

**RESOURCE CONSERVATION AND RECOVERY ACT
FACILITY INVESTIGATION FIELD SAMPLING PLAN
FOR THE**

**FORMER GM POWERTRAIN DIVISION LIVONIA
12200 MIDDLEBELT ROAD, LIVONIA, MICHIGAN**

USEPA ID #MID000718874

by

**Haley & Aldrich of Michigan, Inc.
Ann Arbor, Michigan**

for

**Revitalizing Auto Communities
Environmental Response Trust
Ypsilanti, Michigan**

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1. INTRODUCTION

1.1 General

This document presents the Field Sampling Plan (FSP) for the monitoring environmental activities and sampling activities that Revitalizing Auto Communities Environmental Response Trust of Ypsilanti, Michigan (RACER) (formerly General Motors Corporation [GMC]) will conduct at the Former General Motors (GM) Livonia Powertrain Facility, located at 12200 Middlebelt Road, Livonia, Michigan (the Site, see Figure 1). RACER has entered into negotiations with the Region 5 of the United States Environmental Protection Agency (USEPA) to undergo Corrective Action at the Site under a Performance Based Corrective Action Agreement, to be executed under the Resource Conservation and Recovery Act (RCRA). This agreement is being negotiated despite that hazardous waste has not been stored at the Site for more than 90 days, and the Site has not been subject to RCRA interim status. This FSP has been developed on behalf of RACER by Haley & Aldrich of Michigan, Inc. (Haley & Aldrich) and is a supporting document to the RCRA Facility Investigation (RFI) Work Plan (RFI Work Plan) for the Site that has been prepared under a separate cover. Also supporting the RFI Work Plan under separate covers are the Quality Assurance Project Plan (QAPP) and the Public Involvement Plan (PIP).

1.2 Site Background and Description

On June 1, 2009, GMC filed for Chapter 11 protection under United States bankruptcy code. On 10 July 2009, GMC was renamed Motors Liquidation Company (MLC), and on the same day, some of the operating assets of GMC were sold to a newly-formed company "General Motors Company". General Motors Company changed its name to General Motors LLC (GM LLC) on 16 October 2009. On 1 April 2011, the responsibility for environmental remediation of the property was transitioned from MLC to the RACER.

The Site, approximately 40 acres, is a generally square-shaped tract of land that is situated in a mixed industrial / commercial / residential area. It is located east of Middlebelt Road between Industrial Road and Plymouth Road, in Wayne County, Michigan. The Site is bordered on the north by the CSX Railroad tracks. Commercial property is located beyond the railroad tracks to the north. The Site is bordered to the east and south by a residential and commercial area. The Site is bordered on the west by City of Livonia Fire Station and Middlebelt Road. Beyond Middlebelt Road, to the west, is a large industrial property.

A single building occupies the Site which, until June 2010, was used for machining operations associated with automotive manufacturing. There is approximately 1.2 million square feet under roof. Former operations included an engine plant, warehouse, and a wastewater treatment plant. The original building was constructed in 1971 and operated as Livonia Machining, which encompassed approximately 20 percent of the existing floor space. In 1984, there was a large expansion for engine work and a new warehouse.

Topographically, the Site is flat. The general area has a gradual gradient from east to southeast. Surface water flow in the areas of the building and the paved driveways and parking areas are largely controlled

by drainage structures along roadways and in paved areas. The City of Livonia Municipal Water Department provides drinking water to the Site.

Previous reports associated with the Site state that surface soil texture in the area typically consists of fill and some sandy or silty deposits, generally less than ten feet thick. Underlying the surface soils is a thick firm silty clay layer, locally referred to as “blue clay”, with occasional sand lenses and pebbles (e.g. till). with occasional sand lenses and pebbles, which is locally referred to as “blue clay”. The “blue clay” layer is often greater than 100 feet thick in the Livonia area and has an inherently low hydraulic conductivity. Underlying the surface, shallow, and deep soils are bedrock deposits classified as Paleozoic Era, Devonian System and Upper Devonian Series.

Previous reports for environmental investigations at the Site have described the stratigraphy as creating two groundwater systems: a perched system with a superficial layer, and a confined system within the bedrock. Previous reports have also indicated perched groundwater being encountered approximately three feet below ground surface, and groundwater flow direction generally to the west.

Based on review of available records, investigations of the Site have been limited to the assessment and closure of underground storage tanks (USTs), as well as a more recent environmental assessment performed in general accordance with the American Society for Testing and Materials (ASTM) document E 1527-05.

1.3 Project Goals and Objectives

The overall goal of the RFI is to characterize the nature and extent of any release of hazardous waste and/or hazardous constituents at the Site which may pose an unacceptable risk to human health and the environment.

To meet these goals, the objective of the RFI is to collect data of sufficient quality and quantity to support an assessment of potential current and future risks to human health and the environment associated with releases of hazardous waste and/or hazardous constituents.

Specifically, the RFI will:

- Determine whether releases of hazardous waste/constituents have occurred to soil, groundwater, surface water, or sediment at AOIs identified in Table I of the RFI Work Plan;
- Characterize the source(s) of a release and determine the nature and extent of constituents in environmental media to the extent necessary to protect human health and the environment;
- Characterize actual and potential migration pathways, actual and potential human and environmental receptors, and current and reasonably expected future land and groundwater uses;
- Assess potential risk to human health and the environment associated with releases of hazardous waste/constituents;

- Determine whether interim corrective measures are necessary to control current unacceptable human exposures, or to control migration of contaminated groundwater;
- Provide sufficient data to support a demonstration that current human exposures to contamination above applicable criteria are under control, and that the migration of groundwater contaminated above acceptable levels is stabilized; and
- Determine if final corrective measures are necessary to mitigate all current and future unacceptable risks, if any, to human health and the environment.

The results of the RFI will be used to demonstrate that: 1) all current human exposures to media contaminated with hazardous waste and/or hazardous constituents above risk-based levels are under control; and 2) migration of groundwater contaminated with hazardous waste and/or hazardous constituents above acceptable levels is stabilized within any existing areas of contamination, and any discharge of contaminated groundwater to surface water is either insignificant or shown to be currently acceptable. This demonstration will be documented in Environmental Indicators Reports for Human Health (CA725) and Groundwater (CA750). The results of the RFI will be used to support the selection of final Corrective Measures necessary to protect human health and the environment from identified current and future unacceptable risks due to releases of hazardous waste or hazardous constituents at the Site.

1.4 Overview of Data Collection Field Activities

The anticipated field activities include:

- Complete soil borings using direct-push methods or hollow-stem auger methods for soil sample collection and/or the installation of groundwater monitoring wells;
- Collect unsaturated soil samples, including QA/QC samples, for analytical testing for select Target Compound List (TCL) analytes and Michigan 10 metals;
- Develop monitoring wells;
- Collect groundwater samples, including QA/QC samples, for analytical testing for select TCL analytes and Michigan 10 metals; and
- Provide survey control for all soil borings and monitoring wells.

Haley & Aldrich has developed uniform standard operating procedures (SOPs) to be used by the field teams. These procedures are referenced in this FSP and included in Appendix A.

As existing Haley & Aldrich SOPs are modified or new SOPs are developed, the updated SOPs will be used for activities covered by this FSP, as appropriate.

2. FIELD PROCEDURES AND ACTIVITIES

This section provides an overview of the field procedures to be implemented during Site investigation activities.

2.1 Sample Designation System

Each soil and groundwater sample will be assigned an identifying name (sample designation). The root sample designation will consist of the type of sample (for example, soil or groundwater), a designated sample number starting at 100, the full date in parenthesis, followed by a suffix that provides information regarding the interval sampled, if applicable. For example, SB-100(11-1-2010) (08-10) would identify a soil boring sample taken on November 1, 2010 from the 8- to 10-foot interval. Further sample designation examples can be found in the associated QAPP in Section 7.2.

Duplicate field samples for both soil and groundwater samples for QA/QC purposes will be indicated by the prefix “DUP,” followed by the number of the duplicate in sequence, and then the date sampled in parenthesis. For example, the twentieth duplicate sampled at the Site on 10 October 2010 would be labeled DUP-20(10-10-10).

Additional sample volumes collected for matrix spike (MS) and matrix spike duplicate (MSD) analyses will be noted on the chain of custody (COC) forms, and the associated additional sample containers will be labeled with the appropriate suffix (MS or MSD) after the sample collection date.

2.2 Field Documentation

Field personnel will provide comprehensive documentation covering all aspects of field sampling, field analysis, and sample chain of custody. This documentation will constitute a record that will allow reconstruction of field events to aid in the data review and interpretation process. All documents, records, and information relating to the performance of the fieldwork will be retained in the project file. The various forms of documentation to be maintained during field procedures include:

- *Daily Documentation* – A field logbook will be kept, consisting of a waterproof, bound notebook that will record all Site activities. All logbook entries will be made with permanent ink. Any additions or corrections to the field logbook information will be single-lined out, dated, and initialed. Field logbooks will be filled out in accordance with the Field Logbook SOP found in Appendix A.
- *Sampling Information* – Detailed notes will be made as to the exact Site of sampling, physical observations, personnel present and weather conditions (as appropriate).
- *Sample Chain of Custody* – COC forms will be handled in accordance with the COC Sampling, Handling and Shipping SOP.
- *Field Equipment, Calibration, and Maintenance Logs* – To document the calibration and maintenance of field instruments, calibration and maintenance logs will be maintained for each piece of field equipment that is not factory-calibrated. Field instrument calibration will be documented in accordance with the calibration manuals included with the sampling equipment.

Information collected in the field through visual observation, manual measurement, or field instrumentation will be recorded in field notebooks or data sheets, or on prepared forms. Such data will be reviewed, by the appropriate task manager, for adherence to specific requirements associated with the groundwater investigation and for consistency. Concerns identified as a result of this review will be discussed with the field personnel, corrected if possible, and as necessary, incorporated into the data evaluation process.

Where appropriate, field data forms and calculations will be processed and included in appendices to investigation reports. The original field logs, documents, and data reductions will be maintained with the project file at the Haley & Aldrich office in Ann Arbor, Michigan.

2.3 Soil Boring and Sampling Procedures

Soil borings will be completed using hollow-stemmed auger (HSA) with split-spoon samplers, Rotosonic drilling methods, or to the extent feasible, direct push (using Geoprobe®) technology. The borings will be abandoned after sampling using bentonite slurry tremied from the bottom of the borehole to the ground surface. Soil samples for stratigraphic definition will be collected continuously as described in Haley & Aldrich SOP for Soil Drilling and Sample Collection in Appendix A.

If boring refusal is encountered, a new boring will be initiated and the previous boring abandoned. Any petroleum sheen observed during the drilling and monitoring well installation will be noted on the boring logs.

A photoionization detector (PID) will be used to obtain headspace readings of each sample interval, as well as to provide health and safety monitoring for field personnel during the drilling program, in accordance with the SOP for PID Air Monitoring and Field Screening included in Appendix A.

