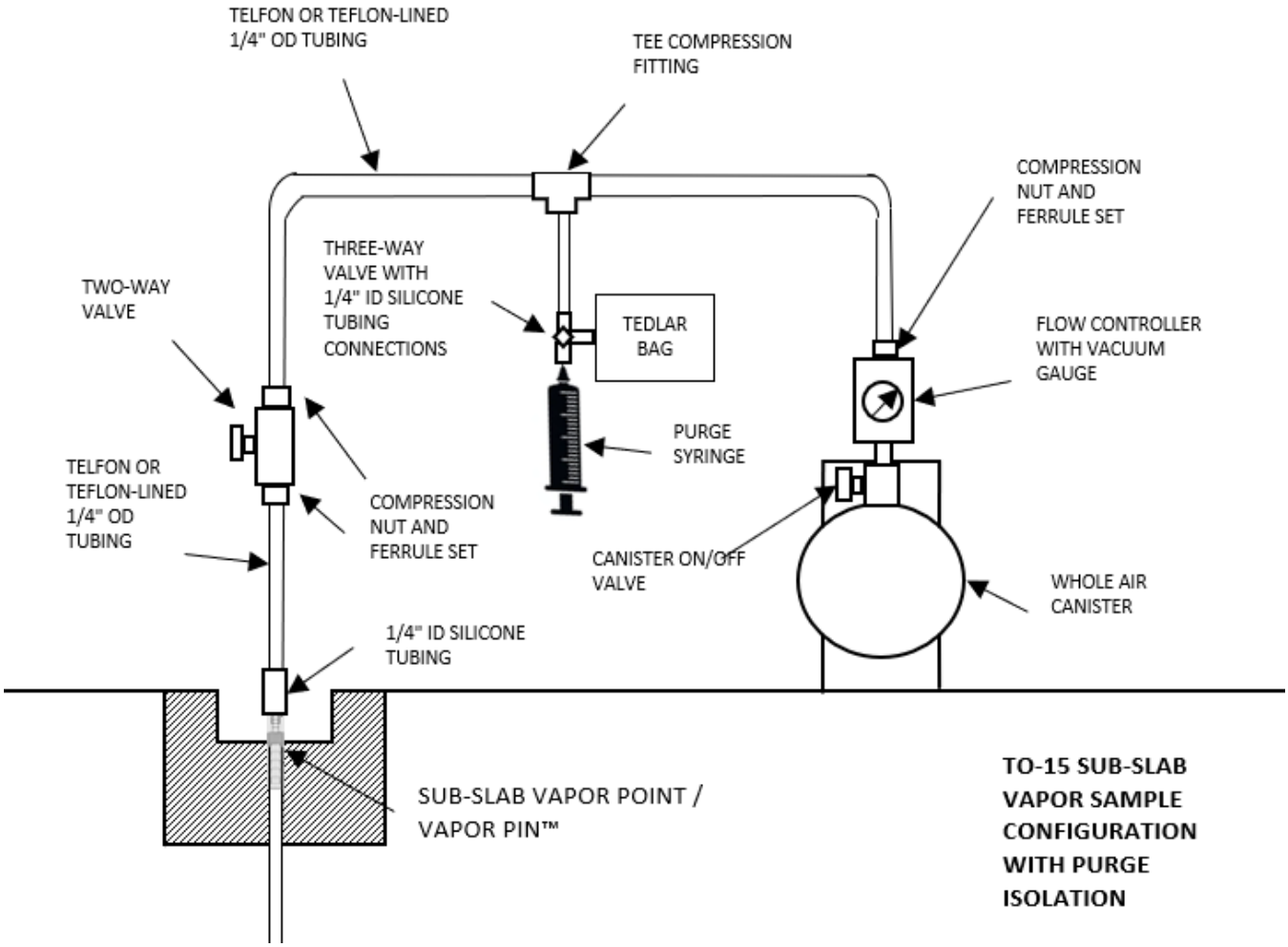
8.1 Sample Train Assembly

The following procedures should be used to collect a soil vapor sample using a whole air stainless-steel canister. These methods can be used for both soil vapor probe samples and interior sub-slab soil vapor samples collected from both permanent and temporary sample point installations. Two configurations of the sample train are acceptable in most jurisdictions; confirm with the project regulatory authority.

