RCRA Facility Investigation Work Plan

CITGO Terminal
East Chicago, Indiana

CITGO Petroleum Corporation

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1. Introduction

GHD Services, Inc. (GHD) has prepared this Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Work Plan (Work Plan) on behalf of CITGO Petroleum Corporation (CITGO) for the CITGO Terminal (Facility or Site) in East Chicago, Indiana (U.S. EPA RCRA I.D. IND095267381). The Work Plan has been prepared in accordance with Administrative Order on Consent (AOC) between the United States Environmental Protection Agency – Region 5 (U.S. EPA) and CITGO, with an effective date of January 24, 2020.

The CITGO Terminal property is presented on Figure 1.1. The CITGO Terminal encompasses approximately 228.5 acres. The property is located to the north of the Former Cities Refinery.

In accordance with the AOC and Corrective Action Framework (CAF), the purpose of the RFI investigation is to:

1. Describe the nature and extent of any releases of hazardous waste and hazardous constituents at or from the Facility that may pose an unacceptable risk to human health and the environment
2. Explain whether each release poses an unacceptable risk to human health and the environment
3. Provide the basis for those conclusions, including an evaluation of the risks
4. Provide a basis for developing the final corrective measures for the Facility

Additional phases of investigation may be required, as necessary. The need for further data collection will be based on the investigation results, and will be completed in consultation with the U.S. EPA. Separate work plans will be prepared for additional phases of investigation, as necessary, which will include investigation locations, vertical extent, density, methodology, COPCs, screening data, and corresponding rationale. Separate work plans will be reviewed and approved by U.S EPA consistent with the approved CAF systematic planning process.

2. Background

Prior to the execution of their respective AOCs, CITGO and OXY USA, Inc. (OXY) jointly coordinated efforts to conduct a Site Perimeter Investigation, covering both the CITGO Terminal and the Former Cities Refinery. The Site Perimeter Investigation was completed in accordance with the "Site Perimeter Investigation Work Plan – Phase I" submitted to the U.S. EPA on March 13, 2019. The U.S. EPA commented on the submission and responses were provided to the U.S. EPA on April 14, 2019. The U.S. EPA approved the Work Plan, as modified by the responses, on April 19, 2019. The primary goal of the Site Perimeter Investigation was to investigate the perimeter of the CITGO Terminal and the Former Cities Refinery to identify potential off-Facility impacts. The results of the Site Perimeter Investigation were presented to U.S. EPA during a September 24, 2019 meeting which included the conceptual scope of work for the next phase of investigation (the basis of this Work Plan). The Investigation Results Report was submitted to U.S. EPA on October 31, 2019.

CITGO and OXY may continue to coordinate efforts to increase efficiency and avoid duplication of elements of the corrective action of relevance to both parties. CITGO and OXY are proceeding under separate AOCs and CAFs for their respective portions of the contiguous property that was once owned by Cities Service Oil Company.

3. RFI Scope of Work

The soil and groundwater sampling design and procedures shall be consistent with applicable guidance, including but not limited to: Soil Screening Guidance (U.S. EPA 1996, 2002); Guidance on Choosing a Sampling Design for Environmental Data Collection (U.S. EPA 2002); and Incremental Sampling Methodology (ITRC 2012).

3.1 Monitoring Well Installation

Twenty new monitoring wells are proposed for this phase of the RFI investigation. The proposed monitoring well locations are presented on Figure 3.1. In general, the RFI investigation locations were selected for one or more of the following reasons:

- Evaluate locations with elevated LIF or MIP response from the Site Perimeter Investigation
- Evaluate locations on or near the Facility perimeter with potential soil or groundwater impacts
- Evaluate former operational areas, historical investigation areas, utilities
- Evaluate groundwater flow across the Facility, and evaluate the potential for utility interference/preferential pathways

Monitoring wells will be constructed from 2-inch diameter PVC. A 5-foot screen is proposed for monitoring wells that are installed to collect a sample from a targeted depth based on the Site Perimeter Investigation membrane interface probe (MIP) results responses and a 10-ft screen across the water table is proposed for all other monitoring wells. Due to the high groundwater table, typical monitoring well completion details may need to be modified, or the ground surface may need be raised, where required (to ensure a minimum 2 feet of bentonite sealing, etc.). Either stickup or flush mount protective casings are proposed, as appropriate based on the locations of the well.

Following installation, the monitoring wells will be surveyed in Indiana West State Plane NAD83 horizontal coordinate system and the NAVD88 vertical datum for location and reference point elevations to support the evaluation of groundwater flow directions. The groundwater monitoring wells will be developed and gauged with a dual phase probe to determine groundwater elevation and to identify the presence/absence of light non-aqueous phase liquid (LNAPL). Investigation derived waste generated from the installation of the monitoring wells and development of the monitoring wells will be managed in accordance with applicable laws.

Monitoring wells will be installed and developed in accordance with GHD's Standard Operating Procedures (SOPs) which are included in the Sampling and Analysis Plan (SAP) presented in Appendix A.

3.2 Soil Sampling

GHD proposes to collect one surface soil sample (0-2 ft bgs), plus applicable Quality Assurance/Quality Control (QA/QC) samples, as specified in the Quality Assurance Project Plan (QAPP) which is presented in Appendix B, during the installation of each monitoring well to evaluate the potential for direct contact exposures. In accordance with the CAF, soil samples will be analyzed for target compound list (TCL) volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), and target analyte list (TAL) inorganics.

Samples will be collected and analyzed in accordance with the procedures outlined in the SAP (Appendix A) and QAPP (Appendix B).

3.3 Groundwater Sampling

Quarterly groundwater sampling events and quarterly gauging events for one year or four events are proposed as part of the scope of work. Investigation derived waste generated from the quarterly groundwater sampling events will be managed in accordance with applicable laws.

Prior to the collection of groundwater samples, a full round of static groundwater elevations will be collected from all new groundwater monitoring wells (20). Groundwater elevations will be measured to the nearest 0.01 ft using a dual phase probe. If LNAPL is present, a correction to the measured groundwater level will be made based on the specific gravity and thickness of the LNAPL. Static groundwater elevations will be collected in accordance with GHD's SOPs which are included in the SAP provided in Appendix A.

One representative groundwater sample will be collected from each monitoring well using low-flow procedures (e.g., low flow sampling at a rate between 0.1 and 0.5 liter per minute [L/min]), plus applicable QA/QC. In accordance with the CAF, groundwater samples will be analyzed for TCL VOCs, TCL SVOCs, and dissolved TAL inorganics.

Samples will be collected and analyzed in accordance with the procedures outlined in the SAP (Appendix A) and QAPP (Appendix B).

3.4 LNAPL Sampling

If measurable LNAPL thickness is reported in any of the monitoring wells, no groundwater sample will be collected. Instead, a LNAPL sample will be collected (if sufficient LNAPL can be recovered), and analyzed for TCL VOCs, TCL SVOCs, and TAL inorganics. LNAPL samples will also be evaluated for physical properties (e.g., specific gravity, viscosity), as applicable.

Samples will be collected and analyzed in accordance with the procedures outlined in the SAP (Appendix A) and QAPP (Appendix B).

3.4.1 LNAPL Mobility Evaluation

Evaluation of LNAPL mobility, if reported in wells, will be based on an assessment of LNAPL transmissivity (T_n). The evaluation of T_n provides a standardized science-based method to quantify the potential mobility and recoverability of LNAPL at a given site. Results can be compared against widely accepted de minimis criteria to assess whether LNAPL may be considered to be sufficiently mobile such that hydraulic recovery may be feasible and/or provide some technical benefit in terms of reducing LNAPL saturations (or mass) in the interest of mitigating LNAPL migration potential. Where T_n is found to be of de minimis magnitude, LNAPL is considered to be largely present at residual levels and hydraulically immobile and unrecoverable. Where this is the case, LNAPL mass recovery efforts will not provide a technical benefit in terms of mitigating mobility potential since the LNAPL body as a whole will already be largely immobile.

The testing will be performed pursuant to the methodology contained in ASTM International (ASTM) Standard E2856-13 *Standard Guide for Estimation of LNAPL Transmissivity* (May 2013) using the baildown technique at selected wells with in-well LNAPL thickness greater than 0.5 feet. The test involves the rapid removal of LNAPL from the well (via bailer), followed by the monitoring of LNAPL recharge into the well using an oil-water interface probe. The LNAPL monitoring continues until the observed in-well LNAPL recharge data provides sufficient information to estimate T_n. Wells exhibiting no LNAPL or less than 0.5-feet in-well LNAPL thickness will be assumed to represent at de minimis LNAPL mobility/recoverability condition by default.

LNAPL transmissivity will be estimated based on the observed LNAPL recharge rates and/or LNAPL drawdown recovery (depending on the analytical solution) using the American Petroleum Institute (API) *LNAPL Transmissivity Workbook: Calculation of LNAPL Transmissivity from Baildown Test Data* (September 2012). The API workbook uses the field data from a baildown test to estimate LNAPL transmissivities using three different solutions for unconfined conditions: Bouwer & Rice; Cooper & Jacob; and Cooper-Bredehoeft-Papadopulos. The detailed field methodology and data treatment techniques associated with LNAPL transmissivity estimations are detailed in ASTM E2856-13.

The results will be compared against a guideline de minimis criterion of 0.8 ft^2/day (0.08 m^2/day) recommended by the Interstate Technology & Regulatory Council (ITRC Publication No. LNAPL-3, 2018). Values of T_n greater than the de minimis criterion indicate hydraulic LNAPL recovery is technically feasible and may be beneficial in providing a meaningful reduction in LNAPL saturation and mobility. Where T_n is less than the de minimis criterion, it can be assumed that most of the LNAPL exists as unrecoverable residual. When this is the case, ongoing LNAPL recovery efforts are not expected to provide a meaningful reduction in LNAPL saturation; and therefore, will not provide a beneficial change in subsurface conditions.

For wells exhibiting elevated T_n values, additional work may be required to quantify the potential benefit of LNAPL recovery. While T_n describes whether a minimum LNAPL recharge rate can be sustained such that there may be a mobility/recoverability concern, it does not quantify what fraction of the LNAPL in place might be considered mobile and/or recoverable. Additional work in this regard may be based on a targeted soil core sampling and petrophysical laboratory testing program that will allow an additional quantification of LNAPL mobility and an assessment of the need for and expected value of LNAPL recovery in terms of the realistic potential change in subsurface conditions. If necessary, additional work related to LNAPL mobility will be detailed in future phases of work.

3.5 Screening Levels/Risk Assessment

RFI investigations will continue until there is sufficient data to define the vertical and horizontal extent of COPC-impacted soil and groundwater.

Data will be initially screened against IDEM published background levels for metals. Data below the IDEM published background levels will not be evaluated further. Remaining data will be screened against the 2019 IDEM screening and closure tables, which are based on the 2018 U.S. EPA Regional Screening Levels (RSLs) (residential at property boundary and industrial at the CITGO Terminal). For chemicals with maximum contaminant levels (MCLs), they will be used in lieu of IDEM screening levels for drinking water. COPC impacts will be delineated to residential land use criteria at the property boundary, but any corrective actions will consider actual land use (i.e., industrial, on site) and may incorporate institutional/engineering controls to eliminate potential exposure pathways.

Risk assessments will estimate human health and ecological risk under reasonable maximum exposure for both current and reasonably expected future land use scenarios. In conducting the risk assessments, Respondent will consider the Risk Assessment Guidance for Superfund (RAGS) or other appropriate U.S. EPA guidance. Respondent will use appropriate conservative screening values when screening to determine whether further investigation is required. Appropriate screening values, which will be determined by U.S. EPA after consultation between U.S. EPA and CITGO, may include those derived from Federal Maximum Contaminant Levels, U.S. EPA Regional Screening Levels for Chemical Contaminants, U.S. EPA Region 5 Ecological Screening Levels, RAGS, Indiana Screening Levels, and U.S. EPA technical documents and tools.

3.6 RFI Scope of Work Summary

The following presents a summary of the proposed RFI investigation field activities:

RFI Scope of Work	Quantity
Monitoring Well Installation	20 wells
Soil Sampling Event	1 event - 20 investigative soil samples, plus QA/QC
Groundwater Sampling Events	Quarterly events – 20 groundwater samples, plus QA/QC, per event
Gauging	Quarterly events - 20 monitoring well locations
LNAPL Sampling	If LNAPL is encountered and sufficient LNAPL can be recovered, LNAPL will be analyzed in place of a groundwater sample
LNAPL Mobility	If the in-well thickness of LNAPL is greater than 0.5 ft, conduct transmissivity testing

The proposed locations of the 20 monitoring wells are presented in Figure 3.1.

A breakdown of each proposed investigation location, the associated Site Perimeter Investigation location with LIF/MIP data (if applicable), the proposed screen length and target depths, and a brief description of the rationale for each well is presented in Table 3.1.

The RFI investigation is intended to be iterative and adaptive based on conditions encountered in the field. Pending the results of the initial 20 investigation locations, additional phases may be identified during or after the quarterly monitoring program, as needed, consistent with the scope and objectives outlined in Section 1 above.

4. Deliverables

An interim RFI data report summarizing the results of this Work Plan and an updated Conceptual Site Model (CSM), including proposed additional activities, if any, will be prepared for submittal to the U.S. EPA following two rounds of quarterly groundwater sampling. Subsequent quarterly groundwater results will be included in either the quarterly progress reports or in a subsequent interim RFI data report(s) (if applicable).

Once it has been determined that sufficient data has been obtained to describe the nature and extent of any releases of hazardous waste and hazardous constituents at or from the Facility that may pose an unacceptable risk to human health and the environment, a final RFI Report will be developed and submitted to the U.S. EPA by no later than October 1, 2021 unless a revised date is agreed to by both U.S. EPA and CITGO. The RFI report will describe the nature and extent of any releases of hazardous waste and hazardous constituents at or from the Facility that do or do not pose an unacceptable risk to human health and the environment, and provide the basis for those conclusions, including an evaluation of the risks. The investigation shall include a consensus driven balance between qualitative and quantitative high-resolution investigation techniques.

5. Schedule

The following presents a tentative schedule for the implementation of this Work Plan, following U.S. EPA approval.

Field activities related to this Work Plan will be initiated in Spring 2020, or within 60 days of U.S. EPA approval of this Work Plan, whichever is later. CITGO and OXY may continue to coordinate efforts to increase efficiency and avoid duplication of elements of the corrective action of relevance to both parties.

An interim RFI data report, as described in Section 4 above, will be submitted following the completion of two quarterly rounds of groundwater sampling.

The current conceptual project schedule as identified in the CAF is presented in Appendix C.

6. Administrative Requirements

The AOC provides for the following Reporting and Administrative requirements under Section VII. Paragraph 22.

6.1 Job Creation

Job creation has been considered in the development of this Work Plan. Local vendors will be utilized where practicable to perform field activities.

During the Site Perimeter Investigation in 2019, local vendors were commissioned to complete surveying, utility clearance, hydro-excavation, and fencing. Drillers with specialized equipment were commissioned from out of state (Ohio). Local GHD staff conducted field oversight activities. The project utilized approximately 1,200 hours of on-Site labor, or approximately 6.92 full-time equivalents (FTE) for the duration of field activities (approximately 1-month or 0.58 FTE averaged over the year).

The project utilized approximately 1,000 hours of off-Site labor, or approximately 0.48 FTE averaged over the year, which included technical/professional labor facilitating project management, coordination, work plans, reports, visuals, etc.

Therefore in 2019, the project created several temporary professional, management, technical, and skilled trade jobs (on-Site and off-Site labor) accounting for a FTE of 1.06.

A similar FTE value is expected for work proposed in 2020.

6.2 Public Repository

A public repository will be established at a local East Chicago, IN (2401 E Columbus Drive) library for information regarding Facility activities and to conduct public outreach and involvement activities, as needed. Community involvement is expected to be limited and will be addressed at the time of the Statement of Basis. The topic may be revisited if conditions change or if there is significant public inquiry.

6.3 Green Remediation Best Management Practices

Green Remediation Best Management Practices (BMPs) will be considered when completing the RFI for the Facility in accordance with U.S. EPA 542-F-16-002 "Green Remediation Best Management Practices" to evaluate and minimize the environmental footprint of activities involved in cleaning up contaminated sites.

Activities proposed in this Work Plan include investigation and monitoring. The following BMPs will be considered when implementing this Work Plan:

- Work has been scheduled for Spring 2020, thus reducing the amount of fuel needed for heating or cooling equipment and supplies
- Wherever practicable, local vendors, product suppliers, and laboratories, will be utilized
- Identify local sources of trucks and machinery equipped with advanced emission controls and clean alternative fuels
- Identify the nearest facility to be used for disposing of wastes
- Recycle purge and decontamination water as petroleum contact water, which may be generated from the investigations
- Establish electronic networks for data transfers, team decisions, and document preparation, and select electronic products through tools such as the Electronic Product Environmental Assessment Tool (EPEAT)
- Reduce travel through teleconferencing and compressed work hours
- Select facilities with green policies for worker accommodations and meetings

When developing interim measures and remedial alternatives to implement, Green Remediation Best Management Practices will be considered and will continue to be evaluated.

6.4 Quarterly Progress Reports

In accordance with the AOC, quarterly progress reports will be submitted to U.S EPA by the fifteenth day of the month after the end of each quarter. The report will list work performed to date, data collected, problems encountered, project schedule, and percent project completed.

6.5 Semi-Annual Meetings

The parties (CITGO and U.S. EPA) will communicate frequently and in good faith and will meet (either by phone or in-person) on at least a semi-annual basis to discuss the work proposed and performed as part of the RFI.

LEGEND

🟩 CITGO TERMINAL (228.5 ACRES)
🟦 FORMER CITIES REFINERY (93.2 ACRES)

0 300 600 ft

N

Coordinate System:
IN83-WF

GHD

CITGO TERMINAL
EAST CHICAGO, INDIANA

FACILITY LOCATIONS

Project No. **11209494**
Date **February 2020**

FIGURE 1.1

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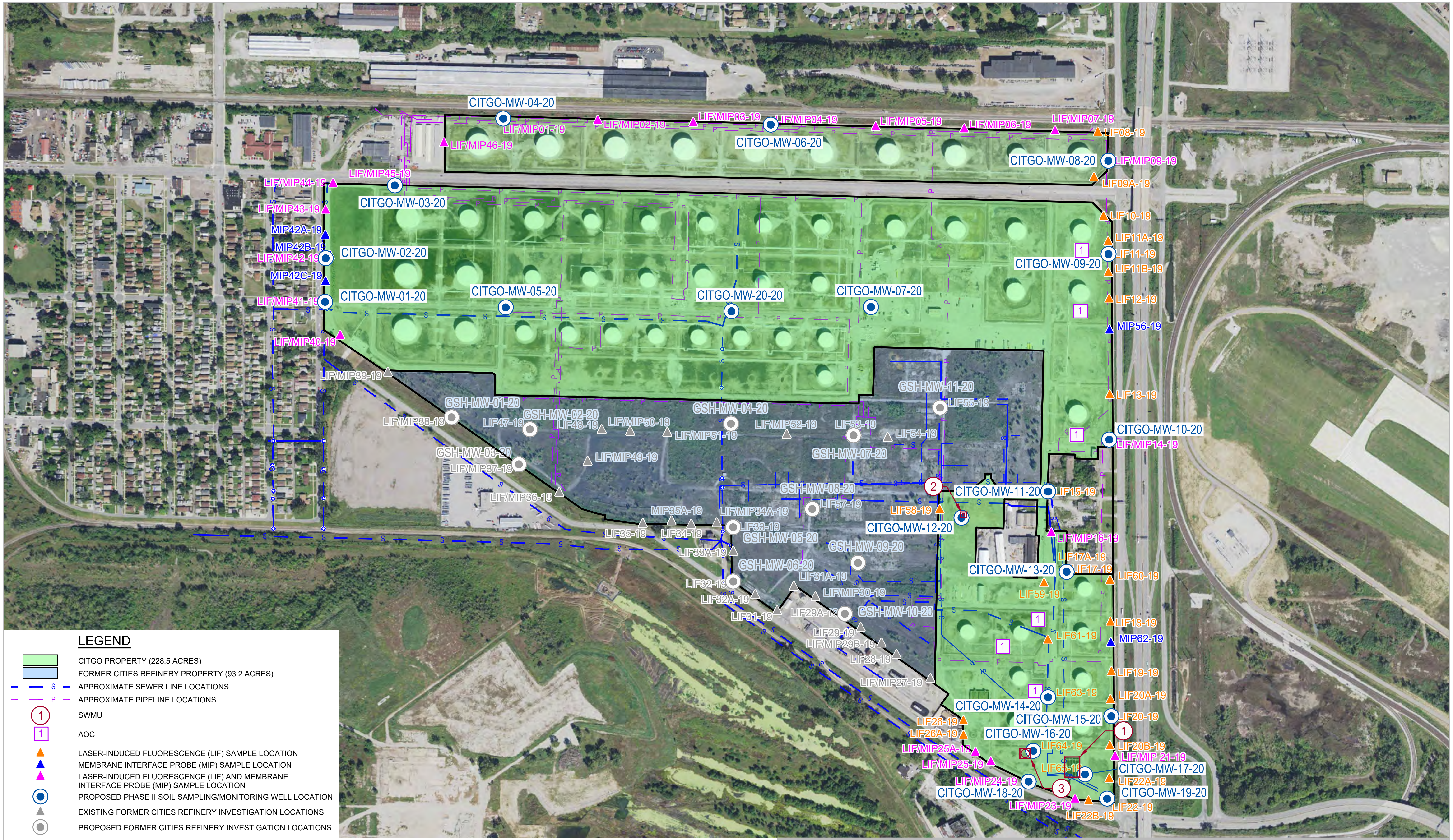
Plot Date: 21 February 2020 3:02 PM



LEGEND

🟩	CITGO PROPERTY (228.5 ACRES)
🟦	FORMER CITIES REFINERY PROPERTY (93.2 ACRES)
— S —	APPROXIMATE SEWER LINE LOCATIONS
— P —	APPROXIMATE PIPELINE LOCATIONS
①	SWMU
1	AOC
▲	LASER-INDUCED FLUORESCENCE (LIF) SAMPLE LOCATION
▲	MEMBRANE INTERFACE PROBE (MIP) SAMPLE LOCATION
▲	LASER-INDUCED FLUORESCENCE (LIF) AND MEMBRANE INTERFACE PROBE (MIP) SAMPLE LOCATION
◉	PROPOSED PHASE II SOIL SAMPLING/MONITORING WELL LOCATION
▲	EXISTING FORMER CITIES REFINERY INVESTIGATION LOCATIONS
◉	PROPOSED FORMER CITIES REFINERY INVESTIGATION LOCATIONS

SOLID WASTE MANAGEMENT UNITS (SWMU)
1. OIL-WATER SEPARATOR
2. FORMER TANK NO. 195
3. TANK NO. 88

AREAS OF CONCERN (AOC)
1. FORMER OIL-SATURATED SOIL AREA (OSS)
2. FORMER ASBESTOS-CONTAMINATED SOIL AREA

NOTE: FORMER ASBESTOS-CONTAMINATED SOIL AREA NOT IDENTIFIED (AOC 2)

Coordinate System:
IN83-WF

GHD

CITGO TERMINAL
EAST CHICAGO, INDIANA

Project No. 11209494
Date February 2020

PROPOSED INVESTIGATION LOCATIONS

FIGURE 3.1

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Plot Date: 21 February 2020 3:02 PM

Source: 2016 AERIAL IMAGE FOR LAKE COUNTY, INDIANA IMAGE PROVIDED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) AS PART OF THE NORTH AMERICAN IMAGE PROGRAM (NAIP).

Table 3.1

Proposed Investigation Rationale
CITGO Terminal
East Chicago, IN

Proposed MW Location	Associated Site Perimeter Investigation Location	Max LIF Response (%RE)	LIF Response Above Baseline (Y or N)	Max PID (uVx10^5) (approx.)	Max FID (uVx10^5) (approx.)	MIP Response Above Baseline (Y or N)	Proposed Screen Length (ft)(1)	Target Screen Depth (ft bgs)	Well Location (perimeter or internal)	Purpose/Rationale
CITGO Property										
CITGO-MW01-20	LIF/MIP41-19	11.9	N	0.13	0.05	N	10	Water Table	Perimeter	Utility evaluation (Combined sewer) / Neighboring Properties (Residential
CITGO-MW02-20	LIF/MIP42-19	18.2	N	0.14	0.14	**Y**	5	5-10	Perimeter	MIP Response / Neighboring Properties (Residential
CITGO-MW03-20	LIF/MIP45-19	2.4	N	0.17	0.06	N	10	Water Table	Perimeter	Active Pipelines (Several) / Neighboring Properties (Residential
CITGO-MW04-20	LIF/MIP01-19	1.6	N	0.2	0.08	N	10	Water Table	Perimeter	Groundwater contouring (Spacing
CITGO-MW05-20	none	-	-	-	-	-	10	Water Table	Internal	Groundwater contouring (Spacing) / Utility evaluation (City Water
CITGO-MW06-20	LIF/MIP04-19	2.5	N	0.19	0.11	**Y**	5	5-10	Perimeter	Low MIP responses / Groundwater contouring (Spacing)
	LIF/MIP05-19	1.9	N	0.18	0.16	**Y**				
	LIF/MIP06-19	2	N	0.19	0.11	**Y**				
CITGO-MW07-20	none	-	-	-	-	-	10	Water Table	Internal	Office area evaluation / Groundwater contouring (Spacing
CITGO-MW08-20	LIF/MIP09-19	31.5	**Y**	>0.25	0.11	**Y**	10	Water Table	Perimeter	LIF/MIP response / Groundwater contouring (Spacing
CITGO-MW09-20	LIF11-19	56.1	**Y**	na	na	na	10	Water Table	Perimeter	Former AOC (Oil stained soil) / LIF response / Groundwater contouring (Spacing)
	LIF11A-19	6.7	**Y**	na	na	na				
	LIF11B-19	18.5	**Y**	na	na	na				
CITGO-MW10-20	LIF/MIP14-19	1.8	N	0.18	0.16	**Y**	5	2-7	Perimeter	MIP Response / Groundwater contouring
CITGO-MW11-20	LIF15-19	122.7	**Y**	na	na	na	10	Water Table	Perimeter	LIF Response
CITGO-MW12-20	LIF58-19	121.6	**Y**	na	na	na	10	Water Table	Internal	SWMU (Former Tank 195) / LIF Response
CITGO-MW13-20	LIF17-19	116.5	**Y**	na	na	na	10	Water Table	Perimeter	LIF Response / Groundwater contouring
	LIF17A-19	57.7	**Y**	na	na	na				
CITGO-MW14-20	LIF63-19	46.5	**Y**	na	na	na	10	Water Table	Internal	Former AOC (Oil stained soil) / LIF Response
CITGO-MW15-20	LIF20-19	115.8	**Y**	na	na	na	10	Water Table	Perimeter	LIF Response
	LIF20A-19	2.1	N	na	na	na				
	LIF20B-19	40.6	**Y**	na	na	na				
CITGO-MW16-20	LIF64-19	121.3	**Y**	na	na	na	10	Water Table	Internal	SWMU (Former Tank 88) / LIF Response
CITGO-MW17-20	LIF65-19	44.8	**Y**	na	na	na	10	Water Table	Internal	SWMU (Oil water separator) / LIF Response
CITGO-MW18-20	LIF/MIP23-19	4.6	N	0.17	0.1	**Y**	5	7-12	Perimeter	MIP Response
	LIF/MIP24-19	8.1	N	0.17	>0.16	**Y**				
	LIF/MIP25-19	1.7	N	0.18	>0.16	**Y**				
CITGO-MW19-20	LIF22-19	48.1	**Y**	na	na	na	10	Water Table	Perimeter	LIF Response / Groundwater (Contouring)
	LIF22A-19	38	**Y**	na	na	na				
	LIF22B-19	7.3	**Y**	na	na	na				
CITGO-MW20-20	none	-	-	-	-	-	10	Water Table	Internal	Groundwater contouring (Spacing) / Utility evaluation (City Water

Notes:

🟦 - Probable false positive (gravel fluorescence)
na - not analyzed
(1) 5-foot screen used where there is a MIP response at the perimeter. All other monitoring well locations will have 10-foot screens and will straddle the water tabl
- Shallow soil samples (0-2') are to be collected from each monitoring well location and analyzed for TCL VOCs, TCL SVOCs, and TAL inorganic
- Shallow groundwater sample are to be collected using low-flow sampling procedures and analyzed for TCL VOCs, TCLS SVOCs, and dissolved TAL inorganic
- If LNAPL is present no groundwater sample will be collected but if there is sufficient product an LNAPL sample will be collected and submitted for analysis of TCL VOCs, TCL SVOCs, TAL inorganics, and physical properties (specific gravity, viscos

Appendices

Appendix A
Sampling and Analysis Plan (SAP)

Sampling Analysis Plan (SAP)

CITGO Terminal
East Chicago, Indiana

CITGO Petroleum Corporation

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Appendix Index

1. Introduction

This Sampling Analysis Plan (SAP) is submitted and forms part of the work plans prepared to complete the Resource Conservation and Recovery Act (RCRA) Facility Investigation. This SAP has been prepared by GHD Services, Inc. (GHD) on behalf of CITGO Petroleum Corporation (CITGO) for the CITGO Terminal (Facility) in East Chicago, Indiana (United States Environmental Protection Agency [U.S. EPA] Identification Number IND092567381).

The SAP describes procedures for the collection of surface, subsurface soil samples, and groundwater samples. Field Method Guidelines (FMGs) are included in Appendix 1. The SAP provides additional detail on procedures where a FMG is unavailable. If no FMG is available for the particular field method, a complete description of the method will be provided in this text.

2. General Sampling Protocols

2.1 Sampling

Samples will be collected at the locations and frequencies specified in the work plans. As discussed in Quality Assurance Project Plan (QAPP), samples will be collected in order of decreasing analyte volatility (i.e., volatile organic compounds (VOCs) first, semi-volatile organic compounds (SVOCs) second, which are followed by containers for the remaining analysis). A summary of the investigation plan including sample collection and analysis is provided in the RFI Work Plan.

The following protocols will be employed during all sampling conducted during the RFI:

1. All sampling instruments and equipment will be cleaned in accordance with the protocol presented herein prior to collecting samples for chemical analyses at each location (refer to FMG 9.0).
2. A double pair of disposable nitrile gloves will be used at each sample location for chemical analyses. A new overpair will be used for each sample. Additional glove changes at each sample location will be made for conditions such as: if the gloves are observed to be torn, or the gloves are suspected of being soiled from a source other than the sample media itself.
3. Quality assurance samples will be collected as outlined in the QAPP.
4. All sampling generated wastes such as gloves, tyvek, etc. will be collected and containerized for proper disposal (refer to FMG 10.0).
5. Samples will be labelled noting the project name, Facility, unique sample number, sample location, sample interval (if appropriate), analysis required, preservative added, date, time and sampler's initials, in accordance with the QAPP. All sample preservation protocols will be followed in adherence with the QAPP. A hard cover bound field book and/or field forms will be maintained to record all samples and sampling events (refer to FMG 1.4).
6. Containers for sample collection and preservation requirements will be determined as required by the analytical parameters (refer to the QAPP). All sample bottles will be provided

by the laboratory and will be prepared using a standard laboratory validated washing procedure.

7. All collected sample shipments for chemical analysis will be iced in supplied coolers after collection and labelling. Any remaining space will be filled with packing to cushion the containers within the shipment coolers. Each cooler will be sealed with two seals comprised of Chain-of-Custody tape (or custody seal) and the sampler's name. The cooler will then be sealed with packing tape (refer to FMG 6.10).

   All samples will be delivered to the laboratory by a commercial courier.

8. Samples will be shipped under chain-of-custody procedures as outlined in the QAPP and FMG 6.10.

2.2 Equipment Cleaning

Upon mobilization of the drill rig to the Facility, and prior to commencing work, the drill rig and all associated equipment will be thoroughly cleaned in accordance with FMG 9.0. Cleaning of non-dedicated downhole equipment will be completed prior to use and between each borehole.

2.3 Waste Handling

All soil cuttings, development/purge water, excess sampling water, and decontamination water/fluids will be placed in containers and stored in GSH’s designated disposal area (as required) until they can be properly characterized, in accordance with FMG 10.0. All soil cuttings and/or water collected during well purging and development will be tested using the Toxicity Characteristics Leaching Procedure (TCLP) to determine appropriate disposal options. This waste will be properly stored, characterized, and disposed according to appropriate regulations.

2.4 Utility Clearance

Prior to commencing work at the Facility, all utilities will be cleared in accordance with FMG 1.3.

For this project, the following state utility clearance service is:

• Indiana 811:	800-382-5544 or 811 when in Indiana

All locations on-Facility must be cleared through the Facility contact:

• Mr. Peter Krivas	219-765-2020

If Facility utility maps and a Facility-specific knowledge are insufficient to locate utilities, a private utility located may also be used.

2.5 Field Instrument Use and Calibration

All field instruments utilized during the field implementation will be used and calibrated in accordance with FMG 8.0.

3. Soil Sampling Protocols

3.1 Subsurface Soil Sampling

Soil samples will be collected continuously during drilling to identify and classify soil materials (refer to FMGs 2.2, 2.3, 2.6, and 6.1). Drilling techniques for subsurface soil sampling will include hollow-stem auger and/or direct-push methods. Soil samples will be collected using the standard penetration test method and/or Shelby tubes, or alternately, continuous sampling techniques such as direct push methodologies (e.g., Geoprobe). All collected soil samples will be described and classified according to the Unified Soil Classification System (USCS), as described in FMG 2.6).

The soil samples selected for chemical analyses will be collected in accordance with FMG 6.1 and Section 4 of the QAPP. Additional details (not included in the FMGs) for collecting VOC samples are provided below:

- VOC analysis will utilize the methanol field preservation kit as follows:
  - Using the 10-gram sampling device, transfer one 10-gram soil plug from the sample point to the 40-ml VOA vial containing methanol. Quickly cap and tighten the lid.
  - For soils being preserved for volatile analyses, one vial is needed per test. For each analysis, place 10 grams of soil into a 40-ml, tared vial containing 10 milliliters of methanol.
  - Put soil from the sample point in the dry weight jar, and screw the cap tight.

Dry weight analysis must be performed from an unpreserved container. This container can be from another test being performed or a separate 2-oz plastic container can be used.

The quality assurance/quality control (QA/QC) procedures for the analyses are outlined in the QAPP.

3.2 Surface Soil Sampling

Surface soil samples will be collected in accordance with the following protocols:

1. Surficial soil samples will be collected using a pre-cleaned stainless steel trowel or other appropriate tool (e.g., hand auger, SPT, Shelby tube, etc.). Each sample will consist of soil from the 0-2-foot interval (excluding pavement). Any surficial debris (i.e., grass cover) should be removed from the area where the sample is to be collected using a separate pre-cleaned device.
2. A double pair of disposable nitrile gloves will be used at each sample location (the outer gloves will be changed for each sample).
3. Prior to use, for each sample, all sampling equipment will be pre-cleaned using the prescribed decontamination procedure (refer to FMG 9.0).
4. Samples for VOC analysis will be collected using methanol preservation kit as follows:
   - Using the 10-gram sampling device, transfer one 10-gram soil plug from the sample point to the 40-ml VOA vial containing methanol. Quickly cap and tighten the lid.

  - For sols being preserved for volatile analyses, one vial is needed per test. For each analysis, place 10 grams of soil into a 40-ml, tared vial containing 10 milliliters of methanol.
  - Put soil from the sample point in the dry weight jar, and screw the cap tight.
5. Samples for chemical analysis will be in accordance with FMG 6.1.
6. The sample locations will be surveyed upon completion.

3.3 Borehole Abandonment

Upon completion of soil boring/sampling, the boreholes will be abandoned/sealed in accordance with FMG 2.5.

4. Hydrogeologic Investigation

4.1 Monitoring Well Installation Procedures

Monitoring well installations will be completed in accordance with U.S. EPA technical guidance and referenced FMGs, where available. Soil samples for stratigraphic definition will be collected continuously in accordance with FMGs 2.3 and 6.1. All cuttings will be containerized and disposed of in accordance with FMG 10.0.

The overburden monitoring wells will be completed in accordance with FMGs 3.1 and 3.2.

4.2 Water Level Measurements

Following installation of the monitoring wells, a ground elevation and a top of casing (TOC) measuring point elevation survey will be conducted for all recently completed wells. The groundwater elevation at each well will be measured in accordance with FMG 5.1 and will be completed within a 24-hour period in order to avoid readings over potential changes in weather. All data will be reduced to water elevations and contoured, if applicable.

4.3 Slug Injection Tests

Slug injection tests will be completed in accordance with FMG 5.2.

4.4 Well Development

All monitoring wells will be developed prior to sampling in accordance with FMG 3.6.

4.5 Well Decommissioning

All well abandonment/decommissioning will be completed in accordance with FMG 3.7, as necessary.

5. Groundwater Quality Sampling Protocols

All wells used for groundwater quality monitoring will be sampled utilizing low-flow sampling techniques according to FMG 6.4. Monitoring and sample collection for non-aqueous phase liquid will be completed in accordance with FMG 6.5, if applicable. Wells will not be sampled for groundwater analyses if NAPL is present in the well.

6. Field Log and Field Forms

The written field data will be recorded on standardized, pre-printed field forms or in a field log book, in accordance with FMG 1.4.

7. Sample Shipment and Containers

All samples collected and submitted to the laboratory for analysis will be handled and shipped in accordance with FMG 6.10 and Section 2 of this SAP.

Appendix 1
Field Method Guidelines

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UTILITY CLEARANCE

LIST OF FORMS
(Following Text)

FMG 1.3-01	PROPERTY ACCESS/UTILITY CLEARANCE RECORDS
FMG 1.3–02	UTILITY CLEARANCE CHECKLIST (ACTIVE FACILITIES)

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UTILITY CLEARANCE

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

Invasive field investigation activities such as drilling, soil gas surveys, test excavation or remedial construction activities require location of underground utilities prior to initiating work. Such clearance is sound practice in that it minimizes the potential for damage to underground facilities and more importantly, is protective of the health and safety of personnel. Under no circumstances will invasive activities be allowed to proceed without obtaining proper utility clearance by the appropriate public agencies and/or private entities. **This clearance requirement applies to all work on both public and private property, whether located in a dense urban area or a seemingly out-of-the-way rural location.**

The responsibility of obtaining this clearance lies with the Consultant or Contractor performing the work.

In most states such utility clearance is required by law, and obtaining clearance includes contacting a public or private central clearance agency via a "one-call telephone service and providing them with proposed exploration location information. This is discussed in more detail herein. It is important to note that public utility agencies may not, and usually don't have information regarding utility locations on private property. As such, utility clearance on CITGO property must be cleared using available site drawings, and written approval must be obtained from personnel with appropriate knowledge of existing utilities. In the event the utility clearance is required for an active facility, the Facility Area Manager (FAM) will be the single source of contact for utility clearances.

PROCEDURES REFERENCED

- FMG 1.1 - Interior and Exterior Inspections
- FMG 1.2 - Soil-Gas Surveys (Passive and Active)

- FMG 2.0 - Subsurface Investigations
- FMG 4.1 - EM Survey

PROCEDURAL GUIDELINES

- Before marking any proposed exploration or underground construction locations, it is critical that all readily available information on underground utilities and structures be obtained. This includes publicly available information as well as information in the possession of private landowners. Any drawings obtained must be reviewed in detail for information pertaining to underground utilities. The FAM will be the single point of contact for utility clearances at active facilities. At active facilities Form FMG 1.3-02 - Utility Clearance Checklist (Active Facilities) will be completed.
- Using the information obtained, the site should be viewed in detail for physical evidence of buried lines or structures, including pavement cuts and patches, variation in or lack of vegetation, variations in grading, etc. (Care must also be taken to avoid overhead utilities as well.) Presence of surface elements of buried utilities should be documented, such as manholes, gas or water service valves, catch basins, monuments, or other evidence.
- Overhead utility lines must be taken into account when choosing exploration and excavation locations. Most states require a minimum of 10 feet of clearance between equipment and energized wires. Such separation requirements may also be voltage-based and may vary depending on state or municipality regulations.
- In evaluating clearance from overhead lines, the same restrictions may apply to "drops", or wires on a utility pole connecting overhead and underground lines.
- Using the information obtained and observations made, proposed exploration or construction locations should be marked in the field. Marking locations can be accomplished using spray paint on the ground, stakes, or other means. **All markings of proposed locations should be made in white**, in accordance with the generally accepted universal color code for facilities identification (AWMA 4/99):
  - White: Proposed Excavation or Drilling Location.
  - Pink: Temporary Survey Markings.
  - Red: Electrical Power Lines, Cables, Conduit, and Lighting Cables.
  - Yellow: Gas, Oil, Steam, Petroleum, or Gaseous Materials.
  - Orange: Communication, Alarm or Signal Lines, Cables, or Conduits.
  - Blue: Potable Water.
  - Purple: Reclaimed Water, Irrigation, and Slurry Lines.
  - Green: Sewers and Drain Lines.

- In order to effectively evaluate the proposed locations with these entities, detailed, accurate measurements between the proposed locations and existing surface features should be obtained. Such features can be buildings, street intersections, utility poles, guardrails, etc.
- Obtaining the utility clearance generally involves two entities:
  - The designated "one-call" underground facilities protection organization for the area; and
  - The landowner.

  Both entities must be contacted and the proposed locations evaluated in light of information available for existing underground facilities. The detailed measurement information described above will be required by the "one call" agency. The owners of the applicable, participating, underground utilities are obligated mark their respective facilities at the site in the colors described above. Utility stake-out activities will typically not commence for approximately 72 hours after the initial request is made.
- The public and private utility entities generally only mark the locations of their respective underground facilities within public rights-of-way. Determination of the locations of these facilities on private property will be the responsibility of the project Consultant or Contractor. If available information does not contain sufficient detail to locate underground facilities with a reasonable amount of confidence, alternate measures may be appropriate, as described below. In some cases, the memory of a long-time employee of a facility on private property may be the best or only source of information. It is incumbent on the Consultant or Contractor to exercise caution and use good judgement when faced with uncertainty.

> Note: *It is important to note that not all utilities are participants in the "one-call" agency or process. As such, inquiries must be made with the "one-call" agency to determine which entities do not participate, so they can be contacted independently.*
>
> *Most utility stake-outs have a limited time period for which they remain valid, typically 2 to 3 weeks. It is critical that this time period be taken into account to prevent expiration of clearance prior to completion of the invasive activities, and the need to repeat the stake-out process.*

- Care must be exercised to document receipt of notice from the involved agencies of the presence or absence of utilities in the vicinity of the proposed locations. FMG 1.3-01 - Property Access/Utility Clearance Data Sheet can be used to record contacts made and responses received from each entity.

  Most agencies will generally provide a telephone or fax communication indicating the lack of facilities in the project area. **If contact is not made by all of the agencies identified by the "one-call" process, do not assume that such utilities are not present. Re-contact the "one-call" agency to determine the status.**
- For complicated sites with multiple proposed locations and multiple utilities, it is advisable to arrange an on-site meeting with utility representatives. This will minimize the potential for miscommunication amongst the involved parties.
- Completion of the utility stake out process is not a guarantee that underground facilities will not be encountered in excavations or boreholes; in fact, most "one-call" agencies and

individual utilities do not offer guarantees, nor do they accept liability for damage that might occur. Accordingly, it is advisable that any invasive activities proceed with extreme caution in the upper 4 to 5 feet in the event the clearance has failed to identify an existing facility, or possibly deeper at a facility that has built new surfaces on fill dirt on top of old slabs. This may necessitate hand-excavation or probing to confirm potential presence of shallow utilities. If uncertainty exists for any given utility, extra activities can be initiated to solve utility clearance concerns. These options include:

- Hand digging, augering or probing to expose or reveal shallow utilities and confirm presence and location. In northern climates this may require advancing to below frost line, typically at least 4 feet.
- Screening the proposed work areas with utility locating devices, and/or hiring a utility locating service to perform this task. The private utility locating service is a growing industry that has formed a national organization. The National Utility Locate Contractors Association (NULCA) can be reached at 715-635-6004.

EQUIPMENT/MATERIALS

- White spray paint.
- Wooden stakes, painted white or containing white flagging.
- Color-code key.
- Available drawings.
- Form FMG 1.3-01 - Property Access/Utility Clearance Data Sheet and Form FMG 1.3-02 - Utility Clearance Checklist (Active Facilities).

REFERENCES

American Public Works Association, April 1999, Uniform Color Code (http://www.apwa.net/).

PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

PROJECT NAME: ______________________ PROJECT NUMBER: __________

CITGO REPRESENTATIVE: ______________________

CLIENT: __________ CLIENT REPRESENTATIVE: __________ PHONE: __________

ON-SITE PROPERTY ACCESS APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

OFF-SITE PROPERTY ACCESS APPROVAL (if applicable) __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITY CLEARANCE APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

CONTRACTOR VERIFICATION APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITIES (INDICATE THAT LOCATION/UTILITY PRESENCE WAS CHECKED) *

Borehole/ Excavation Location	Date (m/d/y)	Telephone	Water	Storm Sewer	Sanitary Sewer	Process Sewer	Gas	Electrical	Cable	Overhead Utilities	Other	Comments/Warnings

Additional Comments:

____

____

____

White:	Field Office
Yellow:	Field File
Pink:	Owner/Client/Agent

* Note as appropriate, Contractor, Client or Owner, or Agent to sign, indicating no utilities are at the selected borehole/excavation locations.

UTILITY CLEARANCE CHECKLIST (ACTIVE FACILITIES)

Prior to excavating or penetrating (i.e., soil boring, wells, Geoprobe, etc.) soil on CITGO property, it is necessary to check for underground utilities that may be routed through the area in question. The following process is recommended:

1. Process is intended only for locating utilities on CITGO property.
2. Utilities of concern include, but are not limited to, the following:
   - storm and sanitary sewers, drain tiles, gas, electric, telephone, city water, steam, condensate, process waste, and other process piping.
3. Underground structures such as foundations, tunnels, etc. also require location and identification.
4. Review all site utility, mechanical, electrical, and foundation drawings for the area in question.
5. Interview site personnel familiar with the area.
6. Visually inspect area in question.
7. Look for disruptions in pavement or flooring indicating a trench.
8. Look for manholes, pipe risers, catch basins, fire hydrants, post indicator valves, etc. (PIVs and hydrants are located above a pipe, but don't assume it is the main line. Most often they are above a lateral line.)
9. Check adjacent buildings or structures for locations of utilities entering the ground. In buildings look for services adjacent to machines.
10. Compare the drawings with observations in the field.
11. A pipe and cable locator device should be used to help verify physical location of utilities shown on drawings.
12. Call the following if uncertain of the location of a public utility. They will have maps of storm, sanitary, water, etc. They will also mark the utility's location:
    - Local electric, gas, or telephone companies, contract service, municipal or city water departments and/or engineering departments.
13. Evaluate safety needs and develop a safe operating procedure (SOP).
14. Dig a test pit when utility location cannot be absolutely determined.
15. Identify the utility(s) and mark location.
16. Update record drawings when discrepancy identified in the field.

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DATA RECORDING – FIELD BOOKS/DIGITAL RECORDING

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DATA RECORDING – FIELD BOOKS/DIGITAL RECORDING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure describes protocol for documenting standard investigation activities in the field. Field data serves as the cornerstone for an environmental project, not only for site characterization but for additional phases of investigation or remedial design. Inaccurate or incomplete field data may create significant problems and additional project costs. In addition, recorded field data becomes a legal record of project work, and should be approached with that in mind. Producing legally defensible data includes proper and appropriate recording of field data as it is obtained in a manner that will preserve it for future use.

This procedure provides guidelines for accurate, thorough collection and preservation of written and electronic field data.

PROCEDURES REFERENCED

- FMG 8.0 - Field Instruments – Use/Calibration

PROCEDURAL GUIDELINES

Typical field data to be recorded generally includes, but is not limited to, the following:

- General field observations.
- Numeric field measurements and instrument readings.
- Quantity estimates.
- Sample locations and corresponding sample numbers.
- Relevant comments and details pertaining to the samples collected.

- Documentation of activities, procedures, and progress achieved.
- Contractor pay item quantities.
- Weather conditions.
- A listing of personnel involved in site-related activities.
- A log of conversations, site meetings, and other communications.
- Field decisions made and pertinent information associated with the decisions.

Written Field Data

Written field data is generally recorded on one of two media: a standardized, pre-printed field log form, or a bound field log book. In general, use of a field log form is preferable as it prompts field personnel to make appropriate observations and record data in a standardized format. This promotes completeness and consistency from one person to the next. Most of the CITGO FMGs include standardized field log forms.

In the absence of an appropriate pre-printed form, the data should be recorded in an organized and structured manner in a dedicated project field log book. Log books must be hard-cover, bound so that pages cannot be added or removed, and should be made from high-grade 50 percent rag paper with a water-resistant surface.

The following are guidelines for use of field log forms and log books:

1. Information must be factual and complete. Do not abbreviate.
2. All entries will be made in black indelible ink with a ballpoint pen and will be written legibly. Do not use "rollerball" or felt tip-style pens, since the water-soluble ink can run or smear in the presence of moisture.
3. All pages in a log book must be consecutively numbered. Field log forms should also be consecutively numbered.
4. Each day's work must start a new log book page.
5. At the end of each day, the current log book page must be signed and dated by the field personnel making the entries.
6. When using field log forms, they must also be signed and dated.
7. Make data entries immediately upon obtaining the data. Do not make temporary notes in other locations for later transfer to log forms or log books; this only increases the potential for error or loss of data.
8. Entry errors are to be crossed out with a single line, dated, and initialed by the person making the correction.
9. Do not leave blanks on log forms, if no entry is applicable for a given data field, indicate so with "NA" or a dash ("--").

10. At the earliest practical time, photocopies of log forms and log book pages should be made and placed in the project file as a backup in the event the book or forms are lost or damaged.
11. Log books should be dedicated to one project only, i.e., do not record data from multiple projects in one log book.

Electronic Data

Electronic data recording is widely used in environmental investigation and remediation projects. In general, it involves electronic measurement of field information through the use of monitoring instruments, sensors, gauges, and equipment controls. The following is a list of guidelines for proper recording and management of electronic field data:

1. Field data management should follow requirements of a project-specific data management plan (DMP), if one exists.
2. Use only instruments that have been calibrated in accordance with manufacturer's recommendations.
3. Usage of instruments, controls, and computers for the purpose of obtaining field data should only be performed by personnel properly trained and experienced in the use of the equipment and software.
4. Use only fully licensed software on PCs and laptops. Software piracy, even if unintentional, is a felony and exposes CITGO, its contractors, and their employees to severe criminal and financial penalties.
5. Loss of electronic files may mean loss of irreplaceable data. Every effort should be made to back up electronic files obtained in the field as soon as practical. A backup file placed on a disk and kept in a separate location from the original will minimize the potential for loss.
6. Electronic files, once transferred from field instruments or laptops to office computers, should be protected if possible to prevent unwanted or inadvertent manipulation or modification of data. Several levels of protection are usually available for spreadsheets, including making a file "read-only" or assigning a password to access the file.
7. Protect floppy disks from exposure to moisture, excessive heat or cold, magnetic fields, or other potentially damaging conditions.
8. Remote monitoring is often used to obtain stored electronic data from site environmental systems. A thorough discussion of this type of electronic field data recording is beyond the scope of this FMG. Such on-site systems are generally capable of storing a limited amount of data as a comma-delimited or spreadsheet file. Users must remotely access the monitoring equipment files via modem or other access, and download the data. In order to minimize the potential for loss of data, access and downloading of data should be performed frequently enough to insure the data storage capacity of the remote equipment is not exceeded.

EQUIPMENT/MATERIALS

- Five by seven-inch National 407 Field Book, with high-grade 50 percent rag paper with water-resistant surface, hard-cover, or equivalent.
- Appropriate field log forms.
- Indelible ball point pen (do not use "rollerball" or felt-tip style pens).
- Straight edge.
- Pocket calculator.
- Laptop computer (if required).

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DRILLING TECHNIQUES

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DRILLING TECHNIQUES

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This section will provide a brief description of common methods for conducting subsurface investigations. It should be noted that every drilling technology has its advantages and limitations.

PROCEDURES REFERENCED

- FMG 2.3 - Soil Borings
- FMG 2.4 - Bedrock Coring
- FMG 2.6 - Soil Classification
- FMG 2.7 - Rock Classification
- FMG 3.2 - Overburden and Top of Rock Wells
- FMG 3.3 - Deep Bedrock Wells
- FMG 3.5 - Piezometers
- FMG 3.6 – Well Development

PROCEDURAL GUIDELINES

It is important that the drilling method or methods used minimize disturbance of subsurface materials and not contaminate the subsurface and groundwater. The actual drilling method would be dependent upon site-specific geologic conditions and project requirements. It is important to note that the drilling equipment selected be decontaminated before and between borehole locations to prevent cross contamination (see FMG 9.0 - Equipment Decontamination).

Where possible drilling methods that minimize waste generation (soil cuttings), and wastewater generation (decontamination water), should be selected for CITGO Remediation Team investigation/remedial tasks.

In other settings it may be desirable to dictate drilling procedures that minimize turbidity/maximize the ability to achieve sediment-free groundwater. Generally, rotosonic techniques or rotary spun casing techniques achieve these objectives, or oversizing the borehole/sand pack may be considered, as well.

A brief description of each drilling method, listed in the order most commonly used at CITGO sites, is presented below.

Rotosonic Drilling

This method consists of a combination of rotation with high frequency vibration to advance a core barrel and outer casing to a desired depth. Typically, the core barrel is advanced in 10-foot intervals and then the outer casing is advanced to the core barrel depth and usually requires the injection of small quantities of water. 5-foot and 20-foot intervals are also used, depending on project requirements. Once the vibration is stopped, the core barrel is retrieved, and the sample is vibrated or hydraulically extracted into plastic sleeves or sample trays. The soil materials between the inner and outer casings are displaced into the sidewall of the geologic unit. Usually little to no soil or water is returned to the surface during drilling. The rotosonic method can usually drill easily through formations such as gravel, sand, clay, or glacial till. However, rotosonic drilling is slow in hard overburden formations (e.g., dense glacial till where displacement of soils into the sidewall are difficult), and can be very difficult in bedrock formations.

Monitoring wells shall be installed through the outer casing with minimal formation disturbance and mixing of formation materials. Rotosonic drilling generally requires less time than more traditional methods and minimizes soil mixing and soil disturbance (preferred for well locations where low turbidity is an important objective). Continuous, relatively undisturbed samples can be obtained through virtually any formation. Conventional sampling tools can be employed as attachments (i.e., hydropunch, split spoon, Shelby tube, etc.). No mud, air, water, or other circulating medium is required, although water is injected during advancement of the outer casing. The rotosonic method can drill easily through formations such as gravel, sand, clay, or glacial till. The main limitation of this method is the availability of equipment, the large area required (i.e., drill units are quite large), and costs. In addition, in some soils (e.g., silty sands, clayey sands) extra well development may be required due to displacement and compaction of soil cuttings into the borehole wall.

Hollow-Stem Auger

The hollow-stem continuous-flight auger is among the most frequently used in the drilling of monitoring wells (overburden wells) or for placement of overburden casings for bedrock wells.

The primary advantages of hollow-stem augering are that:

- Generally, no additional drilling fluids are introduced into the formation.
- It is a common drilling method and easy to find drilling companies with that capability.
- Representative geologic soil samples can be easily obtained using split-spoon samplers in conjunction with the hollow-stem augers.
- Monitoring wells can be installed through the augers eliminating the need for temporary borehole casings.

Disadvantages of hollow-stem augering are:

- Creates problems for select parameters.
- May not be possible in environments with strong upward gradients in granular environments.
- Large volumes of cuttings are typically generated.
- Decontamination is fairly time consuming/labor intensive.
- Relatively slow when compared to direct-push methods (soil sampling tasks).

Installing monitoring wells through hollow-stem augers is a relatively simple process although precautions need to be taken to ensure that the well is properly backfilled. This can be particularly problematic in cases where flowing/heaving sand is present.

Hollow-stem augers are available with inside diameters of 2.5, 3.25, 4.0, 4.25, 6.25, 8.25, 10.25, and 12.25 inches. The most commonly used are 4.25 inches for 2-inch (5 cm) monitoring wells and 6.25 inches for 4-inch (10 cm) monitoring wells. Boreholes can usually be drilled with hollow-stem augers to depths up to 100 feet (30 m) in unconsolidated clays, silts, and sands. Removing augers in flowing sand conditions while installing monitoring wells may be difficult since the augers have to be removed without being rotated. A bottom plug or pilot bit assembly should be utilized to keep out soils and/or water that have a tendency to plug the bottom of the augers during drilling. If flowing sands are encountered, potable water (analyzed once for contaminants of concern) may be poured into the augers to equalize the pressure to keep the formation materials and water from coming up into the auger once the bottom plug is removed.

Direct-Push (Geoprobe™)

Direct-push refers to the sampler being "pushed" into the soil material without the use of drilling to remove the soil. This method relies on the amount of the drill weight combined with rapid percussion for advancement of the tool string. Discrete soil samples are continuously obtained. Groundwater and vapor samples can also be collected utilizing this method. Subsurface investigations typically probe to depths of 30 feet or more, depths will vary based on site-specific geology. The direct-push equipment typically advances either 4-feet long or 5-feet long samplers and drill rods.

Direct-push method is widely used for underground storage tank (UST) investigations and property investigations. This method is used extensively for initial site screening activities to delineate vertical and horizontal plume presence and can significantly reduce investigative costs.

This method is more popular due to the limited cuttings that are produced during the sampling process and the rapid sampling process speed. However, due to compaction of soils into the narrow diameter soil sampler, it is common that full recovery of the sampled interval is not obtained. The soil sampler tip displaces some soil into the borehole sidewall.

Depending on the diameter of the soil sampler tubing used, pre-pack well screens and riser pipe can be installed directly through the drill rods. Alternatively, most direct-push drill rigs can advance hollow-stem augers to limited depths, with some machines able to advance large diameter augers in certain conditions.

Rotary Method

This method consists of a drill rod attached to a drill bit (soils: tricone, drag; rock: button studded, diamond studded) that rotates and cuts through the soils and rock. The cuttings produced are forced to the surface between the borehole wall and the drill rod by drilling fluids which generally consist of water, drilling mud (mixed with water), or air. The drilling fluids not only force the cuttings to the surface but also keep the drilling bit cool. Using rotary methods for well installations can be difficult as it usually requires several steps to complete the installation. First, the borehole is drilled; then temporarily cased; then the well is installed; and then the temporary casing is removed. In some cases, the borehole may remain open without installing a casing, but this will only occur in limited instances (i.e., cohesive soils).

i) Water Rotary

When using water rotary, the potable water supply should be analyzed for contaminants of concern. Water rotary is the preferred rotary method since the potable water is the only fluid introduced into the borehole during drilling. However, the use of water as a fluid is generally only successful when drilling in cohesive soils. The use of potable water (only) also reduces well development time, when compared to mud rotary.

ii) Air Rotary (typically used in rock)

When using air rotary, the air compressor must have an in-line oil filter system assembly to filter the oil mixed with the air coming from the compressor. This will help eliminate contaminant introduction into the formation. The oil filter system should be regularly inspected. Air compressors not having an in-line oil filter system are not acceptable for air rotary drilling. A cyclone velocity dissipater or similar air containment system should also be used to funnel the cuttings and produced water to one location rather than letting the cuttings blow uncontrolled out of the borehole. Air rotary may not be an acceptable method for well installation where certain contaminants are present in the formation. Alternatively, it may be necessary to provide treatment for the air being exhausted from the borehole during the installation process.

iii) <u>Mud Rotary</u>

Mud rotary is the least preferred rotary method because contamination can be introduced into the borehole from the constituents in the drilling mud (i.e., Ohio, Michigan). The drilling muds are generally non-toxic and do not introduce contaminants into the borehole, however, it is possible for mud to infiltrate permeable zones and can affect water quality by sorbing metals and polar organic compounds (Aller et al., 1991). Chemical composition and priority pollutants analysis may be obtained from the manufacturer. Mud rotary shall utilize only potable water and pure (no additives) bentonite drilling muds. The viscosity of the drilling mud shall be kept as low as possible in order to expedite well development. Proper well development is essential to ensure the removal of all the drilling mud and to return the formation to its previously undisturbed state. This usually requires significant surging and purging, jetting, airlifting, or a combination of these well development methods. Simply pumping is not sufficient.

<u>Dual-Wall Reverse Circulation Air Method of Drilling</u>

This method consists of two concentric strings of drill pipe (an outer casing and a slightly smaller inner casing). The outer drill pipe is advanced using rotary drilling with a donut-shaped bit attached to the dual casing string. The drill bit cuts an area only the width of the two casings and annulus between. Compressed air is continually forced down the annulus between the inner casing and outer casing carrying the drill cuttings and groundwater to surface. At the surface, the inner casing is connected to a cyclone hopper where the drill cuttings and groundwater fall out the bottom of the hopper, and air is dispersed out the top. The dual wall provides a fully cased borehole in which to install a monitoring well. The only soil or groundwater materials exposed at any time are those at the drill bit, providing depth-discrete soil sample cuttings in the drill returns. The potential for carrying contamination from one stratum to another is minimal. Depth-specific groundwater samples can be collected during drilling; however, since the groundwater is aerated, analysis for volatile compounds may not be valid, or additional purging with a pump may be required.

<u>Well Points</u>

In some limited cases, well points (sand points) are driven into place without the use of augers. This method provides no information on the geologic condition (other than the difficulty of driving which may be related to formation density). Well points are most often used simply to provide dewatering of a geologic unit prior to excavation in the area. Well points are also used in monitoring shallow hydrogeologic conditions such as in stream beds or adjacent to streams/ponds for monitoring hydraulic head and geochemical conditions. Well points are typically less than 1.25-inch diameter, which may restrict available well development or sampling methods.

REFERENCES

Numerous publications are available describing current monitoring well design and construction procedures.

Driscoll, F.G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division.

EPA/625/6-90/0166 (July 1991), Handbook Ground Water Volume II: Methodology.

Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc.

National Water Well Association, 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells.

Environmental Protection Agency (1986), RCRA Groundwater Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

In addition, the following ASTM publications apply:

ASTM D5474	Guide for Selection of Data Elements for Ground-Water Investigations
ASTM D5787	Practice for Monitoring Well Protection
ASTM D5521	Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
ASTM D5978	Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells
ASTM D5299	Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities
ASTM D5092	Standard Practice for Design and Installation of Ground Water Monitoring Wells in an Aquifer.

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SOIL BORINGS

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SOIL BORINGS

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

The following presents a description of the methods generally employed for the advancement of boreholes and the collection of subsurface soil samples. Boreholes are typically installed to define geologic conditions for hydrogeologic and geotechnical evaluation; to allow the installation of monitoring wells and piezometers; and to allow the collection of subsurface soil samples (generally above the water table) for chemical analysis.

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, post-hole augers, vibratory hammers). However, the most common methods used by CITGO to advance boreholes are rotosonic drilling techniques, hollow-stem augers (HSA), or the use of a direct-push equipment. Rotosonic drilling and direct-push techniques are preferred boring approaches at CITGO Facilities. FMG 2.2 - Drilling Techniques, provides insight into the advantages/disadvantages of these drilling methods.

PROCEDURES REFERENCED

- FMG 1.3 - Utility Clearance
- FMG 2.2 - Drilling Techniques
- FMG 2.6 - Soil Classification
- FMG 2.7 - Rock Classification
- FMG 6.1 - Surficial Soil Sampling
- FMG 6.15 - PFAS/POFA Sampling

PROCEDURAL GUIDELINES

The following activities must be undertaken prior to undertaking a borehole installation and subsurface soil sampling program.

i) Assemble all equipment and supplies required per the Work Plan.

ii) Obtain a site plan and any previous stratigraphic logs. Determine the appropriate number and location of boreholes to be installed and the depths of samples for chemical analysis.

iii) Contact the analytical group to arrange/determine:
  - Laboratory;
  - Glassware/sample jars;
  - Cooler;
  - Shipping details;
  - Start date;
  - Expected duration; and
  - Arrange bids if appropriate between the CITGO Lab program accepted labs for best cost.

iv) Establish borehole locations in field using available permanent landmarks and conducting swing ties or by surveying methods if necessary.

v) Arrange for utility clearance of franchised utilities and site utilities.

vi) Arrange for hydrovac/air knifing services to daylight utilities/clear locations, if required by the project and clear locations with onsite personnel.

vii) Prepare FMEAs to be reviewed prior to drilling.

viii) Determine notification needs with the Project Manager. Confirm all appropriate groups have been notified of the planned sampling event like the regulatory groups, landowner, CITGO facility personnel, and laboratory.

ix) Determine the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

Once the prior planning and preparation activities are completed, the borehole installation and subsurface soil sampling program can proceed. The typical series of events which takes place is:

- Locating and marking of borehole locations (if not already completed).
- Equipment decontamination.
- Final visual examination of proposed drilling area for utility conflicts/final hand auger or post-hole check to verify utility absence.
- Daylighting of utilities, if required
- Advancement of borehole and collection of the soil sample.

- Field screening of soil sample.
- Description of soil sample. [Form FMG 2.6-01 - Stratigraphy Log - Overburden (Page 1/Page 2) will be used to record data.]
- Sample preparation and packaging.
- Abandonment of boreholes or installation of monitoring well.
- Surveying of borehole locations and elevations.
- Field note completion and review.
- Double check all equipment, personal protective equipment (PPE), field notebooks for possible contaminants especially if sampling for per- and polyfluoroalkyl substances (PFAS)/ perfluorooctanoic acid (PFOA) (see FMG 6.15-PFAS/POFA Sampling for special considerations if sampling for PFAS/PFOA).

i) Locating and Marking of Boreholes/Final Visual Check

The proposed borehole locations marked on the site plan are located in the field and staked. On most sites, this will likely be done several days in advance of the drill rig arriving on site. Unless boreholes are to be installed on a fixed grid, the proposed locations are usually strategically placed to assess site conditions.

Once the final location for the proposed boring has been selected and utility clearances are complete (FMG 1.3 – Utility Clearance), one last visual check of the immediate area should be performed before drilling proceeds. This last visual check should confirm the locations of any adjacent utilities (subsurface or overhead) and verification of adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

ii) Borehole Advancement

If possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to verify the absence of buried utilities and pipelines. Alternatively, hydrovac/air knifing can be used to daylight the hole prior to drilling. This procedure should clear the area to the full diameter of the drilling equipment which will follow.

If it is necessary to relocate any proposed borehole due to terrain, utilities, access, refusal, etc., the Project Manager must be notified and an alternate location will be selected using previous methods.

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated. All decontamination must be conducted in accordance with the project-specific plans or the methods presented in FMG 9.0 - Equipment Decontamination.

The clean augers/tooling are covered with clean plastic sheeting (check for PFAS/PFOA in sheeting materials if sampling for PFAS/PFOA, see FMG 6.15-PFAS/POFA Sampling for special considerations) to prevent contact with foreign materials. For geotechnical, geologic, or hydrogeologic studies where contaminants will not be tested, it is sufficient to clean the drilling equipment simply by removing the excess soils.

Collection of soil samples is one of the most important considerations in selecting drilling methods. Therefore, the need for reviewing drilling techniques (FMG 2.2 - Drilling Techniques) and the site objectives must first be considered. Soil Classification will be completed in accordance with FMG 2.6 - Soil Classification. Sections iii) and iv) describe borehole soil sampling procedures using direct-push tooling and HSA/split-spoon sampling (Standard Penetration Testing - SPT), respectively.

iii) Subsurface Sample Collection Methods

Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test or other sampling technique is performed on essentially undisturbed soil is acceptable. The drilling method is to be selected based on the subsurface conditions. Each of the following procedures have proven to be acceptable for specific subsurface conditions:

- Conventional drilling with continuous flight hollow-stem auger (HSA) method (with inside diameter between 2.2 and 6.5 inches) using split-spoon samplers (Standard Penetration Test – STP) or Shelby tube samplers; Direct-push samplers, advanced using a percussion/vibratory hammer (Geoprobe™ or equivalent);
- Rotosonic (sonic) drilling, advanced using a 5-6” diameter, 5-10 foot long steel core barrel by an oscillator within the drill head that generates a high-frequency, resonant energy and is combined with rotational movement;
- Hand–held/driven split-spoon sampling equipment, portable hammer and split-spoon sampling equipment (final depth will be limited).

Several drilling methods are not acceptable. These include: jetting through an open tube sampler and then sampling when the desired depth is reached; use of continuous flight solid auger equipment below the groundwater table in non-cohesive soils; casing driven below the sampling depth prior to sampling; and advancing a borehole with bottom discharge bits.

The following subsections describe the specific methods for completing direct-push sampling, core barrel sampling, split-spoon sampling and Standard Penetration Testing (SPT), and Shelby tube sampling. The following section, Soil Core Chemical Sample Collection Procedure describes the soil sampling procedure for chemical analysis, once a soil core is recovered from any of the above sample collection devices.

Direct-Push/Macro-Core™ Soil Sample Method

The operation of the direct-push soil sampler (e.g., Macro-core™, Dual Tube™, or equivalent) consists of "pushing" the sampler into the subsurface and then retrieving it using a direct-push soil probing machine. The collected soil core is contained within an internal soil liner (acetate, polyethylene, or Teflon) (check soil liner material if sampling for PFAS/PFOA, see FMG 6.15-PFAS/POFA Sampling for special considerations) and removed from the sampler once returned to the ground surface. Sampler length is variable depending on equipment available (2 feet, 4 feet, 5 feet). Once the soil liner has been removed and the outer sampler decontaminated, a new liner is inserted and the sampler reassembled. The clean sampler is then driven back down the same hole to collect the next soil sample.

Once driven to the required depth, the sampler body/soil liner and soil core is removed from the borehole for inspection and sample collection. Once above grade the sampler is opened by the probe operator and the liner removed and cut open (opened with a dual blade cutting tool), to expose the soil for inspection and sampling.

The sampler body and ends are decontaminated, a new liner is inserted, and the sampler reassembled for collection of the next interval (ensure the liner is free of PFAS/PFOA if sampling for PFAS/PFOA, see FMG 6.15-PFAS/PFOA Sampling for special considerations). The clean sampler is then advanced back down the same hole to collect the next soil sample. The Macro-Core™ sampler can be used in either the open-tube or closed-point sampling mode. The open-tube is most commonly used method, typically employed in stable soil conditions when the borehole does not collapse. The closed-point system seals the cutting shoe opening until the sampler is at the next sample interval, this prevents collapsed soil from entering the sampler as it is advanced back down the hole. Once at the sample depth, the closed-point is unthreaded and released from the cutting shoe area, such that it rides on top of the soil core as it is being driven into the next interval.

Soil Core Chemical Sample Collection Procedure, presented below, describes the soil sampling procedure for chemical analysis, once a soil core is recovered from the direct-push sampler.

Sonic Core Barrel Sample Method

Once the core barrels are advanced to the required depth, the inner core barrel is pulled from the ground, and the soil sample is extruded using vibration from the drill head. Soil Core Chemical Sample Collection Procedure, presented below, describes the soil sampling procedure for chemical analysis, once a soil core is recovered from the sampler.

Split Spoon Sampling and Standard Penetration Testing (SPT) Sampling and Testing Procedure

This method is used to obtain representative samples of subsurface soil materials and to determine a measure of the in situ relative density of the subsurface soils. The test methods described below must be followed to obtain accurate SPT values.

SPT sampling is performed by using a split barrel sampler in accordance with ASTM D1586. The split barrel sampler, or split spoon, consists of an 18- or 24-inch long, 2-inch outside diameter tube, which comes apart length wise into two halves. The split spoon is typically driven in advance of an HSA string which allows collection of the disturbed but representative soil sample.

Once the borehole is advanced to the target depth and the borehole cleaned of cuttings, representative soil samples are collected in the following manner:

- The split-spoon sampler should be inspected to ensure it is properly cleaned and decontaminated (if sampling for PFAS/PFOA, ensure that the cleaner is free of PFAS/PFOA, see FMG 6.15-PFAS/PFOA Sampling for special considerations). The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
- The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole. Do not allow the sampler to drop onto the soil.
- After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appear to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.
- Mark the drill rods in three or four successive 6-inch (0.15 m) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (0.15 m) increment.

The sampler is then driven continuously for either 18 or 24 inches (0.45 or 0.60 m) by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inches) (760 mm, ±25 mm) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586). The number of blows applied in each 6-inch (0.15 m) increment is counted until one of the following occurs:

- A total of 50 blows have been applied during any one of the 6-inch (0.15 m) increments described above;
- A total of 100 blows have been applied;
- There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is "bouncing" on a stone or bedrock); or
- The sampler has advanced the complete 18 or 24 inches (0.45 or 0.60 m) without the limiting blow counts occurring as described above.

In some cases where the limiting number of blow counts has been exceeded, the field supervisor may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential.

On the field form, record the number of blows required to drive each 6-inch (0.15 m) increment of penetration. The first 6 inches is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (0.15 m) of penetration is termed the "standard penetration resistance" or the "N-value".

Note: If the borehole has sloughed and there is caved material in the bottom, the split spoon may push through this under its own weight, but now the spoon is partially "pre-filled". When the spoon is driven the 18 or 24 inches representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Two problems arise:

1. *The top part of the sample is not representative of the in-place soil at that depth; and*
2. *The SPT value will be artificially higher toward the bottom of the drive interval since the spoon was packed full. These conditions should be noted on the field log.*

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the geologist/engineer work surface.

Note: A table made out of two sawhorses and a piece of plywood is appropriate, or a drum, both covered with plastic sheeting.

The open shoe and head are removed by hand, and the sampler is tapped so that the tube separates.

Note: Handle each split spoon with clean disposable gloves if environmental issues are being investigated.

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core. Note that surficial or shallow soils may be lodged in the auger borehole, thus split spoon samples from depth may contain sloughed material including topsoil/grass or fill materials previously encountered.

Caution must be used when conducting SPT sampling below the groundwater table, particularly in sand or silt soils. These soils tend to heave or "blow back" up the borehole due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil, and the syringe-like effect of pulling the center plug from the augers for sampling. To equalize the hydraulic pressure, the inside of the HSA must be filled with water (preferred) or drilling mud. The drilling fluid level within the boring or HSAs needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level.

Heaving conditions and the use of water or mud should be noted on the field logs.

Soil Core Chemical Sample Collection Procedure, presented below, describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a split-spoon sampler.

SPT sampling below the water table in sands and silt occasionally results in low SPT values being obtained due to the heaving effect disturbing the soil especially if the water level in the hole has not been maintained at the in-situ water level. Suspect low N values should be noted on the field logs. If it is critical to have accurate N values below the water table, other methods can be employed, such as conducting a dynamic cone penetration test. This quick and easy test involves attaching a cone shaped tip to the end of the drill rods, and driving the tip into the ground similar to the SPT method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet through a formation without augering. Blow counts are recorded for each foot (0.3 m) of advancement.

A variation of split barrel sampling involves the use of a longer barrel (continuous sampler) in conjunction with HSAs. The sampling barrel is installed inside the auger with a swivel attachment to limit rotation of the barrel. After completion of a 5-foot auger penetration, the auger is left in place and the continuous sampler barrel retrieved from the borehole. The sampler should be handled and the sample retrieved in the same way as described above for SPT sampling.

Thin-Walled Samplers (Shelby Tubes)

Thin-walled samplers are used to collect relatively undisturbed samples (as compared to split-spoon samples) of soft to stiff clayey soils. Shelby tubes are commonly used. The Shelby Tube has an outside diameter of 2 or 3 inches and is 3 feet long. These undisturbed samples are used for certain laboratory tests of structural properties (consolidation, hydraulic conductivity, shear strength) or other tests that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587, and are briefly described below.

- The soil deposit being sampled must be cohesive in nature, and relatively free of sand, gravel, and cobble materials, as contact with these materials will damage/collapse the sampler.
- Clean out the borehole to the sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the sampling operation.
- Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or HSA as carefully as possible to avoid disturbance of the material to be sampled.
- Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler into the formation without rotation by a continuous and relatively rapid motion; usually hydraulic pressure is applied to the top of the drill rods.

- Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.
- In no case should the length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 inches for cuttings.
- The tube may be rotated to shear the bottom of the sample 2 to 3 minutes after pressing in, and prior to retrieval to ensure the sample does not slide out of the tube. Lift the weight of the rods off of the tube prior to rotating.
- Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

On occasion it may be required that extraction of the sample from the tube be conducted in the field for chemical sample collection. The following procedure should be followed.

- A sample extruder, which consists of a clamp arrangement to hold the tube and a hydraulic ram to push the sample through the tube, is usually mounted on the side of the rig. To prevent cross-contamination, be certain that the extruder is field cleaned between each sample.
- The sample is then extruded into a carrying tray; these are often made from a piece of 4-inch or 6-inch diameter PVC pipe cut lengthwise. Be certain that the carrying tray is field cleaned between each sample. The sample is carried to the work station to describe the sample, trim the potentially cross-contaminated exterior, and select the area for sample collection (see Section 2.4 - Soil Core Chemical Sample Collection Procedure). Form FMG 2.3 -01 - Soil Sample Selection Details shows the method for obtaining a soil sample from a Shelby tube soil core.
- The Shelby tube may then be thoroughly field cleaned and decontaminated for reuse. Since they are thin-walled, the tubes are easily damaged, crimped, or otherwise distorted during handling or pushing. The Shelby tube should be inspected before use and any which are significantly damaged should be rejected.

Soil Core Chemical Sample Collection Procedure, presented below, describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a Shelby tube sampler.

iv) Soil Core Chemical Sample Collection Procedure

The following describes the collection of soil samples for chemical analysis from a split-spoon soil core, Shelby tube soil core, direct-push sample core, or sonic core barrel. Form FMG 2.3-01 - Soil Sample Selection Details shows the soil sample selection details. Sample preparation and selection is as follows:

- Record soil core recovery and soil stratigraphy data.
- Discard upper and lower ends of sample core (± 3 inches).

- If clayey soils are present use a pre-cleaned stainless steel knife to cut the remaining core longitudinally, alternatively if sandy soils are present, use a clean stainless-steel spoon to scrape away the soil surface.
- Screen the exposed soil surface with a photoionization detector (PID) to monitor for the presence of volatile organics.
- With a sample knife or spoon, remove soil from the center portion of the core and place in the sample jar (when only one aliquot is required), or when more than one aliquot is required place soils in a pre-cleaned stainless steel bowl for homogenization.
- Do not sample large stones and natural vegetative debris.
- Homogenize the soil and place directly into the sample jars. Do not homogenize soil for VOC analyses.
- Place collected samples on ice or cooler packs in laboratory-supplied shipping coolers.
- Package and transport the sample in accordance with FMG 6.10 - Sample Handling and Shipping.

When only one sample container is required, the collected soil will be placed directly into the clean, pre-labeled sample jar. When more than one sample container requires filling or samples will be split for duplicate analyses; the soils will first be homogenized in a pre-cleaned stainless steel bowl; and then placed into the respective sample containers. It is important that soil samples be mixed as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Soil samples collected for volatile organic compounds (VOCs) analyses shall not be mixed.

Exception is noted for the collection of VOCs which require special sample collection methods and is usually collected first to minimize VOC loss. VOCs are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected in triplicate using an EnCore Sampler™, or equivalent sampler, (triplicate samples collected per manufacturer's instructions). Samples for VOCs are typically collected first, without homogenization or extra handling to limit the loss of volatile constituents.

The VOC sample collection methodology will be identified in the Work Plan, which will dictate the sample method. The methodology for VOC sampling varies from area to area, so careful review of this issue in advance of the field efforts is required.

If PFAS/PFOA is being analyzed, specialized collection procedures, containers and equipment should be utilized (see 6.15-PFAS/POFA Sampling).

v) Borehole Completion

At the completion of the soil boring, once the soil/groundwater samples have been collected, the borehole annulus is then abandoned. Borehole abandonment options are identified in FMG 2.5 -

Borehole Abandonment/Sealing. Each boring will be surveyed to establish vertical/horizontal information; field ties (i.e., swing ties) will also be collected to document the boring location. Once completed, a stratigraphic log will be prepared for reporting purposes.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Form 2.6-01 - Stratigraphy Log - Overburden (Page 1/Page 2).
- Tape measure.
- Cutting Instrument.
- Plastic sheeting (free from PFAS/PFOA if sampling for PFAS/PFOA).

REFERENCES

ASTM D420-93 - Guide to Site Characterization for Engineering, Design, and Construction Purposes.

ASTM D1452-80 - Practice for Soil Investigation and Sampling by Auger Borings.

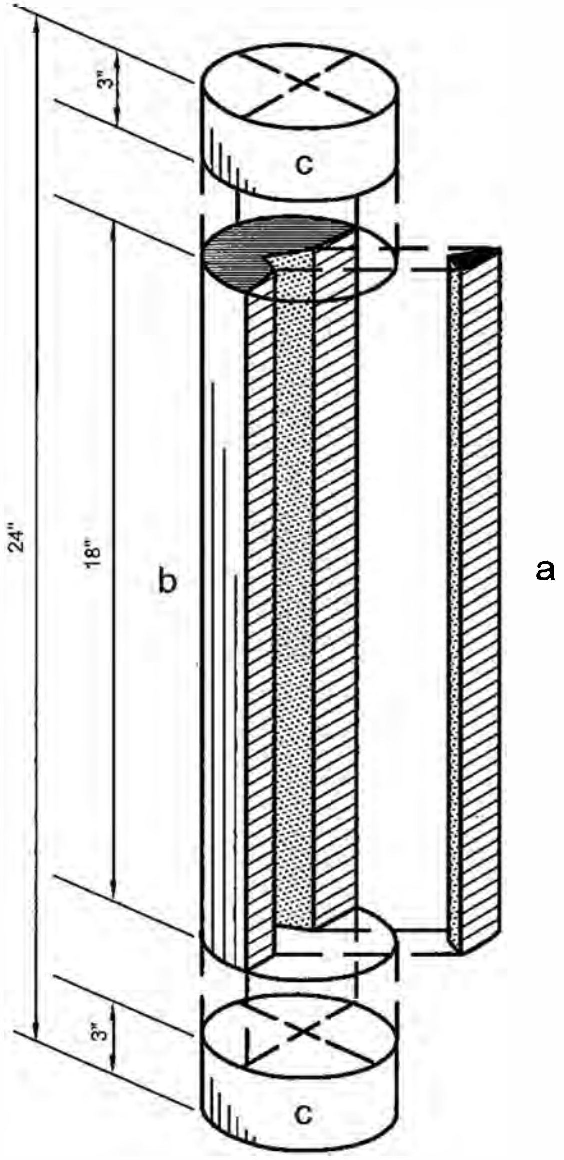
ASTM D1586-84 - Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D1587-94 - Practice for Thin-Walled Tube Geotechnical Sampling of Soils.

ASTM D2488-93 - Practice for Description and Identification of Soils (Visual-Manual Procedure).

EPA OSWER-9950.1, 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.

National Water Well Association, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. 1989.



TYPICAL SOIL CORE

a

PORTION OF SAMPLE FOR CHEMICAL ANALYSIS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT ACCEPTABLE

-STORAGE - REFRIGERATED (4°C)

-SHIPPING - ON ICE BY COURIER TO DESIGNATED LAB

b

PORTION OF SAMPLE TO BE RETAINED FOR GEOLOGIC RECORDS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT A PROBLEM

-CONTAINER: - CLEAN GLASS JAR
- CLEAR GLASS IS SUITABLE

-STORAGE - IN STANDARD SHIPPING CARTON
- NO REFRIGERATION REQUIRED

c

PORTION OF SAMPLE TO BE DISCARDED

-DISCARDED WITHIN 55 GALLON DRUM MAINTAINED ON-SITE

figure 2.3

SOIL SAMPLE SELECTION DETAILS

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BOREHOLE ABANDONMENT/SEALING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

The following procedure describes common techniques for the abandonment/sealing of overburden boreholes. Borehole completion may have been performed by a rotosonic drilling technique, direct push sampling device, hollow-stem augering/split-spoon sampling, solid-stem augering, or other soil sample collection techniques. The method of borehole abandonment selected for a program will be dependent on a number of factors such as: depth to groundwater, presence of contamination [and degree of contamination i.e., light or dense non-aqueous phase liquids (NAPL)], confining layer presence and/or physical setting (i.e., open field/vacant land, vs. facility setting). The Work Plan guiding these activities (soil boring/boring closure) will dictate which method of borehole abandonment/sealing is required. The borehole abandonment/sealing techniques reviewed in the following consist of:

- Soil cutting backfill;
- Bentonite chip backfill;
- Cement/bentonite grout backfill using tremie techniques; or
- Bentonite slurry using tremie techniques.

Boreholes need to be abandoned and sealed properly to prevent surface water entry to the groundwater regime, to eliminate any physical hazard, and to prevent/protect groundwater movement from one aquifer to another.

PROCEDURES REFERENCED

- FMG 2.3 - Soil Borings
- FMG 3.1 – Well Construction Materials

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

PROCEDURAL GUIDELINES

Soil Cutting Backfill

Typically employed when working above groundwater table and at shallow depths (maximum depth 2 feet).

- The final depth of borehole will be measured and recorded.
- Cuttings are dropped into borehole after sample equipment is removed.
- Drill rod and/or probe rodding is used to compact/compress cuttings to allow return of all cuttings back into borehole.
- Mound final surface of cuttings above ground surface to allow settlement and promote surface water runoff away from boring. Final restoration will be completed in accordance with needs of the CITGO Facilities representative and/or the CITGO Project Manager.
- Borehole abandonment will be documented in field records/notes.

Bentonite Chip Backfill

Typically employed when working above or just into the groundwater table.

- Excess cuttings have been drummed for disposal or excess cuttings have been spread at ground surface.
- The depth of the borehole will be measured and recorded.
- Bentonite chips (bentonite gravel) will be dropped into borehole as hollow-stem augers are removed, or after the boring equipment has been removed from the borehole (solid-stem auger, probing tools, split-spoon samplers).
- Sufficient water will be needed to hydrate bentonite chips as they are placed.
- The bentonite chip backfill will be extended to within 1 foot of ground surface, the final borehole space will be backfilled with native soil and mounded slightly to allow settlement and promote surface water runoff away from the boring. Alternatively, the borehole cuttings may be mixed with bentonite to complete the abandonment/sealing task. Final restoration will be completed in accordance with needs of the CITGO Facilities representative and/or the CITGO Project Manager.
- Borehole abandonment will be documented in field records/notes.

Cement/Bentonite Grout Backfill

Typically employed when working below the groundwater table, or in an area where a confining layer exists and the potential for groundwater/NAPL movement along a preferential pathway (i.e., former borehole) must be eliminated. Cement/bentonite grout sets up hard, like a soft concrete. If future site development is planned or excessive surface water may be present, neat bentonite grout may be preferred.

- The final depth of borehole will be measured and recorded.
- The volume of grout required will be calculated from the above measurements.
- A grout mix of one bag (94 pounds) of Portland cement and 3 pounds of bentonite with approximately 7.5 gallons of clean water will be prepared.
- Using a tremie tube placed at the base of the borehole the grout will be pumped until observed at the required elevation. The tremie tube will be raised as the grout level rises (positive displacement technique).
- The bentonite/grout backfill will be extended to within 1 foot of ground surface, the final borehole space will be backfilled with native soil and mounded slightly to allow settlement and promote surface water runoff away from boring. Final restoration will be completed in accordance with the CITGO Facility representative and/or the CITGO Project Manager.
- Borehole abandonment will be documented, noting depth of borehole, volume of grout used and mix ratio.
- Groundwater displaced from the borehole may or may not require containment depending on borehole setting and/or water quality.

Note: At the completion of borehole abandonment/sealing activities (regardless of methodology employed) it is necessary to check for surface settlement a few days after work completion to determine if the borehole area requires "topping off".

Final Restoration

The area around the borehole and the borehole surface shall be restored as directed by the CITGO Facility representative (e.g., asphalt, concrete, vegetation). Time for borehole settlement may be permitted, then final restoration performed; or alternatively final restoration may be required immediately in active interior work areas.

Cleanup

The area around the borehole shall be completely cleaned up of any investigation related materials (litter, etc.).

EQUIPMENT/MATERIALS

- Grout pump/mixing equipment.
- Form FMG 2.6-01 - Stratigraphic Log (Overburden) (Page 1/Page 2).

REFERENCES

ASTM D5299 "Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities.

United States Environmental Protection Agency (1992) "Guide to Management of Investigation-Derived Wastes", Quick Reference Fact Sheet.