2.4 Lithologic Characterization

To provide a vertical profile of the subsurface conditions, soil samples will be collected continuously for visual classification using split-spoon, Rotosonic, or direct push sampling methods from the ground surface to the bottom of each boring. Lithologic characterization of soils will be performed in accordance with the Haley & Aldrich SOP for Soil Description located in Appendix A.

Visual descriptions of the subsurface lithology will be evaluated to assess the extent to which the geologic unit may influence migration of light nonaqueous phase liquid (LNAPL) and dissolved-phase constituents at the Site. The visual descriptions will also provide a vertical profile of the subsurface. This information will be used to prepare detailed boring/well logs and geologic cross sections of the subsurface area. Specific details in the lithologic descriptions normally include the following:

2.5 Monitoring Well Installation Procedures

Monitoring wells will be installed and developed in accordance with the Haley & Aldrich SOP for Monitoring Well Installation located in Appendix A. Monitoring wells will generally be screened to straddle the encountered water table with 10-foot well screens. However, if permeable soil layers are

present below the water table, it may be appropriate to screen the monitoring well across these layers. In addition, although deeper wells are not anticipated to be installed during the initial drilling mobilization, it is likely that for future mobilizations, deeper wells (paired with shallow wells) will be installed. Deeper monitoring wells will be installed with 5-foot well screens.

2.6 Medium-Specific Procedures and Sampling Methods

Procedures for the various data collection tasks are summarized in the following subsections. Detailed field procedures are included in Appendix A. Appendix A also contains other investigation-related procedures, such as cleaning equipment; packing, handling, and shipping samples; executing and monitoring sample chain of custody; and obtaining field measurements.

2.6.1 Soil Sampling Methods

Procedures for collecting soil samples for chemical analysis are included in the Haley & Aldrich SOP for Soil Drilling and Sampling (Appendix A) as well as the Michigan Department of Environmental Quality's (MDEQ) Remediation and Redevelopment Division (RRD) Memorandum 2, Sampling and Analysis (Op Memo 2) (MDEQ, 2004). Soil samples may be selected for analytical characterization from samples collected during installation of the soil boreholes, as stated in the applicable SOP. In general, unless otherwise stated in the applicable SOP, one soil sample will be collected from each borehole at the interval with the highest PID reading and/or observed impact (for example, the presence of LNAPL, odors, etc.). An additional soil sample may be collected if there are additional observations of impact at other intervals throughout the boring. If no impact is observed and there are no increased PID readings, then the sample will be collected above the water table. Saturated soil samples will not be submitted for laboratory analysis.

Soil samples will be collected as described in each of the SOPs. The soil samples will be analyzed for:

- TCL volatile organic compounds (VOCs);
- TCL polycyclic aromatic hydrocarbons (PAHs);
- TCL polychlorinated biphenyls (PCBs); and/or
- Michigan 10 metals (Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Mercury, Selenium, Silver, and Zinc).

Field QC samples will be collected and analyzed in accordance with the Haley & Aldrich SOP for soil sampling.

PID readings will be recorded throughout the length of the soil boring at 2 foot intervals.

2.6.2 Monitoring Well Development

Each permanent monitoring well will be allowed to sit for at least 24 hours after installation. Well development will be accomplished using low-flow methods and in accordance with the SOP for Low Flow Groundwater Purging and Sampling found in Appendix A. Each well will be surged slowly for at least 10 minutes for every five-foot interval of the screened interval. The well is then purged at a rate of 200 to 500 milliliters/minute (ml/min) until sediment is removed and turbidity is less than or equal to 5 nephelometric units (NTUs), or until all water is evacuated from the well.

2.6.3 Groundwater Elevation and LNAPL Measurements

Water-level measurements will be collected from each monitoring well in accordance with procedures set forth in the Haley & Aldrich SOP for Water-Level and NAPL Thickness Measurement Procedures. Measurements will be collected with a water-level probe or an oil/water interface probe, as appropriate, and measured to the nearest 0.01 foot (ft). Water levels will be converted to elevations using the surveyed measurement point (i.e., top of casing) elevations.

The water-level measurements will be used to calculate groundwater elevations and to estimate groundwater flow direction.

2.6.4 LNAPL Sampling Methods

Because LNAPL may be observed, sampling of LNAPL may be warranted. If LNAPL sampling is performed, the Haley & Aldrich SOP for LNAPL Fluid Sample Collection will be followed (Appendix A).

2.6.5 Groundwater Sampling and Analysis

PID readings of the well headspace of each monitoring well will be recorded in the field log book or monitoring well log.

Groundwater samples will be collected from existing and newly installed monitoring wells. Low-flow sampling, using a peristaltic pump, will be employed for groundwater sampling at each monitoring well location using the sampling procedures described in the SOP for Low-Flow Groundwater Purging and Sampling (Appendix A).

Groundwater will be purged and groundwater parameter readings will be recorded every 5 minutes to verify stabilization. The parameters should be stabilized for at least 3 consecutive readings before a sample is collected. One representative groundwater sample from each monitoring well will be collected in the field and measured for dissolved oxygen (DO), temperature, specific electrical conductance, turbidity, pH, and oxidation-reduction potential (ORP). If the turbidity prior to sampling is greater than 20 Nephelometric Turbidity Units, in addition to total metal samples filtered samples will also be obtained using a 0.45-micron

disposable filter and submitted for dissolved metal analysis. For more information on filtering procedures, see the SOP for Low-Flow Groundwater Purging and Sampling (Appendix A).

Groundwater samples will be analyzed using USEPA SW-8260B methods for:

- TCL VOCs;
- TCL PAHs; and/or
- Michigan 10 metals.

Field QC samples will be collected and analyzed in accordance with the QAPP.

2.7 Equipment Decontamination and Cleaning

Prior to collecting any samples for laboratory analyses, all reusable sampling equipment and tools or dedicated equipment will be thoroughly cleaned before and after use in accordance with the Haley & Aldrich SOP for Field equipment Decontamination.

2.8 Waste Handling

Water associated with sample collection and handling, as well as excess waters from well development and sample equipment cleaning, will be placed in drums or other appropriate containers, stored on-Site, and labeled appropriately. The material contained within the drums will be analyzed for waste characterization parameters by the analytical laboratory prior to disposal. Other waste materials developed as a result of sampling activities, such as personal protective equipment (PPE), will be placed in drums and stored on-Site. An inventory of drums containing waste materials will be kept by the supervising geologist.

Investigation-derived waste (IDW), including soil cuttings generated as a result of drilling and sampling, will be placed in drums or other appropriate containers (e.g., roll-off boxes), stored on-Site, and labeled by the supervising geologist. An inventory of all IDW generated during the investigation will be kept by the Project Manager.

Disposal of IDW will be facilitated through third-party carriers and disposal facilities.

3. FIELD INSTRUMENTS

All field screening equipment will be calibrated immediately prior to each day's use and more frequently if required. Information regarding calibration and use of various field instruments will be provided with each piece of equipment. The calibration procedures will conform to the manufacturer's standard instructions. Records of all instrument calibration will be maintained by field personnel, and copies of the instrument manuals will be maintained on-Site with each corresponding piece of equipment.

3.1 Portable Photoionization Analyzer

The photoionization analyzer will be a Photovac MicroTip (or equivalent) (Photovac), equipped with a 10.6 eV lamp. The Photovac is capable of ionizing and detecting compounds with an ionization potential of less than 10.6 eV. Calibration will be performed according to the procedures outlined in user's manual.

3.2 Oil Interface Probe

The thickness of LNAPL, if present in monitoring wells, will be measured using an oil interface probe. The interface probe will be checked once to a standard to assess if the meter has been correctly calibrated by the manufacturer or vendor. If the markers are incorrect, the probe will be sent back to the manufacturer or vendor.

3.3 Groundwater Field Parameter Measurements

All groundwater samples will be analyzed for field parameters. The groundwater will be collected using a flow through cell, equipped with meters to continuously read pH, specific conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), and temperature. Each meter will have separate calibration solution provided with the equipment and will be calibrated according to manufacturer's instructions.

3.3.1 pH Meter

The pH of the groundwater will be measured with a pH meter. The meter will be calibrated at the start of each day of use, and after very high or low readings as required by this plan. National Institute of Standards and Technology traceable standard buffer solutions that bracket the expected pH range will be used. The standards will most likely be a pH of 4.0, 7.0, and 10.0 standard units. The pH calibration and slope knobs will be used to set the meter to display the value of the standard being checked. The calibration data will be recorded on the calibration log or in the field logbook.

3.3.2 Specific Conductivity Meter

Specific conductivity will be measured with a specific-conductivity meter. Calibration checks using the appropriate conductivity standard for the meter will be performed at the start of each

day of use, and after very high or low readings, as required by this plan. Successive readings must be within five percent to be acceptable. The calibration data will be recorded on the calibration log or in the field logbook.

3.3.3 Dissolved Oxygen (DO) Meter

DO will be measured through a DO meter, which will be calibrated, and the condition of the DO sensor will be checked at the start of each day of use. Calibration and maintenance of the DO meter will be conducted in accordance with the manufacturer's specifications. The calibration data will be recorded in the calibration log or the field logbook.

3.3.4 Oxidation-Reduction Potential (ORP) Meter

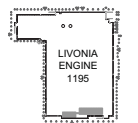
The ORP meter will be calibrated at the start of each day of use. Calibration and maintenance of the ORP meter will be conducted in accordance with the manufacturer's specifications. The calibration data will be recorded in the calibration log field logbook.

3.3.5 Groundwater Level Meter

Groundwater elevation will be measured with a water-level meter. The water-level cable will be checked once to a standard to assess if the meter has been correctly calibrated by the manufacturer or vendor. If the markers are incorrect, the probe will be sent back to the manufacturer or vendor.

3.3.6 Turbidity Meter

Groundwater turbidity will be measured using a turbidity meter. The turbidity meter will be calibrated daily prior to use. Calibration and maintenance will be conducted in accordance with the manufacturer's specifications. Calibration and maintenance information will be recorded in the calibration log or field logbook.