Sub-Slab Port Assembly for Vapor Pin™ with Barb Fitting using the Sample Configuration with Purge Isolation

1. Pre-assemble the sample train for each sub-slab port to be sampled (Vapor Pin® with barb fitting). Cut three ~10-inch pieces of 1/4- inch OD Teflon®, Teflon® lined, or Nylaflow tubing and 1 ~6-inch piece of the same tubing.
2. Connect one piece of the 10-inch tubing to the two opposite sides of the stainless-steel tee with compression nuts and ferrule sets. Install a compression nut and ferrule set to the other side of each tubing piece.
3. Remove the cap from the canister and connect the flow controller with in-line particulate filter and vacuum gauge. The flow controller attaches directly to the canister and the pre-set rate dictates the sample duration. The laboratory may have connected the canister and flow controller prior to shipping. Attach the canister and flow controller assembly to the tubing from one side of the stainless-steel tee.
4. Unless the flow controller manifold came with a purge port and valve, one will need to be added. Cut a short length (~6-inches) of 1/4- inch OD Teflon®, Teflon® lined, or Nylaflow tubing. Connect to the open end of the tee fitting using a compression nut and ferrule set. This tee adds a leg to the sample train that will be used to purge “dead” air from the sample train.
5. Connect the purge syringe with three-way valve and/or air pump to the free end tubing from the tee using a length short piece of 1/4-inch ID silicone tubing.
6. Attach a two-way compression valve to the remaining free end of the tee tubing. Cut another 6-inch piece of 1/4-inch OD Teflon tubing and connect to the other side of the two-way valve with a compression nut and ferrule set. The two-way valve will be immediately adjacent to the sample point in the train assembly. This valve is used to isolate the sample train from the sample point prior to sampling in order to test the sample train’s integrity. See Section 8.3 for purging details.
7. When collecting duplicate or other quality assurance/quality control (QA/QC) samples as required by applicable regulations and guidance, couple two canisters using a stainless-steel compression duplicate sample tee-fitting supplied by the laboratory. Attach flow controller with in-line particulate filter and vacuum gauge to duplicate sample tee.
8. Attach the terminal end of the two-way compression valve to the sample port as appropriate. This may be done using the options below:
    a. Use a section of silicone tube to connect the Teflon sample tubing to the barbed fitting of a Vapor Pin® port.
    b. Use Swagelok® or equivalent compression fittings to connect Teflon tubing to the sample port. Teflon tape should never be used on Swagelok® or equivalent compression fittings.

A schematic of the first suggested sample train setup isolating the purge line is illustrated below:

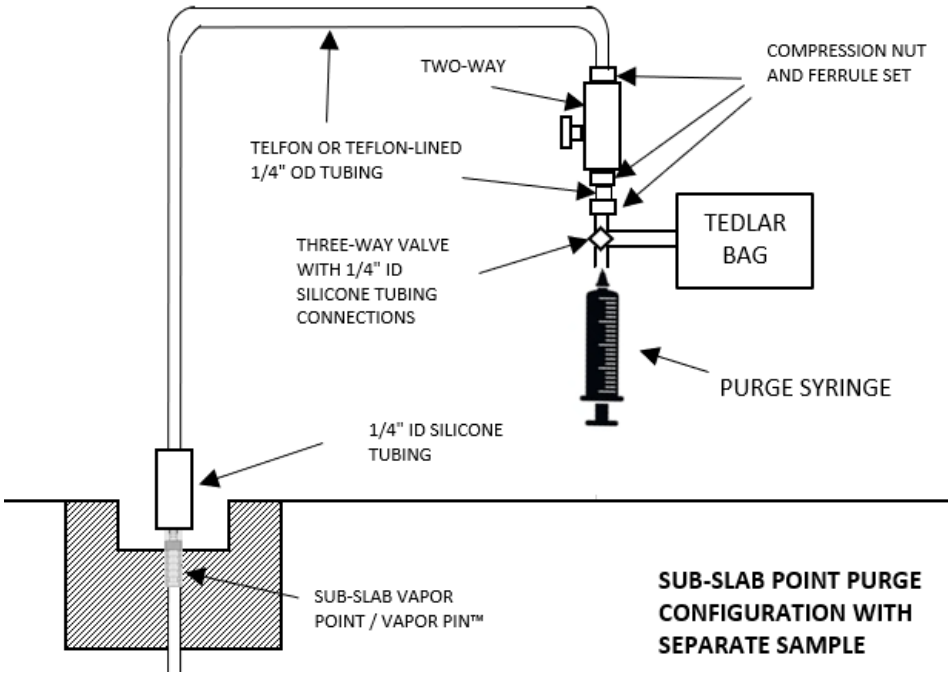


Sub-Slab Port Assembly for Vapor Pin™ with Barb Fitting using Separate Purge and Sample Configuration

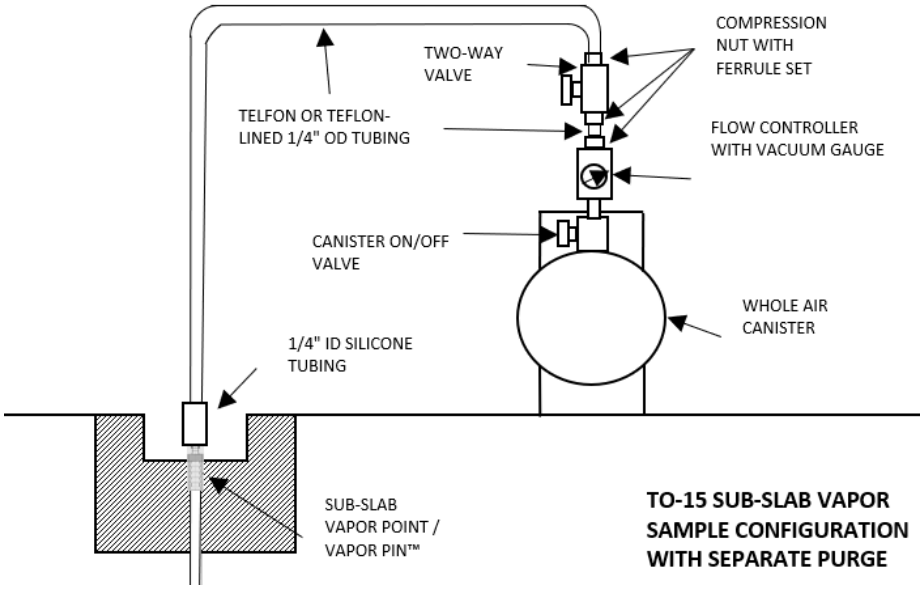
1. Pre-assemble the sample train for each sub-slab port to be sampled (Vapor Pin® with barb fitting). Cut an approximate 18-inch length and a 1-inch length of Teflon or Teflon-lined 1/4-inch OD tubing. Cut a 2-inch piece of 1/4-inch ID silicone tubing. Connect the silicone tubing to one end of the 18-inch length of tubing. Connect a stainless-steel two-way valve with compression fittings to the other side of the Teflon tubing. Connect the 1-inch piece of Teflon tubing to the other side of the two-way valve. Connect a compression nut and ferrule set to the other end of the 1-inch piece of Teflon tubing for the connection to the canister. This sample train is found within the well vault at permanent soil vapor probes.
2. Assemble the sample train by removing the cap from the canister and connecting the flow controller with in-line particulate filter and vacuum gauge. The flow controller attaches directly to the canister and the pre-set rate dictates the sample duration. The laboratory may have connected the canister and flow controller prior to shipping.

3. At sub-slab ports, connect the silicone end of the sample train to the barb fitting of the Vapor Pin®. For both sub-slab ports and soil vapor wells, connect a three-way valve to a syringe using the Lok-Lur tip. Connect one end of the sample train to the three-way valve with a 1-inch piece of silicone tubing and the last end to a Tedlar bag with a 1-inch piece of silicone tubing. A personal air pump capable of 200 milliliters per minute (mL/min) can be substituted for the syringe. See Section 8.3 for purging details.