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SOIL CLASSIFICATION

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SOIL CLASSIFICATION

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INTRODUCTION

The stratigraphic log is a factual description of the soil at the borehole location and is relied upon to interpret the soil characteristics, and their influence and significance in the subsurface environment. The accuracy of the stratigraphic log is to be verified by the person responsible for interpreting subsurface conditions. An accurate description of the soil stratigraphy is essential for a reasonable understanding of the subsurface conditions. Confirmation of the field description by examination of representative soil samples by the project geologist, hydrogeologist, or geotechnical engineer (whenever practicable) is recommended.

The ability to describe and classify soil correctly is a skill that is learned from a person with experience and by systematic training and comparison of laboratory results to field descriptions.

It is CITGO Remediation Team's Policy to log soils according to the Unified Soil Classification System (USCS) described in the following.

PROCEDURES REFERENCED

- FMG 2.1 - Test Pits
- FMG 2.3 - Soil Borings

PROCEDURAL GUIDELINES

Several methods for classifying and describing soils or unconsolidated sediments are in relatively widespread use. The Unified Soil Classification System (USCS) is the most common. With the USCS, a soil is first classified according to whether it is predominantly coarse-grained or fine-grained.

The description of fill soil is similar to that of natural undisturbed soil except that it is identified as fill and not classified by USCS group, relative density, or consistency. Those logging soils must attempt to distinguish between soils that have been placed (i.e., fill) and not naturally present; or soils that have been naturally present but disturbed (i.e., disturbed native).

It is necessary to identify and group soil samples consistently to determine the subsurface pattern or changes and non-conformities in soil stratigraphy in the field at the time of drilling. The stratigraphy in each borehole during drilling is to be compared to the stratigraphy found at the previously completed boreholes to ensure that pattern or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observations and manual tests (adapted from ASTM D2488, visual-manual procedures) are used to classify and group soil samples in the field and are summarized in this subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. Visual-manual procedures used for soil identification and classification include:

- Visual determination of grain size, soil gradation, and percentage fines.
- Dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) tests for identification of inorganic fine-grained soil (e.g., CL, CH, ML, or MH).
- Soil compressive strength and consistency estimates based on thumb indent and pocket penetrometer (preferred) methods.

The three main soil divisions are: coarse-grained soil (e.g., sand and gravel), fine-grained soil (e.g., silt and clay), and soil with high natural organic matter content (e.g., peat and marl).

Coarse-grained Soil

The USCS group symbols for coarse-grained soil are primarily based on grain or particle size, grain size distribution (gradation), and percent fines (silt and clay content).

Coarse-grained soils are then further subdivided according to the predominance of sand and gravel. Coarse-grained soil is made up of more than 50 percent, by weight, sand size, or larger (75 μm diameter, No. 200 sieve size or larger). It is noted that there are other definitions for coarse-grained or coarse textured soil and for sand size in other soil classification systems, such as soil having greater than 70 percent particles equal to or greater than 50 μm diameter.

Descriptions for grain size distribution of soil include; poorly graded (i.e., soil having a uniform grain size or missing grain size fractions (gap graded), SP and GP) and well graded (i.e., poorly sorted; having wide range of particle sizes with substantial intermediate sizes, SW and GW).

Coarse-grained soils are further classified based on the percentage of silt and clay it contains (fines content). Coarse-grained soils containing greater than 12 percent fines is commonly described as dirty. This description arises from the soil particles that adhere when the soil is rubbed between the hands or adhere to the sides of the jar after shaking or rolling the soil in the jar. The jar shake test which results in segregation of the sand and gravel particles is also used as a visual aid in determining gravel and sand percentages.

Examples of the group symbol, name, and adjectives used to describe the primary, secondary, and minor components of soil are; GW - Sandy Gravel (e.g., 70 percent gravel and 30 percent sand) or Sandy Gravel trace silt (less than 10 percent silt), and SP - Sand, uniform.

Relative density is an important parameter in establishing the engineering properties and behavior of coarse-grained soil. Relative density of non-cohesive (granular) soil is determined from standard penetration test (SPT) blow counts (N values) (after ASTM Method D1586).

The SPT gives a reliable indication of relative density in sand and fine gravel. N values in coarse-grained soil are influenced by a number of factors that can result in overestimates of relative density (e.g., in coarse gravel and dilatent silty fine sand) and can be conservative and underestimate the relative density (e.g., sand below the groundwater table and uniform coarse sand). These effects will be assessed by the project geotechnical engineer, if required, and need not be taken into account by field personnel.

Other dynamic methods, such as modified SPT and cone penetration tests, are used on occasion to supplement or replace the SPT method for certain site-specific conditions. The details of all modifications to the SPT or substitute methods should be recorded as they are required to interpret test results and correlate to relative density.

Fine-grained Soil

A soil is fine-grained if it is made up of half or more of clay and silt [i.e., fines greater than 50 percent by weight passing the 75 μm (No. 200) sieve size]. A description of visual-manual field methods and criteria (after ASTM D2488) that are used to further characterize and group fine-grained soil (e.g., CL, CH, ML, or MH) including dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) follows. Fine-grained soils are subdivided on a basis of the liquid limit and the degree of plasticity.

The accurate identification of silts and clays can be aided by the use of some single field tests. Clay is sticky, will smear readily, and can be rolled into a thin thread even when the moisture content is low. When it is dry, clay forms hard lumps. Silt on the other hand, has a low dry strength, can be rolled into threads only at high moisture content, and a wet silt sample will puddle when it is tapped.

Criteria for Describing Dry Strength

Description	***Criteria***
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.

Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen crumbles into powder with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

Criteria for Describing Dilatancy

Description	***Criteria***
None	No visible change in small wetted specimen when rapidly shaken in palm of hand.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing or stretching.

Criteria for Describing Toughness

Description	***Criteria***
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

Criteria for Describing Plasticity

Description	***Criteria***
Nonplastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Examples of group symbol identification based on visual-manual procedures and criteria for describing fine-grained soil are:

Group Symbol	***Dry Strength Plasticity***	***Dilatency***	***Toughness***
ML	None to low Slight	Slow to rapid	Low or thread cannot be formed
CL	Medium to high Low	None to slow	Medium
MH	Low to medium Low	None to slow	Low to medium
CH	High to very high High	None	High

A requirement for positive classification by USCS group symbols (as described in Test Method ASTM D2487) is laboratory determination of particle size characteristics, liquid limit and plasticity index. The need for this type of testing will be determined by the project geologist, hydrogeologist, or geotechnical engineer.

Examples of name terminology that accompanies the group symbols are ML - Sandy Silt (e.g., 30 percent sand) and CL - Lean Clay with sand (e.g., 15 to 29 percent sand).

The correlation between N value and consistency for clays is rather unreliable. It is preferable to determine consistency using more appropriate static test methods, particularly for very soft to stiff clay soil. N value estimates of consistency are more reasonable for hard clay.

Unconfined compressive strength (Su) may be estimated in the field from the pocket penetrometer test method. To obtain a pocket penetrometer estimate of consistency and compressive strength, the soil core is cut perpendicular to the core length, the length of core (minimum 4 inches) is held in the hand and a moderate confining pressure is applied to the core (not sufficient to deform the core); the penetrometer piston tip is slowly inserted into the perpendicular face of the core until the penetrometer indents into the soil core to the mark indicated on the tip of the penetrometer piston; the penetrometer estimate of soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft (in tons per square foot or other unit of pressure as indicated) indicated by the shaft ring marker, or in some models, by the graduated piston reading at the shaft body. To obtain an average estimate, this procedure is completed several times on both ends and mid cross-section of the core. For Shelby tube (or thin wall sampler) samples the pocket penetrometer tip is applied to the exposed bottom of the sample at several locations.

Estimates of compressive strength for clay soil of very soft to stiff consistency are better established by in situ shear vane tests or other static test methods.

The description of consistency (or strength) is an important element in determining the engineering properties and strength characteristics of fine-grained cohesive soil. Consistency terms (e.g., soft, hard) are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil.

The ease and pattern of soil vapor and groundwater movement in the subsurface is influenced by the natural structure of the soil. Soil structure, for the most part, depends on the depositional environment and, to a lesser extent, climate.

Visual Appearance/Other Features

Those logging soils should also note the presence, depth and components of fill soils (if evident) and note the distinction between disturbed native soils (i.e., excavation likely performed) vs. undisturbed native soils.

Other features such as color, root presence/structure, and soil fractures should also be recorded. Soil fractures should be described noting fracture orientation (i.e., horizontal/vertical), length/aperture and appearance of soil infilling, oxidation and/or weathering (if present).

Field Sample Screening

Upon the collection of soil samples, the soil is screened with a photoionization detector (PID) for the presence of organic vapor. This is accomplished by running the PID across the soil sample. Record the highest reading and sustained readings.

Note: The PID measurement must be done upwind of the excavating equipment or any running engines so that exhaust fumes will not affect the measurements.

Another method of field screening is head space measurements. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. Alternatively, plastic sealable bags maybe utilized for field screen in lieu of glass containers. The jar should only be partially filled. Shake the jar and set aside for at least 30 minutes. After the sample has equilibrated, the lid of the jar can be opened; the foil is punctured with the PID probe and the air (headspace) above the soil sample is monitored. Record this headspace reading on the field form or in the field book. The selection of samples for chemical analysis may be specified in the Work Plan or be dependent in part on the PID responses.

Note: Perform all headspace readings in an area that is not subject to wind. Also, in the winter, it is necessary to allow the samples to equilibrate in a warm area (e.g., site trailer, van, etc.). This requirement is dictated by the Work Plan.

All head space measurements must be completed under similar conditions to allow comparability of results.

NAPL Detection

During soil examination and logging, the sampler shall carefully check for the presence of light or dense non-aqueous phase liquid (NAPL). NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

Visual Description	***Fraction of Soil Pore Volume Containing NAPL***
Saturated	>0.5
Some	0.5 to 0.25
Trace	<0.25

A complete description of NAPL, must describe the following:

- Color.
- Quantity.
- Density (compared to water i.e., light/floats or heavy/sinks).
- Odor (if observed).
- Viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like).

The presence of an "iridescent sheen" by itself does not constitute "NAPL presence", but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense), from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, [i.e., separate soil by hand (wearing disposable gloves)] and perform a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during the sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are several more sophisticated tests available to confirm/identify NAPL presence, these are:

- UV fluorescent analysis.
- Hydrophobic dyes.
- Centrifugation.
- Chemical analysis.

Typically consultants will utilize organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

Note: When describing the presence of vegetative matter in the soil sample, do not use the term "organic" as this often leads to confusion with regards to the presence of organic chemicals (i.e., NAPL).

EQUIPMENT/MATERIALS

- Pocket knife or small spatula.
- Small handheld lens.
- Form FMG 2.6-01 - Stratigraphic Log - Overburden (Page 1/Page 2).
- Tape measure.

REFERENCES

American Society for Testing and Materials (1991), Standard D1452-80, "Practice for Soil Investigation and Sampling by Auger Borings", "Annual Book of ASTM Standard", Section 4, Volume 04.08.

ASTM Standards on Environmental Sampling (1995), Standard D2488-93, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)"

ASTM Standards on Environmental Sampling (1995), Standard D4700-91, "Guide for Soil Sampling from the Vadose Zone".

ASTM Standards on Environmental Sampling (1995), Standard D1586-92, "Test Method for Penetration Test and Split-Barrel Sampling of Soils".

ASTM Standard D2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)".

Geotechnical Gauge, Manufactured by W.F. McCollough, Beltsville, MD.

Sand Grading Chart, by Geological Specialty Company, Northport, Alabama.

Stratigraphy Log (Overburden)

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Project name ______________________
Project number ______________________
CITGO Site ______________________
Location ______________________

Drilling contractor ______________________
Driller ______________________
Surface elevation ______________________
Weather (A.M.) ______________________
(P.M.) ______________________

Hole designation ______________________
Date/Time started ______________________
Date/Time completed ______________________
Drilling method ______________________
Supervisor ______________________

Stratigraphic Intervals (Depths in ft/m BGS)			**Sample Description**	**Sample Details**										**Chemical Analysis**	**Grain Size/ Other Analysis**
			Order of descriptors: Soil type symbol(s) - primary component(s), (nature of deposit), secondary components, relative density/consistency, grain size/plasticity, gradation/structure, colour, moisture content, supplementary descriptors.			**Penetration Record Split Spoon Blows (Record N-Values & Recoveries)**									
From	**At**	**To**	**Note: Plasticity determination requires the addition of moisture if the sample is too dry to roll (indicate if moisture was added or not).**	**Sample Number**	**Sampling Method**	**6"**	**6"**	**6"**	**6"**	**N**	**R**	**Sample Interval**	**PID/FID (ppm)**		

Notes and Comments

Depth of borehole caving ____________________ Depth of first groundwater encounter ____________________ Topsoil thickness ____________________
Water level in open borehole on completion ____________________ After ____________________ Hours ____________________
Notes: ____
____
____

Soil Classification System (U.S.C.S.)
(ASTM D2488 Visual-Manual Procedure)

Major Divisions			Group Symbol	Typical Description
Highly Organic Soils (see note below)			PT	Peat and other highly organic soils
Coarse-Grained Soils (more than half by weight larger than no. 200 sieve size)	Gravels more than half of coarse fraction larger than no. 4 sieve size	"Clean" Gravels	GW	Well graded gravel, gravel-sand mixtures, ≤ 5% fines
			GP	Poorly graded gravels and gravel-sand mixtures, ≤ 5% fines
		"Dirty" Gravels	GM	Silty gravels, gravel-sand-silt mixtures, ≥ 15% fines
			GC	Clayey gravels, gravel-sand-clay mixtures, ≥ 15% fines
	Sands more than half of coarse fraction smaller than no. 4 sieve size	"Clean" Sands	SW	Well graded sands, gravelly sands, ≤ 5% fines
			SP	Poorly graded sands, or gravelly sands, ≤ 5% fines
		"Dirty" Sands	SM	Silty sands, sand-silt mixtures, ≥ 15% fines
			SC	Clayey sands, sand-clay mixtures, ≥ 15% fines
Fine-Grained Soils (more than half by weight passes no. 200 sieve size)	Silts below "A" line on plasticity chart; negligible organic content		ML	Inorganic silts and very fine sand, rock flour, silty sands of slight plasticity
			MH	Inorganic silts, micaceous or diatomaceous, fine sandy or silty soils
	Clays above "A" line on plasticity chart; negligible organic content		CL	Inorganic clays of low to medium plasticity, gravelly, sandy, or silty clays, lean clays
			CH	Inorganic clays of high plasticity, fat clays
	Organic silts & organic clays below "A" line on plasticity chart		OL	Organic silts and organic silty clays of low plasticity
			OH	Organic clays of high plasticity

Note:

Use dual symbols for coarse-grained soils if soil is estimated to contain 5% to 15% fines (equals "with").

Non-Cohesive (Granular) Soil

Relative Density	Blows Per Foot (N-Value)
Very Loose	Less than 5
Loose	5 to 9
Compact	10 to 29
Dense	30 to 50
Very Dense	Greater than 50

Cohesive (Clayey) Soil

Consistency	Blows Per Foot (N-Value)
Very Soft	0 to 2
Soft	3 to 4
Firm	5 to 8
Stiff	9 to 15
Very Stiff	16 to 30
Hard	Greater than 30

Grain Size Classification
(based on standard sieve sizes)

Cobbles		Greater than 3 inches (76 mm)
Gravel		3 in. to No. 4 (4.76 mm)
	Coarse Gravel	3 in. to 3/4 in.
	Fine Gravel	3/4 in. to No. 4 (4.76 mm)
Sand		No. 4 (4.76 mm) to No. 200 (0.074 mm)
	Coarse Sand	No. 4 (4.76 mm) to No. 10 (2.0 mm)
	Medium Sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
	Fine Sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt		No. 200 (0.074 mm) to 0.002 mm
Clay		Less than 0.002 mm

Component Percentage Descriptors
(estimate to nearest 5%)

Coarse Grained Soils	
Noun(s) (e.g., sand, gravel)	Major Component
Adjective (e.g., silty, clayey)	Greater than 15%
With (e.g., with silt, with clay)	5% to 15%
Trace (e.g., trace silt, trace clay)	Less than 5%

Fine Grained Soils	
Noun(s) (e.g., silt, clay)	Major Component
Adjective (e.g., sandy, gravelly)	Greater than 30%
With (e.g., with sand)	15% to 30%
Few (e.g., few sand)	5% to 15%
Trace (e.g., trace sand)	Less than 5%

Soil Structure Terms

Stratified
Laminated
Fissured
Blocky
Lenses/Seams
Homogeneous

Moisture

Dry
Moist
Wet

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WELL CONSTRUCTION MATERIALS

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WELL CONSTRUCTION MATERIALS

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INTRODUCTION

In environmental subsurface investigations, the information used to evaluate subsurface conditions often relies heavily on the installation of quality groundwater monitoring wells. The application and use of the proper well construction materials to the specific well installation is crucial to obtaining representative and reliable groundwater samples.

The two general types of wells are groundwater monitoring wells and pumping (also referred to as recovery, extraction, or withdrawal) wells. The specific use of a groundwater well dictates the types of materials used to construct it.

This FMG outlines the general types and use of well construction materials and considerations involved in selecting appropriate materials for specific well installation applications. Installation of these materials are described in detail in the specific well installation FMGs listed below.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden and Top of Rock Wells
- FMG 3.3 - Deep Bedrock Wells
- FMG 3.4 - Pump Wells
- FMG 3.5 - Piezometers

EQUIPMENT DESCRIPTIONS

Well Screen

Well screen is the portion of the well pipe that contains appropriately sized openings and allows groundwater to enter the well. The screen materials used in groundwater monitoring wells are crucial to ensuring the installation of an efficient, productive, and durable groundwater well.

The diameter of the well screen is generally dependent upon the application of the well. For monitoring wells used in groundwater level measurements and groundwater sampling, screen diameter will generally be 2.0-inch inner diameter (ID) flush-threaded screen segments (piezometers are typically 1.0-inch ID but may be 2-inch also). These screen segments are typically available in 10-foot lengths. Four-inch diameter or larger well screens are usually reserved for recovery or production well applications where larger diameters permit greater groundwater withdrawal rates. Larger diameter wells also allow a well to serve additional functions such as housing oil recovery systems.

Screen material will be either thermoplastic Schedule 40 polyvinyl chloride (PVC) (ASTM D1785, ASTM D2665, ASTM F480) or Schedule 5 Type 316 stainless steel, depending primarily on the depth of the well and the groundwater quality (degree and nature of contamination). Shallower depths and generally low levels of contaminants in groundwater allow for PVC applications, whereas greater depths and severely degraded groundwater quality, or the presence of free-phase oils or solvents, may necessitate stainless steel due to its greater strength and resistance to chemical degradation. It should be noted that PVC and stainless steel are appropriate for the vast majority of environmental applications and are generally accepted by regulatory agencies. Well materials other than PVC or stainless steel should be used only in certain instances, to be determined and approved by the Project Manager on a case-by-case basis.

Certain applications such as investigation of inorganic (metals) concentrations in groundwater, or the presence of low pH (acidic) conditions, may preclude the use of stainless steel wells. Stainless steel, which contains molybdenum in addition to its iron content, may leach out metal compounds which could lead to misleading groundwater analysis results.

PVC may likewise leach out or degrade specific thermoplastic elements of its composition which may compromise the well integrity or groundwater analyses. PVC generally performs well in acidic groundwater conditions; however, it may degrade in the presence of certain organic compounds such as ketones, aldehydes, or chlorinated compounds in high concentrations. Certain additives to the PVC may also affect groundwater quality.

Well screen slot sizes and well screen type will also be consistent for groundwater monitoring wells. Screen slot size is typically 0.010 inches; 0.020-inch slot size may be more appropriate for coarser formation materials or where the well may serve as a recovery well for free-phase oils. For monitoring applications, slot type should be either factory machine-slotted or continuous-wrap slotted. Perforated, bridge-slotted or louver-slotted well screens are generally not acceptable for most environmental applications and should be avoided.

Screen slot sizes may vary from these two sizes when used in production or recovery (pumping) well applications where the need to maximize groundwater withdrawal is essential. In such cases, screen slot sizes can be manufactured to exact specifications for a particular well based on particle size analysis results and formation transmissivity or permeability.

Well Riser Pipes and Casings

Well riser pipe is a solid extension of the well screen that extends from the screen up to the surface. The riser pipe protects the well screen, prevents outside groundwater from entering the well, and allows groundwater pumped from down in the open interval to be routed up through the well to the surface.

Well riser pipe should be of the same material and size as the well screen described above. In instances to be determined and approved by the Project Manager on a case-by-case basis only, differing materials may be approved for use in the same well (e.g., stainless steel well screen connected to PVC riser). Well risers should extend to the surface and should either be cut at grade in flush-mount completions or as an approximately 3-foot stickup to be covered with a steel protective casing.

Well riser pipe sections shall be flush-threaded and fitted with neoprene, rubber, or other appropriately constructed, durable o-rings to properly seal the threaded pipe joints. Glues or cements are not to be used in well construction.

In installations of bedrock monitoring wells, which have an open rock monitoring interval and a permanent well casing that extends from bedrock to the surface, the permanent casing (or casings in telescoping wells) shall be made of carbon steel or low-carbon steel (greater than 0.8 percent carbon and less than 0.8 percent carbon, respectively). The well casing should be a minimum of 4 inches in diameter (at least 4 inches diameter for the innermost casing).

On sites wells where dense, non-aqueous phase liquid (DNAPL) is present or may be a concern, in screened wells it is advisable to install a collection sump on the base of the well below the well screen to collect infiltrated DNAPL for possible measurement and/or sampling. Sumps should be installed as a 1- to 5-foot section of solid riser material with a sealed bottom placed below the well screen.

Sand Packs

The filter pack, or sand pack, installed in a well replaces formation material immediately around a well with a more permeable material (sand). The sand pack separates the well screen from the formation, increases the hydraulic diameter of the well, and prevents fines (silt or clay) from entering or clogging the well screen.

Sand pack of an appropriate size shall be utilized based on the well screen slot size being used. Sand pack size should be chosen so that the majority of the sand (sand pack has inherent variation in its particle grain size distribution) is larger than the screen slot size while sized small enough to prevent deleterious amounts of formation fines from entering the well through the sand pack. Screen slot sizes of 0.010-inch and 0.020-inch typically use a sand pack such as Morie or U.S. Silica No. 1, No. 0, No. 00N, or equivalent.

Sand pack shall be washed silica sand with a silica content of at least 95 percent. Sands should meet one or more of the following requirements: NSF 61, AWWA B-100, ANSI, or equivalent standards for uniformity and chemical inertness. In cases to be determined and approved by the Project Manager on a case-by-case basis only, differing sand pack materials may be approved for use in a well. Sand packs used for production and recovery wells with larger screen slot sizes will use larger particle sized sand packs of the same type and quality. The slot size and sand pack size for recovery wells should be chosen based on results of formation grain size distribution analysis.

Seals

Bentonite and grout seals are installed above the sand pack to isolate the monitoring interval and prevent groundwater from infiltrating into the well screen from other water-bearing zones. Seals also prevent migration of backfill or formation materials downward into the sand pack.

Bentonite is the generic name for a group of a naturally occurring clay minerals (montmorillonites) that come in a variety of forms: pellets, chips, granulated, or powdered. This material is commercially available as "Wyoming Bentonite". When hydrated it swells to many times its original volume and forms an ultra-low permeability clay seal.

Bentonite chips or pellets are generally used to create a seal immediately above the sand pack. The chips/pellets are dropped inside the augers or well casing by hand down through the water column onto the top of the sand pack. Care must be taken to prevent "bridging" of the bentonite particles in the casing above the target zone. Measurements of the depth to the top of the seal must be obtained during installation of the seal to ensure its proper position and thickness. In the absence of significant water in a casing or borehole, potable water must be added to hydrate the bentonite. The bentonite seal will be allowed to set for a minimum of one-half hour, in order to hydrate properly, before additional seals (grout) are applied. Once the bentonite has set for one-half hour the grout seal may be placed, as described below.

In saline groundwater environments, such as where ocean water may infiltrate the monitoring interval, a zeolite-based seal material may be used, as saline conditions may hamper the performance of bentonite pellets.

Portland cement grout (grout) forms a concrete-like seal that can be more manageable than bentonite (e.g., able to be pumped through a water pump). Grout is generally placed on top of the hydrated bentonite seal to form a solid cement seal around the well riser up to the surface. In certain circumstances, only under approval of the CITGO Project Manager, soil cuttings may be used to backfill the borehole in lieu of grout.

The grout mixture will consist of one 94-pound bag of Portland cement and 3 to 5 pounds of powdered bentonite added per sack of cement. Two pounds of calcium chloride may also be added (under certain conditions, e.g., very cold days) to accelerate the setting time of the grout, as well as to increase the dry strength of the grout. The grout will be thoroughly mixed with 6.5 gallons of potable water per sack of cement. Grout is generally placed using either the tremie or Halliburton grouting methods. These are described in the specific well installation FMGs.

Protective Casings and Surface Seals

Once the well screen, riser, and all seals have been placed to ground surface, the well riser must be protected. This includes protection from vehicles, damage, surface water infiltration, and weather. This is typically accomplished using either a flush-mount roadbox or a stickup casing.

Flush-mount roadboxes are circular steel casing segments with a heavy-duty steel lid with locking bolts. These units are widely available and come in a number of diameters and lengths, depending on the well diameter. A stickup protective casing is generally a length of carbon or stainless-steel pipe with a locking top.

For a typical 2-inch monitoring well, the roadbox should be at least 6 inches in diameter; a stickup casing should be at least 4 inches in diameter. A roadbox should be at least 12 inches in length (they are typically 16 to 18 inches long) and is installed flush with the ground surface. A stickup casing should be at least 5 to 6 feet long such that approximately 2.5 to 3 feet is below ground surface and 2.5 to 3 feet is protruding above grade. In wells where a permanent steel casing is installed (serves as the well riser pipe) and brought to the ground surface, it may be used as the protective casing provided it is equipped with a semi-permanent, metal, locking cap or cover that can be affixed to the steel casing.

Flush-mount installations should have at least the last 18 inches of the open borehole filled with coarse sand, placed up to ground surface to allow drainage of surface water infiltration down through and out of the roadbox. This also prevents infiltrating surface water from accumulating up over the top of the well riser and draining down into the well. This sand drain is not necessary in the locking cap stickup casings.

Both roadbox and stickup casings must be secured in the ground with concrete, which also serves as a surface seal.

In areas of high vehicle traffic activity, protective steel bollards should be installed. This is typically a vertically oriented, concrete-filled, steel pipe (minimum 4 inches diameter) cemented at least 3 feet into the ground, acting as a "guard rail" for the well casing and preventing it from being damaged by vehicles. Three bollards should be placed around a well to provide adequate protection.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Well screen and riser materials.
- Sand pack.
- Bentonite pellets/chips.
- Powdered bentonite.
- Portland cement.

REFERENCES

ASTM D1785-99, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

ASTM D2665-00, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.

ASTM F480-00, Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and Schedule 80.

ASTM A53/A53M-01, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless for Ordinary Uses.

Campbell, M.D., and Lehr, J.H., Water Well Technology, McGraw Hill, 1973.

Cold Weather Concreting, ACI Committee 306, Materials Journal, Volume 85, Issue 4, July 1, 1988.

Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.

Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.

USEPA, 1986, RCRA Groundwater Monitoring Technical Enforcement Guidance Document, Office of Solid Waste and Emergency Response, 1986.

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OVERBURDEN AND TOP OF ROCK MONITORING WELL INSTALLATION

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure describes procedures for the installation of overburden groundwater monitoring wells.

PROCEDURES REFERENCED

- FMG 1.3 – Utility Clearance
- FMG 2.2 – Drilling Techniques
- FMG 3.1 – Well Construction Materials
- FMG 3.7 – Well Development
- FMG 6.15 – PFAS/PFOA Sampling
- FMG 9.0 – Equipment Decontamination
- FMG 10.0 – Waste Characterization

EQUIPMENT/MATERIALS

The following lists the equipment and materials used for the installation of overburden wells.

1. Site Plan, Field Sampling Plan, and/or Work Plan, with proposed soil boring/monitoring well locations.
2. Personal protective equipment (PPE) as required by the site-specific Health and Safety

Plan (HASP).

3. Drilling equipment appropriate for the site and investigation objectives.
4. Well construction materials appropriate for the intended use of the groundwater monitoring well. FMG 3.1 – Well Construction Materials outlines the general types and use of well construction materials, and considerations involved in selecting materials for specific well applications.
5. Water level meter.
6. Weighted tape measure, graduated in tenths of a foot.
7. Electronic water level probe.
8. Locks and keys for locking the completed groundwater monitoring wells.
9. A heavy-duty folding ruler for measuring soil sample recovery and noting stratigraphic changes.
10. Permanent marker for labeling the well cover or casing.

DRILLING PROCEDURES

FMG 2.2 – Drilling Techniques presents descriptions of various drilling methods that are available, including rotosonic, direct-push, hollow-stem auger, rotary spun casing, and dual-wall reverse circulation air techniques. Regardless of the method chosen, the following procedures will be followed:

- Construct a temporary decontamination pad from plywood sheets, 2 X 6 boards and 6-millimeter (minimum thickness) plastic capable of fitting the drill rig. An alternate containment structure may be used as long as it is suitable to contain the decontamination waste material.
- Drilling and sampling equipment will be decontaminated prior to drilling, between samples that are being collected for laboratory analysis, and prior to leaving the site in accordance with the FMG 9.0 – Equipment Decontamination.
- No oils or grease will be used on equipment introduced into the borehole.
- Environmental grade grease may be used to lubricate drill threads (for per- and polyfluroalkyl substances (PFAS)/perfluorooctanoic acid (PFOA) use restrictions if sampling for PFAS/PFOA, see FMG 6.15 – PFAS/PFOA Sampling).
- Drilling-generated waste materials will be characterized in accordance with FMG 10.0 - Waste Characterization.
- The depth to the target interval may be determined from an existing adjacent monitoring well/boring or from information obtained from sampling the borehole. The criteria for determining the target interval to be monitored will be presented in the project Work Plan. Typically, an 8-inch diameter borehole will be advanced to the target interval, although a larger- or smaller-sized borehole may be necessary based on the objectives of the

groundwater monitoring program. For example, a larger diameter sand pack may be desirable to limit the mobilization of particulates from the soil column in response to sampling activities, or a smaller diameter well and sand pack may be practical due to access limitations.

- Unless otherwise approved, a minimum annular space of one inch should be maintained between the well casing and the borehole casing or augers to facilitate proper placement of the sand pack and seal materials and to minimize the chance for “bridging” of the materials.
- In instances where the borehole is advanced deeper than the target interval, a hydrated bentonite pellet seal will be installed to bring the bottom of the boring to within 6 inches of the target interval. Six inches of filter sand will then be placed above the bentonite seal prior to installing the well to prevent the introduction of clay particles into the well.
- In some areas where the water table is known to be at or near the top of bedrock, the base of the overburden well may be installed at the top of bedrock.

WELL INSTALLATION

The well installation procedures presented below are the recommended guidelines. Due to variations in subsurface conditions, changes in these well installation guidelines may be necessary (e.g., to accommodate installation of the protective casing in instances where the water table is very shallow, or to properly monitor a thin water bearing unit).

Well construction materials are discussed in FMG 3.1 – Well Construction Materials. Well screen lengths of 5 or 10 feet are typically used; however, other screen lengths may be applicable depending on subsurface conditions. Water table monitoring wells will be constructed with the screen straddling the water table, and with approximately 7 feet of a 10-foot well screen or 3-feet of a 5-foot well screen extending below the water table. The screen placement should allow for fluctuation in groundwater levels, and well screen lengths may need to be increased if groundwater is known to fluctuate more than a few feet. Monitoring wells installed in confined aquifers should center on the permeable confined unit without overlapping across impermeable unit and possibly cross-connecting vertical aquifers.

Top of Rock (TOR) monitoring wells should be constructed in such a fashion that the bottom of the well screen is placed on the top of the bedrock. Depending on project requirements, a sump consisting of blank well casing material, may be installed to the bottom of the well screen and sumped a couple of feet into the rock to measure and possible collect suspected DNAPL. When installing TOR monitoring wells, a temporary casing should be utilized during the installation process to minimize contamination drawdown and seal off overlying aquifers.

Once the target well depth is reached, a pad of sand is placed below the base of the well screen and the well materials are placed in the borehole. As the augers or drill casing are slowly removed, sand filter pack is placed in the annular space around the well screen and casing from the base of the screen to approximately 2 feet above the screen. A shallow water table may necessitate a shorter sand pack. The filter pack shall consist of clean, uniform, well-rounded silica sand of an appropriate size based on the screen slot size being used and the soil particle size in the screened interval, as specified in the Work Plan and/or dictated by site conditions. The types of sand used as filter pack are discussed in detail in FMG 3.1 – Well Construction Materials.

A hydrated bentonite seal with a minimum thickness of 2 feet is placed above the sand pack. If the water table elevation is at least several feet above the top of the sand pack, a 2-foot thick (minimum) layer of bentonite pellets will be placed above the sand pack using a tremie pipe. No coated bentonite pellets will be used in monitoring well drilling or construction, due to the potential for cross-contamination. The seal will be hydrated and allowed to set for approximately 45 minutes. Granular or flaked pH-neutral bentonite will be hydrated and used for seals placed above the water table. The types of sealing and grouting materials are discussed in detail in FMG 3.1 – Well Construction Materials. Grout should not be used directly above or below the sand pack without a hydrated bentonite seal.

During the placement of the sand pack and bentonite seal, a weighted tape will be employed to provide constant measurements and help prevent bridging. Above the bentonite seal, Portland cement grout containing three to five percent bentonite will be tremied into place. If the total well depth is 20 feet or less, the bentonite seal may be extended to the base of the surface seal. The augers or drill casing will be gradually pulled during the addition of the filter pack, bentonite seal and cement-bentonite grout seal.

Accurate measurements of the material depths will be made during installation. The volume of materials needed will be calculated and compared to the actual volume used. Materials used, and depths of placement will be recorded on FMG 3.2-01 – Overburden Well Installation Report.

The well casing will be secured with a vented lockable cap. If the well is located in a high traffic area, the casing will be protected by a flush-mounted roadway box installed with a sand drain and set in a concrete seal. It is recommended that the surface seal extend a minimum of three inches outside the well casing, to allow for a proper seal and to resist damage from frost. A lockable gripper plug must be installed at the top the inner well casing. In cases where the well is in a flowing artesian condition, an inflatable packer may be used to prevent the groundwater from discharging to the surface. Alternatively, in low traffic areas, the well casing may be cut above grade and completed with 4- or 6-inch diameter steel protective, lockable, casing with approximately 3 ft of stick up, set in a concrete surface seal. Details regarding the type of appropriate well covers and concrete surface seals are contained in FMG 3.1 – Well Construction Materials.

After installation, the monitoring well will be labeled with the well identification and a reference point for water level and depth measurements will be marked on the inner well casing. The well will also be locked unless deemed unnecessary by the CITGO Project Manager. Locks placed on site monitoring wells should be keyed alike and made of material that is resistant to corrosion such as heavy-duty aluminum alloy with a chrome-plated hardened steel shackle, brass tumbler, and double steel locking mechanism (e.g., American Lock® brand locks or similar). The well will be allowed to sit for at least 24 hours prior to well development to allow grout to harden, in accordance with FMG 3.7 – Well Development. Following installation, tie-in measurements to a minimum of two nearby site features will be made and recorded. Monitoring wells will generally be surveyed following their installation.

DOCUMENTATION OF WELL DESIGN AND CONSTRUCTION

The following information regarding the design and construction of each well will be recorded on the form FMG 3.2-01 – Overburden Monitoring Well Installation Report, or equivalent:

- Date/time of installation;
- Drilling method;
- Surveyed well location;
- Borehole diameter and well diameter;
- Well depth;
- Screened Interval;
- Casing materials;
- Screen materials and design;
- Screen slot size/length;
- Filter pack material/grain size;
- Sealant materials (percent bentonite);
- Sealant materials (lbs./gallon of cement);
- Sealant placement method;
- Surface seal design/construction;
- Type of protective well cap; and
- Detailed drawing of well.

EQUIPMENT CLEANING

Drilling equipment and well materials (casing and screen) will be cleaned using high-pressure steam-cleaning equipment and potable water, in accordance with FMG 9.0 – Equipment Decontamination. Drilling equipment will be cleaned prior to use on the site, between monitoring well locations, and at the completion of the drilling program, prior to leaving the site.

DISPOSAL METHODS

All Investigation-Derived Waste (IDW), including water generated during decontamination procedures will be handled in accordance with the site waste disposal plan in coordination with the Client and the site Resource Manager (RM), and FMG – 10.0 – Waste Characterization.

REFERENCES

American Society for Testing and Materials (ASTM) (1991), Standard D1452-80, "Practice for Soil Investigation and Sampling by Auger Borings", Annual Book of ASTM Standard, Section 4, Volume 04.08.

American Society for Testing and Materials (1991), Standard D5092, "Practices for Design and Installation of Ground Water Monitoring Wells in Aquifers", Annual Book of ASTM Standard, Section 4, Volume 04.08.

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.

Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.

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Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.

Form FMG 3.2 - 01

OVERBURDEN MONITORING WELL INSTALLATION REPORT

Well No.

Boring No.

PROJECT ______________________

LOCATION ______________________

CLIENT ______________________

CONTRACTOR ______________________

DRILLER ______________________

PROJECT MANAGER ______________________

FIELD REP. ______________________

DATE INSTALLED ______________________

WATER LEVEL ______________________

Ground Elev. ____________ ft

Top of Casing Elev. ____________

Location ______________________

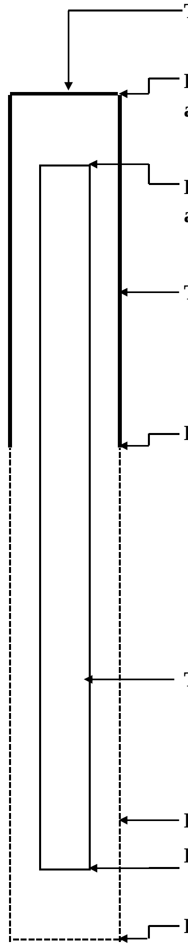
☐ **Guard Pipe**

☐ **Roadway Box**

SOIL CONDITIONS	BOREHOLE BACKFILL

(Bottom of Exploration)

(Numbers refer to depth from ground surface in feet)



Type of protective cover/lock ______________________

Height/Depth of top of guard pipe/roadway box above/below ground surface ____________ **ft**

Height/Depth of top of riser pipe above/below ground surface ____________ **ft**

Type of protective casing: ______________________

Length ____________ **ft**

Inside Diameter ____________ **in**

Depth of bottom of guard pipe/roadway box ____________ **ft**

Type of Backfill	Depth Interval (in ft)

Type of casing pipe: ______________________

Inside diameter of casing pipe ____________ **in**

Screen Interval ________ **ft** **Slot size** _____ **Material** _______

Diameter of borehole ____________ **in**

Depth of bottom of well ____________ **ft**

Depth of bottom of test borehole ____________ **ft**

(Not to Scale)

* - Elevation Datum = _________________

COMMENTS: ______________________

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WELL DEVELOPMENT

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure is for the development of groundwater monitoring wells that have been installed in overburden, top of bedrock, or deep bedrock formations. Before a newly constructed well can be used for water quality sampling, measuring water levels, or aquifer testing, it must be developed. Well development refers to the procedure used to clear the well and formation around the screen of fine-grained materials (sands, silts, and clays) produced during drilling or naturally occurring in the formation. Sampling should not be done for 1-2 weeks after well development to allow the well to return to normal groundwater conditions.

Well development is completed to remove fine grained materials from the well but in such a manner as to not introduce fines from the formation into the sand pack. Well development continues until the well responds to water level changes in the formation (i.e., a good hydraulic connection is established between the well and formation) and the well produces clear, sediment-free water to the extent practical.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden and Top of Rock Wells
- FMG 3.3 – Deep Bedrock Wells
- FMG 6.15 – PFAS/PFOA Sampling
- FMG 10.0 - Waste Characterization

PROCEDURAL GUIDELINES

The well development procedures presented below are the recommended standards. However, due to variations in conditions, changes in these standards may be necessary in order to facilitate successful monitoring well development.

Well development can be accomplished by using in-place pumps or by using portable equipment; either peristaltic, bladder, or other appropriate pumps depending on well depth. In the case of developing wells installed utilizing the mud rotary methods (least preferred method) it would be beneficial to surge the well prior to and during development to help break down the filter cake that may have built up on the well screen.

- Don appropriate safety equipment.
- All equipment used for development purposes entering each monitoring well will be cleaned using a soapy wash [laboratory grade, confirm no presence of per- and polyfluroalkyl substances (PFAS) or perfluorooctanoic acid (PFOA) if sampling for PFAS/PFOA (see FMG 6.15 – PFAS/PFOA Sampling for further details)], tap water rinse, isopropyl alcohol rinse (or other rinse agent that is appropriate for site-specific conditions), and distilled/deionized water rinse.
- Uncap well and allow water level to stabilize. Attach appropriate pump and lower tubing into well.
- Turn on pump. If well runs dry, shut off pump and allow to recover.
- Collect the groundwater sample in a glass jar to determine relative turbidity, and measure and record the temperature, pH, turbidity, and specific electrical conductance.
- The above steps will be repeated until groundwater is relatively silt-free; no further change is noted; the temperature, pH, turbidity, and specific conductance readings have stabilized to within 10 percent.
- The time period between development and groundwater sampling will be dependent upon the project objectives, and the chemicals of concern (COCs). When sampling for COCs sensitive to turbidity presence (i.e., semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), metals), an extended time period between the development activity and the sampling event will be observed. On CITGO sites, sampling will be conducted in accordance with the following:

Primary COC	***Time Period Between Development and Sampling***
General Chemistry	1 week
Volatile organic compounds (VOCs)	1 week
SVOCs, PCBs, Metals	2 weeks

Waste Disposal

- All waste generated will be disposed in accordance to the methods and procedures contained in FMG 10.0 - Waste Characterization through the onsite Resource Manager, if the site is active.
- All water generated during cleaning and development procedures will be collected and contained in accordance to the site-specific disposal requirements.
- Personal protective equipment, such as gloves, disposable clothing, and other disposable equipment, resulting from personnel cleaning procedures and from soil sampling and handling activities, will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

EQUIPMENT/MATERIALS

- Appropriate health and safety equipment.
- Knife.
- Power source (e.g., generator, battery).
- Field book.
- Form FMG 3.6-01 - Well Development and Stabilization Form.
- Well keys.
- Graduated pails.
- Surge block
- Form FMG 3.6-01 - Well Development and Stabilization Form.
- Well keys.
- Graduated pails.
- Pump and tubing.
- Cleaning supplies (including non-phosphate soap, buckets, brushes, laboratory-supplied distilled/deionized water, tap water, isopropyl alcohol or other site-specific rinse agent (e.g., nitric acid solution), aluminum foil, plastic sheeting, etc.).
- Water level meter.
- pH/temperature/conductivity meter.
- Turbidity meter.
- Clear glass jars (e.g., drillers' jars).

REFERENCES

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.

Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.

WELL DEVELOPMENT AND STABILIZATION FORM

PROJECT NAME: **PROJECT NO.:**
DATE OF WELL DEVELOPMENT:
DEVELOPMENT CREW MEMBERS:
PURGING METHOD:
SAMPLE NO.:
SAMPLE TIME:

WELL INFORMATION

WELL NUMBER:
WELL TYPE (diameter/material)
MEASURING POINT ELEVATION:
STATIC WATER DEPTH: **ELEVATION:**
BOTTOM DEPTH: **ELEVATION:**
WATER COLUMN LENGTH:
SCREENED INTERVAL:
WELL VOLUME:

Note: For 2-inch diameter well: 1 foot = 0.14 gallons (Imp) or 0.16 gallons (US)
1 meter = 2 liters

	UNITS	***1***	***2***	***3***	***4***	***5***	***TOTAL/ AVERAGE***
VOLUME PURGED (volume/total volume):							
FIELD pH:							
FIELD TEMPERATURE:							
FIELD CONDUCTIVITY:							
CLARITY/TURBIDITY VALUES:							
COLOR:							
ODOR:							
COMMENTS:							

COPIES TO:

CITGO TERMINAL	FIELD METHOD GUIDELINE NO.: FMG 3.7
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CITGO PETROLEUM CORPORATION	
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WELL DECOMMISSIONING

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WELL DECOMMISSIONING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure is for the decommissioning/abandonment of groundwater monitoring wells that have been installed in overburden, top of bedrock, or deep bedrock formations. Well decommissioning refers to the procedure used to properly abandon or remove the monitoring well from the formation while taking the proper precautions to help eliminate cross-contamination.