KEY PLAN
NOT TO SCALE

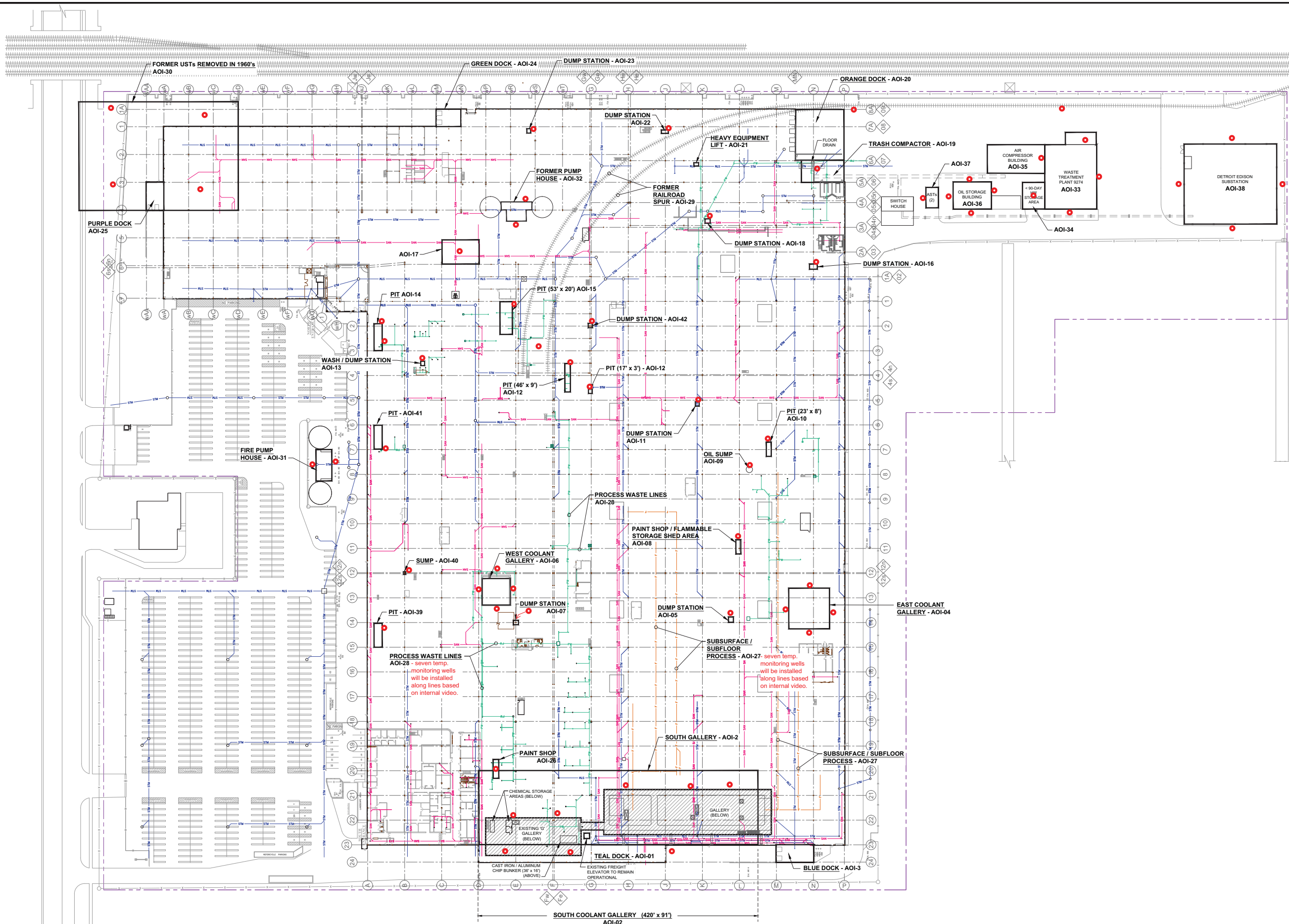
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Drawn By: SJL
Designed By: DK
Checked By: DK
Approved By:
Stamp:

GMPT - LIVONIA
SITE ID: 1195
LIVONIA, MICHIGAN

SITE PLAN, AREAS
OF INTEREST AND
PROPOSED
INVESTIGATIONS

1

Sheet: 1 of 1



NOTES

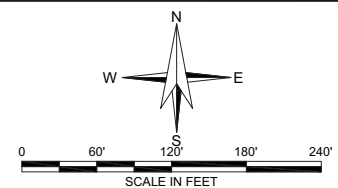
- ALL LOCATIONS APPROXIMATE AND BASED ON ONE OR MORE OF THE FOLLOWING:
 - GMPT - LIVONIA DRAWING NUMBER AE-01, DATED 11-15-2009 (PREPARED BY GENERAL MOTORS CORPORATION)
 - GMPT - LIVONIA DRAWING NUMBER CS1-00, DATED 11-15-2009 (PREPARED BY GENERAL MOTORS CORPORATION)
 - SITE PLAN AND MATERIAL STORAGE AREAS, DRAWING NUMBER 2, DATED 10-22-2007 (PREPARED BY TETRA TECH, INC.)
 - OVERALL PLOT PLAN, DRAWING NUMBER P-1, DATED 4-4-1979 (PREPARED BY GENERAL MOTORS CORPORATION)

- APPROXIMATE LOCATIONS OF AOI AND SITE FEATURES MARKED DURING SITE RECONNAISSANCE CONDUCTED ON 10/12/2011 - 10/13/2011. ALSO INCLUDES INFORMATION GATHERED FROM SPCC PLAN, DATED FEB 11, 2000 RECEIVED FROM DEQ THROUGH FOIA REQUEST.

LEGEND

- APPROXIMATE PROPERTY BOUNDARY
- RAILROAD TRACKS
- STORM SEWER
- SANITARY SEWER
- PROCESS WASTE LINES
- BELOW GROUND FLOOR FLUME

- PROPOSED TEMPORARY MONITORING WELL LOCATION (APPROX.)



APPENDIX A

Haley & Aldrich Standard Operating Procedures

1.1 UTILITY CLEARANCE

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 Delphi plant property must be cleared using available site drawings, and written approval must be obtained from plant personnel with appropriate knowledge of existing utilities.

PROCEDURES REFERENCED

- 2.0 Subsurface Investigations

PROCEDURE

- 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.
- Using the information obtained, the site should be viewed in detail for physical evidence of buried lines or structures, including pavement cuts and patches,

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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 ft. 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 to 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.
- **Notes: 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 two to three 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.

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 four to five feet in the event the clearance has failed to identify an existing facility. 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 four 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

- White Spray paint
- Wooden stakes, painted white or containing white flagging
- Color-code key
- Available drawings

REFERENCE

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

1.2 FIELD DATA RECORDING – FIELD BOOKS, LOG FORMS AND ELECTRONIC DATA

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 also 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

- 6.0 Field Instruments - Use And Calibration

PROCEDURE

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; and
- 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.

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% 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.

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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. Personnel properly trained and experienced in the use of the equipment and software should only perform usage of instruments, controls and computers for the purpose of obtaining field data.
4. Use only fully licensed software on PCs and laptops.
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 SOP. 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

- 5” by 7” National 407 Field Book, with high-grade 50% 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).

REFERENCES

2.1 DRILLING TECHNIQUES/BACKGROUND INFORMATION

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 limitations.

PROCEDURES REFERENCED

- 2.2 Soil Borings
- 2.3 Bedrock Coring
- 2.5 Soil Classification
- 2.6 Bedrock Logging and Classification
- 3.2 Overburden Wells
- 3.3 Top of Bedrock Wells
- 3.4 Deep Bedrock Wells

DRILLING METHODS

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. It is important to note that the drilling equipment selected be decontaminated before and between borehole locations to prevent cross contamination (see SOP 7.0). Where possible drilling methods that minimize waste generation (soil cuttings), and waste water generation (decon water), should be selected for Delphi 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.

Rotosonic Drilling

This method consists of a combination of rotation with high frequency vibration to advance a core barrel to a desired depth. Once the vibration is stopped, the core barrel is retrieved, and the sample is vibrated or hydraulically extracted into plastic sleeves or sample trays. 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. The rotosonic method can drill easily through formations such as rock, 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.

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 percussion for advancement of the tool string. Discrete soil samples are continuously obtained as well groundwater and vapor samples can also be collected utilizing this method. Subsurface investigations typically probe to depths of 30 feet or more, although depths will vary based on site-specific geology. 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 becoming more popular due to the limited cuttings that are produced during the sampling process and the sampling process speed. The use of the Geoprobe™ 6600 also allows for the installation of 2-inch diameter monitoring wells.

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 that generally consist of water, drilling mud, 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 shall 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 shall 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 shall also be used to funnel the cuttings 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) Mud Rotary

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 commonly infiltrate and affect water quality by sorbing metals and polar organic compounds. 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.

Hollow-Stem Auger

The hollow-stem continuous-flight auger (HSA) 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;
- representative geologic soil samples can be easily obtained using split-spoon samples in conjunction with the hollow-stem augers; and
- 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;
- large volumes of cuttings are typically generated;

- decon is fairly time consuming/labor intensive; and
- 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 sand is present.

Hollow-stem augers are available with inside diameters of 2.5, 3.25, 4.0, 4.25, 6.25, 8.25, and 10.25 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.

Dual-Wall Reverse Circulation Air Method of Drilling

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 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 carrying the drill cuttings and groundwater. 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 disbursed 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. Therefore, 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.

Well Points

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.

REFERENCE

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

1. Driscoll, F.G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division.
2. Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc.
3. EPA/625/6-90/0166 (July 1991), Handbook Ground Water Volume II:Methodology
4. National Water Well Association, 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells
5. Environmental Protection Agency (1986), RCRA Groundwater Monitoring Technical Enforcement Guidance Document, OSWER-9950.1

In addition, the following ASTM publications apply:

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

2.2 SOIL BORINGS

INTRODUCTION

The following presents a description of the methods generally employed for the installation 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 to advance boreholes are roto sonic drilling techniques, hollow-stem augers (HSA), or the use of a direct-push equipment. SOP 2.1 Drilling Techniques/Background, provides insight into the advantages/disadvantages of these drilling methods.

PROCEDURES REFERENCED

- 1.1 Utility Clearance
- 2.1 Drilling Techniques/Background Information
- 2.5 Soil Classification
- 2.6 Bedrock Logging and Classification
- 5.1 Soil Sample Collection

BOREHOLE REQUIREMENTS

The following activities must be undertaken prior to installing a borehole.

- i) Obtain a site plan and any previous stratigraphic logs. Determine the exact number and location of boreholes to be installed and the depths of samples for chemical analysis.
- ii) Coordinate lab services including:
 - glassware/sample jars;
 - cooler;

- shipping details;
 - start date; and
 - expected duration.
- iii) Establish borehole locations in field using available landmark or by surveying methods if necessary.
 - iv) Arrange for utility clearance of franchised utilities and site utilities.
 - v) Determine notification needs with the Project Manager. Notify the regulatory groups, landowner, Delphi Facility personnel, and laboratory of the sampling event.
 - vi) 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 work sequence is as follows:

- 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;
- advancement of borehole and collection of the soil sample;
- field screening of soil sample;
- description of soil sample (Form 2.6-01 will be used to record data);
- sample preparation and packaging;
- abandonment of boreholes;
- surveying of borehole locations and elevations; and
- field note completion and review.

i) Location 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 placed at biased locations.

Once the final location for the proposed boring has been selected and utility clearances are complete, 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. This procedure should clear the area to the full diameter of the drilling equipment that will follow. **(Only if underground utilities are suspected in the area, or requested by client.)**

If it is necessary to relocate any proposed borehole due to terrain, utilities, access, etc., the Field Coordinator/Task Manager must be notified and an alternate location will be selected. If moved, details of new location should be recorded in field log book.