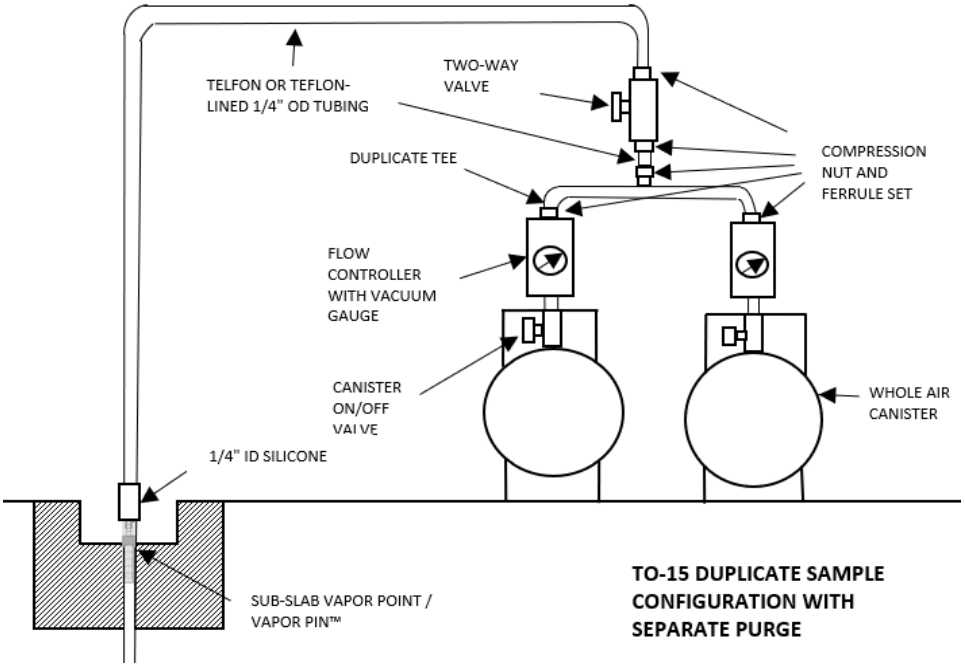
A schematic of the suggested second type of sample train setup is illustrated below:



4. Once purging is complete, close the two-way valve, then disconnect the silicon tubing next to the two-way compression valve from the sample assembly. Connect the canister and flow controller using the installed compression nut.



5. When collecting duplicate or other quality assurance/quality control (QA/QC) samples as required by applicable regulations and guidance, couple two canisters using stainless-steel duplicate sample T-fitting supplied by the laboratory. Attach flow controller with in-line particulate filter and vacuum gauge to duplicate sample tee-fitting as illustrated below.



8.2 Sample Documentation

Record weather information at the beginning of each day of the sampling event at a minimum. If appropriate record weather information during the middle and end of each day of the sampling event. Use the weather function in the FieldNow® Standard – Vapor Intrusion Sampling Log application. If using a field sampling form contact the local airport or other suitable information source (e.g., weatherunderground.com, or NOAA) to obtain the following information:

- Wind speed and direction;
- Ambient temperature;
- Barometric pressure; and
- Relative humidity.

Record information on sample label tags on canister, on field sample log or in the FieldNow® Standard – Vapor Intrusion Sampling Log application, and COC. This includes:

- Canister number;
- Flow controller number;
- Sample ID;
- Start and end times; and
- Canister initial and final vacuum.

Take a photograph of the canister, completed canister tag, and surrounding area.

8.3 Sample Collection

At sub-slab ports, connect the sample train to the sub-slab port barb fitting with 1/4-inch ID silicone tubing. The two-way compression valve should be closed. Soil vapor probes are typically completed with all sample train components permanently connected and contained within the manway vault.

Sample collection consists of pre-sampling (i.e., shut-in test, 3-volume purge, and leak check) as well as sampling activities, discussed below. The procedures listed below for the 3-volume purge may also be used to conduct the post-installation purge of the soil vapor sampling point, which should be conducted within 24 to 48 hours following soil vapor sampling point installation, but includes additional calculated volume.