The proper methods for properly abandoning monitoring wells are either by leaving the well materials in place and pressure grouting with a cement/bentonite slurry directly into the well or by over-drilling with augers, removing the well material, and backfilling with a cement-bentonite slurry. Individual state regulations must be reviewed and followed prior to and during well abandonment procedures.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden and Top of Rock Wells
- FMG 3.3 - Deep Bedrock Wells
- FMG 9.0 - Equipment Decontamination
- FMG 10.0 - Waste Characterization

PROCEDURAL GUIDELINES

Pressure Grouting

- The borehole log from the monitoring well needs to be obtained to determine the well construction in order to prepare the proper materials and calculate the quantity of cement/ bentonite slurry that will be required.
- The cement pad and the well protector around the monitoring pad needs to be removed and the immediate area around the monitoring well dug out. The riser pipe is to be cut off approximately 1 to 2 feet below ground surface.
- A tremie pipe will be placed into the well completely to the bottom. A cement/bentonite slurry will then be pressure grouted in to the monitoring well backfilling completely to the surface. The grout will be prepared in the ratio of one bag (94 pounds) of Type I or Type II Portland cement to 3 to 5 pounds of bentonite powder mixed with approximately 7 gallons of potable water. The grout will be allowed to sit for approximately 1 hour to allow any settlement of the cement/bentonite slurry and then augment if needed.

Overdrilling

- Based on the diameter of the monitoring well, this information can be obtained from the well completion diagram, the proper sized augers need to be specified.
- The cement pad and the well protector around the monitoring pad needs to be removed and the immediate area around the monitoring well dug out. The riser pipe is to be cut off approximately 1 to 1 feet below ground surface.
- The augers are then placed over the riser pipe of the monitoring well and then drilling commences. The drilling continues until the final depth to which the monitoring well was installed is reached. The well materials are then removed (pulled) from the augers.
- A cement/bentonite grout will be placed from the bottom of the borehole to the top of the augers. As each flight of augers is removed from the ground, the cement/bentonite grout will continue to be placed in the augers, to the top. This will continue until all the augers have been removed from the borehole. The grout will be prepared in the ratio of one bag (94 pounds) of Type I or Type II Portland cement to 3 to 5 pounds of bentonite powder mixed with approximately 7 gallons of potable water.
- The area final restoration will be completed in accordance with the directions of the CITGO Facility representative (e.g., asphalt, concrete, vegetation). In active work areas final restoration maybe necessary immediately; or time to allow settlement of the abandoned well area may be permitted prior to final restoration being performed.
- Documentation/Notification requirements include modification of the well log to reflect closure and if necessary notification to the appropriate regulatory agency.

Waste Disposal

- All waste generated will be disposed of in accordance with the methods and procedures contained in FMG 10.0 - Waste Characterization.
- All material generated during well decommissioning procedures will be collected and contained on site in roll-off boxes or 55-gallon drums for future analysis and appropriate disposal.
- Personal protective equipment, such as gloves, disposable clothing, and other disposable equipment, resulting from personnel cleaning procedures and from well closure activities, will be placed in plastic bags. These bags will be handled in accordance with the Work Plan.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Well supplies.
- Subsurface boring log.
- Tape measure.

REFERENCES

Michigan Department of Public Health, Ground Water Quality Control Section – Division of Water Supply (1988), Michigan Water Well Grouting Manual, MDPH GW-3-302.

ASTM D5229 "Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and other Devices for Environmental Activities".

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WATER LEVEL MEASUREMENTS

LIST OF FORMS

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WATER LEVEL MEASUREMENTS

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure describes measurement of water levels in groundwater monitoring and extraction wells, piezometers and boreholes. This procedure does not cover automated measurement of water levels with a transducer/datalogger and does not cover measurement of phase-separated liquids.

Water levels in monitoring wells will be measured prior to each sampling event and at other times as indicated in the project Work Plan. Water levels will be acquired in a manner that provide accurate data that can be used to calculate vertical and horizontal hydraulic gradients and other hydrogeologic parameters. Accuracy in obtaining the measurements is critical to insure the useability of the data.

PROCEDURES REFERENCED

- FMG 6.5 - Non-Aqueous Phase Liquid (NAPL)
- FMG 8.0 - Field Instruments – Use/Calibration
- FMG 9.0 - Equipment Decontamination

PROCEDURAL GUIDELINES

In order to provide reliable data, water levels must be collected over as short a period of time as practical. Barometric pressure can affect groundwater levels and, therefore, observation of significant weather changes during the period of water level measurements must be noted. Tidal fluctuations, navigation controls on rivers, rainfall events, and groundwater pumping can also affect groundwater level measurements. Personnel collecting water level data must note if any of these controls are in effect during the groundwater level collection period. Due to possible changes during the groundwater level collection period, it is imperative that the time of data collection at each station be accurately recorded.

In conjunction with groundwater level measurements, surface water (e.g., ponds, lakes, rivers, and lagoons) often are monitored as well. This information is very helpful (and can be critical) in understanding the hydrogeologic setting of the site and most importantly how contaminants may move beneath the site.

The depth to groundwater will be measured with an electronic depth-indicating probe. Prior to obtaining a measurement, a fixed reference point on the well casing shall be established for each well to be measured. Unless otherwise established, the reference point is typically established and marked on the north side of the well casing. Avoid using protective casings or flush-mounted road boxes for reference, due to the greater potential for damage or settlement.

If provided for in the project Work Plan, the elevation of the reference point shall be obtained by accepted surveying methods, to the nearest 0.01 foot.

The water level probe will be lowered into the well until the meter indicates (via indicator light or tone) the water is reached. The probe will be raised above water level and slowly lowered again until water is indicated. The cable will be held against the side of the inner protective casing at the point designated for water level measurements and a depth reading taken. This procedure will be followed three times or until a consistent value is obtained. The value will be recorded to the nearest 0.01 foot on Form FMG 5.1-01 - Groundwater Level Monitoring Report or other designated data recording location if specified in the project Work Plan.

Upon completion, the probe will be raised to the surface and together with the amount of cable that entered the well casing, will be decontaminated in accordance with methods described in FMG 9.0 - Equipment Decontamination.

EQUIPMENT/MATERIALS

- Battery-operated, non-stretch electronic water level probe with permanent markings at 0.01-foot increments (traceable to national measurement standards), such as the Solinst Model 101 or equivalent.
- The calibrated cable on the depth indicator will be checked against a surveyor's steel tape once per quarter year. A new cable will be installed if the cable has changed by more than 0.01 percent (0.01 foot for a 100-foot cable). See also FMG 8.0 - Field Instruments – Use/Calibration.

REFERENCES

ASTM D4750 - Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).

ASTM D6000 - Guide for Presentation of Water-Level Information from Ground-Water Sites.

Form FMG 5.1-01

GROUNDWATER LEVEL MONITORING REPORT

WELL NUMBER

Page **of**

PROJECT
LOCATION
ELEVATION REFERENCED TO:

PROJECT MANAGER
FIELD REP.
DATE

Date	Time	Elapsed Time (days)	Depth of Water from ( ) in ft	Elevation of Water	Remarks	Read By

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

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IN SITU HYDRAULIC CONDUCTIVITY (SLUG TEST) PROCEDURE

LIST OF FORMS

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IN SITU HYDRAULIC CONDUCTIVITY (SLUG TEST) PROCEDURE

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure describes the protocol for performing in situ hydraulic conductivity (slug) tests, including preparation, collection of valid field data, and preliminary evaluation of the data.

A slug test is performed to assess the horizontal hydraulic conductivity of a water-bearing zone. Slug tests are accomplished by stressing the screened water-bearing zone through an instantaneous displacement (with a slug) (or removal of water with a bailer) and subsequently measuring and recording the water level response in the well versus time. If the removal of the slug or bailer does not result in the well recovering more than 5 percent of the "90 percent recovery time", then it is considered an "instantaneous" displacement.

Slug testing in select monitoring wells will be performed after the wells have been installed and developed as covered in the Work Plan. Slug testing data will be acquired in a manner that provides valid data that can be used to calculate the horizontal hydraulic conductivity of the formation tested.

There are two types of slug tests: falling-head tests and rising-head tests. It is generally preferable to do a rising-head slug test due to a number of potential problems that can arise with falling-head tests (some of these may lead to inaccurate hydraulic conductivity estimates). It is strongly recommended that water level measurements should be collected automatically using a datalogger/ pressure transducer system if at all possible, but they may be collected manually using a battery-operated water level measurement probe if necessary.

PROCEDURES REFERENCED

- FMG 3.0 - Monitoring Wells, Pump Wells, and Piezometers

- FMG 5.1 - Water Level Measurements
- FMG 8.0 - Field Instruments – Use/Calibration
- FMG 9.0 - Equipment Decontamination
- FMG 10.0 - Waste Characterization

PROCEDURAL GUIDELINES

A slug test involves rapidly changing the water level in a well and then measuring the water-level response over time. A very quick change in the water level in a well should be effected at the beginning of a slug test using one of several methods:

- Preferably by inserting or withdrawing a solid or sealed object with an appropriate overall density.
- By changing the air pressure in a well, or pneumatic slug testing (only when a pressure transducer is used).
- Only if absolutely necessary, adding or removing a slug of water (bailer).

The method chosen will depend on project needs, equipment availability, water disposal/ treatment options, pertinent laws and regulations, and operator experience.

The protocols that follow assume that a person can effectively perform one of the above methods for rapidly changing the water level in a well at the start of a slug test and can then use either a manual or automatic procedure for measuring water level response over time.

Considerations

Certain activities should be avoided in slug testing. In general, a person should **not** conduct any type of slug testing in a well if:

- The well contains a pipe, a tube, or an obstruction in a depth range where the water level would change.
- The casing diameter in a well varies in the depth range where the water level would change.
- The water level in a well has not yet recovered to nearly static conditions (e.g., 95 percent or more) after a prior disturbance (e.g., drilling, purging, development, previous well testing, etc.).
- Non-aqueous phase liquid (NAPL) is present in a well.

A ***rising-head*** test should generally **not** be conducted:

- By bailing multiple times, rather than creating an instantaneous water level change.

- By pumping to remove water, unless the amount of water to be removed by the pump can be removed nearly instantaneously and any backflush can be eliminated.
- By using bailers. If bailers must be used, avoid:
  - using a bailer that has a leaky check valve, or
  - using a bailer with a diameter so close to that of the casing that groundwater is suctioned into the well while the bailer is raised.
- If the slug cannot be removed nearly instantaneously (e.g., if removal takes over 5 percent of the 90 percent recovery time).

Falling-head tests are generally **not** recommended due to inherent problems associated with reproducibility, the introduction of fluids, and general application restrictions. They are recommended in circumstances when no other option is available. Consult with the Project Manager or an experienced hydrogeologist before undertaking a falling-head test program. Note: under no circumstances should a falling-head test be performed in a well where the static water level is within the screened section of the well.

Pneumatic slug tests (using pressurized air or nitrogen to effect displacement) do not add noise to the data or disturb equipment in the well like other methods. The amount of displacement can be adjusted prior to beginning the test by varying the application of pressure to the riser. A pneumatic slug test can reduce cross-contamination of wells, reduces equipment contact with water that may be hazardous and allows testing where a traditional slug test may be prohibited. While initial equilibration can take time in a pneumatic test, the displacement event is nearly instantaneous.

Field Documentation

The following data should be obtained prior to heading into the field and/or in the field during slug testing and recorded appropriately (e.g., on Form FMG 5.2-01 - Slug Test Data Report), in a field book, and/or onto an electronic form copied to computer disk):

- Client name.
- Site name.
- Testing company.
- Name of tester.
- Date and time of test.
- Well number.
- Well location.
- Well casing, screen and borehole diameters.
- Well open hole section diameter.
- Total depth of well.
- Any unusual well, weather, or hydrologic features or conditions.

- Top-of-riser distance above ground surface.
- Test procedure used (slug, pneumatic, etc.).
- Transport and disposal methods for any water removed.
- Well drilling method (hollow-stem auger, mud rotary, etc.).
- Decontamination procedures.
- Problems and solutions to problems encountered during testing.
- Static water level.

Other information needed for proper slug-test data interpretation includes:

- Depth interval of screen or open section in well.
- Sandpack porosity (if water levels intersect screen).
- Sandpack diameter (if water levels intersect screen).
- Details of stratigraphic profile including soil/rock types and elevations of contacts.
- Hydraulic conductivity of bounding low hydraulic conductivity units, if present (helpful, but not essential).
- Ground surface elevation.

Testing

The steps for conducting a slug test are as follows. Dataloggers should be used to collect water level measurements if at all possible. Manual measurements should only be used if absolutely necessary but can, and should, be used to collect backup data. The steps for conducting a slug test using automatic water level measurements are as follows:

1. Conduct a review of the Work Plan and the Health and Safety Plan with the project field supervisor, and plan, as needed, for notifications to responsible parties and for site access.
2. Gather equipment needed and inspect for operation.
3. Decontaminate all necessary equipment before entering a site and between each well or as required in the Work Plan or in accordance with FMG 9.0 - Equipment Decontamination, if different.
4. Measure and record the static water level (SWL) in the well to be tested, the depth to bottom, and record whether the bottom is a hard or soft (silty) base. Calculate the depth from the SWL to the top of the well screen.
5. Test the pressure transducer and data logger, and obtain well-bottom and SWL pressures, using the following steps:
    - Place the pressure transducer at least several feet below the top of water as well as below the projected depth of the lowest part of the slug to be used.
    - Make pressure readings until three uniform values are read consecutively.

- Raise the datalogger 1 foot from its original position. View the pressure reading to confirm that the change in position was accurately reported by the transducer. Repeat the procedure, if required, lowering the transducer a greater distance and again confirming the readings.
- Return the transducer to its original position and secure the suspension cable to the well casing. Again, make pressure readings until three uniform values are read consecutively. Compare with the original readings to make sure no drift occurs.

6. Perform the following pre-test activities if a rising-head test is to be performed:
   - Allow the slug that will be used to move slowly down into the groundwater. If possible, fully immerse the slug. If there is not enough water in the well for the slug to be fully immersed, then let the bottom of the slug gently come to rest on the well bottom if a hard base can be confirmed, or in the case of a soft well base, enough above the well bottom to avoid immersion in silt. For bailers, prevent agitation of sediment on the bottom of the well as sediment in the bailer may keep the check valve from properly sealing. Ensure that the slug will not bind with the transducer cable and cause the transducer to move.
   - Measure falling pressures during recovery using the pressure transducer until the water level in the well re-equilibrates to near-static conditions (95 percent recovery).
   - Set the pressure transducer below the base of the immersed slug.
7. Perform the following pre-test activities if a rising-head test is conducted utilizing pneumatic slug testing:
   - Once the depth to water and depth to well screen have been determined, the amount of pressure to use during the pneumatic slug testing can be determined. It is important to not depress the SWL to the top of the screen as this can inadvertently inject air/gas into the formation and cause the hydraulic conductivity value to be much lower than the actual value.
8. Start the slug test by creating a nearly instantaneous displacement in water level:
   - For a ***rising-head*** test:
     - Pull the slug rapidly upwards and either remove it from the well (preferred), or secure/suspend it within the well several feet above the SWL if conditions prohibit removing it (for example, depths to water are significant and manual water level measurements must be collected). When using a bailer ensure, upon retrieving the bailer to the surface, that it is not leaking and contains the appropriate volume of water (full if entirely immersed, etc.).
     - Simultaneously pull slug and initiate the datalogger, beginning the measuring/ recording of rising water levels in the well at the predetermined time frequencies (a logarithmic time scale is usually employed).
     - If a bailer is used, listen for cascading water while the bailer is being raised or is suspended, a sign of check valve failure; if failure occurs, clean and repair the valve and start over.
     - If a bailer is used, measure the volume of water removed by the bailer after retrieval.

- For ***pneumatic rising-head*** tests:
  - Install the well-head assembly.
  - Program the pressure transducer using software specific to the transducer. Ensure the transducer is recording prior to pressurization to capture the SWL.
  - Begin pressurizing the well, a pressure equivalent of 2 to 8 feet is recommended. Allow the pressure in the well to stabilize as determined by the pressure gauge on the well-head assembly.
  - Once equilibrium has been reached, release the ball valve and monitor the rise in water level.
- For ***falling-head*** tests, if employed, prepare the test in the same manner as for the rising-head test, but instead add a solid slug or a known volume of water as opposed to removing a slug or bailer of water.

9. Continue measuring the water levels as they change over time until the water in the well rises or falls to the limit specified in the Work Plan (if not specified then usually 90 percent recovery or 1 hour, whichever comes first -- check with Project Manager to be sure). A preset logarithmic sampling interval, with increasing intervals of time, is ideal, usually predetermined by the datalogger's default setup. Check the datalogger to ensure data were collected.
10. Compare the volume of groundwater recovered in the bailer, if one is used, with the volume of groundwater estimated to have been removed from the well (V) based on the initial recorded water level displacement (H) and borehole radius (r), e.g., $V=H\pi r^2$. If, for a rising-head test, the static water level lies within the screened section of the well, then the sandpack porosity (n) and radius (R) must accounted for also in the volume calculation, e.g., $V=H\pi r^2 + nH\pi(R-r)^2$. A similar comparison can be performed if a slug is used. If the volume recovered and the calculated volume do not reasonably correlate, based on site-specific conditions, the test should be performed again.
11. Record all general data in a field book and all pertinent testing data on Form FMG 5.2-01 - Slug Test Data Report.
12. Decontaminate all necessary equipment in accordance with the Work Plan or methods described in FMG 9.0 - Equipment Decontamination.
13. Properly containerize and label spent decontamination fluid or groundwater removed from the well in accordance with the Work Plan or methods described in FMG 10.0 - Waste Characterization.
14. Lock all well caps and secure the site as needed.
15. Submit the slug test data to a qualified scientist or engineer assigned by the Project Manager for interpretation. The data should be interpreted by an experienced hydrogeologist. Calculations should be based on an appropriate model for the known hydrogeologic conditions in the field. Evaluation of slug test data should be performed using an acceptable analytical method; CITGO preference is that slug tests be evaluated using either the Bouwer and Rice (1976) or Hvorslev (1951) method.

Any variations from these procedures should first be approved by the project field supervisor and/or Project Manager.

EQUIPMENT/MATERIALS

- A battery-operated water level measurement probe, marked in 0.01-foot increments.
- Form FMG 5.2-01 - Slug Test Data Report.
- Data logger and laptop computer with fully charged battery (if required).
- A solid or sealed slug (or a clean bailer).
- Clean rope or string for raising and lowering a slug.
- Appropriate container for withdrawn groundwater and/or decontamination fluids.
- If snow or soil removal from over a well might be required, a shovel.
- Site-access and well-cap keys, as needed.
- Site maps (including property lines, wells, topography, etc.), as needed.
- If a well to be slug tested is an artesian flowing well, duct tape, couplings, and extra casing of appropriate diameter for increasing casing height so as to enable measurement of a static water level.
- Pressure transducer of appropriate pressure range for the depths of water to be tested, if needed.

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SLUG TEST DATA REPORT

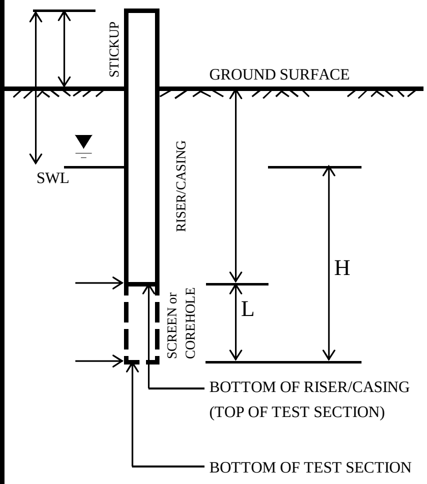
WELL NO.

Page 1 of

PROJECT ______________________ **PROJECT MGR.** ______________
LOCATION ______________________ **FIELD REP.** ______________
CLIENT ______________________ **TEST DATE** ______________

Well Type (overburden, bedrock, etc.) ______________
Installation Date ______________
Displacement method (slug, bailer, pneumatic) ______________
Test Section Length, L (ft.) ______________
Borehole Diameter (in.) ______________
Casing/Riser Diameter (in.) ______________
Interval type (screen, open rock, etc.) ______________
Saturated Thickness, H (ft.) f______________
Soil Description, depths ______________
____

SKETCH/REMARKS



ALL DIMENSIONS IN FEET - Not To Scale

DEPTH/HEIGHT/ELEVATION:

Stick-Up/Stick-Down (ft.) ______________ Static Water Level (ft.) ______________
Top Of Test Interval (ft.) ______________ Depth to Bottom (ft.) ______________
Bottom Of Test Interval (ft.) ______________

WATER LEVEL MEASUREMENT DATA

Clock Time	Time (min:sec)	Elapsed Time (min)	Depth To Water From ________ (ft)	Water Elevation (ft)	Comments

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

CITGO TERMINAL	FIELD METHOD GUIDELINE NO.: FMG 6.1
EAST CHICAGO, INDIANA	EFFECTIVE DATE: AUGUST 17, 2018
CITGO PETROLEUM CORPORATION	
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SURFICIAL SOIL SAMPLING

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SURFICIAL SOIL SAMPLING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

The following procedure describes typical surficial soil sample collection methods for submission of samples to a laboratory for chemical analysis. See FMG 2.3 - Soil Borings for subsurface sampling procedures. See FMG 2.1 - Test Pits for test pit soil sampling procedures.

Soil sampling procedures may vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan requirements and the rationale behind the program. The primary goal of soil sampling is to collect representative samples for examination and chemical analysis (if required). **Any questions regarding whether a sample should be collected or additional samples or different depths should be collected should be directed to the Client while in the field to limit need for remobilization.**

Grab Versus Composite Samples

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample shall be comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses. Composite samples are a mixture of a given number of sub-samples and are collected to characterize the average chemical composition in a given surface area or vertical horizon.

PROCEDURES REFERENCED

- FMG 2.1 - Test Pits
- FMG 2.2 - Drilling Techniques

- FMG 2.3 - Soil Borings
- FMG 2.6 - Soil Classification
- FMG 6.14 – Incremental Soil Sampling
- FMG 6.15 – PFAS/PFOA Sampling
- FMG 6.10 - Sample Handling and Shipping
- FMG 9.0 - Equipment Decontamination

PROCEDURAL GUIDELINES

1. Sample Strategy -Random, Biased, and Grid-Based Sampling

Random Sampling: Random sampling involves selecting locations for sampling in advance using a randomizing method. Therefore, all locations have an equal chance of being sampled for any sample location. Unless there is a strong indication of contaminant presence, such as staining, then soil sample locations may be randomly selected from several areas within the site.

Biased Sampling: Biased sampling involves preferentially selecting locations for sampling based the parameters of interest. If any areas show evidence of contamination, such as staining or vegetative stress, biased samples are normally collected from each area to characterize the contamination present in each area. Biased sampling may reduce sampling variability and the number of samples required. Background and control samples are also biased, since they are collected in locations typical of non-site-impacted conditions.

Grid-Based Sampling: Grid-based sampling involves collecting samples in a regular (grid) pattern. When soil sampling investigations involve large areas, a grid-based soil sampling program can be used. There is no single grid size that is appropriate for all sites. Common grid sizes are developed on 50-foot and 100-foot centers. It is acceptable to integrate several different grid sizes in a single investigation.

See FMG 6.14-Incremental Soil Sampling for further details on collecting samples under the Incremental Sampling Methodology (ISM).

For surficial soil sampling programs, it is also important to consider the presence of structures and drainage pathways that might affect contaminant migration. It is sometimes desirable to select sampling locations in low lying areas which can retain some surface water flow since these areas could provide samples which are representative of historic site conditions (worst-case scenario if surface water flow was a concern).

2. Sample Interval

Surficial soils are generally considered to be soil between ground surface and 6 to 12 inches below ground surface. However, for risk assessment purposes, regulatory authorities often consider soil from ground surface to 2 feet below ground surface to be surficial soil. The exact interval to be considered as surficial soil is often a matter of discussion with the regulatory authorities that review the Work Plan. The sample interval is important to the manner in which the data are ultimately interpreted. Another important factor is the type of soil. If there are different types of soil present at the site, this may have a bearing on the sample interval. For example, it may be important to separately sample a layer of material with high organic carbon content which overlies a layer of fine grained soil.

3. Sampling Procedure

Soil sampling techniques are dependent upon the sample interval of interest, the type of soil material to be sampled, and the requirements for handling the sample after retrieval. The most common method for collection of surficial soil samples involves the use of a stainless-steel trowel or hand auger. Soil samples may also be collected with spoons and push tubes. The sampling equipment is cleaned between sample locations. A typical surficial soil sampling protocol is outlined below:

- Surficial soil samples will be collected using a pre-cleaned stainless steel trowel or other appropriate tool. Each sample will consist of soil from the surface to the depth specified within the Work Plan.
- A new pair of disposable gloves will be used at each sample location. If sampling for per- and polyfluoroalkyl substances (PFAS)/perfluorooctanoic acid (PFOA), special considerations apply, see FMG 6.15-PFAS/PFOA Sampling for further details.

    - Any surficial debris (i.e., grass cover, gravel) should be removed from the area where the sample is to be collected using a separate pre-cleaned device. Gravel presents difficulties for the laboratory in terms of sample preparation and is typically not representative of contaminant concentrations in nearby soil.
    - A pre-cleaned sampling tool will be used to remove the sample from the layer of exposed soil.
    - When only one sample container is required, the collected soil will be placed directly into the clean, pre-labeled sample jar. When more than one sample container requires filling or samples will be split for duplicate analyses; the soils will first be homogenized in a pre-cleaned stainless steel bowl; and then placed into the respective sample containers. It is important that soil samples be mixed as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion

and occasionally turning the material over. Soil samples collected for volatile organic compounds analyses shall not be mixed.

- Samples will be placed on ice or cooler packs in laboratory supplied shipping coolers after collection.

Exception is noted for the collection of volatile organic compounds (VOCs) which require special sample collection methods. VOCs are collected directly into a sample vial (triplicate volume typically required) or collected using an EnCore Sampler™, or equivalent sampler (triplicate samples collected in accordance with manufacturer's instructions). Some VOC analyses require preservation of the sample immediately upon collection (i.e. methanol). Samples for VOCs are typically collected first, without homogenization or extra handling to limit the loss of volatile constituents. Please note that PFAS/PFOA samples will require special handing and containers, see FMG 6.15-PFAS/PFOA Sampling for further details.

The VOC sample collection methodology will be identified in the Work Plan, which will dictate the sample method. The methodology for VOC sampling varies from area to area, so careful review of this issue in advance of the field efforts is required.

EQUIPMENT/MATERIALS

- Drilling equipment and soil sampling tools
- Decontamination fluids and rinse water
- Subsurface boring log
- Tape measure
- Water level probe

REFERENCES

ASTM D1452-80 - Practice for Soil Investigation and Sampling by Auger Borings.

ASTM D1586-84 - Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D1587-94 - Practice for Thin Walled Tube Geotechnical Sampling of Soils.

ASTM D2488-93 - Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM D4700-91 - Guide for Soil Sampling from the Vadose Zone.

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.

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GROUNDWATER SAMPLING

LIST OF FORMS

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GROUNDWATER SAMPLING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure is for the collection of groundwater samples for laboratory analysis.

The objective of most groundwater quality monitoring programs is to obtain samples that are representative of existing groundwater conditions, or samples that retain the physical and chemical properties of the groundwater within an aquifer.

One of the most important aspects of groundwater sampling is acquiring samples that are free of suspended silt, sediment, or other fine-grained particulates. Fine-grained particulates may be comprised of naturally occurring inorganic constituents or adsorbed anthropogenic chemicals and may bias the aqueous phase concentration.

Constituents that may adsorb to fine-grained materials suspended in the groundwater include: polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), and Non-Aqueous Phase Liquids (LNAPL). Monitoring programs where these constituents are suspected or known to be prevalent must employ sampling methods that minimize the entrainment of fine-grained particulates.

The sampling method of "preference" for CITGO sites where fine-grained particulates may be an issue is the "low stress/low flow/very low flow" sampling techniques described within this FMG. Experience has shown that the "low stress/low flow" technique typically achieves representative groundwater samples with minimal fine-grained particulates. In addition to the "low stress/low flow/very low flow" technique, a "typical sample method" has been presented for the collection of constituents less sensitive to particulates presence (i.e., VOCs), or "direct-push sample methods" generally employed as a "pre-screening tool" to evaluate the presence or absence of VOC. Direct-push sample procedures will result in groundwater samples with particulates present. The goal would be to have flow at rates which mimic the natural flow in the aquifer itself.

Lastly, in "extreme" cases "ultra-low flow" techniques have been employed at select sites where "low stress/low flow" methods were used, yet particulate-sensitive constituents continue to bias the analytical results. Ultra-low flow techniques are conducted at purging rates below 100 mL per minute and should only be utilized after careful review and a procedural variance has been approved.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording - Field Books/Digital Recording
- FMG 5.1 - Water Level Measurements
- FMG 6.15 - PFAS/PFOA Sampling
- FMG 8.0 - Field Instruments - Use/Calibration
- FMG 9.0 - Equipment Decontamination

PROCEDURAL GUIDELINES

The following describes four techniques for groundwater sampling: "Low Stress/Low Flow Methods", "Typical Sample Methods", “Passive Diffusion Bag Sample Methods”, and "Direct-Push Methods".

"Low Stress/Low Flow Methods" will be employed to collect representative groundwater samples, and minimize the impact of particulates such as sediment/colloids. Parameters typically affected by particulates present in the sample include PCBs, SVOCs, and inorganic constituents (metals).

The "Typical Sample Methods" will be employed where groundwater samples are collected for the analysis of parameters less sensitive to the presence of particulates such as VOCs and general chemistry.

The “Passive Diffusion Bag (PDB) Sample Methods” are typically employed for the collection of VOCs.

The "Direct-Push Methods" are typically employed for pre-screening areas for chemical presence to aid in determining well placement, or the need for further study.

Note: If non-aqueous phase liquids (NAPL) (light or dense) are detected in a monitoring well, groundwater sample collection will not be conducted, and the Project Manager and Client must be contacted to determine a course of action.
If deemed necessary to sample groundwater from below a LNAPL layer, a suggested sampling procedure has been presented at the end of this Procedural Guidelines section. However, that analysis will always be suspect and results must always be qualified.

Preparatory Requirements

- Verify well identification and location using borehole log details and location layout figures. Note the condition of the well and inform the Project Manager of any required repair work.
- Prior to opening the well cap, measure the breathing space above the well casing with a PID to establish baseline levels. Repeat this measurement once the well cap is opened. If either of these measurements exceeds the air quality criteria in the Health and Safety Plan, field personnel should adjust their PPE accordingly.
- Prior to commencing the groundwater purging/sampling tasks, water level and total well depth measurements must be obtained to determine the volume of water in the well. Refer to FMG 5.1 - Water Level Measurements for details. In some settings, it may be necessary to allow time for the water level to equilibrate. This condition exists if a water tight seal exists at the well cap and the water level has fluctuated above the top of screen; creating a vacuum or pressurized area within the well casing. Three (3) water level checks will verify static water level conditions or changing conditions.
- Calculate the water volume in the well. Typically overburden well volumes consider only the quantity of water standing in the well screen and riser; bedrock well volumes are calculated on the quantity of water within the open corehole and within the overburden casing.

Well Purging and Stabilization Monitoring (Low Stress/Low Flow Method)

Note: The low stress/low flow method described below is the preferred procedure for most CITGO Sites. Bladder pumps/submersible variable rate pumps or peristaltic pumps are typically employed.

- Slowly lower the pump, safety cable, tubing and electrical lines into the well to the depth specified by the project requirements. The pump or tubing should be placed in the well as early as possible before sampling is initiated (this is to minimize well disturbance). In some programs, it may be necessary to install the pumping equipment/tubing approximately 24 hours prior to purging. Peristaltic tubing placement should include a tubing "clamp" at the well head, to minimize vibration transfer into the water column. The pump or tubing intake must be at the mid-point of the well screen to prevent disturbance and resuspension of any sediment in the screen base. Bedrock well sampling may require pump/tubing placement at the depth of specific fracture zone areas or other areas identified within the project-specific Work Plan.
- Before starting the pump, measure the water level again with the pump in the well leaving the water level measuring device in the well when completed.
- Purge the well at 100 to a maximum of 500 milliliters per minute (mL/min). During purging, the water level should be monitored approximately every 5 minutes, or as appropriate. A steady flow rate should be maintained that results in drawdown of 0.3 feet or less. The rate of pumping should not exceed the natural flow rate conditions of the well being sampled. Note: Care should be taken to maintain pump suction and to avoid entrainment of air into the tubing. Equipment should be free from per- and polyfluoroalkyl substances (PFAS)/perfluorooctanoic acid (PFOA) if PFAS/PFOA may be present, is being sampled for or may be sampled for in the future. See FMG 6.15-PFAS/PFOA Sampling for special considerations.

- Record adjustments made to the pumping rates and water levels immediately after each adjustment.
- Calibrate field instrument and document calibration activity. Calibration shall be performed in accordance with manufacturer's recommendations and FMG 8.0 - Field Instruments - Use/Calibration.
- During the purging of the well, monitor and record the field indicator parameters (pH, temperature, conductivity, oxidation-reduction (redox) potential (ORP), dissolved oxygen (DO), and turbidity) approximately every 5 minutes. Stabilization is achieved when three (3) consecutive readings for each parameter are within the following limits:

- pH	±0.1 pH units of the average value of the three readings;
- temperature	±3 percent of the average value of the three readings;
- conductivity	±0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ±0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm;
- ORP	±10 millivolts (mV) of the average value of the three readings;
- DO	±10 percent of the average value of the three readings; and
- turbidity	±10 percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU).

- Should stabilization not be achieved for all field parameters, purging is continued until a maximum of 8 well screen volumes have been purged from the well. Since low-flow purging (LFP) likely will not draw groundwater from a significant distance above or below the pump intake, the screen volume is based upon a 5-foot (1.4 m) screen length. After purging 8 well screen volumes, purging is continued if the purge water remains visually turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the stabilization criteria listed above and appear to be approaching stabilization.
- If low-turbidity samples are critical to the project goals, purging will be extended until turbidity has been reduced to 5 NTU or less.
- The pump should not be removed from the well between purging and sampling.
- Once stabilization has been achieved, direct the discharge of the pump tubing to the appropriate sample containers as specified in the sampling order presented below.
  (see Sampling Techniques)

Well Purging and Stabilization Monitoring (Typical Method)

- The use of bailers for well purging is not recommended due to the surging of the groundwater within the well casing and the potential to increase suspended solids. Submersible bladder pumps are preferred but peristaltic pumps can be used for shallow small (>2.0-inch interior diameter) wells. The pump intake/tubing is typically placed at the mid-point of the screen within overburden wells. Bedrock well sampling may require pump/tubing placement in specific fracture zone areas or other areas identified within the project-specific Work Plan.

- Purge the well until three (3) consecutive well volume measurements of temperature and specific conductivity are approximately plus or minus 10 % and if the pH values are within 1 pH unit of the last three (3) value averages, and the groundwater turbidity values are less than the project-specific Work Plan requirements. If stabilization has not occurred after five (5) well volumes have been removed, continue purging and monitoring until eight (8) well volumes have been removed. Purging rates should not exceed the natural flow rate of groundwater into the well if using very low flow sampling. Elevated purging rates may result in excessive drawdown of the water column, introducing sediment/particulates into the sample and allow oxidation of sediments prior to sample collection.
- Groundwater turbidity may be evaluated by a visual examination or use of a nephelometer. Work Plan-specific goals may exist for turbidity values which may require extending the purging or require an alternate purging method.
- Purging and stabilization activities using a bailer should be performed at the top of the water column, within the riser piping/above the well screen. This will minimize the potential for sediment disturbance/suspension in the screen area and move water from the formation into the well screen/riser area in an effort to remove stagnant groundwater within the well. Bottom-loading bailers are generally employed. The lowering and removal actions are performed slowly to minimize well disturbance. Once stabilization has been attained, the sample aliquots are collected directly from the bailer.
- In the event the well goes dry (poor yielding formations), allow sufficient groundwater recharge to occur and perform sample collection.

Passive Diffusion Bag (PDB) Sampling Technique

Passive diffusion bag sampling techniques are used when sampling for VOCs (excluding certain ketones, ethers and alcohols). PDBs are simple to deploy, eliminate the collection and disposal of purged groundwater, and significantly reduce the cost of sampling. Verify the regulatory agency identifies PDB sampling as an accepted form of sampling for VOCs prior to utilizing the sampling technique.

Passive diffusion bags are made of low density polyethylene which acts as a semi-permeable membrane. The PDBs are either unfilled or prefilled by the manufacturer, are cylindrical in shape and come in a variety of sizes. Prefilled PDBs are filled with ASTM Type II certified, laboratory grade, analyte free, deionized water. Passive diffusion bag sampling methods are as follows:

- Hang the PDB sampler from the provided stainless-steel cable, connect the PDB to the top stainless-steel clip of the line then secure the bottom using a zip-tie.
- Lower the PDB into the monitoring well at the well screen interval. The hanging assembly is labeled and pre-sized for correct sampling depth. The stop cap will keep the bag at the desired depth.
- Wait a minimum of 14 days, or until equilibrium has been achieved between the water in the sampler and the surrounding groundwater prior to retrieving the PDB.
- Wind up the cable, release the PDB from the steel clip and cut the zip-tie.

- Cut a notch at the top of the PDB with decontaminated scissors and gently pour the water into the sample bottles.
- Dispose of PDB appropriately.

Direct-Push Sampling Technique

Generally, the direct-push sampling methods are employed for "pre-screening" groundwater quality (typically VOCs) in selected areas. This method is generally used to evaluate the need for permanent monitoring wells or determine the need for further study. The sampling technique is a direct-push protected-screen sampling technique as described in ASTM D6001 (Standard Guide for Direct Push Water Sampling for Geoenvironmental Investigations). The direct-push sampling technique is summarized as follows:

- Advance borehole to the target depth below the groundwater table.
- Remove the drill rod, assemble the direct–push sample tool and attach it to the drill rod.
- Lower the sample device to the bottom of the borehole using the drill rod.
- Advance the sample device approximately 3 feet into the bottom of the borehole by hydraulically pushing the drill rod.
- Withdraw the drill rods approximately 1 to 2 feet to retract the screen sleeve and to expose the sampler screen to the formation.
- Alternatively, a number of direct-push tools exist that do not require an advance borehole and can be driven directly to the target depth and retracted for sample collection.
- Allow at least 15 minutes from exposing the sampler screen to sample collection to allow silt in the sampler to settle. In tight formations, a longer wait time may be required to allow sufficient groundwater to enter the screen. In some clays, the sample device may not collect sufficient water volume to obtain a sample.
- Lower a small bailer into the sampler, discard initial bail (to acclimate bailer), and collect a water sample. A few bailer volumes may be required to obtain a sufficient volume of water sample. Alternatively, a "Waterra" check ball affixed to tubing maybe employed to collect a groundwater sample, or a peristaltic pump.
- Remove and clean the sampler device after completion of sample collection. Decontaminate sampler for next sample event.

This sampling technique is prone to sediment presence due to the lack of a well screen and sand pack and the limited purging performed before sample collection. A project variance will be required if non-VOC constituents are collected for analysis and results should be qualified on tables as to collection method.

Sampling Techniques

- If an alternate pump is utilized (i.e., Typical Method), the first pump discharge volumes (or bailer volumes) should be discarded to allow the equipment a period of acclimation to the groundwater.
- Samples are typically collected directly from the pump with the groundwater sample discharged into the appropriate sample container. Avoid handling the interior of the bottle or bottle cap and don new gloves for each well sampled to avoid cross-contamination of the sample.
- Order of sample collection:
    - VOCs;
    - SVOCs and PCBs;
    - Total organic carbon (TOC);
    - Total organic halogens (TOX);
    - Extractable organics;
    - Total metals;
    - Dissolved metals;
    - Phenols;
    - Cyanide;
    - Sulfate and chloride;
    - Nitrate and ammonia; and
    - Radionuclides.
- For low stress/low flow sampling, samples should be collected at a flow rate between 100 and 250 mL/min and such that drawdown of the water level within the well does not exceed the maximum allowable drawdown of 0.3 feet.
- For VOC sample containers, the pumping rate should not exceed 100 mL/min. Samples should be transferred directly to the final container 40 mL glass vials completely full and topped with a Teflon cap (if not sampling for PFAS/PFOA). (NOTE: DO NOT OVERFILL AND DISPLACE SAMPLE PRESERVATIVE) Once capped the vial must be inverted and tapped to check for headspace/air presence (bubbles). If air is present the sample vial will be discarded, and re-collected until free of air.
- Field filtration will be performed if required by the project-specific Work Plan. Sediment presence can interfere or bias sample results; false positive findings have been observed when turbid samples are analyzed. Field filtration can eliminate this concern; generally applicable to inorganic/PCB analysis. In-line disposable filter cartridges are generally the easiest and quickest method for field filtration.
- Sample labels/sample identification. All samples must be labeled in accordance to GHD's Laboratory Program including:
    - A unique sample number;
    - Date and time;

  - Parameters to be analyzed;
  - Project Reference ID; and
  - Sampler's initials.
- Labels should be secured to the bottle(s) and should be written in indelible inks or preprinted.
- Field laboratory analysis can be conducted in the field using kits (i.e. HACH Kits or similar). Field analysis can also include alkalinity, chloride, total hardness, iron, etc. The manufacturer’s instructions must be followed to ensure the correct result is obtained. Data determined from the field analysis will be recorded on the appropriate field forms (see FMG 6.9 - Field Quality Control Samples appropriate forms).

Groundwater Sampling Techniques Below LNAPL Layers

Sampling and analysis of groundwater below a LNAPL layer is not performed at CITGO Sites. The rationale for avoiding groundwater analysis below a LNAPL layer is as follows:

- The potential for sample "cross-contamination" with a trace amount of NAPL is very probable; analytical data will be biased "high" based upon this concern and the method and conditions should be noted on any results collected using this technique.
- Analytical data generated from this scenario does not represent "dissolved" constituent presence in groundwater. Dissolved constituents are "best" determined in downgradient locations.

In some instances, it may be required to perform groundwater sampling below a LNAPL layer, possibly at the request of a regulatory group. This should not be done without the prior approval of the Client. If absolutely necessary, this type of sampling may be accomplished in accordance with the following procedure:

- Determine the LNAPL depth and thickness using an interface probe or clear bottom loading bailer.
- Determine the sampling depth, selecting a sample point as far away as possible from the LNAPL interface.
- Using a "capped" outer tube or piping (i.e., 1-inch diameter polyethylene), insert the outer tube to the selected sample interval. The cap should be a slip-on cap affixed to the outer tube using a short "leash" (i.e., stainless steel wire or equivalent). This allows cap recovery once the sampling is complete.
- Insert the sample line (3/8-inch diameter tubing) into the outer tube and "push out" the end cap for sample line entry into the sampling interval.
- Perform purging and sampling using a peristaltic pump.
- Monitor the groundwater level and/or the NAPL level to ensure the LNAPL layer is not drawn to sampling depth. If LNAPL drawdown occurs evaluate the need to proceed further and consider terminating sampling activity.

- This sample should not be referred to on any analysis as a groundwater sample. It should always be referred to as a groundwater/NAPL mixture (GW/NAPL designation).

<u>Sampling Techniques for Per- and Polyfluoroalkyl Substances (PFAS)/Perfluorooctanoic acid (PFOA) by LC/MS/MS</u>

Sampling for PFAS/PFOA is becoming more common. When sampling for PFAS/PFOA, caution must be taken to avoid cross contamination and false positives. Prior to sampling PFAS/PFOA, contact the project laboratory to define a PFAS/PFOA target list. It is recommended to collect additional field/equipment blanks prior to and during sampling to check for residual PFAS/PFOA on sampling equipment due to the potential for cross-contamination issues and the need for very low reporting limits. PFAS/PFOA sampling methods are as follows:

- Using new nitrile gloves, sample for PFAS/PFOA first prior to collecting samples for any other parameter.
- Do not place the bottle cap on any other surface when collecting the sample.
- Avoid all contact with the inside of the sample bottle or its cap.
- After the sample has been collected and capped, place the sample bottle(s) in an individual sealed plastic bag (Ziploc) separate from all other sample parameter bottles.
- Make sure all equipment and sampling containers do not contain potential PFAS containing materials, such as Teflon. Samplers should ensure to the extent possible that PPE and any lotions/etc. do not contain PFAS/PFOA.