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 SOP 7.0

The clean augers/tooling are covered with clean plastic sheeting to prevent contact with foreign materials. For geotechnical, geologic, or hydrogeologic studies where contaminants will not be present, 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 (SOP 2.1) and the Site objectives must first be considered. Soil Classification will be completed in accordance with SOP 2.5. Sections iii) and iv) describe borehole soil sampling procedures using direct-push tooling and hollow stem augering/split spoon sampling (Standard Penetration Testing - SPT), respectively.

iii) Direct-Push/Macro-Core™ Soil Sampler

The operation of the direct-push/Macro-Core™ Soil Sampler (or equivalent) consists of “pushing” the sampler into the subsurface and then retrieved using a direct-push soil probing machine. The collected soil core is contained within an internal soil liner (acetate, polyethylene or Teflon) and removed from the sampler once returned to the ground surface. Sampler length is variable depending on equipment available (2 ft., 4 ft., 5 ft.). Once the soil liner has been removed and the outer sampler de-coned, 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.

The Macro-Core™ sampler can be used in either the open-tube or closed-point sampling mode. The open-core sample mode is most commonly used in stable soil conditions. In unstable soils, the piston rod point system prevents collapsed soil from entering the sampler as it is advanced back down the hole. Once at the sample depth, the piston rod is unthreaded and released. The sampler is then driven into the subsurface to fill the sampler with soil, the piston point rides on top of the soil, as it enters the sampler.

Once recovered the soil liner with collected soils is opened (cut lengthwise) and examined to collected soil screening information, soil logging information, and soils for chemical analysis.

iv) 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. The split spoon is typically driven in advance of a hollow stem auger string which allows collection of the disturbed but representative sample.

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 a hollow stem auger 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. 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; and
- 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 Consultant 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;*
- 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.

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. To equalize the hydraulic pressure, the inside of the HSA must be filled

with water or drilling mud. The drilling fluid level within the boring or hollow-stem augers 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.

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 in conjunction with hollow stem augers. 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 barrel retrieved from the borehole. The sampler should be handled and the sample retrieved in the same way as described above for SPT sampling. This method is quicker than SPT split spoon sampling and the sample is virtually undisturbed because the cutting shoe sits ahead of the auger. No SPT information is collected due to soil sample collection during auger run.

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 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 hollow-stem auger 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;
- package and transport the sample in accordance with Paragraph ix).

On occasion it maybe required to extract the sample from the tube in the field.

- 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 place it in the appropriate container; and
- 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.

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 SOP 2.4 - 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

- Drilling Equipment
- Stratigraphy Log (Overburden) (Form 2.6-01)
- Tape Measure

REFERENCE

1. ASTM D420-93 Guide to Site Characterization for Engineering, Design, and Construction Purposes
2. ASTM D1452-80 Practice for Soil Investigation and Sampling by Auger Borings
3. ASTM D1586-84 Test Method for Penetration Test and Split-Barrel Sampling of Soils
4. ASTM D1587-94 Practice for Thin-Walled Tube Geotechnical Sampling of Soils
5. ASTM D2488-93 Practice for Description and Identification of Soils (Visual-Manual Procedure)
6. National Water Well Association, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.1989
7. EPA OSWER-9950.1,1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document

2.4 BOREHOLE ABANDONMENT/SEALING

INTRODUCTION

The following procedure describes common techniques for the abandonment/sealing of overburden boreholes. Borehole completion may have been performed by hollow stem augering/split spoon sampling, direct push sampling device, 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; or
- cement/bentonite grout backfill 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

- 2.2 Soil Borings

BOREHOLE ABANDONMENT/SEALING PROCEDURE

A. Soil Cutting Backfill

Typically employed when working above groundwater table and at shallow depths.

- The final depth of borehole will be measured and recorded.
- Cuttings are dropped into borehole after augering/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 settlements and promote surface water runoff away from boring.
- Borehole abandonment will be documented in field records/notes.

B. 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 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).
- 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.
- Borehole abandonment will be documented in field records/notes.

C. 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.

- 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 lbs.) of Portland Cement and three 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.
- 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 required 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".

Restoration

The area around the borehole shall be restored as directed by the plant representative (e.g., asphalt, concrete, vegetation).

Cleanup

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

EQUIPMENT/MATERIALS

- Grout pump/mixing equipment
- Test Boring Report

REFERENCE

1. United States Environmental Protection Agency (1992) "Guide to Management of Investigation-Derived Wastes", Quick Reference Fact Sheet
2. ASTM D5299 "Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities

2.5 SOIL CLASSIFICATION

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.

PROCEDURES REFERENCED

- 2.2 Soil Borings

DESCRIPTIONS

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); and
- 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 soils 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 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, 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 are 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 manager, 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

<i>Description</i>	<i>Criteria</i>
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

<i>Description</i>	<i>Criteria</i>
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

<i>Description</i>	<i>Criteria</i>
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

<i>Description</i>	<i>Criteria</i>
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:

<i>Group Symbol</i>	<i>Dry Strength Plasticity</i>	<i>Dilatancy</i>	<i>Toughness</i>
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Slight Medium to high Low	None to slow	Medium
MH	Low to medium	None to slow	Low to medium Low
CH	High to very high	None	High 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 (S_u) 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 (S_u) 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 (S_u) and shear strength or cohesion (c_u) 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 deposition method 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 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 SCREENING

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. The highest reading and sustained readings are recorded.

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 may be 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. This headspace reading on the field form or in the field book is recorded.

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 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:

<i>Visual Description</i>	<i>Fraction of Soil Pore Volume Containing NAPL</i>
Saturated	>0.5
Some	0.5 - 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); and
- 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 careful inspection of the soil separation planes/soil grains is performed 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 a number of more sophisticated tests available to confirm/identify NAPL presence, these are:

- UV fluorescent analysis;
- Sudan IV dye shake test;
- hydrophobic dyes;
- centrifugation; and
- chemical analysis.

For UV fluorescence, soil samples are placed in a Ziploc bag, which are marked with the boring location and depth. The samples are then taken to a dark room where they are placed under a UV light. Samples with DNAPL present in them will fluoresce a milky-white color.

Sudan IV dye shake tests are performed by combining a small amount of soil sample, water and Sudan IV together in a vial with a cap. The Sudan IV is fat-soluble, thus, the dye will be released to the water in the presence of DNAPL. After combining the soil, water and dye, cap the vial and shake vigorously. If DNAPL is present, the water will become a pinkish-red hue.

The Sudan IV dye shake test is dependent upon the nature of the soil that is being tested. Clayey soils have a tendency to cloud the water and obscure the dye release. If clayey soils are the target zone, a combination of visual observation, field and headspace screening, UV fluorescence and Sudan IV dye shake tests should be performed to determine whether DNAPL is present in the soil.

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
- Stratigraphic Log (Overburden) (Form 2.6-01)
- Tape Measure

- Sudan IV dye
- Vial
- Ziplock bags

REFERENCES

1. 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.
2. ASTM Standards on Environmental Sampling (1995), Standard D 2488-93, “Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)”
3. ASTM Standards on Environmental Sampling (1995), Standard D 4700-91, “ Guide for Soil Sampling from the Vadose Zone”.
4. ASTM Standards on Environmental Sampling (1995), Standard D 1586-92, “ Test Method for Penetration Test and Split-Barrel Sampling of Soils”.
5. ASTM Standard D 2487, “ Classification of Soils for Engineering Purposes (Unified Soil Classification System)”.
6. Geotechnical Gauge, Manufactured by W.F. McCollough, Beltsville, MD.
7. Sand Grading Chart, by Geological Specialty Company, Northport, Alabama.

2.5 PROCEDURES FOR SOIL VAPOR MONITORING POINT INSTALLATION

INTRODUCTION

This document includes procedures for the installation of a soil vapor monitoring point intended for the collection of subsurface soil gas samples.

DRILLING PROCEDURES

Operating Procedures 2.1 – Drilling Techniques presents descriptions of various drilling methods that are available, however, due to the relatively shallow monitoring point depth and small diameter (i.e. screen diameter and associated tubing) typically only direct-push methods and hand auger methods (depending on Site access and soil type) apply.

- Utility clearing will be completed in accordance with *Operating Procedure 1.1 - Utility Clearance*.
- Drilling/boring equipment will be decontaminated prior to the installation of the soil vapor point and between successive installations in accordance with *Operating Procedure 7.0 – Equipment Decontamination*.
- No oils or grease will be used on equipment introduced into the borehole.
- Derived waste generated from boring activities will be characterized and disposed of in accordance with *Operating Procedure 8.0 – Waste Characterization*.
- The target depth interval shall be pre-determined by the site-specific Project Work Plan but may be amended based on field observations of the underlying stratigraphy/geology. The bottom of the probe hole should be kept at least 1 foot above the expected water table to ensure that groundwater or water from the capillary fringe does not intersect the sand pack of the probe. Sample collection intervals should be determined by site-specific project sampling objectives. Depending on the type of tooling utilized by a direct-push drilling rig (e.g., Geoprobe) or hand-operated soil vapor sampling kit (e.g. AMS GVP Kit), borehole diameters could range from 1.25 to 2.25 inches.
- Soil classification will be completed in accordance with *Operating Procedure 2.6 – Soil Classification*.
- Special attention should be paid to the moisture content of soils throughout the soil profile. Observations of soil moisture should be noted on the well log for each

boring. If soil moisture data are not available, it may be helpful to collect soil samples during drilling for laboratory determination of soil moisture content adjacent to the probe screen.

SOIL VAPOR POINT INSTALLATION

Once the target depth has been reached, ¼-inch O.D. tubing (stainless steel, Teflon, or nylon) will be connected to a stainless steel screen implant with a minimum length of 6-inches that is designed for soil gas sampling, and deployed down the borehole. The screen implant is connected to one end of the sample tubing and the associated tubing is placed on the inside of the probe rod up to the surface during placement (Note: the tubing should be temporarily capped with a fitting made of inert materials, such as brass or nylon). Depending on soil type (e.g., dry sands with very little fines), the borehole may easily collapse requiring the use of a temporary outer casing (typically a larger diameter probe rod) large enough to allow deployment of the stainless steel screen implant and attached tubing down the temporary casing once the bottom of the casing is in place and at the targeted depth (see Figure 1).

The temporary casing probe rod is slowly removed during the placement of filter pack sand and the bentonite annular seal. Clean, uniform, well-rounded, silica sand should be placed as the filter pack in the annular space around the screen and casing from the base of the screen to approximately 6-inches above the top of the screen implant. The stainless steel screen implants require filter pack silica sand with a particle size larger than the pore size of the screen implant (greater than 0.0057 inch or 0.145 mm).

Granular or flaked bentonite will then be added from the top of the filter pack to approximately 6-inches below ground surface (bgs) to allow room for the flush mount cover. To insure an air tight annular seal, a small amount of distilled water should be added throughout the bentonite placement. (Caution: over hydration of the bentonite could lead to water in the screened interval which may compromise the use of the soil vapor point.) A weighted tape or other measuring device can be utilized to provide accurate measurements and to avoid bridging during the placement of filter pack sand and bentonite.