8.3.1 Shut-in Test and 3-Volume Purge

Conduct a shut-in test, 3-volume purge, and leak check prior to sampling. The shut-in test is conducted first, and then the 3-volume purge is completed concurrently with the leak check. The pre-sampling purge volume conducted immediately prior to sampling includes the internal volume of the tubing and sub-slab port or probe tip. The post-installation purge volume conducted immediately after installation includes the following:

- The internal volume of the tubing and probe;
- The void space of the sand pack around the probe; and
- The void space of the dry bentonite in the annular space.

Sample Train Purge Isolation Setup with Syringe

1. Set-up the helium leak test shroud or water dam test in accordance with applicable TGI, when necessary. Note, the water dam test can only be performed on sub-slab ports not soil vapor probes.
2. Perform a shut-in test or leak-down-test with the two-way compression valve closed to the sample port. Open the three-way valve to the syringe and slowly pull a vacuum at a rate no faster than 1 to 2 mL/second (approximately 60 to 120 mL/min). Quickly close the three-way valve and record the pressure indicated on the gauge.
3. Open the canister valve but do not open the two-way valve on the sample assembly.
4. Record the vacuum indicated on the gauge connected to the canister. Observe the vacuum gauge for at least two minutes and no longer than 10 minutes. If there are no leaks in the system, this vacuum should be held exactly (estimate the decimal place – i.e., 29.1 inches of Hg). Tap the gauge and wait to see if pressure drops on the gauge.
5. If vacuum holds, document values and proceed with purge by opening the two-way sample assembly valve. If not, attempt to rectify the situation by tightening fittings and restart shut-in test.
6. Purge approximately three volumes of air from the sample port and tubing using the syringe or personal air pump capable of rates of <200 mL/min into the Tedlar® bag using a flow rate <200 mL/min. Purge rate should not exceed 200 mL/min or 1 to 1.5 mL per second when using a syringe. Purge volume is calculated using the equation of V = $\pi^2 h$:

$$\textit{Purge volume} = 3 \times \pi \times \textit{inner radius of tubing}^2 \times \textit{length of tubing}$$

7. Purged air will be collected into a Tedlar® bag to so VOCs are not released into interior spaces or the sampler's breathing zone. Perform quality control method tests such as helium leak testing, water dam testing, and/or field screening for VOCs concurrently per the project-specific work plan.
8. Close the three-way valve to the syringe to isolate this leg of the sample train.

Sample Train Separate Purge/Sample Setup with Canister

1. Connect the three-way valve, syringe, and Tedlar bag to the sample train. Open the two-way compression valve and purge approximately three volumes of air from the sample port and tubing using the syringe or personal air pump capable of <200 mL/min into the Tedlar® bag using a flow rate <200 mL/min. Purge rate should not exceed 200 mL/min or 1 to 1.5 mL per second when using a syringe. Purge volume is calculated using the equation above.
2. Close the two-way compression valve and disconnect the syringe purge setup.
3. Connect the canister and flow controller to the sample train. Perform a shut-in test or leak-down-test by opening the canister valve but do not open the two-way valve on the sample assembly.
4. Record the vacuum indicated on the gauge connected to the canister. Observe the vacuum gauge for at least two minutes. If there are no leaks in the system, this vacuum should be held exactly (estimate the decimal place – i.e., 29.5 inches of Hg).
5. If vacuum holds, document values and proceed with sampling by opening the two-way sample assembly valve. If not, attempt to rectify the situation by tightening fittings and restart shut-in test.

8.3.2 Sampling

1. Open the canister valve to initiate sample collection. Record the start time and the initial canister vacuum on the sample log or FieldNow® application. The preference is a starting vacuum of -28 inches of Hg or more, but some canisters may be used in certain jurisdictions with lower starting vacuum. However, ff the initial vacuum registers less than -25 inches of Hg (-27 inches of Hg in Michigan), then the canister is not appropriate for use and another canister should be used. The initial vacuum required varies by jurisdiction; confirm with the project regulatory authority.
2. Check the canister approximately halfway through the sample duration and note progress on sample logs or FieldNow® application. If the vacuum decreases greater than a rate of 200 mL/min or the vacuum stops decreasing during sample collection contact the project team.