Due to the very low reporting levels of PFAS/PFOA, care must be taken during sample collection. The following table summarizes the do's and don'ts of sampling for PFAS/PFOA:

Do Not Use Items	**Do Use Items**
Field Equipment Items	
No Teflon containing materials including Teflon lined bottle caps and bailers	High-density polyethylene (HDPE) and Low-density polyethylene (LDPE)
	Acetate liners for soil samples
No Teflon tubing	Silicon tubing
No waterproof field books	Loose paper (non-waterproof)
No plastic clipboards, binders, or spiral hardcover notebooks	Aluminum field clipboards or with Masonite
No Post-It Notes	Ball-point pens
No chemical (blue) ice packs	Regular ice
Field Clothing and PPE Items	
No new clothing or water resistant, waterproof, or stain-treated clothing, clothing containing Gore-Tex	Well-laundered clothing, defined as clothing that has been washed 6 or more times after purchase, made of synthetic or natural fibers (preferable cotton)
No clothing laundered using fabric softener	No fabric softener

Do Not Use Items	**Do Use Items**
No boots containing Gore-Tex	Boots made with polyurethane and polyvinyl chloride (PVC)
No Tyvek	Cotton Clothing
No cosmetics, moisturizers, hand cream, or other related products on the morning of sampling.	Sunscreens – All Organic Natural Sunscreen, that are “free” or “natural” Check the label
	Insect repellents- various natural products, DEET, but check the label prior to use
Sample Container Items	
No LDPE or glass containers	HDPE or polypropylene
No Teflon -lined caps	Lined or unlined HDPE or polypropylene caps
Rain Gear Items	
No waterproof or resistant rain gear	Tent that is only touched or moved prior to & following sampling activities
Equipment Decontamination Items	
No Decon 90	Alconox and/or Liquinox
No water from an on-site well	Potable water from municipal drinking water supply
Food Items	
No food and drink, with exceptions noted on the right	Bottled water and hydration drinks (Gatorade and Powerade) to be brought and consumed only in the staging area

EQUIPMENT/MATERIALS

- pH meter, conductivity meter, nephlometer, ORP meter, DO meter, temperature gauge.
- Field filtration units (if required).
- Purging/sampling equipment:
    - Peristaltic pump (not suitable for VOCs^1/SVOCs, or drawing water from depths greater than 25 feet^2);
    - Suction pumps (not suitable for LFP, VOCs/SVOCs, or depths greater than 25 feet);
    - Submersible pumps (suitable for VOCs/SVOCs only at low flow rates);
    - Air lift pumps (not suitable for VOCs/SVOCs);
    - Bladder pumps (suitable for LFR and VOCs/SVOCs);
    - Inertia pumps (gaining acceptability for VOCs/SVOCs, generally not suited for CITGO programs); and
    - Bailers.
- Water level probe.
- Sampling materials (containers, log book/forms, coolers, chain-of-custody).
- Project Work Plan.

- Health and Safety Plan.

Note[1]: Peristaltic pump use for VOC collection is acceptable on select EPA/RCRA sites; this technique has gained acceptance in select areas. Where it is permissible to collect VOCs using a peristaltic pump, collection must be performed at a low flow rate (Michigan allows VOC sampling with the peristaltic pump).

Acceptability of the collection of VOCs using the peristaltic pump should be evaluated before the sampling program commences, commonly performed during the project Work Plan development and approval process.

Note[2]: Exception is noted in locations that the suction line can be placed at the desired sample depth (i.e., 100 feet), and the natural recharge maintains a water level within 25 feet of the ground surface.

Field Notes

Field notes must document field activities and measurements collected during the sampling activities. FMG 1.4 - Data Recording - Field Books/Digital Recording describes the data/recording procedure for field activities. The log book/field file should document the following for each well sampled:

- Identification of well.
- PID readings before and after well opening (if required).
- Well depth.
- Static water level depth and measurement technique.
- Sounded well depth.
- Presence of immiscible layers and detection/collection method.
- Well yield – high or low.
- Purge volume, pumping rate, and final disposition.
- Time well purged.
- Measured field parameters and meter calibration records.
- Purge/sampling device used.
- Well sampling sequence.
- Sample appearance.
- Sample odors.
- Sample volume.
- Types of sample containers and sample identification.
- Preservative(s) used.
- Parameters requested for analysis.

- Field analysis data and method(s).
- Sample distribution and transporter.
- Analytical laboratory.
- Chain-of-custody number for shipment to laboratory.
- Field observations on sampling event.
- Name(s) of sampling personnel.
- Climatic conditions including air temperature.
- Problems encountered, and any deviations made from the established sampling protocol.

A standard log form for documentation and reporting groundwater purging and sampling events are presented on Form FMG 6.4-01 - Well Purging Field Information, Form FMG 6.4-02 - Sample Collection Data Sheet, and Form FMG 6.4-03 - Monitoring Well Record for Low-Flow Purging.

Groundwater/Decontamination Fluid Disposal

The project Work Plan will identify the required disposal procedures for groundwater and decontamination fluids. Groundwater disposal methods will vary on a case-by-case basis but may range from:

- Off-site treatment at private treatment/disposal facilities or public owned treatment facilities.
- On-site treatment at Facility-operated facilities.
- Direct discharge to the surrounding ground surface, allowing groundwater infiltration to the underlying subsurface regime (if State allows).
- Direct discharge to impervious pavement surfaces, allowing evaporation to occur.

Decontamination fluids should be segregated and collected separately from wash waters/groundwater containers. Often small volumes of solvents used during the day can be allowed to evaporate if left in an open pail. In the event evaporation is not possible or practical, off-site disposal arrangements must be made with the Facility Resources Manager and the Client.

REFERENCES

ALS, Passive Diffusion Bags (PDBs), http://www.alsglobal.com/us

ASTM D5474 - Guide for Selection of Data Elements for Groundwater Investigations.

ASTM D4696 - Guide for Pore-Liquid Sampling from the Vadose Zone.

ASTM D5979 - Guide for Conceptualization and Characterization of Groundwater Systems.

ASTM D5903 - Guide for Planning and Preparing for a Groundwater Sampling Event.

ASTM D4448 - Standard Guide for Sampling Groundwater Wells.

ASTM D6001 - Standard Guide for Direct Push Water Sampling for Geo-Environmental Investigations.

SGS Sampling, Shipping & Handling or Per and Polyfluorinated Alkyl Substances (PFAS) By LC/MS/MS Fact Sheet – 2017.

USEPA Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (EPA/540/S -95/504).

USEPA RCRA Groundwater Monitoring: Draft Technical Guidance (EPA/530-R-93-001).

WELL PURGING FIELD INFORMATION FORM

JOB# ______ - ___

SITE/PROJECT NAME: ____________________

WELL# ______

WELL PURGING INFORMATION

PURGE DATE (MM DD YY)	SAMPLE DATE (MM DD YY)	WATER VOL. IN CASING (LITRES/GALLONS)	ACTUAL VOLUME PURGED (LITRES/GALLONS)

PURGING AND SAMPLING EQUIPMENT

PURGING EQUIPMENT.........DEDICATED Y N (CIRCLE ONE)

SAMPLING EQIPMENT.........DEDICATED Y N (CIRCLE ONE)

PURGING DEVICE	A - SUBMERSIBLE PUMP	D - GAS LIFT PUMP	G - BAILER	X- ________	PURGING OTHER (SPECIFY)
	B - PERISTALTIC PUMP	E - PURGE PUMP	H - WATERRA®		
SAMPLING DEVICE	C - BLADDER PUMP	F - DIPPER BOTTLE		X- ________	SAMPLING OTHER (SPECIFY)
PURGING DEVICE	A - TEFLON	D - PVC		X- ________	PURGING OTHER (SPECIFY)
	B - STAINLESS STEEL	E - POLYETHYLENE			
SAMPLING DEVICE	C - POLYPROPYLENE			X- ________	SAMPLING OTHER (SPECIFY)
PURGING DEVICE	A - TEFLON	D - POLYPROPYLENE	F - SILICONE	X- ________	PURGING OTHER (SPECIFY)
	B - TYGON	E - POLYETHYLENE	G - COMBINATION TEFLON/POLYPROPYLENE		
SAMPLING DEVICE	C - ROPE	x- ________ (SPECIFY)		X- ________	SAMPLING OTHER (SPECIFY)

FILTERING DEVICES 0.45 ☐ A - IN-LINE DISPOSABLE B - PRESSURE C - VACUUM

FIELD MEASUREMENTS

WELL ELEVATION		(m/ft)	GROUNDWATER ELEVATION		(m/ft)
DEPTH TO WATER		(m/ft)	WELL DEPTH		(m/ft)

pH	TURBIDITY	CONDUCTIVITY	ORP	DO	SAMPLE TEMPERATURE
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)

FIELD COMMENTS

SAMPLE APPEARANCE: ________ ODOR: ________ COLOR: ________ TURBIDITY: ________

WEATHER CONDITIONS: WIND SPEED ________ DIRECTION ________ PRECIPITATION Y/N OUTLOOK ________

SPECIFIC COMMENTS ____________________

I CERTIFY THAT SAMPLING PROCEDURES WERE IN ACCORDANCE WITH APPLICABLE CITGO PROTOCOLS

DATE PRINT SIGNATURE

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

SAMPLE COLLECTION DATA SHEET - GROUNDWATER SAMPLING PROGRAM

PROJECT NAME ______________________________ PROJECT NO. ______________

SAMPLING CREW MEMBERS ______________________________ SUPERVISOR ______________

DATE OF SAMPLE COLLECTION ______________________________

[Note: For 2" dia. well, 1 ft. = 0.14 gal (imp) or 0.16 gal (us)]

Sample I.D. Number	Well No.	Measuring Point Elev. (ft. AMSL)	Bottom Depth (ft. btoc)	Water Depth (ft. btoc)	Water Elevation (ft. AMSL)	Well Volume (gallons)	Bailer Volume No. Bails	Volume Purged (gallons)	Field pH	Field Temp.	Field Cond.	Time	Sample Description & Analysis

Additional Comments: ______________________________

Copies to: ______________________________

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

MONITORING WELL RECORD FOR LOW-FLOW PURGING

Project Data:

Project Name:
Ref. No.:

Date:
Personnel:

Monitoring Well Data:

Well No.:
Measurement Point:
Constructed Well Depth (ft):
Measured Well Depth (ft):
Depth of Sediment (ft):

Screen Length (ft):
Depth to Pump Intake (ft)(1):
Well Diameter, D (in):
Well Screen Volume, V_s (mL)(2):
Initial Depth to Water (ft):

Time	**Pumping Rate (mL/min)**	**Depth to Water (ft)**	**Drawdown from Initial Water Level(3) (ft)**	**pH**	**Temperature ˚C**	**Conductivity (mS/cm)**	**ORP (mV)**	**DO (mg/L)**	**Turbidity (NTU)**	**Volume Purged, V_p (mL)**	**No. of Well Screen Volumes Purged(4)**

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 2 ft above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 5-foot screen length, $V_s = p*(D/2)^2*(5*12)*(2.54)^3$

(3) The drawdown from the initial water level should not exceed 0.3 ft.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stablization criteria and appear to be stablizing), No. of Well Screen Volumes Purged= Vp/Vs.

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NON-AQUEOUS PHASE LIQUID (NAPL)

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NON-AQUEOUS PHASE LIQUID (NAPL)

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure is for monitoring the presence of dense and light non-aqueous phase liquids (DNAPL and LNAPL), and collection of NAPL samples for laboratory analysis in monitoring, observation, and extraction wells.

It should be noted that groundwater sampling and analysis should not be performed in locations where NAPL has been identified.

PROCEDURES REFERENCED

- FMG 5.1 - Water Level Measurements
- FMG 9.0 - Equipment Decontamination

PROCEDURAL GUIDELINES

- Conduct well identification, inspection, and opening in accordance with FMG 5.1 - Water Level Measurements.
- NAPL level measurements are best conducted using a dual phase interface probe. The interface probe uses an optical liquid sensor, in conjunction with an electric circuit to detect the top of a phase-separated liquid and the interface between the phase layer and water (water level). The procedure for use of this probe is:
- For LNAPL:
    - Lower the probe tip into the center of the well until discontinuous beeping is heard (this indicates the top of the LNAPL has been detected). Grasp the calibrated tape at the reference point and note reading. Confirm the reading by slowly raising and lowering the probe to the level of the phase layer.

  - Once the top of the phase layer is confirmed, slowly lower the probe until a continuous sound is heard. This indicates that the water level has been encountered. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
  - Decontaminate the submerged end of the tape and probe prior to the next use in accordance with the Work Plan requirements.
- For DNAPL:
  - Lower the probe tip in the center of the well to the bottom of the well, a discontinuous beeping will be heard if DNAPL is present. Grasp the calibrated tape at the reference point and note reading.
  - Once the bottom of the well is confirmed, slowly raise the probe until a continuous sound is heard. This indicates that the water level has been encountered and represents the top of the DNAPL layer. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
  - Decontaminate the submerged end of the tape and probe prior to the next use and collect a decontamination blank following each cleaning.
- Alternative NAPL measurement methods exist in the event an interface probe is unavailable or not functioning properly. These methods tend to be less accurate than the interface probe but may be used to establish an estimated NAPL measurement.
  - **Clear Bailer –** A clear bottom-loading bailer may be used to estimate NAPL thickness if floating or denser than water. If NAPL presence is suspected, the bailer is carefully lowered to the location of suspected NAPL presence (top of water column/base of water column), and slowly removed and examined for NAPL. If present, the column of NAPL within the clear bailer can be measured to estimate the NAPL thickness within the groundwater column.
  - **Weighted Cord –** Primarily used for DNAPL measurements, a weighted "cotton" string or cord may be lowered to the base of the well and inspected upon retrieval. Typically, the lower DNAPL layer will "coat" the string indicating the approximate thickness of this layer.

Well NAPL Sampling

- Prior to sampling, the level of NAPL in the well should be measured as identified above.
- Various sampling devices can be employed to acquire fluid samples from the top and bottom of the well, including the following:
  - Bottom-loading bailer;
  - Double check value bailer (produces most reliable results);
  - Peristaltic pump for shallow wells (<25 feet in depth); or
  - Inertia pump for deeper wells (up to 300 feet in depth).
- Transfer NAPL to sample containers for shipment to laboratory. NAPL can be sampled to evaluate the physical properties of the fluid or to evaluate chemical composition.

- Decontaminate equipment prior to next use.

Note: Groundwater sampling shall not be performed in locations where NAPL is present.

EQUIPMENT/MATERIAL

- Interface probe.
- Bottom-loading bailer.
- Double check valve bailer.
- Peristaltic pump.
- Inertia pump.
- Work Plan.
- Health and Safety Plan.

REFERENCES

Cohen, Robert M., Mercer, James W. (GeoTrans, Inc.), Robert S. Kerr Environmental Research Laboratory "DNAPL Site Evaluation" Office Research and Development. U.S. Environmental Protection Agency

Cohen, R.M., Brayda, A.P., Shaw, S.T., and Spaulding, C.P.; Fall 1992 "Evaluation of Visual Methods to Detect NAPL in Soil and Water", Groundwater Monitoring Review, Volume 12 No. 4, pp. 132-141.

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SAMPLE HANDLING AND SHIPPING

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SAMPLE HANDLING AND SHIPPING

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

Sample management is the continuous care given to each sample from the point of collection to receipt at the analytical laboratory. Good sample management ensures that samples are properly recorded, properly labeled, not lost, broken, or exposed to conditions which may affect the sample's integrity and that the integrity of the sample can be defended even in court proceedings by the sampling team and the documentation.

All sample submissions must be accompanied with a chain-of-custody (COC) document to record sample collection and submission. When possible, sampling should be batched to prevent completing validation for a small set of samples.

The following sections provide the minimum standards for sample management.

PROCEDURAL GUIDELINES

Field Handling

Prior to entering the field area where sampling is to be conducted, especially at sites with defined exclusion zones, the sampler should ensure that all materials necessary to complete the sampling are on hand.

If samples must be maintained at a specified temperature after collection, proper coolers and ice/cool-packs must be brought out to the field. Consideration should be given to keeping reserve cooling media on hand if sampling events will be of long duration. Conversely, when sampling in extremely cold weather, proper protection of water samples, trip blanks, and field blanks must be considered.

Personnel performing groundwater sampling tasks must check the sample preparation and preservation requirements to ensure compliance with the Work Plan Quality Assurance Project Plan (QAPP). Typical sample preparation may involve pH adjustment (i.e., preservation), sample filtration and preservation, or simply cooling to 4°C. Sample preparation requirements vary from site to site and vary depending upon the analytical method for which the samples will be analyzed.

The sampling personnel must also confirm before the sample event, the amount of bottle filling required for the respective sample containers. Groundwater samples analyzed for volatile organic compounds (VOCs) must not have any headspace within the sample collection vial; whereas when collecting select analytes (i.e., metals) a headspace must be provided to allow addition of the required preservative.

Sample Labeling

Samples must be properly labeled as soon as practical after collection. Note that markers that generate VOCs (i.e. Sharpie® markers) should not be used to write on labels as they can create false positive VOC results in the sample.

Note that the data shown on the sample label is the minimum data required. The sample label data requirements are listed below for clarity.

i) Project name.
ii) Sample number.
iii) Sampler's initials.
iv) Date of sample collection.
v) Time of sample collection.
vi) Analysis required.
vii) Preservatives.

The Work Plan Quality Assurance/Quality Control (QA/QC) specification should be reviewed to determine any additional requirements.

Quite often the analytical laboratory supplying the containers will provide blank sample labels. If these are adequate and convenient they can be used.

Under certain field conditions it is impractical to complete and attach sample labels to the container at the point of sample collection. However, to ensure that samples are not confused, a clear notation should be made on the container with a permanent, non-VOC marker indicating the last three digits of the sample number. If the containers are too soiled or small for marking, the container can be put into a zip-lock bag which can then be labeled.

No one sample number format is adequate for every type of sampling activity. Prior to the start of every project or sub-sampling event within the project, Project Managers and field personnel should devise a sample number format. Sample number formats should be as simple and short as possible. Simple number formats will reduce transcription errors by both Consultants and lab personnel. The sample number format should be comprehensive enough to allow for easy location of detailed sample data within the Site log books. Sample format must also be consistent with any future data management activities. CITGO is migrating to digital recording to minimize transcription errors and reduce management costs.

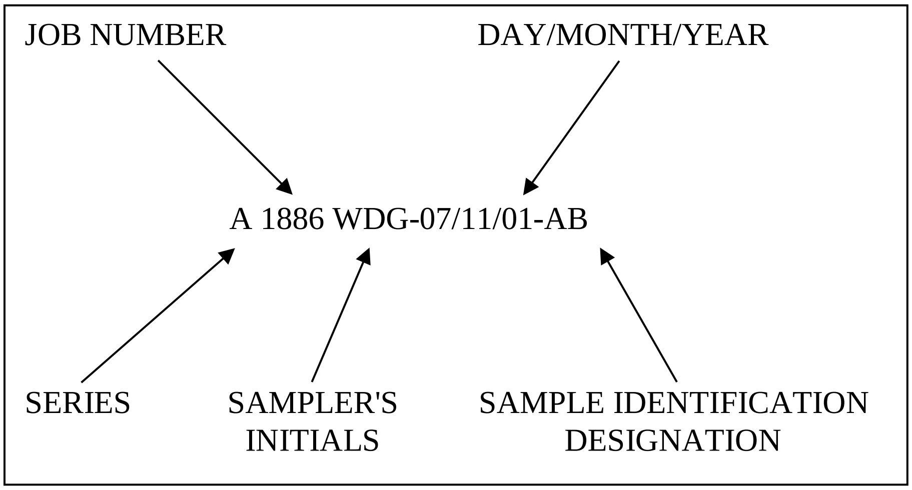
Sample Labels/Sample Identification

All samples must be labeled with:

- A unique sample number (never to be re-used, nor likely to be).
- Date and time.
- Parameters to be analyzed.
- Job number.
- Sampler's initials.

Labels should be secured to the sample container (bottle, Summa® canister, etc.) and should be written in indelible, non-VOC inks. It is also desirable to place wide clear tape over the label before packing in a cooler for label protection during transportation.

The unique sample identification number may follow the format recommended below, or a specific sample protocol for labeling may be specified in the project Work Plan.



This format has been selected to maximize the information content of the sample number. Minor modifications are certainly reasonable.

i) Series is a letter, which designates a group of samples. This might include sample round, or might designate sample type (e.g., sediment, soil, volatile analysis, Round 2 Lower Aquifer wells), or sample source. For example, "A" might mean samples of influent to some treatment system, "B" might mean samples of effluent. Letters should be used, not numbers. Series is optional.

ii) Job number together with the series number will allow easier tracking of samples.

iii) Sampler's initials will allow identification of the sampler, and so allow all project personnel to contact the correct person for information regarding that sample and its collection. The use of three initials is requested. Special arrangements will need to be made if two individuals have the same initials.

iv) Sample date will allow monitoring of actual holding time of samples and should ensure that all sample numbers are unique, even if sample location designation is used in a system, as opposed to assigned at random.

v) Sample identification designation will identify the sample and can be any numerical or letter designation.

The decision of how to assign sample numbers should be made at the beginning of a job or phase and should be consistent throughout the job.

Packaging

When possible, sample container preparation and packing for shipment should be completed in a well organized and clean area, free of any potential cross-contaminants.

Sample containers should be prepared for shipment as follows:

i) Containers should be wiped clean of all debris/water using paper towels (paper towels must be disposed of with other contaminated materials).

ii) Clear, wide packing tape should be placed over the sample label for protection.

While there is no one "best" way to pack samples for shipment, the following packing guidelines should be followed.

i) Plan time to pack your samples (and make delivery to shipper if applicable). Proper packing and manifesting takes time. A day's worth of sampling can be easily wasted due to a few minutes of neglect when packing the samples.

ii) Always opt for more coolers and more padding rather than crowd samples. The cost associated with the packing and shipment of additional coolers is usually always small in comparison with the cost of having to re-sample due to breakage during shipment. Make sure though to minimize the number of COCs and batch samples where possible to reduce the laboratory cost and validation costs that are incurred with each set of samples.

iii) Do not bulk pack. Each sample must be individually padded.

iv) Large glass containers (1 L and up) require much more space between containers.

v) Ice is not a packing material due to the reduction in volume when it melts.

The following is a list of standard guidelines which must be followed when packing samples for shipment.

i) When using ice for a cooling media, always double bag the ice in zip-lock bags.

ii) Double-check to ensure trip and temperature blanks have been included for all shipments containing VOCs, or where otherwise specified in the QAPP.

iii) Enclose the COC form in a zip-lock bag and place copies in each cooler.

iv) Ensure custody seals (two, minimum) are placed on each cooler. Coolers with hinged lids should have both seals placed on the opening edge of the lid. Coolers with "free" lids should have seals placed on opposite diagonal corners of the lid. Place clear tape over custody seals.

v) Ensure that all "Hazardous Material" stickers/markings have been removed from coolers being used which previously contained such materials.

vi) Ensure all proper containers/shipping labels required for the sample shipment are used/adhered to the sample packaging

Note: Never store sterile sample containers in enclosures containing equipment which use any form of fuel or volatile petroleum-based product. An alternate means of secure storage must be planned for.

When conducting sampling in freezing conditions at sites without a heated storage area (free of potential cross contaminants), trip blanks and temperature blanks not being used in a QA/QC role should be isolated from coolers immediately after receipt. Trip and temperature blanks should be double-bagged and kept from freezing.

Chain-of-Custody

COC forms will be completed for all samples collected. The form documents the transfer of sample containers. CITGO is in the process of migrating to digital COCs.

The COC record, completed at the time of sampling, will contain, but not be limited to, the sample number, date and time of sampling, and the name of the sampler. The COC document will be signed and dated by the sampler when transferring the samples.

Each sample cooler being shipped to the laboratory will contain a COC form. The COC form will consist of four copies which will be distributed as follows: The shipper will maintain a copy while the other three copies will be enclosed in a waterproof envelop within the cooler with the samples. The cooler will then be sealed properly for shipment. If one COC is used and there are multiple coolers, copies of the COC should be placed in all coolers. The number of coolers must be written on the COC. Make sure the laboratory knows when there are multiple coolers it is still one batch. The laboratory, upon receiving the samples, will complete the three remaining copies. The laboratory will maintain one copy for their records. One copy will be returned to the Field QA/QC Officer upon receipt of the samples by the laboratory. One copy will be returned with the data deliverables package.

COC records are legal documents and may be evidence in court. They must be completed and handled accordingly.

The following list provides guidance for the completion and handling of all COCs.

i) COCs used should be Consultant standard forms or those supplied by the analytical laboratory. Do not use any COC forms from other labs, even if the heading is blocked out.
ii) COCs must be completed in black ball-point ink only.
iii) COCs must be completed neatly using printed text.
iv) If a simple mistake is made, line out the error with a single line and initial and date next to it.
v) Each separate sample entry must be sequentially numbered.
vi) The use of "Ditto" or quotation marks to indicate repetitive information in columnar entries should be avoided. If numerous repetitive entries must be made in the same column, place a continuous vertical arrow between the first entry and the next different entry.
vii) When more than one COC form is used for a single shipment, each form must be consecutively numbered using the "Page ___ of ___" format. Try to batch as much as possible.
viii) If necessary, place additional instructions directly onto the COC. Do not enclose separate loose instructions.
ix) Include a contact name and phone number on the COC in case there is a problem with the shipment.
x) Before using an acronym on a COC, define clearly the full interpretation of your designation [i.e., Polychlorinated Biphenyls (PCBs)].

Shipment

In all but a few cases, the QA/QC plan for the field work will require shipment of samples by overnight carrier. When possible, samples may be held to ship a batch of samples together by overnight carrier. Samples must be kept at proper temperatures and received at the laboratory with adequate holding times remaining. Issues can be avoided by planning in advance and discussing with the laboratory when holding samples in the field.

Prior to the start of the field sampling, the carrier should be contacted to determine if pickup can be made at the field site location. If pickup at the field site can be made, the "no-later-than" time for having the shipment ready must be determined.

If no pickup is available at the site, the nearest pickup or drop-off location should be determined. Again, the "no-later-than" time for each location should be determined.

Sufficient time must be allowed not only for packaging but also for delivery of samples if this becomes necessary. Driving at high rates of speed in order to make the drop time is unacceptable.

Sample shipments must not be left at unsecured or questionable drop locations (i.e., if the cooler will not fit in a remote drop box do not leave the cooler unattended next to the drop box).

Some overnight carriers do not in fact provide "overnight" shipment to/from some locations. Do not assume; call the carrier in advance before the start of the field work. If overnight shipment is provided, make sure that the correct overnight delivery timeframe is selected. If the samples are collected and to be shipped on a Friday, ensure that the lab will have someone working that Saturday to accept the shipment. All transfers of sample control should be documented on the COC.

Copies of all shipment manifests must be maintained in the field file.

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FIELD INSTRUMENTS – USE/CALIBRATION

LIST OF FORMS
(Following Text)

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FIELD INSTRUMENTS – USE/CALIBRATION

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

A significant number of field activities involve usage of electronic instruments to monitor for environmental screening and health and safety purposes. It is imperative the instruments are used and maintained properly to optimize their performance and minimize the potential for inaccuracies in the data obtained, and to insure worker's health and safety is not compromised. The equipment should also be evaluated for potential per- and polyfluroalkyl substances (PFAS)/perfluorooctanoic acid (PFOA) presence if there is a potential for cross contaminating analytical samples.

This FMG provides guidance on the usage, maintenance and calibration of electronic field equipment, whether for equipment owned by the Consultant or Contractor, or equipment obtained from a rental agency.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording – Field Books/Digital Recording

PROCEDURAL GUIDELINES

- All monitoring equipment will be in proper working order and operated for the purpose for which it was intended, in accordance manufacturer's recommendations before bringing it to the field or using it in the field.
- Field personnel will be responsible for ensuring the equipment is maintained and calibrated in the field to extent practical or returned for office or manufacturer maintenance or calibration if warranted. Calibration is discussed in greater detail below.

- A copy of the Operating Instructions, Maintenance and Service Manual for the equipment being used during a task will be kept with the equipment on-site until the task has been completed and the equipment is no longer on-site.
- Instruments will be operated only by personnel trained in the proper usage and calibration. In the event certification of training is required, personnel will have documentation of such certification with them on site at all times.
- Personnel must be aware that certain instruments are rated for operation within a limited range of conditions such as temperature and humidity. Usage of such instruments in conditions outside these ranges will only proceed with proper approval by a project manager and/or health and safety supervisor as appropriate.
- Instruments that contain radioactive source material, such as x-ray fluorescence analyzers or moisture-density gauges require specific transportation, handling, and usage procedures that are generally associated with a license from the Nuclear Regulatory Commission (NRC) or an NRC-Agreement State. Under no circumstance will operation of such instruments be allowed on site unless by properly authorized and trained personnel, using the proper personal dosimetry badges or monitoring instruments.

Calibration

Calibration of an electronic instrument is critical to insure it is operating properly for its intended use. Such instruments are often sensitive to changes in temperature or humidity, or chemical vapors in the working atmosphere, and as a result their response and ability to monitor conditions and provide data can change significantly.

Calibration of instruments shall be performed and documented in accordance with the manufacturer's recommendations. This includes the following parameters:

- Frequency.
- Use of proper calibration gases or chemical standards.
- Requirements for factory calibration.

Instrument calibration shall be performed in accordance with the following manufacturer recommendations or the suggested "minimum" calibration frequency:

Instrumentation Classification/Group		***Instrumentation***	***Representative Manufacturer Recommended Calibration Frequency***	***Minimum Recommended Calibration Frequency***
Health and Safety	Air Monitoring (Real-Time):	PID, FID, compound-specific or multi-gas meter (typ.), etc.	No Recommendation, Daily or As Needed	Daily
	Air Sampling (non-Real-Time):	Flow meter, personal air sampling device, etc.	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations

Instrumentation Classification/Group		***Instrumentation***	***Representative Manufacturer Recommended Calibration Frequency***	***Minimum Recommended Calibration Frequency***
	Air Monitoring for Confined Space Entry (Real-Time)	Four Gas Meter or Multi-Gas meter with O, LEL, CO, H2S sensors	Daily or before each entry As Needed	Daily
Other Monitoring	Water Sampling:	pH, Cond., Temp., ORP, DO, etc.	Per Manufacturer's Recommendations	Daily, or As Needed
	Physical Parameters:	Velocity/flow meter, pressure transducer, water level meter, oil-water interface probe, etc.	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations
	Other:	Miscellaneous (Troxler nuclear density, etc.)	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations

Notes:

1. Some instrumentation requires factory calibration only.
2. If a significant change in conditions occurs, or in dangerous atmosphere conditions, more frequent calibration should be performed.

Calibration Gas Safety

Several instruments such as photoionization detectors (PIDs), flame ionization detectors (FIDs), oxygen meters, explosimeters, combustible gas indicators, and many others require use of calibration gasses contained in compressed gas cylinders. Many of these gases are combustible or explosive. Care shall be taken to minimize the potential for injury from the use of such compressed gases. Transport, handling, and storage of cylinders, where necessary, shall be performed in accordance with applicable Department of Transportation (DOT) regulations and site requirements.

Calibration will only be performed in areas free of sources of spark, flame, or excessive heat. Smoking will not be allowed in the vicinity of calibration gas usage areas.

Documentation of Calibration

Instrument calibration activities will be documented. Form FMG 8.0-01 - Instrument Calibration Record shall be used to record applicable calibration and maintenance activities. In addition, protocol for documentation outlined in FMG 1.4 - Data Recording - Field Books/Digital Recording shall be followed.

Intrinsically Safe Requirements

Certain work locations may be such that dangerous, ignitable, or explosive conditions exist. In such cases, it may be necessary to utilize only equipment that is rated as "Intrinsically Safe".

Intrinsically safe instrumentation is designed with limited electrical and thermal energy levels to eliminate the potential for ignition of hazardous mixtures.

For site work requiring operation of monitoring instruments in Class I, Division I locations [as defined by the National Fire Protection Agency (NFPA)] only instrumentation rated as Intrinsically Safe will be used. Such equipment (including all accessories and ancillary equipment) must be rated to conform to Underwriters Laboratories (UL) Standard 913, for use in a Class I, Division 1, Groups A, B, C, and D locations. It is also recommended the equipment conform with CSA Standard 22.2, No. 157-92.

Upon completion of the field activities, equipment shall be returned to the possession of the Consultant, Contractor, or Rental Agency accompanied by a written summary of any problems encountered with its use or calibration.

Equipment shall be properly prepared for shipping, including insuring that residual gases (if applicable) are removed from the instrument, and accompanying containers of compressed gases or fluids are properly labeled and sealed.

Equipment Decontamination

Equipment that comes in contact with Site media (water level meters, water quality meters) must be cleaned **before** removal from the site to ensure that chemicals are not transferred to other sites. It is the responsibility of the person who requisitioned the equipment to ensure appropriate cleaning before returning the equipment. Equipment decontamination procedures are typically site specific for unique site compounds.

EQUIPMENT/MATERIALS

- Monitoring equipment specific to work plan tasks.
- Manufacturer's instructions, operation and maintenance information.
- Associated calibration gases, aqueous standards, etc.
- Appropriate shipping containers to facilitate transport without damage to equipment.

REFERENCES

Underwriters Laboratories, Inc. (https://www.ul.com/) Standard UL 913.

National Fire Protection Agency (https://www.nfpa.org/).

Canadian Standards Association (CSA) (https://www.csagroup.org/) Standard 22.2 No. 157.

Form FMG 8.0-01

INSTRUMENT CALIBRATION RECORD

PROJECT ______________________ PROJECT MANAGER __________

LOCATION ______________________ FIELD REP. __________

DATE __________

Instrument	Date Calibrated	By	Standard Used	Decontamination, Maintenance, or Repair Performed	Remarks

Other Remarks: ______________________________

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

CITGO TERMINAL	FIELD METHOD GUIDELINE NO.: FMG 9.0
EAST CHICAGO, INDIANA	EFFECTIVE DATE: AUGUST 17, 2018
CITGO PETROLEUM CORPORATION	
REVISION NO.: 1	REVISION DATE:

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EQUIPMENT DECONTAMINATION

CITGO TERMINAL	FIELD METHOD GUIDELINE NO.: FMG 9.0
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CITGO PETROLEUM CORPORATION	
REVISION NO.: 1	REVISION DATE:

EQUIPMENT DECONTAMINATION

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

This procedure describes decontamination of field equipment potentially exposed to contaminants. Proper decontamination is required to reduce the risk of transfer of contaminants from areas of contamination to other areas and to minimize the potential for cross-contamination that would compromise sample quality. The degree of decontamination required will be dependent on the nature of the activity, equipment used, and on the amount of exposure to contaminants.

PROCEDURES REFERENCED

- FMG 2.0 - Subsurface Investigations
- FMG 5.0 - Aquifer Characterization
- FMG 6.0 - Sample Collection for Laboratory Analysis
- FMG 6.15 – PFAS/POFA Sampling
- FMG 8.0 - Field Instruments – Use/Calibration
- FMG 10.0 - Waste Characterization

PROCEDURAL GUIDELINES

Decontamination activities must be performed in a controlled area outside any exclusion zones established on the site. Care must be taken to minimize the potential for transfer of contaminated materials to the ground or onto other materials. Regardless of the size or nature of the equipment being decontaminated, the process will utilize a series of steps that involve removal of gross material (dirt, grease, oil, etc.), washing with a detergent, and multiple rinsing steps. In lieu of a series of washes and rinse steps, steam cleaning with low-volume, high-pressure equipment (i.e., steam cleaner) is acceptable.

Drill rigs, backhoes, and other exploration equipment must be decontaminated prior to initiating site activities, in between exploration locations to minimize cross-contamination potential, and prior to mobilizing off site after completion of site work. Heavy equipment is generally best deconned with a combination of steam-cleaning equipment and detergent scrubbing. Particular attention should be paid to parts in direct contact with contaminants, e.g., shovels, tires, augers, drilling decks, etc.

Control and containerization of all decontamination fluids is critical. A decontamination pad must be constructed that is appropriate for the size and type of equipment being decontaminated. At a minimum, the decontamination pad will have the following elements:

- An impermeable barrier capable of containing decontamination fluids.
- A low point where fluids will collect and can be pumped into appropriate containers.
- Durability to withstand equipment such as vehicle and foot traffic.
- Appropriate ancillary equipment such as racks to place decontaminated equipment to drain without further exposure to contaminated fluids.
- Labels to alert personnel as to the potential presence of contaminated materials.

Decontamination of Specific Sampling Equipment

Note there is a preference to use pre-packaged disposable equipment rather than create potential for cross contamination and the time spent on decontamination.

The following specific decontamination procedure is recommended:

- Brush loose soil off equipment.
- Wash equipment with laboratory grade detergent (i.e., Alconox or equivalent). Make sure it's appropriate for the types of contaminants [i.e., per- and polyfluoroalkyl substances (PFAS)/ perfluorooctanoic acid PFOA)] (see FMG 6.15 – PFAS/POFA Sampling for further details).
- Rinse with tap water (three rinses minimum).
- Rinse equipment with reagent grade methanol for VOC samples (this requirement may not be appropriate for sites where methanol is a contaminant of concern).
- Rinse equipment with nitric acid for metal samples (especially important for sites with potentially high metals concentrations.
- Rinse equipment with distilled water.
- Allow water to evaporate before reusing equipment

Decontamination of Monitoring Equipment

Because monitoring equipment is difficult to decontaminate, care should be exercised to *prevent* contamination. Sensitive monitoring instruments should be protected when they are at risk of exposure to contaminants. This may include enclosing them in plastic bags allowing an opening for the sample intake. Ventilation ports should not be covered.

If contamination does occur, decontamination of the equipment will be required; however, immersion in decontamination fluids is not possible. As such, care much be taken to wipe the instruments down with detergent-wetted wipes or sponges, and then with deionized water-wetted wipes or sponges.

Disposal of Wash Solutions and Contaminated Equipment

All contaminated wash water, rinsates, solids and materials used in the decontamination process that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and disposed of in accordance with applicable regulations and CITGO requirements. All containers will be labeled with an indelible marker as to contents and date of placement in the container, and any appropriate stickers required [such as polychlorinated bipheyls (PCBs)].

Sampling of containerized wastes will be performed immediately upon completion of the investigations to minimize storage time on site. Storage of decontamination wastes on site will not exceed 90 days under any circumstances.

Level C Decontamination Procedures

The general Level C decontamination procedures to be used when leaving the exclusion zone are as follows:

Step 1:	Equipment drop.
Step 2:	Outer boot cover, outer glove and suit wash with decontamination solution or detergent/potable water.
Step 3:	Outer boot cover, outer glove and suit rinse with potable water.
Step 4:	Tape removal around outer boots and gloves and deposit in PPE waste receptacle properly labeled for disposal.
Step 5:	Boot cover removal.
Step 6:	Outer glove removal.
Step 7:	Suit removal. If disposable place in PPE waste receptacle.
Step 8:	Respirator removal. Clean and disinfect for next use.
Step 9:	Inner glove removal and disposal in PPE waste receptacle.
Step 10:	Wash hands, face, and neck and shower as soon as possible at the end of the day/shift.

It should be noted that the steps above can vary slightly dependent on the task and what PPE is required (e.g., reusable or disposable). Decontamination of Level C PPE is generally accomplished using detergents (surfactants) in water combined with a physical scrubbing action. This process will remove most forms of surface contamination including dusts, many inorganic chemicals, and some organic chemicals.

EQUIPMENT/MATERIALS

Decontamination equipment and solutions are generally selected based on ease of decontamination and disposability.

- Polyethylene sheeting.
- Metal racks to hold decontaminated equipment.
- Soft-bristle scrub brushes or long-handle brushes for removing gross contamination and scrubbing with wash solutions.
- Large galvanized wash tubs, stock tanks, or wading pools for wash and rinse solutions.
- Plastic buckets or garden sprayers for rinse solutions.
- Large plastic garbage cans or other similar containers lined with plastic bags can be used to store contaminated clothing.
- Contaminated liquids and solids should be segregated and containerized in DOT-approved plastic or metal drums, appropriate for off-site shipping/disposal if necessary.

REFERENCES

ASTM D5088 - Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites.

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WASTE CHARACTERIZATION

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WASTE CHARACTERIZATION

It is mandatory that all field activities are performed in a manner that is consistent with Occupational Safety and Health (OSHA) regulations and CITGO's health and safety policy. Prior to completing any field activities, the project-specific Health and Safety Plan (HASP) must be finalized, reviewed, and understood. **In addition, all field activities must comply with federal, state, and local rules and regulations at all times. Any questions that arise should be discussed and resolved with the CITGO Project Manager.**

INTRODUCTION

The following procedure describes the techniques for characterization of investigation derived waste (IDW) for disposal purposes.

It is important to review the health and safety and the waste disposal requirements for the plant with both the CITGO plant Environmental Engineers and the plant Resource Manager (RM) from the CITGO-contracted Resource Management Company, prior to any work. The IDW containment and management procedures, profile sampling requirements, and strategy should be reviewed to provide an estimate to the RM of the waste volumes.

It should be noted that the plant RM will be managing the IDW that is generated. Waste characterization sampling will be performed as directed by the plant RM. The waste characterization results and anticipated quantities will inform the plant RM of the volume of IDW produced. The RM will complete the waste profile and arrange for disposal.

PROCEDURAL GUIDELINES

IDW may consist of soil cuttings (augering, boring, well installation soils, test pit soils, etc.), rock core or rock flour (from coring, reaming operations), groundwater (from well development, purging, and sampling activities), decontamination fluids, personal protective equipment (spent gloves, tyveks) (PPE), and disposal equipment (DE).

This procedure applies when disposition of investigation soils and/or groundwater is required in accordance with the project Work Plan. Generally, this procedure is applicable to plants where the CITGO Project Manager has assessed the areas of investigation and has developed a waste handling plan. In some areas and/or sections within a plant it is permitted to return soil cuttings/test pit soils and groundwater to the source area (RCRA guidance allows waste management techniques within an area of concern without 'triggering' new points of waste generation) subject to CITGO Project Manager approval. This is also allowed by some States. In other areas it may not be practical to return cutting/soils to their origin, and are better handled by this characterization/disposal procedure. This practice is consistent with United States Environmental Protection Agency (USEPA) procedure for IDW at RCRA facilities and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (Reference 1, 2).

Typically investigative derived wastes are dealt with following "Best Management Practices"; and are not considered RCRA characteristic or listed waste until proven to be listed and/or identified characteristically hazardous waste. Evidence has to be definitive. Investigative soils and groundwater should not be considered a listed waste (in most circumstances) due to the lack of generator knowledge concerning chemical source, chemical origin, and timing of chemical introduction to the subsurface. Consequently, waste sampling and characterization is performed to determine if the wastes exhibit a characterization of hazardous waste. Once the waste characterization and a determination is made, best management practices apply consistent with RCRA.

The disposal of soil cuttings and/or purged groundwater must be reviewed on a case-by-case basis prior to initiation of field activities. Two scenarios typically exist:

i) Sufficient plant and/or site information exists and State regulations allow that investigative cuttings and/or purged groundwater to be placed back into the borehole or spread on the ground surface. No disposal required.

ii) Site conditions warrant that all materials handled will be contained and disposed of consistent with the RCRA and/or State requirements.

DISPOSAL PROCEDURES

The following outlines the waste characterization procedures to be employed when IDW disposal is required. The CITGO Remediation Team is now working with the plant RM to manage IDW disposal. Waste characterization sampling will be performed as directed by the CITGO Environmental Engineer(s). The waste characterization results and anticipated quantities will inform the plant RM of the volume of IDW produced. The RM will then set up a direct Purchase Order (PO) with the CITGO Remediation Team to complete the waste profile and dispose of the waste (e.g. contact the CITGO Remediation Team Project Manager).

Soil/Rock Cuttings

Soils removed from boring activities and well construction tasks (including, rock flour from bedrock coring) will be contained within an approved container, suitable for transportation and disposal.

- Once placed into the approved container, any free liquids (i.e., groundwater) will be poured off for disposal as waste fluids, or solidified within the approved container using a solidification agent such as speedy-dri (or equivalent). No free liquid as determined by the "paint filter test" shall be present.