After the construction of the annular seal, an appropriate sized flush mount cover will be installed to protect the soil vapor point. Pre-mixed concrete will be used to secure the flush mount cover in place and to provide a sufficient surface seal for the soil vapor point. Although a 4-inch flush mount cover is typically sufficient for either indoor or outdoor soil vapor point installations, site conditions may warrant use of other materials (e.g., larger diameter cover, traffic rated cover). Details regarding the type of appropriate well covers and concrete surface seals are similar to those found in most

monitoring well installations and are discussed in *Operating Procedure 3.1 – Well Construction Materials*.

At the completion of the vapor point installation, the temporary tubing cap will be removed and the tubing will be equipped with a gas tight brass or nylon valve near the end of the tubing. If sampling with a Summa[®] canister is planned, the end of the tubing can be fitted with a brass or stainless steel Swagelok[®] (or similar) compression fitting, as long as the fitting is compatible with the canister and flow controller connections.

Upon completion of the installation of the sampling point, valve, and fittings, the volume of air in the tubing and sand pack will be calculated. Approximately three (3) times the calculated volume of air will be slowly (< 100 ml/Min) purged immediately after installation and sealing of the sampling point. Samples should not be collected for 24 to 48 hours after installation of the sampling point and purging of the sand pack. Purging will be accomplished using a large graduated syringe, pre-calibrated personnel air sampling pump, hand-operated vacuum pump, or a Summa[®] canister that has been designated for purging only. Purge volumes should be recorded and included in the reporting for the installation of the soil gas monitoring point.

EQUIPMENT/MATERIALS

The following equipment and materials are used for the completion of a soil vapor monitoring point:

- Appropriate personal protective equipment (PPE) as required by the site specific Health and Safety Plan.
- Site Plan, Field Sampling Plan, and/or Work Plan, with proposed soil vapor monitoring point locations.
- Drilling/boring equipment appropriate for the Site and in certain instances dictated by the proposed location.
- Soil vapor monitoring point materials including; tubing, vapor screen implant, silica sand filter pack, bentonite seal material, distilled water, flush mount well cover, concrete mix, and associated fittings and connections for capping the tubing and securing the vapor point. (Materials are further defined throughout this Operating Procedures.)
- Weighted tape measure.
- Purge pump calibrated to remove initial ambient air within tubing and borehole.

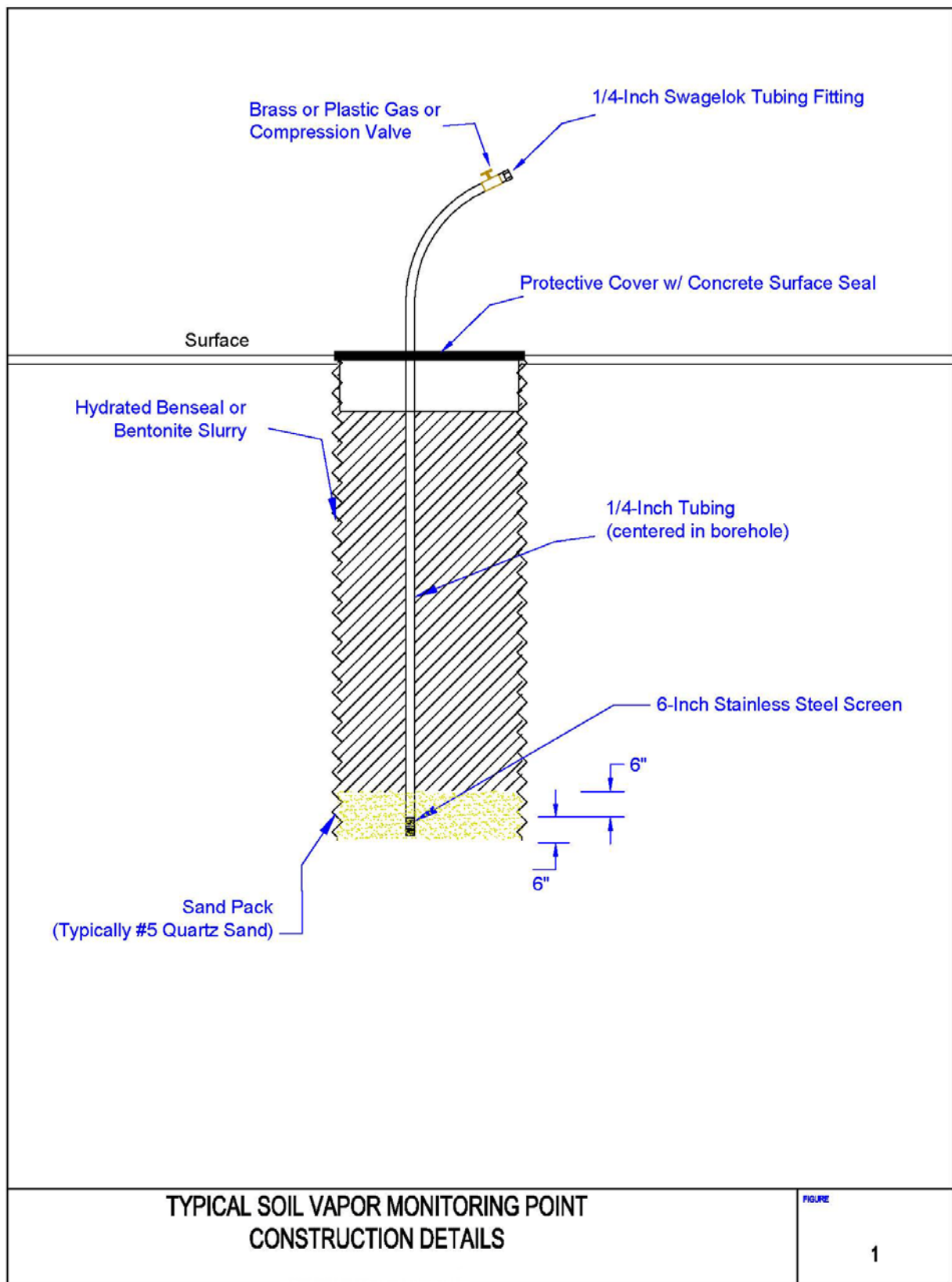
WASTE MANAGEMENT

The waste materials generated by these activities should be minimal. Personal protective equipment, such as gloves, disposable clothing, and other disposable equipment will be disposed of in accordance with Operating Procedure 8.0 – Waste Characterization.

REFERENCE

1. 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.

2. American Society for Testing and Materials (1991), Standard D2113-83 (87), “Diamond Core Drilling for Site Investigations”, Annual Book of ASTM Standards, Section 4, Volume 04.08.
3. 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.
4. API, 2004. Collecting and Interpreting Soil Gas Samples from the Vadose Zone: A Practical Strategy for Assessing the Subsurface-Vapor-to-Indoor-Air Migration Pathway at Petroleum Hydrocarbon Sites. American Petroleum Institute, Final Draft, October, 2004.
5. Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.
6. Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.
7. Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.
8. Hartman, 2004. How to Collect Reliable Soil-Gas Data for Risk-Based Applications – Specifically Vapor Intrusion. Part 3 – Answers to Frequently Asked Questions. LUSTLine Bulletin 48, November 2004.
9. State of California, 2003. State of California Advisory – Active Soil Gas Investigations. Department of Toxic Substances Control and California Regional Water Quality Control Board, Los Angeles Region. January 28, 2003
10. State of California. 2005. Interim Final: Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air. Department of Toxic Substances Control, California Environmental Protection Agency, December 15, 2004 (Revised February 7, 2005).



3.1 WELL CONSTRUCTION MATERIALS

INTRODUCTION

In environmental subsurface investigations, the information used to evaluate subsurface conditions often relies on the installation of appropriate 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 with which it is constructed.

This SOP 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 is described in detail in the specific well-installation SOPs listed below.

PROCEDURES REFERENCED

- 3.2 Overburden Monitoring Well Installation
- 3.3 Top of Bedrock Well Installation
- 3.4 Deep Bedrock Well Installation

MATERIAL DESCRIPTIONS

A. Well Screen

The screen is the portion of the well 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 (I.D.) flush-threaded screen segments (piezometers are typically 1.0-inch inner diameter but may also be 2-inch). These screen segments are typically available in 10-foot lengths. Four-inch diameter or larger well screens are usually used 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 extraction oil recovery systems.

Screen material will be either thermoplastic Schedule 40 PVC (PolyVinylChloride) (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 Consultant 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 cause 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.

B. Well Riser Pipes and Casings

Well riser pipe is a solid extension of the well 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, low-carbon steel ($\geq 0.8\%$ carbon and $\leq 0.8\%$ carbon, respectively), or PVC. The well casing should be a minimum of 4 inches in diameter (at least 4-inch diameter for the innermost casing).

C. 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 #1, #0, #00N, or equivalent.

Sand pack shall be washed silica sand with a silica content of at least 95%. Sands should meet one or more of the following requirements: NSF Standard 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.

D. 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.

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 (2) 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 SOPs.

E. 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 2.5-3 feet is below ground surface and 2.5-3 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 stick-up 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 (min. 4-in diameter) cemented at least 3 ft. 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

- Drilling equipment
- Well screen and riser materials
- Sand pack

- Bentonite pellets/chips
- Powdered bentonite
- Portland cement

REFERENCE

1. ASTM D1785-99, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
2. ASTM D2665-00, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.
3. ASTM F480-00, Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.
4. ASTM A53/A53M-01 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless for Ordinary Uses.
5. Campbell, M.D., and Lehr, J.H., Water Well Technology, McGraw Hill, 1973.
6. Cold Weather Concreting, ACI Committee 306, Materials Journal, Volume 85, Issue 4, July 1, 1988.
7. Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.
8. Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.
9. USEPA, 1986, RCRA Groundwater Monitoring Technical Enforcement Guidance Document, Office of Solid Waste and Emergency Response, 1986.

3.2 PROCEDURES FOR OVERBURDEN MONITORING WELL INSTALLATION

INTRODUCTION

This procedure presents the drilling, installation, and completion of overburden monitoring wells. The design and installation of monitoring wells involves the drilling of boreholes into various types of geologic formations. Designing and installing monitoring wells may require different drilling methods and installation in the overburden. However, due to specific site and monitoring requirements, the procedure may be revised as necessary to reflect these site-specific needs. Prior planning is required for the selection of the appropriate drilling method and selection of well materials.

PROCEDURES REFERENCED

- 2.5 Soil Classification
- 3.6 Well Development
- 5.1 Soil Sampling
- 7.0 Equipment Decontamination
- 8.0 Waste Characterization

DRILLING PROCEDURES

- Drilling and sampling equipment arriving on site will be decontaminated prior to drilling in accordance with the Decontamination and Waste Disposal Procedure.
- Drilling generated waste materials will be disposed according to the Decontamination and Waste Disposal Procedure.
- Record construction and geologic information on the attached subsurface boring log.