8.3.3 Termination of Sample Collection

1. Sampling canisters should not be left unattended. For example, a 1-liter canister will typically take approximately 5 to 30 minutes, so even brief inattention or distraction can mistakenly lead to the canister reaching 0 inches of Hg or water in the tubing damaging the equipment.
2. Record the final vacuum on the sample collection log or FieldNow® Standard – Vapor Intrusion Sampling Log app. Stop collecting the sample by closing the canister valve then the sample train valve. The canister should have a minimum amount of vacuum (approximately 5 inches of Hg or slightly greater). Check with the project team on final pressure requirements as these vary by region.
3. Record the date and local time (24-hour basis) of valve closing on the canister tag, sample collection log or FieldNow® Standard – Vapor Intrusion Sampling Log application, and COC form.
4. Refill the Tedlar® bag with purged air with enough air to fill the bag via the purge to pump or syringe. Connect the Tedlar® bag to the PID and record stabilized VOC concentration on sample collection log. Disconnect the PID then connect the methane meter to the Tedlar® bag. Make sure to activate the pump on the methane meter, if not automatically started once turned on, and then allow time for vapor to flow through the meter to collect readings. Record stabilized methane concentration readings on sample collection log.
5. Disconnect sample tubing from the sample port and replace any coverings or abandon as appropriate to mitigate tripping hazards.
6. Remove the flow controller from the canister, re-install the brass plug on the canister fitting, and tighten with the appropriate wrench. If the canister and flow controller were shipped pre-assembled from the laboratory do not disassemble; simply re-install the brass plug on the flow controller fitting.
7. Verify the appropriate forms and sample labels are filled out appropriately as directed by the laboratory (e.g., affix card with a string).
8. Package the canister and flow controller per DOT regulations for return shipment to the laboratory. These regulations can be found at the Transportation Safety Program's Team Site on the Source. The canister does not require preservation with ice or refrigeration during shipment. Refer to TGI – Soil Gas Methane Monitoring for Shipping Determination of Soil Gas Samples if sampling in an area with unknown or known methane conditions. A shipping determination form is required for shipment of any type of samples prior to field mobilization.
9. Complete and verify the COC form and place the requisite copies in a shipping container. Close the shipping container and affix a custody seal to the container closure. Ship the container to the laboratory via overnight

carrier (e.g., Federal Express) or sign COC over to courier. Consult with the project team on appropriate shipping speeds and shipment insurance.

9 Waste Management

No specific waste management procedures are required.

10 Data Recording and Management

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

11 Quality Assurance

Quality assurance and quality control (QA/QC) will be conducted following project requirements.

11.1 Duplicate Samples

Duplicate samples should be collected in the field as a quality assurance step per project requirements. Generally, one duplicate is taken per 10 or per 20 samples analyzed, but project specific requirements should take precedence. A duplicate tee is required when collecting soil vapor duplicate samples.

11.2 Equipment Blank

Equipment blank samples may be collected in the field as a quality assurance step in order to verify and evaluate the effectiveness of decontamination procedures for new, recycled, or reused materials (i.e., syringes, Swagelok® fittings, 1/4-inch tubing) per project requirements. Generally, one equipment blank sample is taken per 20 sample locations, but project specific requirements should take precedence. Equipment blank sampling steps detailed below:

1. Connect decontaminated reusable sampling supplies, in line with a clean, laboratory provided soil vapor manifold and 1-liter canister to a laboratory provided nitrogen-filled canister.
2. Conduct a shut-in test as described in section 8.3.1. Please note: a 3-volume purge and leak test are not necessary for the equipment blank.
3. Collect a sample (generally following the steps from sections 8.3.2 and 8.4.3 using the nitrogen

canister as the vapor source. Gas collection readings from a PID and methane meter are not necessary for the equipment blank.

12 References

DiGiulio et. al. 2003. Draft Standard Operating Procedure (SOP) for Installation of Sub-Slab Vapor Probes and Sampling Using EPA TO-15 to Support Vapor Intrusion Investigations. http://www.cdphe.state.co.us/hm/indoorair.pdf.

DiGiulio et. al. 2006. Assessment of Vapor intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples. USEPA. EPA/600/R-05/147.