- Contained soils will be screened for the presence of volatile organic compounds (VOCs), using a photoionization detector (PID); this data will be logged for future reference.
- Once screened, full and closed, the container will be labeled in accordance with the plant labeling requirements and placed into the plant container storage area. At a minimum, the following information will be shown on each container label: date of filling/generation, plant name, source of soils (i.e., borehole or well), and plant contact and any additional regulatory labelling requirements. If necessary, the exterior of the container will be cleaned to remove any lose dirt/cuttings.
- Prior to container closure, representative samples from a percentage of the containers will be collected for waste characterization purposes and submitted to the project laboratory. The waste characterization sampling scheme will be dictated by the Work Plan, coordinated with the plant RM, and will establish the volume of soils required for analysis (depending on parameters required), the number of containers considered representative, the homogenization procedure, volatile analysis collection procedure (if required), and preparation handling requirements. Typically at a location where an undetermined site-specific parameter group exists, sampling and analysis may consist of the full RCRA Waste Characterization (ignitability, corrosivity, reactivity, toxicity), or a subset of the above based upon data collected, historical information, and generator knowledge. This will be determined under the plant RM’s direction, with the approval of CITGO.

Groundwater

Well construction development, purging, and sampling groundwater which requires disposal will be contained. Containment may be performed in 55-gallon drums, tanks suitable for temporary storage (i.e., Nalgene or plant provided tanks 500 to 1,000 gallons) or if large volumes of groundwater are anticipated, drilling "frac" tanks may be utilized (20,000 gallons ±), or tanker trailer (5,000 to 10,000 gallons ±). In all cases, the container/tank used for groundwater storage must be clean before use such that cross-contamination does not occur. Do not mix grout purge or mixing water with other well fluids, as the high pH from cement grout can create an unintended hazardous waste. Grout water should be drummed separately.

Decontamination Waters/Decontamination Fluids

- Decontamination waters and/or fluids will be segregated, contained, and disposed of accordingly.
- Decontamination waters may be disposed of with the contained groundwater once analytical results have been acquired. Depending on the extent of chemistry present it may be appropriate to discharge the decontamination waters to the Publicly Owned Treatment Works (POTW); or discharge to an on-site treatment system; or send off-site for treatment. Proper permitting may be required.

- Spent Solvent/Acid Rinses - Solvents and acids used during decontamination activities must be segregated and disposed separately from the groundwater/decontamination water. Often if only small amounts of solvents are involved these can be left to evaporate. If large volumes are involved then containerization, labeling, and storage is required.

PPE/DE

- Several disposal options exist for spent PPE/DE generated from investigation tasks. The options typically employed are:
  - i) Immediately disposed of within on-site dumpster/municipal trash, if properly decontaminated; or
  - ii) If known to be contaminated with RCRA hazardous waste, disposed of off-site at a RCRA Subtitle C facility; or alternatively PPE/DE decontaminated and disposed of on site within dumpster/municipal trash; or
  - iii) Contained and stored until the final remedy is implemented.

WASTE CHARACTERIZATION PROCEDURES

Waste characterization will be performed under the plant RM's direction, with the approval of CITGO. The Work Plan, in coordination with the plant RM, will identify the appropriate sampling strategy and analytes required to determine the IDW characteristics and disposal requirements. USEPA SW-846 (Reference 5, Chapters 9 and 10) describes the rationale for sampling plan development and sampling procedures. Generally, random sampling and preparation of a composite sample of the media is employed for most investigative programs.

Sampling procedures for IDW are:

- Solid Wastes - Grab sampling using pre-cleaned sample spoons from bulk piles, lugger boxes, or as drums are being filled is commonly employed. In some instances, sufficient media mixing may be evident to permit drum sampling from a random number of drums by accessing only the top solids. In other instances where stratification is evident, a sample trier/hand auger or device to collect from the entire vertical profile is required. Typically, a composite sample(s) from representative areas of the container(s) is homogenized and submitted for analysis. If VOCs are being evaluated, compositing and homogenization is not permitted. Individual grab samples are typically required for VOCs.
- Waste Waters - Grab sampling techniques using pre-cleaned bailers or sampling pumps are typically employed. Waters in bulk are typically sampled once using a bailer or pump. The Work Plan will outline the appropriate sample frequency and analytes necessary to adequately

characterize the contained waters. Facility sewer discharge permit parameters will be evaluated when disposal to the POTW is being considered.

Note: If non-aqueous phase liquid (NAPL) is present special sampling and handling requirements will apply. Precautions to separate the NAPL from the wastewater will commonly be employed, due to the special material handling and waste disposal requirements when dealing with phase materials.

- Spent Solvent/Acid Rinses - The need for sampling must be determined in consultation with the waste management organization handling the materials. If known that only the solvent and/or acids are present, then direct disposal/treatment using media specific options maybe possible without sampling (i.e., incineration).
- PPE/DE - Typically not sampled and can be included with the disposal of the solid wastes or decontaminated and disposed in the plant refuse.

EQUIPMENT/MATERIALS

- Sample spoons, trier, auger.
- Sample mixing bowl.
- Sampling bailer, or pump.
- Sample glassware.

REFERENCES

USEPA RCRA - Guidance and Policies: Management of Remediation Waste Under RCRA (October 1998).

USEPA RCRA - Management of Contaminated Media (October 1998).

USEPA CERCLA Guidance (Options Relevant to RCRA Facilities): Guide to Management of Investigation-Derived Wastes (January 1992).

USEPA Office of Solid Waste - SW-846 Chapter 9 Sampling Plan, Chapter 10 Sampling Methods (September 1986).

about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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Appendix B
Quality Assurance Project Plan (QAPP)

Quality Assurance Project Plan

CITGO Terminal
East Chicago, Indiana

CITGO Petroleum Corporation

GHD | 455 Phillip Street Unit #100A Waterloo Ontario N2L 3X2 Canada | 11209494 | Report No 3 | February 2020

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QAPP Worksheet #1 & 2: Title and Approval Page
(UFP-QAPP Manual Section 2.1)
(EPA 2106-G-05 Section 2.2.1)4

1. Project Identifying Information
    1. CITGO Terminal (IND 095 267 381)
    2. East Chicago, State of Indiana
    3. GHD Project Number 11209494

2. Settling Work Parties' Project Coordinator

____Signature
CITGO Project Coordinator – Scott Buckner Date

3. Settling Work Parties' Supervising Contractor - GHD

____Signature
Project Director – Michael Tomka Date

____Signature
Project Manager – John-Eric Pardys Date

____Signature

Quality Assurance Manager – Angela Bown Date

____Signature

Project Chemist – James Abston Date

4. United States Environmental Protection Agency - Region 5

____Signature
Remedial Project Manager – Renee Wawczak Date

____Signature

QAPP Reviewer - TBD Date

5. List plans and reports from previous investigations relevant to this project

Investigation Results Report – Phase I, submitted October 31, 2019

QAPP Worksheet #3 & 5: Project Organization and QAPP Distribution
(UFP-QAPP Manual Section 2.3 and 2.4)
(EPA 2106-G-05 Section 2.2.3 and 2.2.4)

QAPP Worksheet #4, 7, & 8: Personnel Qualifications and Sign-off Sheet
(UFP-QAPP Manual Sections 2.3.2 – 2.3.4)
(EPA 2106-G-05 Section 2.2.1 and 2.2.7)

Organization: U.S. EPA

Name	Project Title/Role	Education/Experience	Specialized Training/Certifications	Signature*/Date
Renee Wawczak	EPA Project Manager			
TBD	QAPP Reviewer			

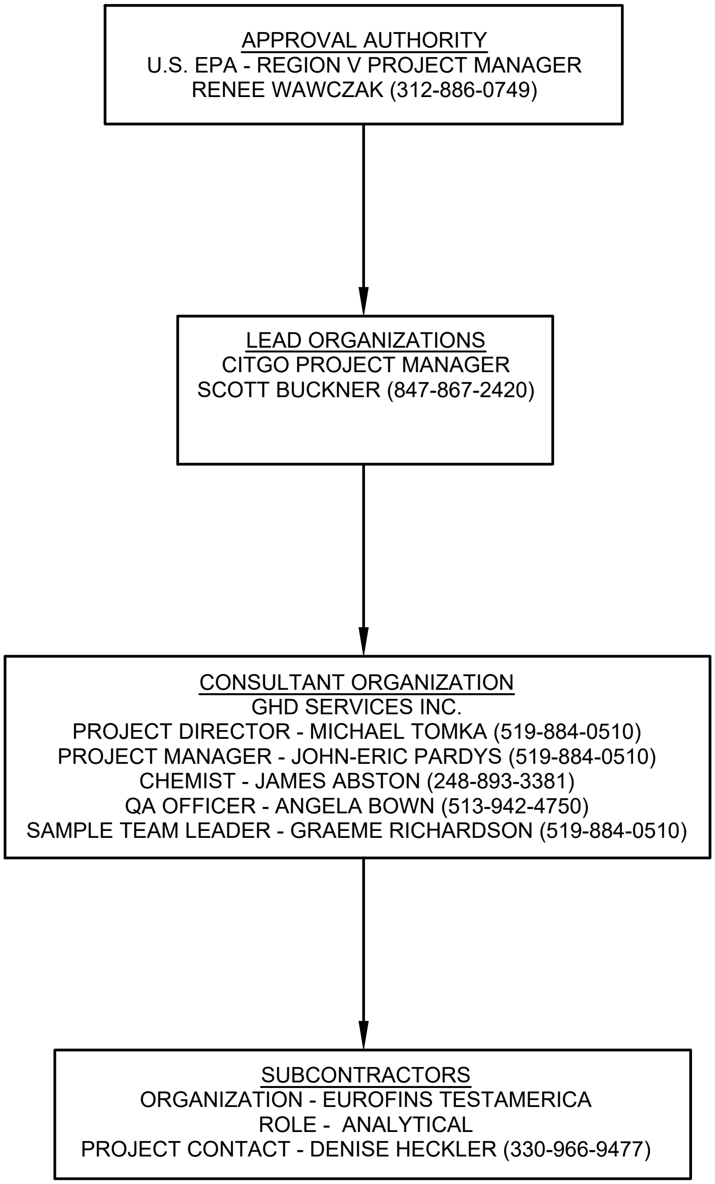
Organization: GHD Services Inc.

Name	Project Title/Role	Education/Experience	Specialized Training/Certifications	Signature*/Date
Michael Tomka	Project Manager	B.A.Sc. in Civil Engineering/28 years	P.E.	
James Abston	Project Chemist/Data Validator	BS in Physics and Mathematics/28 years		
Angela Bown	QA Manager	B.S. Environmental Management; A.S. Laboratory Technology; 30+ years of experience in environmental laboratory operations and data validation		

Organization: Eurofins TestAmerica, Canton

Name	Project Title/Role	Education/Experience	Specialized Training/Certifications	Signature*/Date
Denise Heckler	Laboratory Project Manager	BS Chemistry, Youngstown State University, 1988. 30 years environmental lab experience		
Mark Loeb	Quality Assurance Manager	BS Chemistry, University of Akron, 31 years environmental lab experience		

* Signatures indicate personnel have read and agree to implement this QAPP as written.



APPROVAL AUTHORITY
U.S. EPA - REGION V PROJECT MANAGER
RENEE WAWCZAK (312-886-0749)

LEAD ORGANIZATIONS
CITGO PROJECT MANAGER
SCOTT BUCKNER (847-867-2420)

CONSULTANT ORGANIZATION
GHD SERVICES INC.
PROJECT DIRECTOR - MICHAEL TOMKA (519-884-0510)
PROJECT MANAGER - JOHN-ERIC PARDYS (519-884-0510)
CHEMIST - JAMES ABSTON (248-893-3381)
QA OFFICER - ANGELA BOWN (513-942-4750)
SAMPLE TEAM LEADER - GRAEME RICHARDSON (519-884-0510)

SUBCONTRACTORS
ORGANIZATION - EUROFINS TESTAMERICA
ROLE - ANALYTICAL
PROJECT CONTACT - DENISE HECKLER (330-966-9477)

CITGO TERMINAL
EAST CHICAGO, INDIANA

11194478-00

Oct 21, 2019

PROJECT ORGANIZATIONAL CHART

QAPP WORKSHEET #5

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QAPP Worksheet #6: Communication Pathways
(UFP-QAPP Manual Section 2.4.2)
(EPA 2106-G-05 Section 2.2.4)

Communication Driver	**Organization**	**Name**	**Contact Information**	**Procedure (timing, pathway, documentation, etc.)**
Regulatory agency interface	CITGO	Scott Buckner	Sbuckne@citgo.com 847-867-2420	Analytical data and project information such as changes to the QAPP, schedule and field activities will be forwarded to the Agency per the SOW.
Regulatory agency interface – Alternate	GHD Services, Inc	Michael Tomka	michael.tomka@ghd.com 519-884-0510	Analytical data and project information such as changes to the QAPP, schedule and field activities will be forwarded to the Agency per the SOW.
Regulatory agency interface	*USEPA Region 5 Remedial Project Manager*	Renee Wawczak	312-886-0749	Provide feedback to GHD regarding analytical data and project information such as changes to the QAPP, schedule and field activities.
Field, data, and reporting progress reports; unexpected events; emergencies; non-conformances	GHD Services Inc.	Michael Tomka	michael.tomka@ghd.com 519-884-0510	Frequent updates on all routine aspects of the project, and immediate updates on non-routine aspects of the project will be provided by phone and/or email to
Field progress reports	GHD Services Inc.	Graeme Richardson	graeme.richardson@ghd.com 519-884-0510	Daily field progress reports will be phoned or emailed to the GHD PM.
Stop work due to safety issues	GHD Services Inc.	All Personnel	All Personnel	STOP WORK IMMEDIATELY-NOTIFY PM.
QAPP changes prior to field work	GHD Services Inc.	Angela Bown	Angela.Bown@ghd.com	Changes to the QAPP prior to field work will be made by Angela Bown and approved by PM as needed.
QAPP changes during project execution	GHD Services Inc.	Angela Bown	Angela.Bown@ghd.com	Changes to the QAPP during project execution will be made by Angela Bown and approved by PM as needed.

Communication Driver	**Organization**	**Name**	**Contact Information**	**Procedure (timing, pathway, documentation, etc.)**
Field corrective actions	GHD Services Inc.	Graeme Richardson	graeme.richardson@ghd.com 519-884-0510	Field corrective actions will be documented by FIELD TECH and communicated to the GHD PM immediately.
Sample receipt variances	TestAmerica, Inc.	Denise Heckler	Denise.Heckler@testamericainc.com 800-456-9396	Sample receipt variances will be documented by Denise Heckler and communicated to James Abston within 48 hours.
Laboratory quality control variances	TestAmerica, Inc.	Denise Heckler	Denise.Heckler@testamericainc.com 800-456-9396	Laboratory quality control variances will be documented by Denise Heckler and communicated to James Abston within 48 hours.
Analytical corrective actions	TestAmerica, Inc.	Denise Heckler	Denise.Heckler@testamericainc.com 800-456-9396	Analytical corrective actions will be documented by Denise Heckler and communicated to Angela Bown within 48 hours.
Data verification issues, e.g., incomplete records	GHD Services Inc.	James Abston	James.Abston@ghd.com	Data verification issues will be documented by James Abston and will notify Denise Heckler of any incomplete lab records and request corrective actions.
Data validation issues, e.g., on-compliance with procedures	GHD Services Inc.	James Abston	James.Abston@ghd.com	Data validation issues will be documented by James Abston in the data validation report. PM will be notified of deficiencies as needed.
Data review corrective actions	GHD Services Inc.	James Abston	James.Abston@ghd.com	Corrective actions will be documented in the data validation report by James Abston. PM will be notified of corrective actions as needed.

QAPP Worksheet #9: Project Planning Session Summary
(UFP-QAPP Manual Section 2.5.1 and Figures 9-12)
(EPA 2106-G-05 Section 2.2.5)

Date of planning session: September 24, 2019
Location: USPEA Region V, Chicago Office
Purpose: Phase I results

Participants: TBD

Name	Organization	Title/Role	Email/Phone
Renee Wawczak Mario Mangino Todd Gmitro Mike Beedle	U.S. EPA	Project Manager Project Director	wawczak.renee@epa.gov mangino.mario@epa.gov gmitro.todd@epa.gov beedle.michael@epa.gov
Scott Buckner Peter Krivas	CITGO	Project Manager Facility Manger	Sbuckne@citgo.com Pkrivas@citgo.com
Rick Passmore	GSH	Project Manager	Rick_passmore@oxy.com
Michael Tomka Matt Rousseau	GHD	Project Manager LNAPL Expert	Michael.tomka@ghd.com Matt.Rousseau@ghd.com

Notes/Comments:

- Chemical of Potential Concern (COPCs) were identified consistent with the draft CAF provided by EPA (TCL VOCs, TCL SVOCs, TAL Metals, and 1,4-dioxane)

Consensus decisions made:

- No objections to the list were identified.

Action Items:

Action	Responsible Party	Due Date

QAPP Worksheet #10: Conceptual Site Model
(UFP-QAPP Manual Section 2.5.2)
(EPA 2106-G-05 Section 2.2.5)

Conceptual Site Model (CSM)

Current and Future Site Land Use

Current Land Use: Industrial None
Projected Future Land Use: Industrial

Current and Future Surrounding Property Land Use

Mixed residential, commercial, industrial and limited recreational

Sources and Extent of Known Contamination

Sources of contamination could include wastes from former petroleum refinery related operations. Previous investigations have identified the presence of select volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals.

Sufficient data is not currently available to conclusively determine the extent of contamination.

The extent of impacts of VOCs, SVOCs, 1,4-dioxane, and metals will be confirmed in subsequent phases of the RFI.

Contamination Transport/Migration Pathways

Contaminant transport and migration pathways include the following:
- Hydrocarbon migration through the subsurface to groundwater
- Groundwater to surface water (Grand Calumet River)
- Hydrocarbon vapor intrusion potential

Exposure Receptors

Potential on-site exposure receptors include:
- Routine workers
- Maintenance or construction workers
- Trespassers

Potential off-site exposure receptors include:
- Routine workers
- Maintenance or construction workers
- Trespassers

Potential off-site ecological receptors include:
- Natural area to the south
- Grand Calumet River

Exposure Point and Exposure Mediums include:
- Surface soil
- Subsurface soil
- Groundwater
- Indoor air

Exposure Routes

Potential exposure routes include:
- Soil dermal direct contact
- Soil or groundwater ingestion
- Soil vapor inhalation from contaminated soil or groundwater
- Inhalation of fugitive dust

It is noted that institutional or engineering controls will be employed to prevent exposure by any of these potential exposure routes, and that none of these pathways have been confirmed to exist as of this date, but will continue to be investigated as part of the RFI.

Discussion of Unknowns and Uncertainty

The delineation of Constituents of Potential Concern (COPCs) is currently unknown and ongoing. Historical data and knowledge are being used to design a biased sampling plan for the Former Refinery.
The current COPCs, as supported by historical investigations, for soil and groundwater are as follows:
- Target compound list (TCL) VOCs (Method 8260),
- TCL SVOCs (Method 8270),
- target analyte list (TAL) metals (Method 6010/7470) and
- 1,4-dioxane.

QAPP Worksheet #11: Project/Data Quality Objectives
(UFP-QAPP Manual Section 2.6.1)
(EPA 2106-G-05 Section 2.2.6)

1. **State the Problem**

From approximately 1929 to 1972, Empire Refining Company, and then Cities, or subsidiaries of Empire or Cities operated a refining and bulk storage terminal complex consisting of approximately 322 total acres, of which the crude oil refinery operations were located on portions of the 93.5 acre Former Cities Refinery. The refining operation ceased on or about 1972. The bulk storage terminal continued to operate subsequent to closure of the refinery and is currently owned and operated by CITGO (since 1983).

The refinery operations formerly located on the Facility produced gasoline, diesel, tractor fuel, kerosene, fuel oil, range oil, petroleum coke, naphtha, and other related materials.

In accordance with Section 13 of the Order the objectives of the Resource Conservation and Recovery Act Facility Investigation Remedy Selection Track (RCRA First) program are to:

- Determine the nature and extent of releases of hazardous waste and hazardous constituents at or from the Facility
- Identify and evaluate interim corrective measures to control human exposures to contamination or to stabilize the migration of contaminated groundwater
- Demonstrate human exposures to contamination are under control and migration of contaminated groundwater is stabilized

2. **Identify the Goals of the Study**

The data to be collected as part of the (RCRA First) as specified in the Order and the Corrective Action Frameworks (CAFs) are necessary to determine the nature and extent of impacts to groundwater and soil such that informed decisions can be made regarding potential risks to human and ecological receptors. The data will be used to update the CSM and address data gaps. The data will be compared to screening levels and will receive site-specific evaluation to assess risk to receptors. The data will therefore ultimately help identify potential remedial alternatives to address or prevent exposure to contamination present at concentrations that pose an unacceptable risk to receptors.

3. **Identify Information Inputs**

   Presents the rationale and types of data that are required to fill data gaps in the CSM. The data may be used for evaluation of risk (ecological and human health).

4. **Define the Boundaries of the Study**

   The boundaries of the study area are shown in the CAFs. The list of constituents of potential concern (COPC) are as follows:

   - Target Compound List (TCL) volatile organic compounds (VOCs) (Method 8260)
   - TCL semi-volatile organic compounds (SVOCs) (Method 8270)
   - Target Analyte List (TAL) metals (Method 6010/7470)
   - 1,4-dioxane.

5. **Develop the Analytic Approach**

   Laboratory analytical methods are presented in Worksheet #28.

6. **Specify Performance or Acceptance Criteria**

   The analytical results will be compared to the project action levels (PALs) detailed on Worksheet #15. To compare site data to the applicable PALs, the selected laboratory must be able to achieve Reporting Detection Limits (RDLs) that are low enough to measure constituent concentrations below the PALs to ensure laboratory sensitivity is sufficient. In cases where conventional test methods are not able to achieve detection limits that are lower than PALs, rules for evaluating the data are required that help the Project Team determine with reasonable satisfaction whether the constituent poses a potentially unacceptable risk. Analytical data reported by the laboratory use the following reporting conventions: all concentrations less than the MDL and RDL will be considered non-detects and will be reported with a “U” qualifier; between the MDL and RDL will be reported with a “J” qualifier; and at or above the RDL will be reported with no qualifier. In the event that a target analyte has a PAL between the MDL and RDL, the “J” flagged data will be accepted to achieve project goals. The inability to quantifiably compare individual analytes to PALs with confidence must be addressed in the risk evaluation uncertainty analysis in each risk assessment.

7. **Develop the Detailed Plan for Obtaining Data**

   The basis for the sampling design is to fill data gaps by collecting additional data. Refer to Worksheet #17 for details regarding Sample Design and Rationale, and Worksheets #19, 20, 24-28, and 30 for analysis design requirements. GHD will collect the samples and submit to Eurofins for analyses. The laboratory will submit a final complete analytical report in electronic format. The analytical report submitted by the laboratory shall conform to all reporting and deliverable requirements. Files for the data shall be inventoried and maintained by GHD and shall consist of the following; work plan and supporting plans; project logbooks, field data records, sample identification documents; chain-of-custody records; laboratory data; correspondence; report notes; calculations etc.; references; copies of pertinent literature; photos; maps; drawings, etc. and final report.

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater/Soil/LNAPL
Analytical Group or Method: TCL VOC: SW-846 8260C
SOP: NC-MS-019, Rev. 6
Concentration Level: Low

Data Quality Indicator (DQI)	**QC sample or measurement performance activity**	**Measurement Performance Criteria**
Analytical Precision (laboratory)	BFB Tune	BFB Tune Criteria must be met per SW-846 Method 8260C
Analytical Accuracy/Bias (laboratory)	Initial Calibration (ICAL) Curve	%RSD and %D must be met per SW-846 Method 8260C; COD (R^2) $\geq$ 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8260C
Analytical Sensitivity (laboratory)	Continuing Calibration (CCAL) Standards	%D or % Drift must be met per SW-846 Method 8260C; Minimum Mean Response Factors must be met per SW-846 Method 8260C
Analytical Accuracy/Bias (laboratory)	Internal Standards	50-200% Recovery of the response of the previous continuing calibration standard
Analytical Accuracy/Bias (laboratory)	Surrogates	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	Must meet established Laboratory Limits
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates - Second Source	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Method Blanks	No target analyte concentrations > RDL
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	Must meet established Laboratory acceptance criteria

Overall accuracy/bias (contamination)	Field Blanks/Trip Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	Waters: RPD ≤ 50% when VOCs are detected in both samples ≥ 5 times RDL Soils/LNAPL : RPD ≤ 100% when VOCs are detected in both samples ≥ 5 times RDL
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix:	Groundwater
Analytical Group or Method:	DBCP & EDB/SW-846 8011
SOP:	NC-GC-040, Rev. 2
Concentration Level:	Low

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Analytical Accuracy/Bias (laboratory)	Initial Calibration Curve (ICAL)	%RSD must be met per SW-846 Method 8011; COD (R^2) > 0.99 for linear or quadratic curves, if used
Analytical Accuracy/Bias (laboratory)	Continuing Calibration Verification (CCV) Standards	%D must be met per SW-846 Method 8011
Analytical Accuracy/Bias (laboratory)	Surrogates	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	Must meet established Laboratory Limits
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates - Second Source	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Blanks (Method blanks & continuing calibration blanks)	No target analyte concentrations > RDL
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	Must meet established Laboratory acceptance criteria
Overall accuracy/bias (contamination)	Field Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	RPD ≤ 50% when analytes are detected in both samples ≥ 5 times RDL

Data Quality Indicator (DQI)	**QC sample or measurement performance activity**	**Measurement Performance Criteria**
Analytical Precision (laboratory)	Dual Column Results	RPD ≤ 40% between primary and confirmation columns
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix:	Groundwater/Soil/LNAPL
Analytical Group or Method:	TCL SVOC/SW-846 8270D
SOP:_	NC-MS-018, Rev. 8
Concentration Level:	Low

Data Quality Indicator (DQI)	**QC sample or measurement performance activity**	**Measurement Performance Criteria**
Analytical Precision (laboratory)	DFTPP Tune	DFTPP Tune Criteria must be met per SW-846 Method 8270D
Analytical Accuracy/Bias (laboratory)	Initial Calibration (ICAL) Curves	%RSD and %D must be met per SW-846 Method 8270D; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D
Analytical Sensitivity (laboratory)	Continuing Calibration (CCAL) Standards	%D or %Drift must be met per SW-846 Method 8270D; Minimum Mean Response Factors must be met per SW-846 Method 8270D
Analytical Accuracy/Bias (laboratory)	Internal Standards	50-200% of the response of the previous continuing calibration standard
Analytical Accuracy/Bias (laboratory)	Surrogates	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	Must meet established Laboratory Limits
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates - Second Source	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Method Blanks	No target analyte concentrations > RDL
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	Must meet established Laboratory acceptance criteria

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Overall accuracy/bias (contamination)	Field Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	Waters: RPD ≤ 50% when SVOCs are detected in both samples ≥ 5 times RDL Soils/LNAPL: RPD ≤ 100% when SVOCs are detected in both samples ≥ 5 times RDL
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix:	Groundwater
Analytical Group or Method:	TCL SVOC/SW-846 8270D-SIM
SOP:	ED-MSS-009, Rev. 7
Concentration Level:	Low

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Analytical Precision (laboratory)	DFTPP Tune	DFTPP Tune Criteria must be met per SW-846 Method 8270D-SIM
Analytical Accuracy/Bias (laboratory)	Initial Calibration (ICAL) Curve	%RSD and %D must be met per SW-846 Method 8270D-SIM; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D-SIM
Analytical Sensitivity (laboratory)	Continuing Calibration (CCAL) Standards	%D or %Drift must be met per SW-846 Method 8270D-SIM; Minimum Mean Response Factors must be met per SW-846 Method 8270D-SIM
Analytical Accuracy/Bias (laboratory)	Internal Standards	50-200% of the response of the previous continuing calibration standard
Analytical Accuracy/Bias (laboratory)	Surrogates	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	Must meet established Laboratory Limits
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates - Second Source	Must meet established Laboratory Limits
Analytical Accuracy/Bias (laboratory)	Laboratory Method Blanks	No target analyte concentrations > RDL
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	Must meet established Laboratory acceptance criteria

Data Quality Indicator (DQI)	**QC sample or measurement performance activity**	**Measurement Performance Criteria**
Overall accuracy/bias (contamination)	Field Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	RPD ≤ 50% when SVOCs are detected in both samples ≥ 5 times RDL
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater/Soil/LNAPL
Analytical Group or Method: TAL Metals/SW-846 6010
SOP: NC-MT-012, Rev. 9
Concentration Level: Low

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Analytical Accuracy/Bias (laboratory)	Initial Calibration Curve Standards	Initial Calibration Criteria must be met per SW-846 Method 6010 Minimum R $\geq$ 0.995
Analytical Accuracy/Bias (laboratory)	Initial Calibration Verification (ICV)-Second Source	Analyze at the beginning of each analytical run; 90-110% Recovery
Analytical Accuracy/Bias (laboratory)	Initial calibration blank (ICB)	Analyze immediately after ICV; No target analyte concentrations > RDL
Analytical Sensitivity (laboratory)	Low Level Continuing Calibration Verification (CCV) Standard	Analyze at the beginning of each analytical run; 80-120% Recovery
Analytical Accuracy/Bias (laboratory)	Interference Check Solution Analysis (ICSAB)	Analyze at the beginning of each analytical run; 80-120% Recovery
Analytical Accuracy/Bias (laboratory)	Interference Check Solution Analysis (ICSA)	Analyze at the beginning of each analytical run; results for the non-interfering elements with reporting limits $\leq$ 10 ug/L must fall within ± 2 times the RL from zero. ICSA results for the noninterfering elements with RLs > 10 ug/L must fall within ± RL from zero.
Analytical Sensitivity (laboratory)	Continuing Calibration Verification (CCV) Standard	Analyze every 10 samples; 90-110% Recovery
Analytical Accuracy/Bias (laboratory)	Continuing Calibration blank (CCB)	Analyze every 10 samples; No target analyte concentrations > RDL
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	80-120% Recovery
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates-Second Source	RPD ≤ 20%
Analytical Accuracy/Bias (laboratory)	Laboratory Method Blank	No target analyte concentrations > RDL

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	75-125% recovery; RPD ≤ 20% for results > 5 times RDL
Analytical Accuracy/Bias (matrix interference)	Laboratory Duplicate	RPD ≤ 20% for results > 5 times RDL
Analytical Accuracy/Bias (matrix interference)	Serial Dilution	%D ≤ 10% (20% for 6010D) for analyte concentrations > 10 times RDL
Overall accuracy/bias (contamination)	Field Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	Waters: RPD ≤ 50% when metals are detected in both samples ≥ 5 times RDL Soils/LNAPL: RPD ≤ 100% when metals are detected in both samples ≥ 5 times RDL
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #12: Measurement Performance Criteria
(UFP-QAPP Manual Section 2.6.2)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater/Soil/LNAPL
Analytical Group or Method: Mercury/SW-846 7470A/SW-846 7471
SOP: NC-MT-014, Rev. 9
Concentration Level: Low

Data Quality Indicator (DQI)	**QC sample or measurement performance activity**	**Measurement Performance Criteria**
Analytical Accuracy/Bias (laboratory)	Initial Calibration Standards	Initial Calibration Criteria must be met per SW-846 Method 7470A Minimum R ≥ 0.995
Analytical Sensitivity (laboratory)	Initial Calibration Verification (ICV) Standard-Second Source	Analyze at the beginning of each analytical run; 90-110% Recovery
Analytical Accuracy/Bias (laboratory)	Initial calibration blank (ICB)	Analyze immediately after ICV; No target analyte concentrations > RDL
Analytical Sensitivity (laboratory)	Detection Limit Standard (CRA)	50-150% Recovery
Analytical Sensitivity (laboratory)	Continuing Calibration Verification (CCV) Standard	Analyze every 10 samples; 80-120% Recovery
Analytical Accuracy/Bias (laboratory)	Continuing Calibration Blank (CCB)	Analyze every 10 samples; No target analyte concentrations > RDL
Analytical Accuracy/Bias (laboratory)	Laboratory Control Samples-Second Source	80-120% Recovery
Analytical Precision (laboratory)	Laboratory Control Sample Duplicates-Second Source	RPD ≤ 20%
Analytical Accuracy/Bias (laboratory)	Laboratory Method Blank	No target analyte concentrations > RDL

Data Quality Indicator (DQI)	QC sample or measurement performance activity	Measurement Performance Criteria
Analytical Accuracy/Bias (matrix interference)	Matrix Spike/Matrix Spike Duplicates	75-125% recovery; Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL
Analytical Accuracy/Bias (matrix interference)	Laboratory Duplicate	Waters: RPD ≤ 20% for results > 5 times RDL Soils/LNAPL: RPD ≤ 35% for results > 5 times RDL
Overall accuracy/bias (contamination)	Field Blanks	No target analyte concentrations > RDL
Overall Precision	Field Duplicates	Waters: RPD ≤ 50% when metals are detected in both samples ≥ 5 times RDL Soils/LNAPL: RPD ≤ 100% when metals are detected in both samples ≥ 5 times RDL
Completeness	See Worksheet #34	See Worksheet #34

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: LNAPL
Analytical Method: SW-846 Method 8260C
SOP: NC-MS-019, Rev. 6
Concentration level (if applicable): Low

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
71-55-6	1,1,1-Trichloroethane	NA	NA	1000	1000	21.0
79-34-5	1,1,2,2-Tetrachloroethane	NA	NA	1000	1000	8.90
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	NA	2000	2000	39.0
79-00-5	1,1,2-Trichloroethane	NA	NA	1000	1000	12.0
75-34-3	1,1-Dichloroethane	NA	NA	1000	1000	17.0
75-35-4	1,1-Dichloroethene	NA	NA	1000	1000	18.0
120-82-1	1,2,4-Trichlorobenzene	NA	NA	1000	1000	7.30
96-12-8	1,2-Dibromo-3-chloropropane	NA	NA	1000	1000	50.0
106-93-4	1,2-Dibromoethane	NA	NA	1000	1000	10.0

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable

[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
95-50-1	1,2-Dichlorobenzene	NA	NA	1000	1000	8.60
107-06-2	1,2-Dichloroethane	NA	NA	1000	1000	10.0
78-87-5	1,2-Dichloropropane	NA	NA	1000	1000	8.20
541-73-1	1,3-Dichlorobenzene	NA	NA	1000	1000	4.80
106-46-7	1,4-Dichlorobenzene	NA	NA	1000	1000	8.00
78-93-3	2-Butanone	NA	NA	4000	4000	43.0
591-78-6	2-Hexanone	NA	NA	4000	4000	20.0
108-10-1	4-Methyl-2-pentanone	NA	NA	4000	4000	48.0
67-64-1	Acetone	NA	NA	4000	4000	170
71-43-2	Benzene	NA	NA	4000	4000	12.0
75-27-4	Bromodichloromethane	NA	NA	1000	1000	9.90
75-25-2	Bromoform	NA	NA	1000	1000	19.0
74-83-9	Bromomethane	NA	NA	2000	2000	29.0
75-15-0	Carbon disulfide	NA	NA	1000	1000	12.0
56-23-5	Carbon tetrachloride	NA	NA	1000	1000	6.40
108-90-7	Chlorobenzene	NA	NA	1000	1000	6.40
75-00-3	Chloroethane	NA	NA	2000	2000	61.0
67-66-3	Chloroform	NA	NA	1000	1000	8.80
74-87-3	Chloromethane	NA	NA	2000	2000	14.0
156-59-2	cis-1,2-Dichloroethene	NA	NA	1000	1000	6.90
10061-01-5	cis-1,3-Dichloropropene	NA	NA	1000	1000	7.90
110-82-7	Cyclohexane	NA	NA	2000	2000	40.0
124-48-1	Dibromochloromethane	NA	NA	1000	1000	12.0

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
75-71-8	Dichlorodifluoromethane	NA	NA	2000	2000	16.0
100-41-4	Ethylbenzene	NA	NA	1000	1000	5.40
98-82-8	Isopropylbenzene	NA	NA	1000	1000	6.50
79-20-9	Methyl Acetate	NA	NA	5000	5000	25.0
1634-04-4	Methyl tert-Butyl Ether	NA	NA	4000	4000	7.10
108-87-2	Methylcyclohexane	NA	NA	1000	1000	12.0
75-09-2	Methylene chloride	NA	NA	1000	1000	77.0
100-42-5	Styrene	NA	NA	1000	1000	5.60
127-18-4	Tetrachloroethene	NA	NA	1000	1000	12.0
108-88-3	Toluene	NA	NA	1000	1000	17.0
156-60-5	trans-1,2-Dichloroethene	NA	NA	1000	1000	9.20
10061-02-6	trans-1,3-Dichloropropene	NA	NA	1000	1000	20.0
79-01-6	Trichloroethene	NA	NA	1000	1000	9.70
75-69-4	Trichlorofluoromethane	NA	NA	2000	2000	16.0
75-01-4	Vinyl chloride	NA	NA	2000	2000	18.0
1330-20-7	Total Xylenes	NA	NA	2000	2000	6.20

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Soil
Analytical Method: SW-846 Method 8260C
SOP: NC-MS-019, Rev. 6
Concentration level (if applicable): Low

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
71-55-6	1,1,1-Trichloroethane	640000	B	5.00	5.00	0.820
79-34-5	1,1,2,2-Tetrachloroethane	8400	B	5.00	5.00	1.43
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	910000	B	5.00	5.00	1.28
79-00-5	1,1,2-Trichloroethane	2100	B	5.00	5.00	1.13
75-34-3	1,1-Dichloroethane	50000	B	5.00	5.00	0.693
75-35-4	1,1-Dichloroethene	320000	B	5.00	5.00	0.903
120-82-1	1,2,4-Trichlorobenzene	81000	B	5.00	5.00	0.572
96-12-8	1,2-Dibromo-3-chloropropane	74	B	10.0	10.0	3.61

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018

B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6

C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
106-93-4	1,2-Dibromoethane	500	B	5.00	5.00	0.770
95-50-1	1,2-Dichlorobenzene	380000	B	5.00	5.00	1.11
107-06-2	1,2-Dichloroethane	6400	B	5.00	5.00	0.772
78-87-5	1,2-Dichloropropane	22000	B	5.00	5.00	0.851
541-73-1	1,3-Dichlorobenzene	NA	NA	5.00	5.00	0.816
106-46-7	1,4-Dichlorobenzene	36000	B	5.00	5.00	0.882
78-93-3	2-Butanone	28000000	B	20.0	20.0	3.56
591-78-6	2-Hexanone	280000	B	20.0	20.0	4.08
108-10-1	4-Methyl-2-pentanone	3400000	B	20.0	20.0	3.71
67-64-1	Acetone	85000000	B	25.0	25.0	21.0
71-43-2	Benzene	17000	B	5.00	5.00	0.698
75-27-4	Bromodichloromethane	4100	B	5.00	5.00	0.679
75-25-2	Bromoform	270000	B	5.00	5.00	2.40
74-83-9	Bromomethane	9500	B	5.00	5.00	0.988
75-15-0	Carbon disulfide	740000	B	5.00	5.00	1.16
56-23-5	Carbon tetrachloride	9100	B	5.00	5.00	3.25
108-90-7	Chlorobenzene	390000	B	5.00	5.00	0.916
75-00-3	Chloroethane	2100000	B	5.00	5.00	1.22
67-66-3	Chloroform	4500	B	5.00	5.00	0.788
74-87-3	Chloromethane	150000	B	5.00	5.00	1.04
156-59-2	cis-1,2-Dichloroethene	220000	B	5.00	5.00	0.651
10061-01-5	cis-1,3-Dichloropropene	25000	B	5.00	5.00	1.44
110-82-7	Cyclohexane	280000	B	10.0	10.0	1.38

CAS Number	Analyte	Project Action Limit (PAL) (µg/kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
124-48-1	Dibromochloromethane	120000	B	5.00	5.00	2.78
75-71-8	Dichlorodifluoromethane	120000	B	5.00	5.00	0.943
100-41-4	Ethylbenzene	81000	B	5.00	5.00	1.05
98-82-8	Isopropylbenzene	270000	B	5.00	5.00	0.832
79-20-9	Methyl Acetate	29000000	B	25.0	25.0	3.40
1634-04-4	Methyl tert-Butyl Ether	660000	B	5.00	5.00	0.820
108-87-2	Methylcyclohexane	NA	NA	10.0	10.0	1.23
75-09-2	Methylene chloride	490000	B	25.0	25.0	12.0
100-42-5	Styrene	870000	B	5.00	5.00	1.16
127-18-4	Tetrachloroethene	110000	B	5.00	5.00	0.730
108-88-3	Toluene	820000	B	5.00	5.00	0.773
156-60-5	trans-1,2-Dichloroethene	1900000	B	5.00	5.00	0.465
10061-02-6	trans-1,3-Dichloropropene	25000	B	5.00	5.00	1.03
79-01-6	Trichloroethene	5700	B	5.00	5.00	0.633
75-69-4	Trichlorofluoromethane	1200000	B	5.00	5.00	1.08
75-01-4	Vinyl chloride	830	B	5.00	5.00	0.837
1330-20-7	Total Xylenes	260000	B	10.0	10.0	1.59

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater
Analytical Method: SW-846 Method 8260C
SOP: NC-MS-019, Rev. 6
Concentration level (if applicable): Low

CAS Number	Analyte	Project Action Limit (PAL) (μg/L)	PAL Reference	Project Quantitation Limit Goal (μg/L)	Laboratory-RDL[1] (μg/L)	Laboratory-MDL[2] (μg/L)
71-55-6	1,1,1-Trichloroethane	200	A	1.00	1.00	0.240
79-34-5	1,1,2,2-Tetrachloroethane	0.76	C	1.00	1.00	0.130
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	10000	C	1.00	1.00	0.410
79-00-5	1,1,2-Trichloroethane	5	A	1.00	1.00	0.0900
75-34-3	1,1-Dichloroethane	28	C	1.00	1.00	0.170
75-35-4	1,1-Dichloroethene	7	A	1.00	1.00	0.190
120-82-1	1,2,4-Trichlorobenzene	70	A	1.00	1.00	0.260
95-50-1	1,2-Dichlorobenzene	600	A	1.00	1.00	0.150
107-06-2	1,2-Dichloroethane	5	A	1.00	1.00	0.210

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

CAS Number	**Analyte**	**Project Action Limit (PAL) (µg/L)**	**PAL Reference**	**Project Quantitation Limit Goal (µg/L)**	**Laboratory-RDL[1] (µg/L)**	**Laboratory-MDL[2] (µg/L)**
78-87-5	1,2-Dichloropropane	5	A	1.00	1.00	0.150
541-73-1	1,3-Dichlorobenzene	NA	NA	1.00	1.00	0.150
106-46-7	1,4-Dichlorobenzene	75	A	1.00	1.00	0.160
78-93-3	2-Butanone	5600	C	10.0	10.0	1.16
591-78-6	2-Hexanone	38	C	10.0	10.0	0.540
108-10-1	4-Methyl-2-pentanone	6300	C	10.0	10.0	0.420
67-64-1	Acetone	14000	C	10.0	10.0	5.41
71-43-2	Benzene	5	A	1.00	1.00	0.130
75-27-4	Bromodichloromethane	80	A	1.00	1.00	0.170
75-25-2	Bromoform	80	A	1.00	1.00	0.760
74-83-9	Bromomethane	7.5	C	1.00	1.00	0.420
75-15-0	Carbon disulfide	810	C	1.00	1.00	0.280
56-23-5	Carbon tetrachloride	5	A	1.00	1.00	0.260
108-90-7	Chlorobenzene	100	A	1.00	1.00	0.140
75-00-3	Chloroethane	21000	C	1.00	1.00	0.830
67-66-3	Chloroform	80	A	1.00	1.00	0.130
74-87-3	Chloromethane	190	C	1.00	1.00	0.200
156-59-2	cis-1,2-Dichloroethene	70	A	1.00	1.00	0.160
10061-01-5	cis-1,3-Dichloropropene	4.7	C	1.00	1.00	0.610
110-82-7	Cyclohexane	70	C	1.00	1.00	0.240
124-48-1	Dibromochloromethane	80	A	1.00	1.00	0.390
75-71-8	Dichlorodifluoromethane	200	C	1.00	1.00	0.350
100-41-4	Ethylbenzene	700	A	1.00	1.00	0.110