- The depth to the target interval may be determined from an existing adjacent monitoring well/boring or from information obtained from split spoon sampling of the borehole. The criteria for determining the target interval to be monitored will be presented in the Project Work Plan. An 8-inch diameter borehole will be advanced to the target interval using a minimum 4¼-inch inside diameter (I.D.) hollow-stem auger.
- In the instances where the borehole is advanced deeper than the target interval, a 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 further well installation.
- In some areas where the water table is known to be at or near the top of bedrock, the base of the overburden well will be installed at the top of bedrock.
- Continuous split-spoon samples may be collected, if required by applicable project Work Plan. (see Subsurface Soil Sampling Procedure). If collected, soil samples will be classified in accordance with the Soil Classification Procedure.

WELL CONSTRUCTION

- The well construction procedures presented below are the recommended standards. However, due to variations in subsurface conditions, changes in these well construction standards may be necessary in order to facilitate the installation of the protective casing.
- Overburden wells will be constructed of either 2-inch Schedule 40 Flush-threaded Virgin PVC or type 316 Stainless Steel. Type of well material to use will be dependent upon known subsurface conditions. Wells constructed of PVC are preferable; however in situations where sufficient levels of chlorinated solvents are present to affect the PVC well integrity, stainless steel will be the material of choice. Wells of mixed construction materials are not acceptable. The well screen will consist of machine slot or continuous wrap PVC or Stainless Steel with screen slot size appropriate for the type of subsurface material. It is anticipated that PVC will be used at the site.
- The bottom of the well screen will be placed to the bottom of the borehole. Ideally, the top of the well screen should be greater than 4 feet below grade. As the augers are slowly removed, clean washed silica sand filter pack will be placed in the annular space around the well screen and casing from the base of the screen to at least 2 feet above the screen.

- In wells that exhibit a water table elevation above the sand pack, a minimum of 2-foot thick layer of bentonite pellets will be placed above the sand pack. The seal will be hydrated and allowed to set for approximately 30 minutes.
- Cement/bentonite grout will be placed from the top of the bentonite seal to a point 5 feet below existing ground surface where conditions allow. 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.
- Accurate measurements of the material depths will be made by sounding the annulus during installation. The volume of materials needed will be calculated and compared to the actual volume used. Material depths will be recorded on the well installation report log (attached).
- 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 9-inch flush-mounted roadway box set in a concrete seal. Alternatively, in low traffic areas, the well casing may be cut above grade and completed with 4 or 6-inch diameter steel protective casing with approximately 3 feet of stick up, set in a concrete surface seal.
- For flush-mounted wells, a 9-inch diameter, water-tight protector will be installed complete with a sand drain. A lockable gripper plug will top the PVC casing.
- After installation, the monitoring well will be labeled with the well identification and a reference point for water level and depth measurements will be notched into the well casing. The well will be allowed to sit for at least 24 hours prior to well development, and for one week between development and groundwater sampling.

EQUIPMENT

- Drilling Equipment
- Well Supplies
- Subsurface Boring Log
- Overburden Well Log
- Tape Measure

REFERENCE

1. 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.
2. American Society for Testing and Materials (1991), Standard D2113-83 (87), “Diamond Core Drilling for Site Investigations”, Annual Book of ASTM Standards, Section 4, Volume 04.08.
3. 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.
4. New York State Department of Environmental Conservation (1988), Draft Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Division of Mineral Resources.
5. Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.
6. Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.
7. Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.

3.3 WELL DECOMMISSIONING PROCEDURES

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 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 back filling with a cement bentonite slurry.

PROCEDURES REFERENCED

- 3.2 Procedures for Overburden Well Installation
- 7.0 Equipment Decontamination
- 8.0 Waste Characterization

WELL DECOMMISSIONING PROCEDURES

1. 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 one to two-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 one hour to allow any settlement of the cement/bentonite slurry and then augment if needed.

2. 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 one to two-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.
- 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 in accordance to the methods and procedures contained in the Waste Characterization SOP.
- 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 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

- Drilling Equipment
- Well Supplies
- Monitoring Well Abandonment Form
- Tape Measure

REFERENCE

1. Michigan Department of Public Health, Ground Water Quality Control Section – Division Of Water Supply (1988), Michigan Water Well Grouting Manual, MDPH GW-3-302
2. ASTM D5229, “Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes and other Devices for Environmental Activities”.

3.4 WELL DEVELOPMENT PROCEDURES

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.

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

- 3.2 Procedures for Monitoring Well Installation
- 8.0 Waste Characterization

WELL DEVELOPMENT PROCEDURES

- The well development procedures presented below are the recommended standards. However, due to variations in conditions, changes in these well development standards may be necessary in order to facilitate the successful completion of developing the monitoring well. Well development can be accomplished by using in-place pumps or using manual equipment; either peristaltic, bladder, or other appropriate pumps depending on well depth.

- Don appropriate safety equipment.
- Attach appropriate pump and lower tubing into well.
- Turn on pump. If well runs dry, shut off pump and allow to recover.
- Surging will be performed by raising and lowering the pump in the well to open and close the check valve in the pump several times to pull fine-grained material from the well. Collect the groundwater sample in a glass jar to determine relative turbidity, and measure and record the temperature, pH, and specific electrical conductance.
- The fourth and fifth steps will be repeated until groundwater is relatively silt-free; no further change is noted; and the temperature, pH, and specific conductance readings have stabilized to within 10% or 10 well volumes and 5 times the volume of water used to complete the well have been removed.
- The developing equipment will be raised two feet and then Steps 4 and 5 will be repeated.
- Step 6 will be repeated until entire well screen has been developed.

WASTE DISPOSAL

- All waste generated will be disposed in accordance to the methods and procedures contained in the Waste Disposal SOP.
- All water generated during cleaning and development procedures will be collected and contained on site in 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 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

- Appropriate health and safety equipment
- Knife
- Power source (generator)
- Field book
- Well Development Form
- Well keys
- Graduated pails
- Pump and tubing
- Cleaning supplies (including non-phosphate soap, buckets, brushes, laboratory-supplied distilled/deionized water, tap water, cleaning solvent, aluminum foil, plastic sheeting, etc.)
- Water level meter
- pH/temperature/conductivity meter
- Clear glass jars (e.g., drillers' jars)

REFERENCE

1. Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.
2. Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.
3. Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.

4.1 MANUAL WATER LEVEL MEASUREMENT PROCEDURE

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 transducers/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 provides 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

- 5.3 Non-Aqueous Phase Liquid (NAPL) Monitoring and Sample Collection
- 6.0 Field Instruments – Use And Calibration
- 7.0 Equipment Decontamination

PROCEDURE

In order to provide reliable data, water level monitoring events should 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 will 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 roadboxes 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-ft.

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 feet on the Groundwater Level Monitoring Report form 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 Equipment Decontamination Procedure.

EQUIPMENT

- Battery-operated, non-stretch electronic water level probe with permanent markings at 0.01 ft. 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% (0.01 feet for a 100-foot cable). See also the Field Instruments – Use and Calibration Procedure.
- Groundwater Level Monitoring Report form.

REFERENCE

- ASTM 4750 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

4.2 IN-SITU HYDRAULIC CONDUCTIVITY (SLUG TESTING) PROCEDURE

INTRODUCTION

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

A slug test is performed to assess the 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 the water level response in the well over time.

Slug testing in select monitoring wells will be performed after the wells have been installed and developed as covered in the RFI 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). Measurements can be collected manually using a battery-operated water level measurement probe or automatically using a datalogger/pressure transducer system.

PROCEDURES REFERENCED

-
- 3.0 Monitoring Wells, Pump Wells and Piezometers
- 4.1 Manual Water Level Measurement
- 6.0 Field Instruments – Use And Calibration
- 7.0 Equipment Decontamination

PROCEDURE

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:

- Adding or removing a slug of water
- Inserting or withdrawing a solid or sealed object with an appropriate overall density
- Changing the air pressure in a well (only when a pressure transducer is used)

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 effectively can 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.

A manual procedure usually is feasible only if a water-bearing zone being tested has a relatively low to moderate hydraulic conductivity (e.g., less than 10^{-3} cm/s). A person can confirm that a manual water-level measurement procedure is feasible using Step 7 below.

If the hydraulic conductivity of a water-bearing zone is relatively high, then water levels in a well may change too rapidly for an accurate manual measurement. In that case, automatic data collection using a pressure transducer and a data logger should be used.

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 or tube of more than nominal diameter, 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 level change
- The water level in a well has not yet recovered to nearly static conditions (e.g, 95% 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

- Pumping to remove water, unless the amount of water to be removed by the pump can be removed nearly instantaneously and any back-flush can be eliminated
- Using a bailer that has a leaky check valve
- 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

A *falling-head* test should generally **not** be conducted if:

- The static water level (SWL) in a well is within the open/screened interval (unsaturated flow)
- Water to be added could be contaminated
- Water to be added contains significant clay, silt, bacteria, algae or other agents that can cause plugging of soil pores, well screen, or rock fractures
- Water to be added is distilled or deionized and could thus mobilize fine particles, leading to plugging and reduced apparent hydraulic conductivity
- The amount of water to be added cannot be added nearly instantaneously (e.g., if pouring takes over 5% of the “90%-recovery” time)
- Laws or regulations prohibit addition of water to the water-bearing zone to be tested

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 appropriate form 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 diameter
- Well screen or 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
- Transport and disposal methods for any water removed
- 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)
- Stratigraphic horizon materials and elevations
- Hydraulic conductivity of bounding low-permeability units, if present
- Ground-surface elevation

Manual Data Measurement for “Slow-Recovery” Wells

The steps for conducting a slug test using manual water-level measurements are as follows:

1. Conduct a review of the RFI Work Plan and the Health and Safety Plan with the Project Coordinator, and plan for notifications to responsible parties and for site access, as needed.
2. Gather and inspect equipment needed for operation.
3. Decontaminate all necessary equipment before entering a site and between each slug test. In some instances, but *only* if proper authorization is obtained, equipment may not have to be decontaminated between wells. In those instances, slug tests will be performed starting with the cleanest wells and continuing to more contaminated wells. This, however, requires prior knowledge of contaminant distribution in groundwater, knowledge that is not always available with an acceptable degree of certainty. In all cases, equipment should be decontaminated after the end of the testing program.
4. Measure and record the SWL of the well to be tested.
5. Perform the following pre-test activity if a ***rising-head*** test is to be done:
 - Lower the water level probe and record the depth to the base of the well.
 - Allow the bailer or slug to slowly move down into the groundwater. If possible, fully immerse the bailer or slug. If there is not enough water in the well for the bailer to be fully immersed, then let the bottom of the bailer gently come to rest on the well bottom, or a few inches above the well bottom. Reduce agitation of the sediment on the bottom of the well as sediment in the bailer may keep the check valve from properly sealing.
 - Measure the slowly falling water levels using the probe until the water level in the well re-equilibrates to static conditions (within 0.02 feet of SWL).
 - Set the probe below the anticipated depth of the base of the bailer or slug (the most effective position to allow immediate subsequent readings).
6. Start the slug test by creating a nearly instantaneous displacement in water level:

For a *rising-head* test:

- Pull the bailer or slug rapidly upward, and either take it out of the well or secure it so that its base always stays above the static water level.
- Immediately start measuring and recording rising water levels in the well at the predetermined time frequency using the probe. Record as quickly as can accurately be done.
- If a bailer is used, listen for cascading water while the bailer is being raised or remains suspended in the well, 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 a *falling-head* test:

- Use a water level probe to measure the depth to SWL and to the base of the well.
- If a bailer will be used for initial displacement of groundwater, fill it with potable water and make sure that it is not leaking.
- Start the test by quickly lowering the bailer or slug downwards into the groundwater so that, if possible, its top lies below the static water level; if not possible, lower the bailer or slug to a point several inches above the base of the well. If the bailer or slug does not remain fully submersed throughout the test, the interpreter of the data needs to know the depth of the top of the bailer or slug to account for the change in effective well radius once the water level falls below the top.
- Alternatively, if a container of water will be poured into the well to cause the initial displacement, enlarge its opening to the size of the diameter of the well so that pouring can occur rapidly. Start the test by rapidly adding water to the well.
- Immediately start measuring and recording falling water levels over time in the well using the probe. Record levels as quickly as can accurately be done.