USEPA. 1999a. Compendium Method TO-15. Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). Center for Environmental Research Information. Office of Research and Development. January.

USEPA. 2015. Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. OSWER Publication 9200.2-154. June.

New York State Department of Health (NYSDOH). 2005. DRAFT “Guidance for Evaluating Soil Vapor Intrusion in the State of New York” February 23, 2005.

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TGI – Groundwater and Soil Sampling Equipment Decontamination

Rev: 3

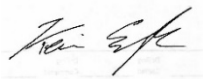
Rev Date: August 30, 2023

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	February 23, 2017	All	Conversion from SOP to TGI	Cassandra McCloud / Pete Frederick
	1	May 8, 2020	4, 5	Added note regarding use of Liquinox and 1,4-Dioxane	Marc Killingstad
	2	June 14, 2022	All	Conversion to new TGI format and minor edits.	Kevin Engle / Marc Killingstad
	3	August 30, 2023	All	Annual review completed by SME. Updated Rev 1.	Marc Killingstad

Approval Signatures

Prepared by: 8/30/2023



Name (Preparer) Date

Reviewed by: 8/30/2023

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document is intended to provide guidance to staff performing decontamination procedures at project sites. The content in this document describes the intended use, scope and application, personnel qualifications, equipment, cautions, health and safety considerations, procedures, waste management, data recording and management, and quality assurance of decontamination procedures.

2 Intended Use and Responsibilities

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

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

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

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

3 Scope and Application

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

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

4 Personnel Qualifications

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

5 Equipment List

The equipment required for equipment decontamination is presented below. Note that certain contaminants may require specific materials be used that are not captured in this list. Always review project and contaminant specific TGIs or work plans to ensure proper equipment is utilized. Note for per- and polyfluoroalkyl substances (PFAS) see *TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

- Health and safety equipment, including appropriate personal protective equipment (PPE), as required in the site HASP
- Deionized water that meets the analytical criteria for deionized water with no detectable constituents above the reporting limits for the methods to be used and analytes being analyzed for. Deionized water is used for inorganics, and organic-free water for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, etc.
- Non-phosphate detergent such as Alconox® or, if sampling for phosphorus or phosphorus- containing compounds, Liquinox (or equivalent). NOTE: Liquinox has shown to provide false positives for 1,4-Dioxane and should not be used at sites where that may be a constituent of concern (COC).
- Tap water
- Rinsate collection plastic containers

- Department of Transportation (DOT)-approved waste shipping container(s), as specified in the work plan, field sampling plan, or regulatory requirements if decontamination waste is to be shipped for disposal
- Brushes
- Large heavy-duty garbage bags
- Spray bottles
- (Optional) – Isopropyl alcohol (free of ketones) or methanol. These can be wipes or diluted with water (usually 1part isopropyl/methanol to 10 parts water) if a spray is needed.
- Airtight, sealable plastic baggies, such as Ziploc®-type
- Plastic sheeting

6 Cautions

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

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

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

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

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

7 Health and Safety Considerations

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

8 Procedure

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

will be handled by workers wearing clean gloves, properly changed to prevent cross-contamination. The procedures detailed in this section provide an overview of common decontamination techniques. Additional steps may be required based on the type of contaminant present or client/site requirements.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.
2. Wash with detergent solution (Alconox®, Liquinox® or equivalent) to remove all visible particulate matter and any residual oils or grease. NOTE: Liquinox® has shown to provide false positives for 1,4-Dioxane and will not be used at sites where that may be a COC.
3. If equipment is very dirty, precleaning gross debris with a brush and tap water may be necessary.
4. If non-aqueous phase liquids are present, the use of isopropyl alcohol (free of ketones) or methanol is recommended. Cloth wipes or diluted solution can be used to remove the non-aqueous phase liquids that are hard to remove with detergent solution in step 2. Consult with project manager if non-aqueous phase liquids are present onsite and design an appropriate decontamination procedure that includes step 4.
5. Rinse with deionized water.

Decontaminating Submersible Pumps

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

9 Waste Management

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

10 Data Recording and Management

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

are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

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

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

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

Containers with decontamination fluids will be labeled.

11 Quality Assurance

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

12 References

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

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

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