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
98-82-8	Isopropylbenzene	450	C	1.00	1.00	0.0900
79-20-9	Methyl Acetate	20000	C	10.0	10.0	1.72
1634-04-4	Methyl tert-Butyl Ether	140	C	1.00	1.00	0.0700
108-87-2	Methylcyclohexane	NA	NA	1.00	1.00	0.330
75-09-2	Methylene chloride	5	A	1.00	1.00	2.62
100-42-5	Styrene	100	A	1.00	1.00	0.100
127-18-4	Tetrachloroethene	5	A	1.00	1.00	0.150
108-88-3	Toluene	1000	A	1.00	1.00	0.140
156-60-5	trans-1,2-Dichloroethene	100	A	1.00	1.00	0.190
10061-02-6	trans-1,3-Dichloropropene	4.7	C	1.00	1.00	0.670
79-01-6	Trichloroethene	5	A	1.00	1.00	0.100
75-69-4	Trichlorofluoromethane	5200	C	1.00	1.00	0.450
75-01-4	Vinyl chloride	2	A	1.00	1.00	0.200
1330-20-7	Total Xylenes	10000	A	2.00	2.00	0.150

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix:	Groundwater
Analytical Method:	SW-846 Method 8011
SOP:	NC-GC-040, Rev. 2
Concentration level (if applicable):	Low

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
96-12-8	1,2-Dibromo-3-chloropropane	0.2	A	0.02	0.02	0.00300
106-93-4	1,2-Dibromoethane	0.05	A	0.02	0.02	0.00600

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[1] Reporting Detection Limit

[2] Non Sample-Specific Method Detection Limit

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018

B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6

C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: LNAPL
Analytical Method: SW-846 Method 8270D
SOP: NC-MS-018, Rev. 8
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/Kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
92-52-4	1,1'-Biphenyl	NA	NA	20000	20000	432
123-91-1	1,4-Dioxane	NA	NA	20000	20000	780
108-60-1	bis(2-Chloroisopropyl)ether	NA	NA	20000	20000	312
95-95-4	2,4,5-Trichlorophenol	NA	NA	20000	20000	294
88-06-2	2,4,6-Trichlorophenol	NA	NA	20000	20000	408
120-83-2	2,4-Dichlorophenol	NA	NA	20000	20000	318
105-67-9	2,4-Dimethylphenol	NA	NA	20000	20000	408
51-28-5	2,4-Dinitrophenol	NA	NA	96000	96000	2460
121-14-2	2,4-Dinitrotoluene	NA	NA	20000	20000	342
606-20-2	2,6-Dinitrotoluene	NA	NA	20000	20000	348
91-58-7	2-Chloronaphthalene	NA	NA	20000	20000	378
95-57-8	2-Chlorophenol	NA	NA	20000	20000	216
91-57-6	2-Methylnaphthalene	NA	NA	20000	20000	59.4
95-48-7	2-Methylphenol	NA	NA	20000	20000	402
88-74-4	2-Nitroaniline	NA	NA	96000	96000	306
88-75-5	2-Nitrophenol	NA	NA	20000	20000	204

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (µg/Kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
91-94-1	3,3'-Dichlorobenzidine	NA	NA	96000	96000	294
99-09-2	3-Nitroaniline	NA	NA	96000	96000	192
534-52-1	4,6-Dinitro-2-methylphenol	NA	NA	96000	96000	2820
101-55-3	4-Bromophenyl-phenylether	NA	NA	20000	20000	282
59-50-7	4-Chloro-3-methylphenol	NA	NA	20000	20000	3060
106-47-8	4-Chloroaniline	NA	NA	20000	20000	312
7005-72-3	4-Chlorophenyl phenyl ether	NA	NA	20000	20000	216
108-39-4; 106-44-5	3 & 4-Methylphenol	NA	NA	40000	40000	1200
100-01-6	4-Nitroaniline	NA	NA	96000	96000	216
100-02-7	4-Nitrophenol	NA	NA	96000	96000	4860
83-32-9	Acenaphthene	NA	NA	20000	20000	55.2
208-96-8	Acenaphthylene	NA	NA	20000	20000	84.0
98-86-2	Acetophenone	NA	NA	20000	20000	330
120-12-7	Anthracene	NA	NA	20000	20000	138
1912-24-9	Atrazine	NA	NA	20000	20000	660
100-52-7	Benzaldehyde	NA	NA	20000	20000	414
56-55-3	Benzo[a]anthracene	NA	NA	20000	20000	84.0
50-32-8	Benzo[a]pyrene	NA	NA	20000	20000	138
205-99-2	Benzo[b]fluoranthene	NA	NA	20000	20000	138
191-24-2	Benzo[ghi]perylene	NA	NA	20000	20000	108
207-08-9	Benzo[k]fluoranthene	NA	NA	20000	20000	138
111-91-1	Bis(2-chloroethoxy)methane	NA	NA	20000	20000	960
111-44-4	Bis(2-chloroethyl)ether	NA	NA	20000	20000	246
117-81-7	Bis(2-ethylhexyl) phthalate	NA	NA	20000	20000	960
85-68-7	Butyl benzyl phthalate	NA	NA	20000	20000	222
105-60-2	Caprolactam	NA	NA	20000	20000	468
86-74-8	Carbazole	NA	NA	20000	20000	558
218-01-9	Chrysene	NA	NA	20000	20000	59.4
53-70-3	Dibenz[a,h]anthracene	NA	NA	20000	20000	90.0
132-64-9	Dibenzofuran	NA	NA	20000	20000	49.8
84-66-2	Diethyl phthalate	NA	NA	20000	20000	372
131-11-3	Dimethyl phthalate	NA	NA	20000	20000	384

CAS Number	Analyte	Project Action Limit (PAL) (μg/Kg)	PAL Reference	Project Quantitation Limit Goal (μg/Kg)	Laboratory-RDL[1] (μg/Kg)	Laboratory-MDL[2] (μg/Kg)
84-74-2	Di-n-butyl phthalate	NA	NA	20000	20000	300
117-84-0	Di-n-octyl phthalate	NA	NA	20000	20000	660
206-44-0	Fluoranthene	NA	NA	20000	20000	55.8
86-73-7	Fluorene	NA	NA	20000	20000	78.0
118-74-1	Hexachlorobenzene	NA	NA	20000	20000	84.0
87-68-3	Hexachlorobutadiene	NA	NA	20000	20000	150
77-47-4	Hexachlorocyclopentadiene	NA	NA	96000	96000	174
67-72-1	Hexachloroethane	NA	NA	20000	20000	294
193-39-5	Indeno(1,2,3 cd)pyrene	NA	NA	20000	20000	120
78-59-1	Isophorone	NA	NA	20000	20000	210
91-20-3	Naphthalene	NA	NA	20000	20000	456
98-95-3	Nitrobenzene	NA	NA	20000	20000	246
621-64-7	n-Nitroso-di-n-propylamine	NA	NA	20000	20000	53.4
86-30-6	n-Nitrosodiphenylamine	NA	NA	20000	20000	384
87-86-5	Pentachlorophenol	NA	NA	20000	20000	2700
85-01-8	Phenanthrene	NA	NA	20000	20000	66.0
108-95-2	Phenol	NA	NA	20000	20000	342
129-00-0	Pyrene	NA	NA	20000	20000	60.0

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018

B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6

C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

NA – Not Applicable

[1] Reporting Detection Limit

[2] Non sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Soil
Analytical Method: SW-846 Method 8270D
SOP: NC-MS-018, Rev. 8
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/Kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
92-52-4	1,1'-Biphenyl	66000	B	50.0	50.0	17.0
123-91-1	1,4-Dioxane	74000	B	150	150	15.0
108-60-1	bis(2-Chloroisopropyl)ether	1000000	B	100	100	10.0
95-95-4	2,4,5-Trichlorophenol	8800000	B	150	150	69.0
88-06-2	2,4,6-Trichlorophenol	88000	B	150	150	64.0
120-83-2	2,4-Dichlorophenol	270000	B	150	150	44.0
105-67-9	2,4-Dimethylphenol	1800000	B	150	150	40.0
51-28-5	2,4-Dinitrophenol	180000	B	330	330	142
121-14-2	2,4-Dinitrotoluene	24000	B	200	200	62.0
606-20-2	2,6-Dinitrotoluene	5000	B	200	200	56.0
91-58-7	2-Chloronaphthalene	6700000	B	50.0	50.0	14.0
95-57-8	2-Chlorophenol	550000	B	50.0	50.0	10.0
91-57-6	2-Methylnaphthalene	3430000	B	15.0	15.0	1.96
95-48-7	2-Methylphenol	4500000	B	200	200	31.0
88-74-4	2-Nitroaniline	880000	B	200	200	40.0

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (µg/Kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL^1 (µg/Kg)	Laboratory-MDL^2 (µg/Kg)
88-75-5	2-Nitrophenol	NA	NA	50.0	50.0	13.0
91-94-1	3,3'-Dichlorobenzidine	17000	B	100	100	43.0
99-09-2	3-Nitroaniline	NA	NA	200	200	49.0
534-52-1	4,6-Dinitro-2-methylphenol	7100	B	330	330	80.0
101-55-3	4-Bromophenyl-phenylether	NA	NA	50.0	50.0	14.0
59-50-7	4-Chloro-3-methylphenol	8800000	B	150	150	45.0
106-47-8	4-Chloroaniline	38000	B	150	150	30.0
7005-72-3	4-Chlorophenyl phenyl ether	NA	NA	50.0	50.0	14.0
108-39-4; 106-44-5	3 & 4-Methylphenol	4500000	B	400	400	29.0
100-01-6	4-Nitroaniline	350000	B	200	200	60.0
100-02-7	4-Nitrophenol	NA	NA	330	330	94.0
83-32-9	Acenaphthene	5000000	B	15.0	15.0	2.86
208-96-8	Acenaphthylene	NA	NA	15.0	15.0	4.01
98-86-2	Acetophenone	2500000	B	100	100	11.0
120-12-7	Anthracene	25000000	B	15.0	15.0	2.41
1912-24-9	Atrazine	34000	B	200	200	36.0
100-52-7	Benzaldehyde	1200000	B	100	100	23.0
56-55-3	Benzo[a]anthracene	15000	B	15.0	15.0	3.41
50-32-8	Benzo[a]pyrene	1500	B	15.0	15.0	9.34
205-99-2	Benzo[b]fluoranthene	15000	B	15.0	15.0	6.50
191-24-2	Benzo[ghi]perylene	NA	NA	15.0	15.0	7.10
207-08-9	Benzo[k]fluoranthene	150000	B	15.0	15.0	6.93
111-91-1	Bis(2-chloroethoxy)methane	270000	B	100	100	12.0
111-44-4	Bis(2-chloroethyl)ether	3200	B	100	100	12.0
117-81-7	Bis(2-ethylhexyl) phthalate	550000	B	70.0	70.0	51.0
85-68-7	Butyl benzyl phthalate	4100000	B	70.0	70.0	22.0
105-60-2	Caprolactam	43000000	B	330	330	75.0
86-74-8	Carbazole	NA	NA	50.0	50.0	19.0
218-01-9	Chrysene	1500000	B	15.0	15.0	1.49
53-70-3	Dibenz[a,h]anthracene	1500	B	15.0	15.0	6.92
132-64-9	Dibenzofuran	100000	B	50.0	50.0	13.0
84-66-2	Diethyl phthalate	71000000	B	70.0	70.0	31.0

CAS Number	Analyte	Project Action Limit (PAL) (µg/Kg)	PAL Reference	Project Quantitation Limit Goal (µg/Kg)	Laboratory-RDL[1] (µg/Kg)	Laboratory-MDL[2] (µg/Kg)
131-11-3	Dimethyl phthalate	NA	NA	70.0	70.0	14.0
84-74-2	Di-n-butyl phthalate	NA	NA	70.0	70.0	22.0
117-84-0	Di-n-octyl phthalate	NA	NA	70.0	70.0	28.0
206-44-0	Fluoranthene	3400000	B	15.0	15.0	4.45
86-73-7	Fluorene	3400000	B	15.0	15.0	2.74
118-74-1	Hexachlorobenzene	2900	B	15.0	15.0	2.85
87-68-3	Hexachlorobutadiene	17000	B	50.0	50.0	12.0
77-47-4	Hexachlorocyclopentadiene	2500	B	330	330	62.0
67-72-1	Hexachloroethane	25000	B	50.0	50.0	9.00
193-39-5	Indeno(1,2,3 cd)pyrene	15000	B	15.0	15.0	7.36
78-59-1	Isophorone	8000000	B	50.0	50.0	12.0
91-20-3	Naphthalene	53000	B	15.0	15.0	2.41
98-95-3	Nitrobenzene	71000	B	100	100	13.0
621-64-7	n-Nitroso-di-n-propylamine	1100	B	50.0	50.0	11.0
86-30-6	n-Nitrosodiphenylamine	1500000	B	50.0	50.0	12.0
87-86-5	Pentachlorophenol	14000	B	150	150	58.0
85-01-8	Phenanthrene	NA	NA	15.0	15.0	2.23
108-95-2	Phenol	27000000	B	50.0	50.0	8.00
129-00-0	Pyrene	2500000	B	15.0	15.0	2.14

NOTES:

A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater
Analytical Method: SW-846 Method 8270D
SOP: NC-MS-018, Rev. 8
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
92-52-4	1,1'-Biphenyl	0.83	C	1.00	1.00	0.492
108-60-1	bis(2-Chloroisopropyl)ether	710	C	1.00	1.00	0.551
95-95-4	2,4,5-Trichlorophenol	1200	C	5.00	5.00	1.99
88-06-2	2,4,6-Trichlorophenol	12	C	5.00	5.00	1.80
120-83-2	2,4-Dichlorophenol	46	C	2.00	2.00	0.262
105-67-9	2,4-Dimethylphenol	360	C	2.00	2.00	0.518
51-28-5	2,4-Dinitrophenol	39	C	10.0	10.0	6.21
121-14-2	2,4-Dinitrotoluene	2.4	C	5.00	5.00	2.07
606-20-2	2,6-Dinitrotoluene	0.49	C	5.00	5.00	2.13
91-58-7	2-Chloronaphthalene	750	C	1.00	1.00	0.483
95-57-8	2-Chlorophenol	91	C	1.00	1.00	0.273
91-57-6	2-Methylnaphthalene	36	C	0.200	0.200	0.111
95-48-7	2-Methylphenol	930	C	1.00	1.00	0.209
88-74-4	2-Nitroaniline	190	C	2.00	2.00	0.510
88-75-5	2-Nitrophenol	NA	NA	2.00	2.00	0.564
91-94-1	3,3'-Dichlorobenzidine	1.3	C	5.00	5.00	1.15

NOTES:
A - MCLs
B   2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
99-09-2	3-Nitroaniline	NA	NA	2.00	2.00	0.566
534-52-1	4,6-Dinitro-2-methylphenol	1.5	C	5.00	5.00	2.82
101-55-3	4-Bromophenyl-phenylether	NA	NA	2.00	2.00	0.499
59-50-7	4-Chloro-3-methylphenol	1400	C	2.00	2.00	0.296
106-47-8	4-Chloroaniline	3.7	C	2.00	2.00	0.316
7005-72-3	4-Chlorophenyl phenyl ether	NA	NA	2.00	2.00	0.551
108-39-4; 106-44-5	3 & 4-Methylphenol	930	C	2.00	2.00	
100-01-6	4-Nitroaniline	38	C	2.00	2.00	0.917
100-02-7	4-Nitrophenol	NA	NA	10.0	10.0	2.17
83-32-9	Acenaphthene	530	C	0.200	0.200	0.172
208-96-8	Acenaphthylene	NA	NA	0.200	0.200	0.125
98-86-2	Acetophenone	1900	C	1.00	1.00	0.366
120-12-7	Anthracene	1800	C	0.200	0.200	0.135
1912-24-9	Atrazine	3	C	2.00	2.00	0.952
100-52-7	Benzaldehyde	190	C	2.00	2.00	0.759
56-55-3	Benzo[a]anthracene	0.3	C	0.200	0.200	0.171
50-32-8	Benzo[a]pyrene	0.2	A	0.200	0.200	0.173
205-99-2	Benzo[b]fluoranthene	2.5	C	0.200	0.200	0.154
191-24-2	Benzo[ghi]perylene	NA	NA	0.200	0.200	0.178
207-08-9	Benzo[k]fluoranthene	25	C	0.200	0.200	0.140
111-91-1	Bis(2-chloroethoxy)methane	59	C	1.00	1.00	0.455
111-44-4	Bis(2-chloroethyl)ether	0.14	C	1.00	1.00	0.402
117-81-7	Bis(2-ethylhexyl) phthalate	6	A	5.00	5.00	2.22
85-68-7	Butyl benzyl phthalate	160	C	2.00	2.00	0.666
105-60-2	Caprolactam	9900	C	5.00	5.00	0.934
86-74-8	Carbazole	NA	NA	1.00	1.00	0.490
218-01-9	Chrysene	250	C	0.200	0.200	0.186
53-70-3	Dibenz[a,h]anthracene	0.25	C	0.200	0.200	0.151
132-64-9	Dibenzofuran	7.9	C	1.00	1.00	0.561
84-66-2	Diethyl phthalate	15000	C	5.00	5.00	3.82
131-11-3	Dimethyl phthalate	NA	NA	2.00	2.00	0.515
84-74-2	Di-n-butyl phthalate	NA	NA	5.00	5.00	1.80
117-84-0	Di-n-octyl phthalate	NA	NA	2.00	2.00	0.821

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL^1 (µg/L)	Laboratory-MDL^2 (µg/L)
206-44-0	Fluoranthene	800	C	0.200	0.200	0.160
86-73-7	Fluorene	290	C	0.200	0.200	0.169
118-74-1	Hexachlorobenzene	1	A	0.200	0.200	0.161
87-68-3	Hexachlorobutadiene	1.4	C	1.00	1.00	0.543
77-47-4	Hexachlorocyclopentadiene	50	A	10.0	10.0	1.76
67-72-1	Hexachloroethane	3.3	C	1.00	1.00	0.395
193-39-5	Indeno(1,2,3 cd)pyrene	2.5	C	0.200	0.200	0.135
78-59-1	Isophorone	780	C	1.00	1.00	0.324
91-20-3	Naphthalene	1.7	C	0.200	0.200	0.109
98-95-3	Nitrobenzene	1.4	C	1.00	1.00	0.514
621-64-7	n-Nitroso-di-n-propylamine	0.11	C	1.00	1.00	0.253
86-30-6	n-Nitrosodiphenylamine	120	C	1.00	1.00	0.440
87-86-5	Pentachlorophenol	1	A	10.0	10.0	3.10
85-01-8	Phenanthrene	NA	NA	0.200	0.200	0.167
108-95-2	Phenol	5800	C	1.00	1.00	0.128
129-00-0	Pyrene	120	C	0.200	0.200	0.175

NOTES:

A - MCLs

B 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6

C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6

[1] Reporting Detection Limit

[2] Non sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater
Analytical Method: SW-846 Method 8270D-SIM
SOP: ED-MSS-009, Rev. 7
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
123-91-1	1,4-Dioxane (by SIM)	4.6	C	0.400	0.400	0.174

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: LNAPL
Analytical Method: SW-846 Method 6010
SOP: NC-MT-012, Rev. 9
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7429-90-5	Aluminum	NA	NA	20.0	20.0	5.33
7440-36-0	Antimony	NA	NA	2.00	2.00	0.359
7440-38-2	Arsenic	NA	NA	1.50	1.50	0.316
7440-39-3	Barium	NA	NA	20.0	20.0	0.362
7440-41-7	Beryllium	NA	NA	0.500	0.500	0.0540
7440-43-9	Cadmium	NA	NA	0.500	0.500	0.0480
7440-70-2	Calcium	NA	NA	500	500	36.5
7440-47-3	Chromium	NA	NA	1.00	1.00	0.151
7440-48-4	Cobalt	NA	NA	1.00	1.00	0.200
7440-50-8	Copper	NA	NA	2.50	2.50	0.236
7439-89-6	Iron	NA	NA	20.0	20.0	6.94
7439-92-1	Lead	NA	NA	1.00	1.00	0.282
7439-95-4	Magnesium	NA	NA	500	500	46.1
7439-96-5	Manganese	NA	NA	1.50	1.50	0.309
7440-02-0	Nickel	NA	NA	4.00	4.00	0.233

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7440-09-7	Potassium	NA	NA	500	500	36.1
7782-49-2	Selenium	NA	NA	2.00	2.00	0.469
7440-22-4	Silver	NA	NA	1.00	1.00	0.0810
7440-23-5	Sodium	NA	NA	500	500	62.8
7440-28-0	Thallium	NA	NA	2.00	2.00	0.399
7440-62-2	Vanadium	NA	NA	5.00	5.00	0.822
7440-66-6	Zinc	NA	NA	5.00	5.00	1.37

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Soil
Analytical Method: SW-846 Method 6010
SOP: NC-MT-012, Rev. 9
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7429-90-5	Aluminum	100000	B	20.0	20.0	5.33
7440-36-0	Antimony	43	B	2.00	2.00	0.359
7440-38-2	Arsenic	9.5	B	1.50	1.50	0.316
7440-39-3	Barium	21000	B	20.0	20.0	0.362
7440-41-7	Beryllium	220	B	0.500	0.500	0.0540
7440-43-9	Cadmium	99	B	0.500	0.500	0.0480
7440-70-2	Calcium	NA	NA	500	500	36.5
7440-47-3	Chromium	NA	NA	1.00	1.00	0.151
7440-48-4	Cobalt	32	B	1.00	1.00	0.200
7440-50-8	Copper	4300	B	2.50	2.50	0.236
7439-89-6	Iron	77000	B	20.0	20.0	6.94
7439-92-1	Lead	400	B	1.00	1.00	0.282
7439-95-4	Magnesium	NA	NA	500	500	46.1
7439-96-5	Manganese	2500	B	1.50	1.50	0.309
7440-02-0	Nickel	2100	B	4.00	4.00	0.233

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7440-09-7	Potassium	NA	NA	500	500	36.1
7782-49-2	Selenium	550	B	2.00	2.00	0.469
7440-22-4	Silver	550	B	1.00	1.00	0.0810
7440-23-5	Sodium	NA	NA	500	500	62.8
7440-28-0	Thallium	1.1	B	2.00	2.00	0.399
7440-62-2	Vanadium	550	B	5.00	5.00	0.822
7440-66-6	Zinc	32000	B	5.00	5.00	1.37

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater
Analytical Method: SW-846 Method 6010
SOP: NC-MT-012, Rev. 9
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
7429-90-5	Aluminum	20000	C	200	200	47.3
7440-36-0	Antimony	6	A	20.0	20.0	7.46
7440-38-2	Arsenic	10	A	15.0	15.0	4.05
7440-39-3	Barium	2000	A	200	200	1.33
7440-41-7	Beryllium	4	A	5.00	5.00	0.601
7440-43-9	Cadmium	5	A	5.00	5.00	0.203
7440-70-2	Calcium	NA	NA	5000	5000	307
7440-47-3	Chromium	100	A	10.0	10.0	0.625
7440-48-4	Cobalt	6	C	10.0	10.0	0.752
7440-50-8	Copper	1300	A	25.0	25.0	3.55
7439-89-6	Iron	14000	C	200	200	26.0
7439-92-1	Lead	15	A	10.0	10.0	2.77
7439-95-4	Magnesium	NA	NA	5000	5000	259
7439-96-5	Manganese	430	C	15.0	15.0	2.12
7440-02-0	Nickel	390	C	40.0	40.0	2.20

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

CAS Number	**Analyte**	**Project Action Limit (PAL) (μg/L)**	**PAL Reference**	**Project Quantitation Limit Goal (μg/L)**	**Laboratory-RDL[1] (μg/L)**	**Laboratory-MDL[2] (μg/L)**
7440-09-7	Potassium	NA	NA	5000	5000	557
7782-49-2	Selenium	50	A	20.0	20.0	5.96
7440-22-4	Silver	94	C	10.0	10.0	0.623
7440-23-5	Sodium	NA	NA	5000	5000	560
7440-28-0	Thallium	2	A	20.0	20.0	2.68
7440-62-2	Vanadium	86	C	50.0	50.0	5.56
7440-66-6	Zinc	6000	C	50.0	50.0	9.67

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample-Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: LNAPL
Analytical Method: SW-846 Method 7471
SOP: NC-MT-014, Rev. 9
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7439-97-6	Mercury	NA	NA	0.100	0.100	0.0180

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
NA – Not Applicable
[1] Reporting Detection Limit
[2] Non Sample –Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix:	Soil
Analytical Method:	SW-846 Method 7471
SOP:	NC-MT-014, Rev. 9
Concentration level (if applicable):	

CAS Number	Analyte	Project Action Limit (PAL) (mg/Kg)	PAL Reference	Project Quantitation Limit Goal (mg/Kg)	Laboratory-RDL[1] (mg/Kg)	Laboratory-MDL[2] (mg/Kg)
7439-97-6	Mercury	3.1	B	0.100	0.100	0.0180

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample –Specific Method Detection Limit

QAPP Worksheet #15: Project Action Limits and Laboratory-Specific Detection/Quantitation Limits
(UFP-QAPP Manual Section 2.6.2.3 and Figure 15)
(EPA 2106-G-05 Section 2.2.6)

Matrix: Groundwater
Analytical Method: SW-846 Method 7470A
SOP: NC-MT-014, Rev. 9
Concentration level (if applicable):

CAS Number	Analyte	Project Action Limit (PAL) (µg/L)	PAL Reference	Project Quantitation Limit Goal (µg/L)	Laboratory-RDL[1] (µg/L)	Laboratory-MDL[2] (µg/L)
7439-97-6	Mercury	2	A	0.200	0.200	0.130

NOTES:
A – Maximum Contaminant Level, EPA 822-F-18-001, March 2018
B - 2019 IDEM Screening & Closure Levels, Soil Exposure, Direct Contact, Residential; Table A-6
C - 2019 IDEM Screening & Closure Levels, Ground Water, Tap, Residential; Table A-6
[1] Reporting Detection Limit
[2] Non Sample –Specific Method Detection Limit

QAPP Worksheet #17: Sampling Design and Rationale

(UFP-QAPP Manual Section 3.1.1)
(EPA 2106-G-05 Section 2.3.1)

Scope and objectives of the investigation include characterization of the nature and extent of COPCs to characterize the horizontal and vertical delineation of COPC-impacted soil and groundwater. The RFI will be completed in a phased approach.

CITGO and OXY may coordinate efforts to increase efficiency and avoid duplication for elements of the corrective action where applicable to both parties. CITGO and OXY are proceeding under separate AOCs for the Refinery Site and CITGO Terminal respectively.

Perimeter Investigation

In May 2019 and August 2019, CITGO and OXY jointly conducted a perimeter soil and groundwater screening investigation as set forth in the Site Perimeter Screening Investigation Work Plan dated April 5, 2019 (approved by EPA). The investigation utilized real-time field screening technologies designed to qualitatively detect polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), using laser-induced fluorescence (LIF) and membrane interface probe (MIP).

In September 2019, CITGO and OXY (and other appropriate persons) met with EPA to present the Phase I results. Within 30 days of September 2019 meeting, CITGO and OXY will submit a data report for the Phase I screening investigation activities, including an evaluation of the data.

RFI Investigation

The results of the Perimeter investigation, a review of the historical operations, and physical setting of the Facility were used in the development of the scope, expectations, and objectives for the RFI Investigation. The scope was discussed and agreed upon during the September 2019 meeting between CITGO and EPA.

Unless the parties agree otherwise, Respondents must submit the RFI Work Plan by March 1, 2020 for EPA review and approval. The RFI Work Plan including sampling locations, vertical extent of sampling, density of sampling, and screening data shall be reviewed and approved by EPA consistent with the approved CAF systematic planning process.

Initial soil and groundwater analysis will include the following chemicals of potential concern (COPCs); target compound list (TCL) volatile organic compounds (VOCs) (Method 8260), TCL semi-volatile organic compounds (SVOCs) (Method 8270), target analyte list (TAL) metals (Method 6010/7470) and 1,4-dioxane. The COPCs may be reduced during subsequent phases of investigation. The investigation will also determine the nature and extent of contamination in soil or groundwater or where potentially preferential pathways for historical contamination are identified.

The RFI investigation is intended to be iterative and adaptive based on conditions encountered in the field. Pending the results of the initial investigation, additional phases may be identified during or after the quarterly monitoring program.

Additional phases may include a subsequent Off-site groundwater investigation. Subsequent sampling locations, vertical extent of sampling, and density of screening data shall be reviewed and approved by EPA consistent with the approved CAF systematic planning process.

An interim RFI data report summarizing the results of the RFI Work Plan and an updated Conceptual Site Model (CSM), including proposed additional activities, if any, will be prepared for submittal to the U.S. EPA following two rounds of quarterly groundwater sampling. Subsequent quarterly groundwater results will be included in either the quarterly progress reports or in a subsequent interim RFI data report(s) (if applicable).

Once it has been determined that sufficient data has been obtained to describe the nature and extent of any releases of hazardous waste and hazardous constituents at or from the Facility that may pose an unacceptable risk to human health and the environment, a final RFI Report will be developed and submitted to the U.S. EPA by no later than October 1, 2021 unless a revised date is agreed to by both U.S. EPA and CITGO. The RFI report will describe the nature and extent of any releases of hazardous waste and hazardous constituents at or from the Facility that do or do not pose an unacceptable risk to human health and the environment, and provide the basis for those conclusions, including an evaluation of the risks. The investigation shall include a consensus driven balance between qualitative and quantitative high-resolution investigation techniques.

QAPP Worksheet #18: Sampling Locations and Methods
(UFP-QAPP Manual Section 3.1.1 and 3.1.2)
(EPA 2106-G-05 Section 2.3.1 and 2.3.2)

Sample ID	Matrix[1]	Depth (ft BGS)	Type	Analyte/ Analytical Group	Sampling SOP	Comments
TBD	Groundwater	Water table	Characterize groundwater quality	TCL VOCs, TCL SVOCs, TAL Metals	GHD Field Training Manual 200010 (2) – Section 7.0	
TBD	Soil	0-2	Characterize shallow soil quality	TCL VOCs, TCL SVOCs, TAL Metals	GHD Field Training Manual 200010 (2) – Section 5.0	
IDW – water	Wastewater	NA	Characterize for disposal	TCL VOCs, TCL SVOCs, TAL Metals, PCBs, RCRA Characteristics	GHD Field Training Manual 200010 (2) – Section 7.0	
IDW – soil	Soil	NA	Characterize for disposal	TCLP VOCs, TCLP SVOCs, TCLP Metals, PCBs, RCRA Characteristics	GHD Field Training Manual 200010 (2) – Section 5.0	
LNAPL	NAPL	NA	Characterize NAPL	TCL VOCs, TCL SVOCs, TAL Metals		

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[1] Key: SS = surface soil, S = soil, SD = sediment, GW = groundwater, SW = surface water

QAPP Worksheet #19 & 30: Sample Containers, Preservation, and Hold Times
(UFP-QAPP Manual Section 3.1.2.2)
(EPA 2106-G-05 Section 2.3.2)

Laboratory: Eurofins TestAmerica, Canton
4101 Shuffel Street NW
North Canton, Ohio 44720
Denise Heckler (denise.heckler@testamericainc.com)
Back-up Laboratory: Various Eurofins TestAmerica Network Laboratories
Sample Delivery Method: FedEx

Analyte/ Analyte Group	Matrix	Method/ SOP	Container(s) (number, size & type per sample)	Preservation	Preparation Holding Time	Analytical Holding Time	Data Package Turnaround
Volatile Organic Compounds (VOCs)	Water	SW-846 8260C NC-MS-019, Rev. 6	3, 40-ml VOA vials w/ PTFE-faced silicone septum	pH < 2 with HCl; 4 ± 2°C	NA	14 days	15 BD
DBCP & EDB	Water	SW-846 8011; NC-GC-040, Rev. 2	3, 40-ml VOA vials w/ PTFE-faced silicone septum	pH < 2 with HCl; 4 ± 2°C	NA	14 days	15 BD
Semivolatile Organic Compounds (SVOCs)	Water	SW-846 8270D; NC-MS-018, Rev. 8	1 L amber glass w/PTFE lined lid	4 ± 2°C	7 days	40 days	15 BD
Semivolatile Organic Compounds (SVOCs)-SIM	Water	SW-846 8270D-SIM; ED-MSS-009, Rev. 7	250 mL amber glass w/PTFE lined lid	4 ± 2°C	7 days	40 days	15 BD
TAL Metals	Water	SW-846 6010; NC-MT-012, Rev. 9	500 ml HDPE	pH < 2 with HNO_3; 4 ± 2°C	NA	180 Days	15 BD
Mercury	Water	SW-846 7470A; NC-MT-014, Rev. 9	500 ml HDPE	pH < 2 with HNO_3; 4 ± 2°C	NA	28 days	15 BD
Volatile Organic Compounds (VOCs)	Soil	SW-846 8260C NC-MS-019, Rev. 6	EnCore or TerraCores	4 ± 2°C	48 hours	14 days	15 BD

Analyte/ Analyte Group	Matrix	Method/ SOP	Container(s) (number, size & type per sample)	Preservation	Preparation Holding Time	Analytical Holding Time	Data Package Turnaround
Semivolatile Organic Compounds (SVOCs)	Soil	SW-846 8270D; NC-MS-018, Rev. 8	8 ounce glass jar w/PTFE lined lid	4 ± 2°C	14 days	40 days	15 BD
TAL Metals	Soil	SW-846 6010; NC-MT-012, Rev. 9	8 ounce glass jar w/PTFE lined lid	4 ± 2°C	NA	180 days	15 BD
Mercury	Soil	SW-846 7471; NC-MT-014, Rev. 9	8 ounce glass jar w/PTFE lined lid	4 ± 2°C	NA	28 days	15 BD
TCL VOCs	LNAPL	SW-846 8260C NC-MS-019, Rev. 6	2 ounce glass jar w/ PTFE lined lid	4 ± 2°C	NA	14 days	15 BD
TCL SVOCs	LNAPL	SW-846 8270D; NC-MS-018, Rev. 8	4 ounce glass jar w/ PTFE lined lid	4 ± 2°C	14 days	40 days	15 BD
TAL Metals	LNAPL	SW-846 6010; NC-MT-012, Rev. 9	4 ounce glass jar w/ PTFE lined lid	4 ± 2°C	NA	180 days	15 BD
Mercury	LNAPL	SW-846 7471; NC-MT-014, Rev. 9	4 ounce glass jar w/ PTFE lined lid	4 ± 2°C	NA	28 days	15 BD

QAPP Worksheet #20: Field QC Summary
(UFP-QAPP Section 3.1.1 and 3.1.2)
(EPA 2106-G-05 Section 2.3.5)

Task/Event	Matrix	Analyte/Analytical Group	Field Samples	Field Blanks (1/10)	Field Duplicates (1/10)	Matrix Spike/Matrix Spike Duplicates (1/20)	Trip Blanks (1/cooler for VOCs)	Total # analyses
Groundwater	Groundwater	TCL VOCs	TBD	TBD	TBD	TBD	TBD	TBD
Groundwater	Groundwater	DBCP & EDB	TBD	TBD	TBD	TBD	TBD	TBD
Groundwater	Groundwater	TCL SVOCs	TBD	TBD	TBD	TBD	TBD	TBD
Groundwater	Groundwater	1,4-Dioxane-SIM	TBD	TBD	TBD	TBD	TBD	TBD
Groundwater	Groundwater	TAL Metals	TBD	TBD	TBD	TBD	TBD	TBD
Groundwater	Groundwater	Mercury	TBD	TBD	TBD	TBD	TBD	TBD
Soil	Soil	TCL VOCs	TBD	TBD	TBD	TBD	TBD	TBD
Soil	Soil	TCL SVOCs	TBD	TBD	TBD	TBD	TBD	TBD
Soil	Soil	TAL Metals	TBD	TBD	TBD	TBD	TBD	TBD
Soil	Soil	Mercury	TBD	TBD	TBD	TBD	TBD	TBD
LNAPL		TCL VOCs	TBD	TBD	TBD	TBD	TBD	TBD
LNAPL		TCL SVOCs	TBD	TBD	TBD	TBD	TBD	TBD
LNAPL		TAL Metals	TBD	TBD	TBD	TBD	TBD	TBD
LNAPL		Mercury	TBD	TBD	TBD	TBD	TBD	TBD

QAPP Worksheet #21: Field SOPs
(UFP-QAPP Manual Section 3.1.2)
(EPA 2106-G-05 Section 2.3.2)

SOP # or reference	Title, Revision, Date, and URL (if available)	Originating Organization	SOP option or Equipment Type (if SOP provides different options)	Modified for Project? Y/N	Comments
GHD Field Training Manual 200010 (2)	Revision 0 –July 1, 2015	GHD Services, Inc.	Section 5.0: Soil Sampling Standard Operating Procedures	N	
GHD Field Training Manual 200010 (2)	Revision 0 –July 1, 2015	GHD Services, Inc.	Section 7.0: Water Sampling Standard Operating Procedures	N	
GHD Field Training Manual 200010 (2)	Revision 0 –July 1, 2015	GHD Services, Inc.	Section 13.0: Decontamination of Heavy Equipment Standard Operating Procedures	N	
GHD Field Training Manual 200010 (2)	Revision 0 –July 1, 2015	GHD Services, Inc.	Section 18.0: Soil Excavation and Confirmatory Sampling Standard Operating Procedures	N	

QAPP Worksheet #22: Field Equipment Calibration, Maintenance, Testing, and Inspection
(UFP-QAPP Manual Section 3.1.2.4)
(EPA 2106-G-05 Section 2.3.6)

Field Equipment	Activity	SOP Reference	Title or position of responsible person	Frequency	Acceptance Criteria	Corrective Action
YSI 3560 Water Quality Meter (pH, temperature, conductivity, ORP)	Calibration	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
YSI 3560 Water Quality Meter (pH, temperature, conductivity, ORP)	Maintenance	Operators Manual	Equipment Coordinator	Annually	See Operators Manual	See Operators Manual
YSI 3560 Water Quality Meter (pH, temperature, conductivity, ORP)	Testing	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
YSI 3560 Water Quality Meter (pH, temperature, conductivity, ORP)	Inspection	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
YSI 52 (dissolved oxygen)	Calibration	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
YSI 52 (dissolved oxygen)	Maintenance	Operators Manual	Equipment Coordinator	Annually	See Operators Manual	See Operators Manual
YSI 52 (dissolved oxygen)	Testing	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
YSI 52 (dissolved oxygen)	Inspection	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
DRT-15C (turbidity)	Calibration	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP

Field Equipment	Activity	SOP Reference	Title or position of responsible person	Frequency	Acceptance Criteria	Corrective Action
DRT-15C (turbidity)	Maintenance	Operators Manual	Equipment Coordinator	Annually	See Operators Manual	See Operators Manual
DRT-15C (turbidity)	Testing	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
DRT-15C (turbidity)	Inspection	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
PID Meter	Calibration	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
PID Meter	Maintenance	Operators Manual	Equipment Coordinator	Annually	See Operators Manual	See Operators Manual
PID Meter	Testing	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
PID Meter	Inspection	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP
Dual Phase Probe	Maintenance	Operators Manual	Equipment Coordinator	Annually	See Operators Manual	See Operators Manual
Dual Phase Probe	Testing	GHD SOP	Field Crew Chief	Daily	See GHD SOP	See GHD SOP

QAPP Worksheet #23: Analytical SOPs
(UFP-QAPP Manual Section 3.2.1)
(EPA 2106-G-05 Section 2.3.4)

Eurofins TestAmerica, Canton SOP #	Title and Date	Definitive or Screening Data	Matrix/Analytical Group	Equipment Type	‡Modified for Project? Y/N
NC-MS-019, Rev. 6	*Determination of Volatile Organics by GC/MS Based on Methods 8260C, 8260B, and 8260A, 7/23/18*	Definitive	Water & Soil/VOCs	GC/MS	N
NC-GC-040, Rev. 2	*Ethylene Dibromide (EDB), and 1,2-Dibromo-3-Chloropropane (DBCP) in Water by Microextraction and Gas Chromatography, 1/7/19*	Definitive	Water/VOCs	GC	N
NC-MS-018, Rev. 8	*GC/MS ANALYSIS BASED ON METHODS 8270C, 8270D, and 8270E, 7/2/19*	Definitive	Water & Soil/SVOCs	GC/MS	N
ED-MSS-009, Rev. 7	*Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), SW846 Method 8270D, 6/8/18*	Definitive	Water/SVOCs	GC/MS	N
NC-MT-012, Rev. 9	*INDUCTIVELY COUPLED PLASMA – ATOMIC EMISSION SPECTROSCOPY, SPECTROMETRIC METHOD FOR ELEMENT ANALYSES, 7/1/19*	Definitve	Water & Soil/Metals	ICP/AES	N
NC-MT-014, Rev. 9	*PREPARATION AND ANALYSIS OF MERCURY IN AQUEOUS AND SOLID SAMPLES BY COLD VAPOR ATOMIC ABSORPTION SPECTROSCOPY, 8/5/19*	Definitive	Water & Soil/Mercury	CVAA	N
NC-IP-011, Rev. 8	*ACID DIGESTION FOR AQUEOUS SAMPLES, 10/22/19*	NA	Water/Metals	Hot Plate/Hot Block	N
NC-OP-025, Rev. 9	*CLEANUP PROCEDURES FOR ORGANIC EXTRACTABLE SAMPLES, 1/25/19*	NA	All/Organics	Various	N
NC-OP-037, Rev. 7	*CONTINUOUS LIQUID/LIQUID EXTRACTION OF ORGANIC COMPOUNDS FROM WATERS BASED ON METHOD SW846 3520C AND 600 SERIES, 10/12/18*	NA	Water/Organics	Various	N
NC-OP-038, Rev. 8	*SEPARATORY FUNNEL EXTRACTION OF ORGANIC COMPOUNDS FROM WATERS BASED ON METHOD SW846 3510C AND 600 SERIES, 10/16/19*	NA	Water/Organics	Various	N
NC-09-040, Rev. 6	*SOXHLET (TRADITIONAL) EXTRACTION OF ORGANIC COMPOUNDS FROM SOILS BASED ON METHOD SW846 3540C, 5/25/18*	NA	Soil/Organics	Various	N

Eurofins TestAmerica, Canton SOP #	**Title and Date**	**Definitive or Screening Data**	**Matrix/Analytical Group**	**Equipment Type**	**‡Modified for Project? Y/N**
ED-ORP-002, Rev. 11	*Extraction of Semi-Volatile Organic Compounds in Aqueous Samples and Leachates - Separatory Funnel, SW846 Method 3510C, 3/26/18*	NA	Water/Organics	Various	N
NC-QAM-001, Rev 6	*Quality Assurance Manual, 4/2/19*	NA	NA	NA	N
NC-OP-043, Rev. 3	*Waste Dilution – SW846 Method 3580A, 5/14/18*	NA	Waste/Organics	Various	N
NC-IP-010, Rev. 8	*Acid Digestion for Solid Samples – SW846 Method 3050B, 10/16/18*	NA	Solid/Metals	Various	N

‡ A brief summary of project-specific SOP modifications must be provided on this worksheet or referenced.

QAPP Worksheet #24: Analytical Instrument Calibration
(UFP-QAPP Manual Section 3.2.2)
(EPA 2106-G-05 Section 2.3.6)

Instrument	Calibration Procedure	Calibration Range	Frequency	Acceptance Criteria	Corrective Action (CA)	Title/position responsible for Corrective Action	SOP Reference
GC/MS-VOCs	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	NC-MS-019, Rev. 6
GC-VOCs	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	NC-GC-040, Rev. 2
GC/MS-SVOCs	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	NC-MS-018, Rev. 8
GC/MS-SVOCs-SIM	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	ED-MSS-009, Rev. 7
ICP-AES	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	NC-MT-012, Rev. 9
CVAA	Per SOP	Per SOP	Per SOP	Per SOP	Per SOP	Denise Heckler/Lab PM	NC-MT-014, Rev. 9

QAPP Worksheet #25: Analytical Instrument and Equipment Maintenance, Testing, and Inspection
(UFP-QAPP Manual Section 3.2.3)
(EPA 2106-G-05 Section 2.3.6)

The project team should determine whether it is necessary to complete all fields in this table. For example, if the selected laboratory is operating under a quality system that conforms to ISO 17025:2005, then the activities documented in this table will be documented in the laboratory's quality manual (however named). In this case, it may be acceptable to simply reference the quality manual (including revision number and date.) If the project has specific requirements that are different from those contained in the laboratory's quality manual, however, this table should be completed for those items.