7. 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 RFI Work Plan (usually 90% recovery or 1 hour, whichever comes first). A minimum of 8 to 10 water level measurements should be made prior to stopping the test, with the last data point being collected preferably near the 90%-recovery point, the 1-hour point, or greater. If recovery is sufficiently rapid that the minimum number of points cannot be measured, then re-execute the test using a transducer/data logger.
8. Compare the volume of groundwater recovered in the bailer, if one was 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 be accounted for also in the volume calculation, e.g., $V = H\pi r^2 + nH\pi(R-r)^2$. A similar comparison can be done 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.

9. Record all data in a field book and all pertinent data onto appropriate form.
10. Decontaminate all necessary equipment in accordance with methods described in Equipment Decontamination Procedure.
11. Properly containerize and label spent decontamination fluid or groundwater removed from the well. Refer to Waste Characterization Procedure for guidance.
12. Lock all well caps and secure the site as needed.
13. Submit the slug-test data to a scientist or engineer assigned by the Project Manager to interpret the data. The data should be interpreted based on an appropriate model for the known hydrogeologic conditions in the field. Interpretation should be performed using a widely accepted computer-based model, or, alternatively, using an analytical model described in one or more journal articles by the originator of the model.

Any variations from these procedures should first be approved by the Project Coordinator or Project Manager.

Automatic (Transducer/DataLogger) Data Measurement for “Fast-Recovery” Wells

The steps for conducting a slug test using automatic water-level measurements are as follows:

1. Conduct a review of the RFI 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 slug test. In some instances, but *only* if proper authorization is obtained, equipment may not have to be decontaminated between wells. In those instances, slug tests will be performed starting with the cleanest wells and continuing with more contaminated wells. This, however, requires prior knowledge of contaminant distribution in groundwater, knowledge that is not always available with an acceptable degree of certainty. In all cases, equipment should be decontaminated after the end of the testing program.

4. Measure and record the SWL of the well to be tested.
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 bailer or slug to be used.
 - Make pressure readings until three uniform values are read consecutively.
 - Raise the datalogger one foot from its original position. View the pressure reading to confirm that the transducer accurately reported the change in position.
 - Lower the pressure transducer to the base of the well, and measure and record the pressure there.
 - 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 bailer or slug that will be used to move down into the groundwater. If possible, fully immerse the bailer. If there is not enough water in the well for the bailer to be fully immersed, then let the bottom of the bailer gently come to rest on the well bottom, or a few inches above the well bottom. Prevent agitation of sediment on the bottom of the well as sediment in the bailer may keep the check valve from properly sealing.
 - Measure falling pressures during recovery using the pressure transducer until the water level in the well re-equilibrates to near-static conditions (within 0.02 feet).
 - Set the pressure transducer below the base of the immersed bailer or slug.
7. Start the slug test by creating a nearly instantaneous displacement in water level:

For a *rising-head* test:

- Pull the bailer or slug rapidly upwards, either removing it from the well or secure/suspend it within the well several feet above the SWL.
- Simultaneously pull bailer 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 a *falling-head* test:

- Measure the depth to SWL and to the base of the well using a pressure transducer and a battery-operated water level probe.
- If a bailer is to be used for initial displacement of groundwater, fill it with potable water and make sure it is not leaking.
- Start the test by quickly lowering the bailer (or slug) downwards into the groundwater so that, if possible, its top lies below the static water level; if not possible, lower the bailer (or slug) to a point several inches above the base of the well. If the bailer or slug does not remain fully submersed throughout the test, the interpreter of the data needs to know the depth of the top of the bailer or slug to account for the change in effective well radius once the water level falls below the top.
- Alternatively, if a container of water will be poured into the well to cause the initial displacement, enlarge its opening to the size of the diameter of the well so that pouring can occur rapidly. Start the test by rapidly adding water to the well.
- Immediately after all water has reached the depth of the SWL start measuring and recording falling water levels at the predetermined time frequency in the well using the pressure transducer and data logger (a logarithmic time scale is usually employed)

8. 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 RFI Work Plan (usually 90% recovery or one hour, whichever comes first). A pre-set logarithmic sampling interval, with increasing intervals of time, is ideal, usually predetermined by the datalogger's default setup.
9. 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 be 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.

10. Record all data in a field book and all pertinent data on appropriate form.
11. Decontaminate all necessary equipment in accordance with methods described in Equipment Decontamination Procedure.
12. Properly containerize and label spent decontamination fluid or groundwater removed from the well. Refer to Waste Characterization Procedure for guidance.
13. Lock all well caps and secure the site as needed.
14. Submit the slug-test data to the Project Manager for interpretation. The data should be interpreted based on an appropriate model for the known hydrogeologic conditions in the field. Interpretation should be performed using an accepted, published computer-based model.

Any variations from these procedures should first be approved by the Project Coordinator or Project Manager.

EQUIPMENT

- A battery-operated water level measurement probe, marked in 0.01-foot increments
- Form 5.2-01
- Data logger and laptop computer with fully charged battery (if required)
- A clean bailer or a solid or sealed slug
- Clean rope or string for raising and lowering a bailer or 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 (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
- Appropriate field forms

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5.1 SOIL SAMPLE COLLECTION FOR LABORATORY ANALYSIS

INTRODUCTION

The following procedure describes typical soil sample collection methods for submission of samples to a laboratory for chemical analysis. Two sample situations are presented: soil sampling from surficial soils and soil sampling from sub-surface samplers such as a split-spoon sampler or a direct push sampler.

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 RFI 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).

Grab Versus Composite Samples

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample is comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses.

PROCEDURES REFERENCED

- 2.1 Drilling Techniques/Background Information
- 2.2 Soil Borings
- 2.5 Soil Classification
- 5.4 Sample Handling and Shipping
- 7.0 Equipment Decontamination

SAMPLE COLLECTION

1.0 Surficial Soil Sample Collection

1.1 Sample Strategy -Random, Biased, and Grid-Based Sampling

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.

If any areas show evidence of contamination, such as staining or vegetative stress, biased samples will be collected from each area to characterize the contamination present in each area. Background and control samples are also biased, since they are collected in locations typical of non-Site-impacted conditions.

When soil sampling investigations involve large areas, a grid-based soil sampling program is 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.

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 are capable of retaining 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).

1.2 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 RFI 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 that overlies a layer of fine-grained soil.

1.3 Surface 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. 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;
- 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 (VOC's) which require special sample collection methods. VOC's are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected using an EnCore Sampler™ (triplicate samples collected per manufacturers instructions). Samples for VOC's 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 carefull review of this issue in advance of the field efforts is required.

2.0 Sub-Surface Sample Collection

Sub-surface soil sample collection is typically performed with the help of a drill unit, direct-push probing unit, or hand-driven/held samplers. Typically a boring is advanced incrementally to permit intermittent or continuous sampling to the required depth of chemical sample collection; or alternatively sampling may be initiated if certain conditions are observed (i.e. chemical presence or volatile presence identified from monitoring). Sample collection criteria and locations, are normally stipulated by the Work Plan.

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 method (with inside diameter between 2.2 and 6.5 inches) using split spoon samplers (Standard Penetration Test – SPT) or Shelby tube samplers; or
- direct - push samplers, advanced using a percussion/vibratory hammer (GeoprobeTM or equivalent); or
- hand – held/driven split spoon sampling equipment or 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 split spoon sampling, shelly tube sampling, and direct-push sampling. Section 2.4 describes the soil sampling procedure for chemical analysis, once a soil core is recovered from any of the above sample collection devices.

2.1 Split – Spoon Sampling Method

This method is used to obtain representative samples of subsurface soil materials for sample collection. The test methods described below must be followed to ensure that the soils captured in the split-spoon or shelly tube are relatively undisturbed/representative of the desired soil interval and obtain accurate Standard Penetration Test (SPT) values. The SPT values reflect the sub-surface soils density and is typically measured when performing geo-technical work or environmental borings. This information although not

directly relevant to the collection of chemical samples, is collected because it is beneficial in terms of stratigraphy interpretation and understanding the conditions below grade.

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. Larger spoons are available for use when a larger sample volume is required (4-inch diameter spoons).

Once the borehole is advanced, by an appropriate method (e.g. hollow stem augers), 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. 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; and
- 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 D1586-84). 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 field supervisors work surface.

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

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

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. To equalize the hydraulic pressure, the inside of the HSA must be filled with water. The drilling fluid level within the boring or hollow-stem augers 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.

Section 2.4 describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a split spoon sampler.

2.2 Thin-Walled (Shelby Tubes) Sample Method

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 (such as collection of soils for chemical analysis) that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587-94, 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 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 hollow-stem auger 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 workstation to describe the sample, trim the potentially cross-contaminated exterior, and select the area for sample collection (see section 2.4 collection procedure).
- 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.

Section 2.4 describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a shelby tube sampler.

2.3 Direct- Push Sample Method

The operation of the direct-push samplers (i.e. Macro-Core TM Soil Sampler or equivalent) consists of “pushing and/or vibrating” the sampler into the subsurface using a direct-push unit (i.e. Geoprobe TM soil probing machine or equivalent). The sampler is typically a hollow tube with a threaded drive head, and threaded cutting shoe; provided with an internal sleeve (i.e.liner) that the soil sample is captured in.

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 and a new liner is inserted and the sampler reassembled for collection of the next interval. The clean sampler is then advanced back down the same hole to collect the next soil sample. The Macro-Core TM sampler can be used in either the open-tube or closed-point sampling mode. The open-tube is the 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.

Section 2.4 describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a direct-push sampler.

2.4 Soil Core Chemical Sample Collection Procedure

The following describes the collection of soil samples for chemical analysis from a split spoon soil core, shelly tube soil core, or direct-push sample core.

- record soil core recovery and soil stratigraphy data;
- discard upper and lower ends of sample core (3 inches \pm);
- 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 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
- properly label sample container; and
- place collected samples on ice or cooler packs in laboratory supplied shipping coolers.

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.