Instrument / Equipment	Maintenance/Testing/Inspection Activity	Reference
GC/MS-VOCs	Per NC-QAM-001, Rev. 6, 4/2/19	Eurofins Environment Testing TestAmerica-North Canton, Ohio – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
GC/MS-SVOCs	Per NC-QAM-001, Rev. 6, 4/2/19	Eurofins Environment Testing TestAmerica-North Canton, Ohio – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
GC-VOCs	Per NC-QAM-001, Rev. 6, 4/2/19	Eurofins Environment Testing TestAmerica-North Canton, Ohio – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
ICP-AES	Per NC-QAM-001, Rev. 6, 4/2/19	Eurofins Environment Testing TestAmerica-North Canton, Ohio – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
CVAA	Per NC-QAM-001, Rev. 6, 4/2/19	Eurofins Environment Testing TestAmerica-North Canton, Ohio – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19

QAPP Worksheet #26 & 27: Sample Handling, Custody, and Disposal
(UFP-QAPP Manual Section 3.3)
(EPA 2106-G-05 Section 2.3.3)

Sampling Organization:	GHD Services Inc.
Laboratory:	Eurofins TestAmerica, Canton
Method of sample delivery (shipper/carrier):	FedEx
Number of days from reporting until sample disposal:	180

Activity	Organization and title or position of person responsible for the activity	SOP reference
Sample labeling	GHD/Field Technician	GHD Field Training Manual- 200010 (2), Revision 0, July 1, 2015, Section 4.1
Chain-of-custody form completion	GHD/Field Technician	GHD Field Training Manual- 200010 (2), Revision 0, July 1, 2015, Section 4.2
Packaging	GHD/Field Technician	GHD Field Training Manual- 200010 (2), Revision 0, July 1, 2015, Section 4.2
Shipping coordination	GHD/Field Technician	GHD Field Training Manual- 200010 (2), Revision 0, July 1, 2015, Section 4.2
Sample receipt, inspection, & log-in	Eurofins TestAmerica, Canton/Sample Custodian	Eurofins TestAmerica, Canton – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
Sample custody and storage	Eurofins TestAmerica, Canton/Sample Custodian	Eurofins TestAmerica, Canton – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19
Sample disposal	Eurofins TestAmerica, Canton/Sample Custodian	Eurofins TestAmerica, Canton – Quality Assurance Manual, NC-QAM-001, Rev. 6, 4/2/19

Sample Identification

No one sample identification (ID) format is adequate for every type of sampling activity. Prior to the start of every project or sub-sampling event within the project, Project Managers (PM) and field personnel should devise a sample ID format. Sample IDs **must be unique** and formats should be as simple and consistent as possible. Simple sample IDs will reduce transcription errors by both GHD and lab personnel. The sample ID format should be comprehensive enough to allow for easy location of detailed sample data within the GHD log books. This information and other related information should be entered in the field logbook or sample key which will facilitate entry into GHD's project database.

The unique sample ID may follow one of the two formats recommended below, or a specific sample protocol for labeling may be specified in the project Work Plan or QAPP.

MC-ZZZ-LOC-MMDDYY-XX-NNN

where:

1. MC (Matrix Code) = WG-groundwater, SO-soil
2. ZZZ = abbreviated name of the Site
3. LOC = Well number or sample location identification
4. MMDDYY = Date in month/day/year
5. XX = Sampler's first and last initials
6. NNN = Sequential number for an event or project starting with 001

This format has been selected to maximize the information content of the sample ID. Minor modifications are certainly reasonable.

1. Series letters designate a group of samples. This will typically identify sample matrix (e.g., sediment, soil, groundwater, surface water, air, etc.), or sample source. For example, "WG" means samples of groundwater, "SO" means samples of soil. Letters should be used, not numbers. The sample ID matrix code is not necessarily the same as the matrix code identified in the field sample key or GHD database, it is a simple two letter code used to define matrix as established for the project.

2. Abbreviated name of the Site together with the series number will allow easier tracking of samples.

3. Sample date will allow monitoring of actual holding time of samples and should ensure that all sample numbers are unique, even if sample location designation is used in a system, as opposed to assigned at random.

4. Sampler's initials will allow identification of the sampler and so allow all project personnel to contact the correct person for information regarding that sample and its collection. The use of three initials is preferred. Special arrangements will need to be made if two individuals have the same initials.

5. The sequential number designation will identify the sample, and can be any numerical or letter designation. With multiple sampling crews collecting samples it is advantages to assign blocks of sequential numbers to each thereby avoiding repetition.

Field QC samples should be identified in the following manner:

1. Field blank samples – Field blank samples including equipment blanks, equipment rinsate blanks, media or bottle blanks, and ambient blanks shall be identified in the same format as investigative samples with no indication that they are QC samples. The field logbook shall identify them as QC samples.

2. Field duplicate samples – Field duplicate samples including field replicates, splits and full duplicates shall also be identified in the same format as investigative samples. The field logbook should identify them as QC samples.

3. Trip blank samples – Trip blank samples are used during the collection and transportation of samples for VOC analysis (including light range TPH). Trip blanks are primarily for water samples but may include soils if field preservation is performed. Trip blanks shall be identified in the same format as investigative samples. The field logbook shall identify them as QC samples.

4. Matrix spikes and matrix spike duplicates – These are technically laboratory QC samples but typically require additional volume (triple volume). They shall not be assigned separate sample IDs from the investigative sample as they are just additional volume.

The decision of how to assign sample numbers shall be made at the beginning of a job or phase, and shall be consistent throughout the job. Effort shall be made to eliminate use of the same sequential number on a project.

It is imperative that sample IDs be unique, use of sample locations (well numbers or boreholes numbers) that may repeated may cause problems when data is entered into the database (e.g., data may be overwritten). Samples collected on different days may have the same sequential number, but will have a unique date to identify the different samples. Samples collected on the same day shall include a sample depth or other appropriate difference in the 'LOC' field along with a unique sequential number to avoid potential database issues.

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix: Groundwater/Soil/LNAPL
Analytical Group: VOCs
Analytical Method/SOP: SW-846 8260C/SOP# NC-MS-019, Rev. 6

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
BFB Tune	One every 12 hours	BFB Tune Criteria must be met per SW-846 Method 8260C	Re-tune and reanalyze BFB.	Analyst / Laboratory Quality Assurance Officer	BFB Tune Criteria must be met per SW-846 Method 8260C
Initial Calibration (ICAL) Curve	As needed	%RSD and %D must be met per SW-846 Method 8260C; COD (R^2) $\geq$ 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8260C	Re-calibrate	Analyst / Laboratory Quality Assurance Officer	%RSD and %D must be met per SW-846 Method 8260C; COD (R^2) $\geq$ 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8260C
Continuing Calibration Check	One every 12 hours	%D and Minimum Mean Response Factors must be met per SW-846 Method 8260C	Re-calibrate and reanalyze.	Analyst / Laboratory Quality Assurance Officer	%D and Minimum Mean Response Factors must be met per SW-846 Method 8260C
Internal Standards (IS)	Every sample must be spiked with appropriate IS compounds	50-200% Recovery	Reanalyze samples with outlying recoveries. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	50-200% Recovery

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Surrogates	Every sample must be spiked with appropriate surrogate compounds	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Laboratory Control Sample/LCS Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	Reanalyze LCS/LCSD and all samples in associated batch for failed analytes. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix:	Groundwater
Analytical Group:	GC-VOCs
Analytical Method/SOP:	SW-846 8011/SOP# NC-GC-040, Rev. 2

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Initial Calibration	As Needed	%RSD must be met per SW-846 Method 8011; COD (R^2) > 0.99 for linear or quadratic curves, if used	Re-calibrate	Analyst / Laboratory Quality Assurance Officer	%RSD must be met per SW-846 Method 8011; COD (R^2) > 0.99 for linear or quadratic curves, if used
Initial/Continuing Calibration Verification (ICV/CCV)	Beginning of sequence (ICV), end of sequence and one per every 10 samples analyzed.	%D must be met per SW-846 Method 8011	Re-calibrate and reanalyze. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	%D must be met per SW-846 Method 8011
Surrogates	Every sample must be spiked with appropriate surrogate compounds	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Laboratory Control Sample/LCS Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	Re-prep and reanalyze LCS/LCSD and all samples in associated batch for failed analytes. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits

QC Sample	**Number/Frequency**	**Method/SOP Acceptance Criteria**	**Corrective Action**	**Title/position of person responsible for corrective action**	**Project-Specific MPC**
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Re-prep and reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Initial/Continuing Calibration Blank (ICB/CCB)	Beginning of sequence (ICB), end of sequence and one per every 10 samples analyzed.	No target analyte concentrations > RDL	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix: Groundwater/Soil/LNAPL
Analytical Group: SVOC
Analytical Method/SOP: SW-846 8270D/SOP# NC-MS-018, Rev. 8

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
DFTPP Tune	One every 12 hours	DFTPP Tune Criteria must be met per SW-846 Method 8270D	Re-tune and reanalyze DFTPP.	Analyst / Laboratory Quality Assurance Officer	DFTPP Tune Criteria must be met per SW-846 Method 8270D
Initial Calibration (ICAL) Curve	As needed	%RSD and %D must be met per SW-846 Method 8270D; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D	Re-calibrate	Analyst / Laboratory Quality Assurance Officer	%RSD and %D must be met per SW-846 Method 8270D; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D
Continuing Calibration Check	One every 12 hours	%D and Minimum Mean Response Factors must be met per SW-846 Method 8270D	Re-calibrate and reanalyze.	Analyst / Laboratory Quality Assurance Officer	%D and Minimum Mean Response Factors must be met per SW-846 Method 8270D
Internal Standards (IS)	Every sample must be spiked with appropriate IS compounds	50-200% Recovery	Reanalyze samples with outlying recoveries. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	50-200% Recovery

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Surrogates	Every sample must be spiked with appropriate surrogate compounds	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Laboratory Control Sample/LCS Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	Re-prep and reanalyze LCS/LCSD and all samples in associated batch for failed analytes. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Re-prep and reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix: Groundwater
Analytical Group: SVOCs-SIM
Analytical Method/SOP: SW-846 8270D-SIM/SOP# ED-MSS-009, Rev. 7

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
DFTPP Tune	One every 12 hours	DFTPP Tune Criteria must be met per SW-846 Method 8270D	Re-tune and reanalyze DFTPP.	Analyst / Laboratory Quality Assurance Officer	DFTPP Tune Criteria must be met per SW-846 Method 8270D
Initial Calibration (ICAL) Curve	As needed	%RSD and %D must be met per SW-846 Method 8270D-SIM; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D-SIM	Re-calibrate	Analyst / Laboratory Quality Assurance Officer	%RSD and %D must be met per SW-846 Method 8270D-SIM; COD (R^2) > 0.99 for linear or quadratic curves, if used. Minimum Mean Response Factors must be met per SW-846 Method 8270D-SIM
Continuing Calibration Check	One every 12 hours	%D and Minimum Mean Response Factors must be met per SW-846 Method 8270D	Re-calibrate and reanalyze.	Analyst / Laboratory Quality Assurance Officer	%D and Minimum Mean Response Factors must be met per SW-846 Method 8270D
Internal Standards (IS)	Every sample must be spiked with appropriate IS compounds	50-200% Recovery	Reanalyze samples with outlying recoveries. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	50-200% Recovery

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Surrogates	Every sample must be spiked with appropriate surrogate compounds	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Laboratory Control Sample/LCS Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	Re-prep and reanalyze LCS/LCSD and all samples in associated batch for failed analytes. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Re-prep and reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	Must meet Laboratory Limits	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Must meet Laboratory Limits

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix: Groundwater/Soil/LNAPL
Analytical Group: TAL Metals
Analytical Method/SOP: SW-846 6010/TA-NC SOP# NC-MT-012, Rev. 9

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Initial Calibration	Daily	Initial Calibration Criteria must be met per SW-846 Method 6010 Minimum R $\geq$ 0.995	Perform routine maintenance. Re-calibrate	Analyst / Laboratory Quality Assurance Officer	Initial Calibration Criteria must be met per SW-846 Method 6010 Minimum R $\geq$ 0.995
Initial/Continuing Calibration Verification (ICV/CCV)	Beginning of sequence (ICV), end of sequence and one per every 10 samples analyzed.	90-110% Recovery	Re-calibrate and reanalyze all samples processed with the outlying ICV/CCV.	Analyst / Laboratory Quality Assurance Officer	90-110% Recovery
Low Level Continuing Calibration Verification (CCV) Standard	Analyze at the beginning of each analytical run	80-120% Recovery	Re-analyze once. Re-calibrate and reanalyze all samples processed with the outlying ICV/CCV.	Analyst / Laboratory Quality Assurance Officer	80-120% Recovery
Interference Check Solution Analysis (ICSAB)	Beginning and end of sequence or every 12 hours	Analyze at the beginning of each analytical run; 80-120% Recovery	Re-calibrate and reanalyze all samples processed with the outlying ICV/CCV.	Analyst / Laboratory Quality Assurance Officer	Analyze at the beginning of each analytical run; 80-120% Recovery

QC Sample	**Number/Frequency**	**Method/SOP Acceptance Criteria**	**Corrective Action**	**Title/position of person responsible for corrective action**	**Project-Specific MPC**
Interference Check Solution Analysis (ICSA)	Beginning and end of sequence or every 12 hours	Analyze at the beginning of each analytical run; results for the non-interfering elements with reporting limits < 10 ug/L must fall within + 2 times the RL from zero. ICSA results for the noninterfering elements with RLs > 10 ug/L must fall within + RL from zero.	Re-calibrate and reanalyze all samples processed with the outlying ICV/CCV.	Analyst / Laboratory Quality Assurance Officer	Analyze at the beginning of each analytical run; results for the non-interfering elements with reporting limits < 10 ug/L must fall within + 2 times the RL from zero. ICSA results for the noninterfering elements with RLs > 10 ug/L must fall within + RL from zero.
Laboratory Control Sample	One per preparatory batch of up to 20 samples.	80-120% Recovery	Re-prep and reanalyze LCS and all samples in associated batch for failed analytes. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	80-120% Recovery
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Re-prep and reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Initial/Continuing Calibration Blank (ICB/CCB)	Beginning of sequence (ICB), end of sequence and one per every 10 samples analyzed.	No target analyte concentrations > RDL	Re-calibrate and reanalyze all samples processed with the contaminated ICB/CCB.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	75-125% recovery Waters: RPD ≤ 20% Soils: RPD ≤ 35%	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	75-125% recovery Waters: RPD ≤ 20% Soils: RPD ≤ 35%
Laboratory Duplicate	One per preparatory batch of up to 20 samples.	Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL
Serial Dilution	One per preparatory batch of up to 20 samples.	%D ≤ 20% for analyte concentrations > 10 times RDL	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	%D ≤ 20% for analyte concentrations > 10 times RDL

QAPP Worksheet #28: Analytical Quality Control and Corrective Action
(UFP-QAPP Manual Section 3.4 and Tables 4, 5, and 6)
(EPA 2106-G-05 Section 2.3.5)

Matrix: Groundwater/Soil/LNAPL
Analytical Group: Mercury
Analytical Method/SOP: SW-846 7470A/SW-846 7471/SOP# NC-MT-014, Rev. 9

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
Initial Calibration	Daily	Initial Calibration Criteria must be met per SW-846 Method 7470A or 7471 Minimum R > 0.995	Perform routine maintenance. Re-calibrate.	Analyst / Laboratory Quality Assurance Officer	Initial Calibration Criteria must be met per SW-846 Method 7470A or 7471 Minimum R > 0.995
Initial Calibration Verification (ICV)	Beginning of sequence	90-110% Recovery	Re-calibrate and reanalyze all samples processed with the outlying ICV.	Analyst / Laboratory Quality Assurance Officer	90-110% Recovery
Detection Limit Standard (CRA)	Beginning of sequence	50-150% Recovery	Re-analyze. Re calibrate and reanalyze all samples processed with the outlying CRA.	Analyst / Laboratory Quality Assurance Officer	50-150% Recovery
Continuing Calibration Verification (CCV)	One per every 10 samples analyzed.	80-120% Recovery	Re-calibrate and reanalyze all samples processed with the outlying CCV.	Analyst / Laboratory Quality Assurance Officer	80-120% Recovery
Laboratory Control Sample/LCS Duplicate	One per preparatory batch of up to 20 samples.	80-120% Recovery RPD ≤ 20%	Re-prep and reanalyze LCS/LCSD and all samples in associated batch for failed analytes.	Analyst / Laboratory Quality Assurance Officer	80-120% Recovery RPD ≤ 20%

QC Sample	Number/Frequency	Method/SOP Acceptance Criteria	Corrective Action	Title/position of person responsible for corrective action	Project-Specific MPC
			Qualify data as needed.		
Method Blank	1 per preparatory batch of up to 20 samples.	No target analyte concentrations > RDL	Re-prep and reanalyze the method blank and all samples processed with the contaminated blank. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Initial/Continuing Calibration Blank (ICB/CCB)	Beginning of sequence (ICB), end of sequence and one per every 10 samples analyzed.	No target analyte concentrations > RDL	Re-calibrate and reanalyze all samples processed with the contaminated ICB/CCB.	Analyst / Laboratory Quality Assurance Officer	No target analyte concentrations > RDL
Matrix Spike/Matrix Spike Duplicate	One per preparatory batch of up to 20 samples.	75-125% recovery Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	75-125% recovery Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL
Laboratory Duplicate	One per preparatory batch of up to 20 samples.	Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL	None. Qualify data as needed.	Analyst / Laboratory Quality Assurance Officer	Waters: RPD ≤ 20% for results > 5 times RDL Soils: RPD ≤ 35% for results > 5 times RDL

QAPP Worksheet #29: Project Documents and Records
(UFP-QAPP Manual Section 3.5.1)
(EPA 2106-G-05 Section 2.2.8)

Sample Collection and Field Records

Record	Generation	Verification	Storage location/archival
Field logbook or data collection sheets	Field Technician - TBD	John-Eric Pardys	Project File
Laboratory Supplied Chain-of-Custody Forms	Field Technician - TBD	John-Eric Pardys	Project File
Air Bills	Field Technician - TBD	John-Eric Pardys	Project File
Contractor Daily QC Reports	Field Technician - TBD	John-Eric Pardys	Project File
Deviations	Field Technician - TBD	John-Eric Pardys	Project File
Corrective Action Reports	Field Technician - TBD	John-Eric Pardys	Project File
Correspondence	Field Technician - TBD	John-Eric Pardys	Project File
Photos, maps, & drawings	Field Technician - TBD	John-Eric Pardys	Project File

Project Assessments

Record	Generation	Verification	Storage location/archival
Field audit checklists	Field Technician - TBD	John-Eric Pardys	Project File
Data verification checklists	James Abston	John-Eric Pardys	Project File

Project Assessments			
Record	**Generation**	**Verification**	**Storage location/archival**
Data validation report	James Abston	John-Eric Pardys	Project File
Data usability assessment report	James Abston	John-Eric Pardys	Project File
Corrective Action Forms	James Abston	John-Eric Pardys	Project File
Correspondence	James Abston	John-Eric Pardys	Project File
Laboratory QA Plan	James Abston	John-Eric Pardys	Project File

Laboratory Records			
Record	**Generation**	**Verification**	**Storage location/archival**
Sample Receipt, Custody & Tracking Records	Sample Custodian	Denise Heckler	Laboratory Files
Standard Traceability Logs	Analyst	Denise Heckler	Laboratory Files
Equipment Calibration Logs	Analyst	Denise Heckler	Laboratory Files
Sample Prep Logs	Analyst	Denise Heckler	Laboratory Files
Instrument Run Logs	Analyst	Denise Heckler	Laboratory Files
Equipment Maintenance, Testing, and Inspection Logs	Analyst	Denise Heckler	Laboratory Files
Deviation Reports	Analyst	Denise Heckler	Laboratory Files

Laboratory Records			
Record	**Generation**	**Verification**	**Storage location/archival**
Corrective Action Forms	Analyst	Denise Heckler	Laboratory Files
Instrument Calibration & Method Performance Summaries	Analyst	Denise Heckler	Laboratory Files
Reported Sample Results	Analyst	Denise Heckler	Laboratory Files
Reported Results for Standards, QC Check, and QC Samples	Analyst	Denise Heckler	Laboratory Files
Raw Data for Field Samples, QC Checks, and QC samples	Analyst	Denise Heckler	Laboratory Files
Laboratory Case Narrative	Analyst	Denise Heckler	Laboratory Files
Lab Qualifier Definitions	Analyst	Denise Heckler	Laboratory Files
MDL Study Results	Analyst	Denise Heckler	Laboratory Files
Data Package Completeness Checklists	Analyst	Denise Heckler	Laboratory Files
Extraction/Clean-Up Records	Analyst	Denise Heckler	Laboratory Files
Sample Disposal Records	Sample Custodian	Denise Heckler	Laboratory Files
Correspondence	Laboratory Project Manager	Denise Heckler	Laboratory Files

Parameter	Level 2 Data Package [1]	Level 4 Data Package [1]	Equis 4-file EDD
Groundwater & Soil			
TCL VOCs	X	X	X
SW-846 8011 (Groundwater only)	X	X	X
TCL SVOCs	X	X	X
SVOCs-SIM (Groundwater only)	X	X	X
TAL Inorganics (including Hg)	X	X	X

[1] See Table below for Required Items for Level 2 and Level 4 Data Packages.

Required Item	Level 2 Data Package	Level 4 Data Package
General Report Deliverables		
Sample ID Check (COC versus Lab Deliverables)	x	x
Sample Dates/Times and Sample Receipt Date/Time	x	x
Sample Condition Upon Receipt	x	x
Laboratory Methods/Procedures	x	x
Parameter List	x	x
Laboratory Reporting & Detection Limits establishment & verification	x	x
Case Narrative/Definitions/Corrective Action Reports	x	x
Sample Specific and Batch QC Results	x	x
Sample Preservation and Holding Times	x	x
Method Blank Results	x	x
Field Blank Results (Trip and Rinsate Blanks)	x	x
System Monitoring Compounds (Surrogates) Recoveries	x	x
MS/MSD Recoveries & RPDs-Organics	x	x
MS/MSD, MS/MD Recoveries & RPDs-Inorganics	x	x
Laboratory Control Sample (LCS) Recoveries	x	x
Serial Dilution Results	x	x
Post Digestion Spike Recoveries	x	x
Field Duplicates Results	x	x
Expanded Data Elements		
Instrument Performance Check Forms		x
Initial Calibration Summary		x
Continuing Calibration Forms		x
Initial Calibration Verification Forms		x
Continuing Calibration Verification Forms		x
Internal Standards Summary Form		x
Instrument Blanks Forms		x
ICP Interference Check Samples Forms		x
Compound Identification-library search		x
Chromatography raw data		x
Compound/Analyte Quantitation (raw data)		x
QC Sample raw data		x
Preparation logs raw data		x
Other records (call logs, copies of logbook pages, etc…)		x

QAPP Worksheet #31, 32, & 33: Assessments and Corrective Action
(UFP-QAPP Manual Sections 4.1.1 and 4.1.2)
(EPA 2106-G-05 Section 2.4 and 2.5.5)

Assessments:

Assessment Type	Responsible Party & Organization	Number/Frequency	Estimated Dates	Assessment Deliverable	Deliverable due date
Readiness Review	Project Manager	One assessment one week prior to mobilization.	TBD	Readiness Review Memorandum and Checklist	24 hours following assessment
Field Sampling TSA	Project Chemist	One each on first day of soil and groundwater sampling events.	TBD	TSA Memorandum and Checklist	24 hours following assessment
Management Review	Project Manager and QA Officer	Interim Management Review following site mobilization. Final management review upon completion of field work.	TBD	QA Management Report	48 hours following Management Review
Field Audit	USEPA Region 5 Remedial Project Manager	At the discretion of the USEPA Region 5 Remedial Project Manager	TBD	TBD	TBD

Assessment Response and Corrective Action:

Assessment Type	Responsibility for responding to assessment findings	Assessment Response Documentation	Timeframe for Response	Responsibility for Implementing Corrective Action	Responsible for monitoring Corrective Action implementation
Readiness Review	Task Manager	Readiness Review Corrective Action Response	24 hours from receipt of Readiness Review Memorandum	As directed by PM	Project Manager and QA Officer
Field Sampling TSA	Field Task Manager	Field Sampling Corrective Action Response	24 hours from receipt of Memorandum	Field Task Leader	Project Manager and QA Officer
Laboratory TSA	On-site Analytical Manager	On-site Analytical Corrective Action Response	48 hours from receipt of Memorandum and before further analyses can be conducted.	On-site Analytical Manager	Project Chemist
Management Reviews	Task Manager	QA Management Response	48 hours from receipt of QA Management Report	As assigned in QA Management Response	Project Manager and QA Officer

QAPP Worksheet #34: Data Verification and Validation Inputs
(UFP-QAPP Manual Section 5.2.1 and Table 9)
(EPA 2106-G-05 Section 2.5.1)

Item	Description	Verification (completeness)	Validation (conformance to specifications)
Planning Documents/Records			
1	Approved QAPP	**X**	
2	Contract	**X**	
4	Field SOPs	**X**	
5	Laboratory SOPs	**X**	
Field Records			
6	Field logbooks	**X**	**X**
7	Equipment calibration records	**X**	**X**
8	Chain-of-Custody Forms	**X**	**X**
9	Sampling diagrams/surveys	**X**	**X**
10	Drilling logs	**X**	**X**
11	Geophysics reports	**X**	**X**
12	Relevant Correspondence	**X**	**X**
13	Change orders/deviations	**X**	**X**
14	Field audit reports	**X**	**X**
15	Field corrective action reports	**X**	**X**
Analytical Data Package			
16	Cover sheet (laboratory identifying information)	**X**	**X**
17	Case narrative	**X**	**X**
18	Internal laboratory chain-of-custody	**X**	**X**
19	Sample receipt records	**X**	**X**
20	Sample chronology (i.e., dates and times of receipt, preparation, & analysis)	**X**	**X**
21	Communication records	**X**	**X**
22	RDL/MDL establishment and verification	**X**	**X**
23	Standards Traceability	**X**	**X**
24	Instrument calibration records	**X**	**X**
25	Definition of laboratory qualifiers	**X**	**X**
26	Results reporting forms	**X**	**X**
27	QC sample results	**X**	**X**
28	Corrective action reports	**X**	**X**
29	Raw data	**X**	**X**
30	Electronic data deliverable	**X**	**X**

QAPP Worksheet #35: Data Verification Procedures
(UFP-QAPP Manual Section 5.2.2)
(EPA 2106-G-05 Section 2.5.1)

Records Reviewed	Requirement Documents	Process Description	Responsible Person, Organization
Field logbook	QAPP, GHD Field Training Manual July 2015	Verify that records are present and complete for each day of field activities. Verify that all planned samples including field QC samples were collected and that sample collection locations are documented. Verify that meteorological data were provided for each day of field activities. Verify that changes/exceptions are documented and were reported in accordance with requirements. Verify that any required field monitoring was performed and results are documented.	Daily – Field Leader At conclusion of field activities - Project Manager
Chain-of-custody forms	QAPP, GHD Field Training Manual July 2015	Verify the completeness of chain-of-custody records. Examine entries for consistency with the field logbook. Check that appropriate methods and sample preservation have been recorded. Verify that the required volume of sample has been collected and that sufficient sample volume is available for QC samples (e.g., MS/MSD). Verify that all required signatures and dates are present. Check for transcription errors.	Daily - Field Leader At conclusion of field activities - Project Chemist

Records Reviewed	Requirement Documents	Process Description	Responsible Person, Organization
Laboratory Deliverable	QAPP	Verify that the laboratory deliverable contains all records specified in the QAPP. Check sample receipt records to ensure sample condition upon receipt was noted, and any missing/broken sample containers were noted and reported according to plan. Compare the data package with the CoCs to verify that results were provided for all collected samples. Review the narrative to ensure all QC exceptions are described. Check for evidence that any required notifications were provided to project personnel as specified in the QAPP. Verify that necessary signatures and dates are present.	Before release – Laboratory QA Manager Upon receipt - Project Chemist
Audit Reports, Corrective Action Reports	QAPP	Verify that all planned audits were conducted. Examine audit reports. For any deficiencies noted, verify that corrective action was implemented according to plan.	Project QA Officer

QAPP Worksheet #36
Data Validation Procedures

Data Validator: GHD Services Inc.

Analytical Group/Method:	**TCL VOCs – SW-846 8260**	**TCL SVOCs – SW-846 8270 and SW-846 8270-SIM**
Data deliverable requirements:	Level 4 Data Package; Equis 4-file EDD	Level 4 Data Package; Equis 4-file EDD
Analytical specifications:	WS 28-01	WS 28-02
Measurement performance criteria:	WS 12-01	WS 12-02
Percent of data packages to be validated:	100%	100%
Percent of raw data reviewed:	10%	10%
Percent of results to be recalculated:	10%	10%
Validation procedure:	“Analytical Data Quality Assessment and Validation Standard Operating Procedure”, GHD, Draft Document; Professional Judgment; and applicable guidance from "National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016	“Analytical Data Quality Assessment and Validation Standard Operating Procedure”, GHD, Draft Document; Professional Judgment; and applicable guidance from "National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016
Validation code (see table below):	Validation Code and Label Identifier Table	Validation Code and Label Identifier Table

Analytical Group/Method:	**DBCP & EDB – SW-846 8011**
Data deliverable requirements:	Level 4 Data Package; Equis 4-file EDD
Analytical specifications:	WS 28-03
Measurement performance criteria:	WS 12-03
Percent of data packages to be validated:	100%
Percent of raw data reviewed:	10%
Percent of results to be recalculated:	10%
Validation procedure:	"Analytical Data Quality Assessment and Validation Standard Operating Procedure", GHD, Draft Document; Professional Judgment; and applicable guidance from "National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016

Analytical Group/Method:	**TAL Metals – SW-846 6010**	**Mercury – SW-846 7470 and SW-846 7471**
Data deliverable requirements:	Level 4 Data Package; Equis 4-file EDD	Level 4 Data Package; Equis 4-file EDD
Analytical specifications:	WS 28-08	WS 28-09
Measurement performance criteria:	WS 12-08	WS 12-09
Percent of data packages to be validated:	100%	100%
Percent of raw data reviewed:	10%	10%
Percent of results to be recalculated:	10%	10%
Validation procedure:	"Analytical Data Quality Assessment and Validation Standard Operating Procedure", GHD, Draft Document; Professional Judgment; and applicable guidance from "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016	"Analytical Data Quality Assessment and Validation Standard Operating Procedure", GHD, Draft Document; Professional Judgment; and applicable guidance from "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
Validation code (see table below):	Validation Code and Label Identifier Table	Validation Code and Label Identifier Table

Validation Code and Label Identifier Table		
Validation Code	**Validation Label**	**Description/Reference**
U	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
J+	The result is an estimated quantity, but the result may be biased high.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
J-	The result is an estimated quantity, but the result may be biased low.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016 "National Functional Guidelines for Inorganic Superfund Methods Data Review", USEPA 540-R-2016-001, September 2016
NJ	The analyte has been “tentatively identified” or “presumptively” as present and the associated numerical value is the estimated concentration in the sample.	"National Functional Guidelines for Superfund Organic Methods Data Review", USEPA 540-R-2016-002, September 2016

QAPP Worksheet #37: Data Usability Assessment
(UFP-QAPP Manual Section 5.2.3 including Table 12)
(EPA 2106-G-05 Section 2.5.2, 2.5.3, and 2.5.4)

Identify personnel (organization and position/title) responsible for participating in the data usability assessment:

John-Eric Pardys– GHD-Project Manager
James Abston – GHD-Project Chemist/Data Validator
Angela Bown – GHD-QA Manager
TBD – GHD-Risk Assessor
TBD – GHD-Geologist/Hydrogeologist
TBD – GHD-Field Task Leader
TBD – GHD-Statistician

Describe how the usability assessment will be documented:

Data will be validated using the analytical methods and SOPs referenced on Worksheet #23 and Worksheet #36. In order to assess data quality, these documents specify the consideration of statistical values such as percent recovery, relative percent difference, percent relative standard deviation, and percent difference and the use of equations such as those used to calculate response and calibration factors, quantitation limits and analyte concentrations. A data validation report will be prepared for the sampling event. The report will summarize any identified trends, correlations, or anomalies so that the data user can make informed decisions on the use of the data.

Completeness is defined as the ratio of the number of valid measurements to the total number of measurements necessary to achieve a specified level of confidence in decision making. To be considered complete, the data set must contain all QC check analyses verifying precision and accuracy for the analytical protocol. In addition, all data are reviewed in terms of stated goals in order to determine if the database is sufficient. The QA objective for completeness is to collect and analyze all environmental samples in a manner such that valid data are obtained from a minimum of 95 percent of the samples.

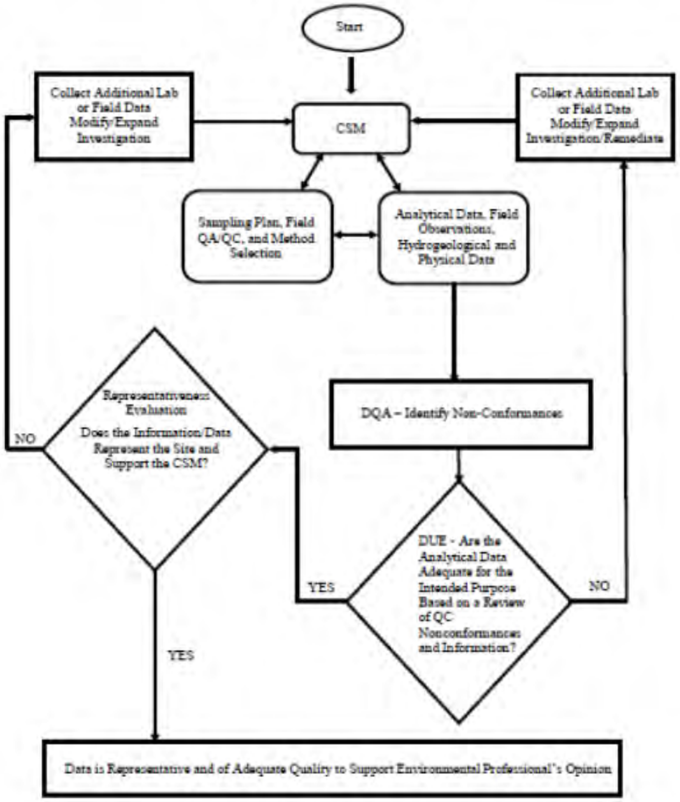
When possible, the percent completeness for each set of samples will be calculated as follows:

$$\% \text{ Completeness} = \frac{\text{Valid Data Obtained}}{\text{Total Data Planned}} \text{ X } 100$$

Summarize the data usability assessment process including statistics, equations, and computer algorithms that will be used to analyze the data:

Step 1	**Review the project's objectives and sampling design** Review the key outputs defined during systematic planning to make sure they are still applicable. Review the sampling design for consistency with stated objectives. This provides the context for interpreting the data in subsequent steps.
Step 2	**Review the data verification and data validation outputs** Review available QA reports, including the data verification and data validation reports. Perform basic calculations and summarize the data (using graphs, maps, tables, etc.). Look for patterns, trends, and anomalies (i.e., unexpected results). Review deviations from planned activities (e.g., number and locations of samples, holding time exceedances, damaged samples, and SOP deviations) and determine their impacts on the data usability. Evaluate implications of unacceptable QC sample results.
Step 3	**Verify the assumptions of the selected statistical method** Verify whether underlying assumptions for selected statistical methods are valid. Common assumptions include the distributional form of the data, independence of the data, dispersion characteristics, homogeneity, etc. Depending on the robustness of the statistical method, minor deviations from assumptions usually are not critical to statistical analysis and data interpretation. If serious deviations from assumptions are discovered, then another statistical method may need to be selected.
Step 4	**Implement the statistical method** Implement the specified statistical procedures for analyzing the data and review underlying assumptions. For decision projects that involve hypothesis testing consider the consequences for selecting the incorrect alternative; for estimation projects (e.g., establishing a boundary for surface soil contamination), consider the tolerance for uncertainty in measurements.
Step 5	**Document data usability and draw conclusions** Determine if the data can be used as intended, considering implications of deviations and corrective actions. Discuss data quality indicators. Assess the performance of the sampling design and Identify limitations on data use. Update the conceptual site model and document conclusions. Prepare the data usability summary report which can be in the form of text and/or a table.

Figure 1: DQA and DUE Flow Chart



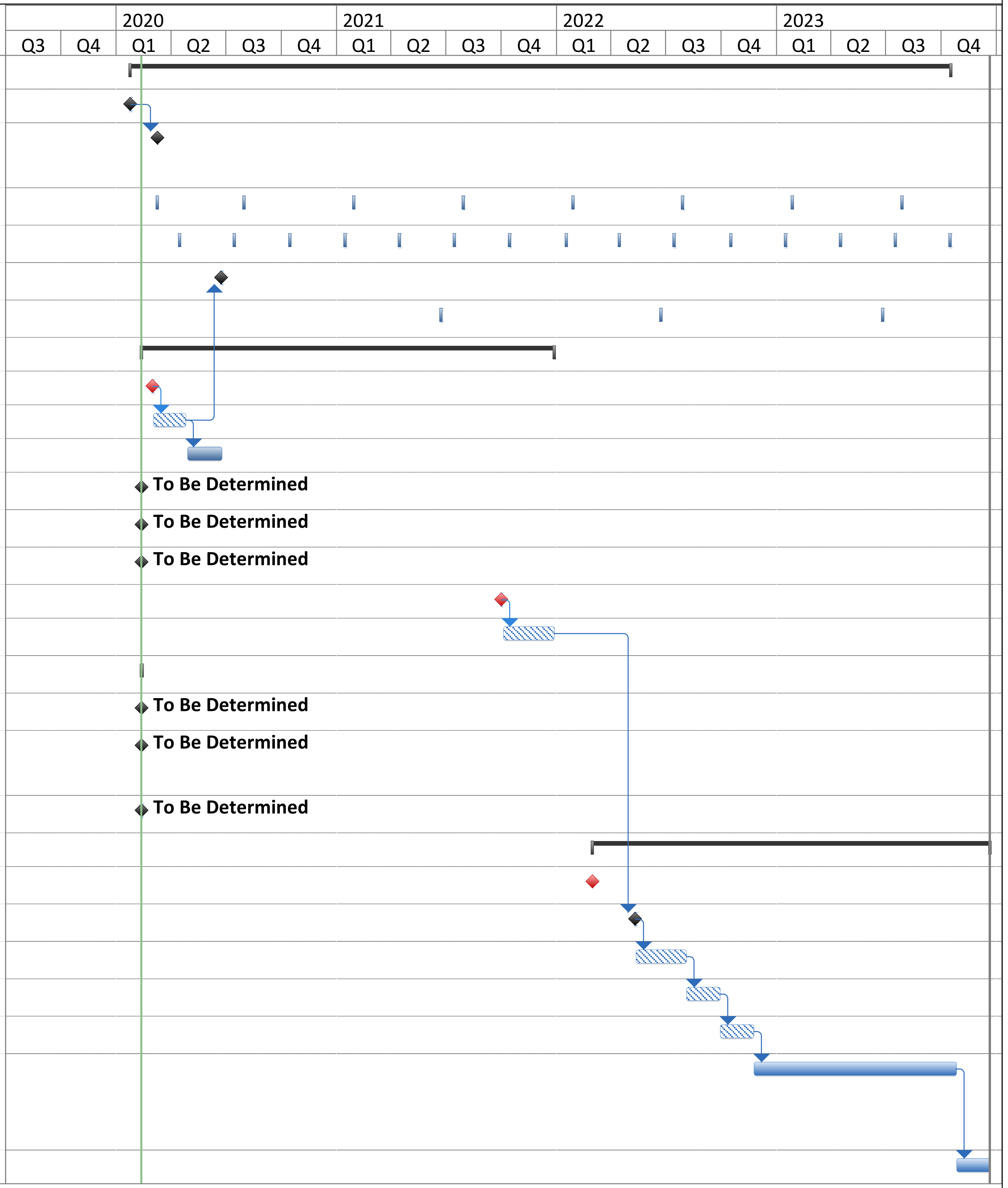
DQA – **Data Quality Assessment** is an assessment of the laboratory quality control data, the laboratory report, and the laboratory narrative by the investigator to identify and summarize QC non-conformances.

DUE – **Data Usability Evaluation** is an evaluation by the investigator to determine if the analytical data (that may include non-conformances) are of sufficient quality for the intended purpose. The DUE uses the results of the DQA and evaluates the quality of the analytical data in relation to the project-specific DQOs and the intended use of the data.

Appendix C
Conceptual Schedule

Draft Project Schedule - AOC
CITGO Terminal
East Chicago, IN

ID	Task Name	Duration	Start	Finish
1	**Administrative**	**965 days**	**Fri 1/24/20**	**Mon 10/16/23**
2	Effective Date of AOC	1 day	Fri 1/24/20	Fri 1/24/20
3	Meeting with U.S. EPA to discuss objectives, expectations, and timelines and provide to EPA for approval a draft CAF (Unless otherwise agreed to by the parties, within 45 Days of the effective date of the Order)	1 day	Mon 3/9/20	Mon 3/9/20
4	Semi-Annual Meetings - Meeting with EPA either by phone or in person on at least a semi-annual basis	877 days	Mon 3/9/20	Fri 7/28/23
13	Quarterly Reports - Fifteenth day of the month after the end of each quarter	906 days	Wed 4/15/20	Mon 10/16/23
29	Financial Assurance - Within 60 days of EPA approval of the RFI workplan (initial estimated cost of work)	1 day	Tue 6/23/20	Tue 6/23/20
30	Financial Assurance Update (Updated annually and/or with subsequent work plans)	523 days	Wed 6/23/21	Mon 6/26/23
34	**RFI**	**481 days**	**Wed 2/12/20**	**Mon 12/27/21**
35	Submit RFI Workplan (With SAP/QAPP) - No later than March 1, 2020	1 day	Sun 3/1/20	Sun 3/1/20
36	EPA Review and Approval of RFI Work Plan	2 mons	Mon 3/2/20	Fri 4/24/20
37	RFI Field Activities	2 mons	Tue 4/28/20	Tue 6/23/20
38	Additional RFI Work Plan(s), as needed	1 day	Wed 2/12/20	Wed 2/12/20
39	EPA Review and Approval of RFI Work Plan(s), as needed	1 day	Wed 2/12/20	Wed 2/12/20
40	RFI Field Activities, as needed	1 day	Wed 2/12/20	Wed 2/12/20
41	Submit RFI Report - No later than October 1, 2021	1 day	Fri 10/1/21	Fri 10/1/21
42	EPA Review and Approval of the RFI Report	3 mons	Mon 10/4/21	Mon 12/27/21
43	**Interim Corrective Measures, as needed**	**1 day**	**Wed 2/12/20**	**Wed 2/12/20**
44	Interim Corrective Measures Work Plan(s), as needed	1 day	Wed 2/12/20	Wed 2/12/20
45	Interim Corrective Measures Implementation, as needed (90 days following submittal of Interim Corrective Measures Work Plan and Schedule)	1 day	Wed 2/12/20	Wed 2/12/20
46	Interim Corrective Measures Report (Either prior to or as part of the Environmental Indicators Report)	1 day	Wed 2/12/20	Wed 2/12/20
47	**Final Corrective Measures**	**472 days**	**Tue 3/1/22**	**Wed 12/20/23**
48	Environmental Indicators Report - No later than March 1, 2022 (unless EPA agrees to extend that deadline)	1 day	Tue 3/1/22	Tue 3/1/22
49	Final Corrective Measures Proposal (Including schedule) - Within 135 days of EPA's approval of the RFI report	1 day	Wed 5/11/22	Wed 5/11/22
50	EPA review and comments, supplemental information / investigation request	3 mons	Thu 5/12/22	Wed 8/3/22
51	Public review and comment	2 mons	Thu 8/4/22	Wed 9/28/22
52	EPA Final Decision	2 mons	Thu 9/29/22	Wed 11/23/22
53	Final Corrective Measures Implementation - (According to the schedule in the Final Decision, i.e. much of the construction completed within one year, or within a reasonable period of time after EPA selects the final corrective measures)	12 mons	Thu 11/24/22	Wed 10/25/23
54	Final Remedy Construction Completion Report (Including an Operation and Maintenance Plan)	2 mons	Thu 10/26/23	Wed 12/20/23



Project: CITGO Terminal, East Chicago, IN
Date: Wed 2/12/204:23 PM

Expected Timeframe ▬	Expected Date ◆	Summary ┌─┐
Contingent Timeframe ▨	Fixed Date ◆	

Note: Per AOC, 'days' refers to calendar days
Schedule subject to change based on regulatory reviews/approvals, weather, and other factors beyond Respondent's control
DRAFT

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about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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