Exception is noted for the collection of volatile organic compounds (VOC's) which require special sample collection methods. VOC's are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected in triplicate using an EnCore SamplerTM (triplicate samples collected per manufacturers instructions). Samples for VOC's 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.

FIELD NOTES

All conditions at the time of sample collection should be properly documented in the field log book. This should include a thorough description of the collection method, sample characteristics, including grain size, color, and general appearance, as well as date/time of sampling and labeling information. The location of the sampling point should be described in a sketch and three measurements (swing ties) should be taken to adjacent permanent structures so that the sample location can be readily identified in the field at a future date if necessary. It is often advisable to have a licensed land surveyor accurately survey the locations.

DECONTAMINATION

In all sampling scenarios measures to prevent cross-contamination must be employed. The sampling device selected must be constructed of an inert material with smooth surfaces that can be readily cleaned.

Heavy equipment used for test pit operations must also be cleaned between each location when collecting samples for chemical analysis.

EQUIPMENT

- Drilling equipment and soil sampling tools
- Decontamination fluids and rinse water
- Subsurface Boring Log
- Tape Measure
- Water Level Probe
- Appropriate sampling containers

REFERENCE

1. 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.
2. Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.
3. Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.
4. ASTM D1452-80 Practice for Soil Investigation and Sampling by Auger Borings.
5. ASTM D1586-84 Test Method for Penetration Test and Split-Barrel Sampling of Soils
6. ASTM D1587-94 Practice for Thin Walled Tube Geotechnical Sampling of Soils
7. ASTM D2488-93 Practice for Description and Identification of Soils (Visual-Manual Procedure)
8. ASTM D4700-91 Guide for Soil Sampling from the Vadose Zone

5.2 GROUNDWATER SAMPLE COLLECTION FOR LABORATORY ANALYSIS

INTRODUCTION

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

The following describes two techniques for groundwater sampling: "Low Stress/Low Flow Methods" and "Typical Sample Methods."

"Low Stress/Low Flow" methods will be employed when it is critical to collect groundwater samples where sediment/colloid presence is significant, particularly in fine-grained formations. Analyses typically sensitive to turbidity/sediment issues are Polychlorinated biphenyls (PCBs), Semi-volatile compounds (SVOCs) and metals.

The "Typical Sample Methods" will be employed where the collection of parameters less sensitive to turbidity/sediment issues are being collected (volatile organics - VOCs, and general chemistry).

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 must be contacted to determine a course of action.

PROCEDURES REFERENCED

- 4.1 Manual Water Level Measurement
- 7.0 Equipment Decontamination

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 Coordinator of any necessary repair work required.
- 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, a water level must be obtained to determine the well volume for hydraulic purposes. Refer to the Manual Water Level Measurement Procedure for details. In some settings it may be necessary to allow the water level time to equilibrate. This condition exists if a watertight seal exists at the well cap and the water level has fluctuated above the top of screen; creating a vacuum or pressurized area in this air space. Three 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.
- Estimate natural groundwater flow rate into well to determine the approximate pumping rate for purging/sampling activities.

WELL PURGING AND STABILIZATION MONITORING (LOW STRESS/LOW FLOW METHOD)

- The preferred method for groundwater sampling will be the low stress/low flow method described below.
- Bladder pumps/submersible variable rate pumps (i.e., Grundfos™ Rediflo or equivalent) 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 intake must be at the mid-point of the well screen to prevent disturbance and resuspension of any sediment in the screen base.
- 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. Care should be taken to maintain pump suction and to avoid entrainment of air in the tubing. Record adjustments made to the pumping rates and water levels immediately after each adjustment.
- During the purging of the well, monitor and record the field indicator parameters (pH, temperature, conductivity, oxidation-reduction (redox) reaction potential (ORP), dissolved oxygen (DO), and turbidity) approximately every five minutes. Stabilization is considered to be achieved when the final groundwater flow rate is achieved, and three consecutive readings for each parameters 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 20 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 20 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 must not be removed from the well between purging and sampling.

WELL PURGING AND STABILIZATION MONITORING (TYPICAL METHOD)

- Typically peristaltic pumps or bladder pumps or submersible pumps are preferred. In most cases bailer use is not desirable.
- Pump placement is typically performed at the mid-point of the screen.
- Purge the well until three consecutive well volume measurements of temperature and specific conductivity are approximately plus or minus 10 percent and if the pH values are within 1 pH unit of the last three value averages, and the groundwater turbidity values are less than 5 NTU. If stabilization has not occurred within the first five well volumes removed, continue purging and monitoring until eight well volumes have been pumped.
- Groundwater turbidity may be evaluated by a visual examination for sediment/silt presence or use of a nephelometer. Work Plan specific goals may exist for turbidity values that may require extending the purging, or require an alternate pumping system.
- Monitoring well purging is accomplished by using in-place pumps or by a peristaltic, bladder or other appropriate pump, depending on the well depth. The pump/hose assembly or bailer used for purging should be lowered into the top of the standing water column and not deep into the column. Typically pump placement at the mid-point of the screen is adequate.

SAMPLING TECHNIQUES

- If an alternate pump is utilized, the first pump discharge 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 being discharged directly 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 contamination of the sample.
- Order of sample collection:
 - Volatile organic compounds
 - Semi-volatile organic compounds
 - Total organic carbon (TOC)
 - Total organic halogens (TOX)
 - Extractable organics
 - Total metals
 - Dissolved metals
 - Phenols
 - Cyanide
 - Sulfate and chloride
 - Nitrate and ammonia
 - Radionuclides
- For low stress/low flow sampling, samples should be collected at a flow rate between 100 and 500 mL/min and such that drawdown of the water level within the well does not exceed the maximum allowable drawdown of 0.3 feet.
- The pumping rate used to collect a sample for VOCs 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. 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 dictated by the project Work Plan.
- Sample labels/sample identification
- All samples must be labeled with:
 - A unique sample number
 - Date and time
 - Parameters to be analyzed
 - Project Reference ID
 - Samplers initials
- Labels should be secured to the bottle and should be written in indelible inks.

EQUIPMENT/MATERIALS

- pH meter, Conductivity meter, Dissolved Oxygen (DO) meter, Oxidation-reduction (redox) reaction potential (ORP) meter, Nephelometer, Temperature gauge
- Field filtration units (if required)
- Purging/sampling equipment
 - Peristaltic Pump (not suitable for VOCs¹/SVOCs or depths >25 feet);
 - Suction Pumps (not suitable for LFP, VOCs/SVOCs, or depths >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 Delphi programs); and
- Water Level Probe
- Sampling Materials (containers, log book/forms, coolers, chain-of-custody)
- Work Plan
- Health and Safety Plan

NOTE¹: PERISTALTIC PUMP USE FOR VOC COLLECTION IS NOT ACCEPTABLE ON EPA/RCRA SITES; THIS TECHNIQUE HAS GAINED ACCEPTANCE IN SELECT AREAS WHERE IT IS PERMISSIBLE TO COLLECT VOCs USING A PERISTALTIC PUMP AT A LOW FLOW RATE (EX. MICHIGAN).

FIELD NOTES

- Field notes must document all the events, equipment used, and measurements collected during the sampling activities. SOP 1.2 describes the data/recording procedure for field activities. The log book should document the following for each well sampled:
 - Identification of well
 - 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 and pumping rate
 - Time well purged

- Measured field parameters
- Purge/sampling device used
- Well sampling sequence
- Sampling 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
- Laboratory shipped to
- Chain of custody number for shipment to laboratory
- Field observations on sampling event
- Name collector(s)
- 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 6.3-01 (Well Purging Field Information Form), 6.3-02 (Sample Collection Data Sheet), and 6.3-03 (Monitoring Well Record for Low-Flow Purging).

GROUNDWATER/DECON FLUID DISPOSAL

- 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
- Decon fluids should be segregated and collected separately from wash waters/groundwater containers.

REFERENCE

1. ASTM D5474 Guide for selection of Data Elements for Groundwater Investigations
2. ASTM D4696 Guide for pore-liquid sampling from the vadose zone
3. ASTM D5979 Guide for conceptualization and characterization of groundwater systems
4. ASTM D5903 Guide for planning and preparing for a groundwater sampling event
5. ASTM D4448 Standard guide for sampling groundwater wells
6. ASTM D6001 Standard guide for direct push water sampling for geo-environmental investigations.
7. USEPA Low-flow (minimal drawdown) ground-water sampling procedures (EPA/540/S-95/504)
8. USEPA RCRA Groundwater Monitoring: Draft Technical guidance (EPA/530-R-93-001)

5.3 NON-AQUEOUS PHASE LIQUID (NAPL) MONITORING AND SAMPLE COLLECTION

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

- 4.1 Manual Water Level Measurement
- 7.0 Equipment Decontamination

NAPL LEVEL MEASUREMENTS

- Conduct well identification, inspection, and opening in accordance with the Manual Water Level Measurement Procedures.
- 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 RFI 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.

- 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 valve 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
- RFI Work Plan
- Health and Safety Plan
- Field Log Book

REFERENCE

1. 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
2. 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, Vol. 12 No. 4, pp. 132-141.

5.4 SURFACE WATER SAMPLE COLLECTION

INTRODUCTION

The procedures presented in this attachment were developed to provide a uniform, standardized approach to collect representative surface water samples. Surface water as referenced herein refers to standing or flowing water above ground surface.

How a sample is collected and handled can affect the quality and interpretation of the sampling results. These procedures are intended to minimize problems associated with variability in sample collection.

PROCEDURES REFERENCED

- 1.2 Field Data Recording
- 4.1 Manual Water Level Measurement
- 5.6 Sample Handling and Shipping
- 7.0 Equipment Decontamination

SAMPLE COLLECTION

- Sample bottles will be labeled prior to sampling using indelible ink.
- Sample locations and analyses will be selected with respect to specific site conditions in RIF. Based on the selection of sample analyses, appropriate sample containers, preservatives, and holding times are stipulated in the QAPP.
- Cover ground with new plastic/polyethylene sheet at each sample location
- Submerge sample container with cap in place with minimal disturbance to surface with open end pointing up upstream. In situations where using the sample container is not feasible, such as with pre-preserved sample containers, a spare sample container will be used as a transfer vessel, and discarded after use.
- Samples should be collected from downstream (flow) to upstream (flow), so disturbance from sampling does not affect sample quality at other locations. All samples should be collected before any physical features of the stream are measured and prior to sediment sampling.

- Slowly fill container continuously. Use the cap to regulate water flow.
- Lift container from water with minimal disturbance.
- Preserve and filter (for metals) as necessary.
 - Water samples that will be tested for dissolved metals will be filtered in the field with a 0.45 micron filter or cartridge or according to procedures described in the U.S. EPA SW-846 Manual, Method 3005. The liquid phase will be acidified with nitric acid, for preservation.
 - Sample glassware should be filled to the very top of the container for volatile organic analysis (VOA). 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.
- Ensure presence of Teflon septum/liner and secure cap tightly.
- Place immediately into cooler containing ice along with necessary trip blanks. The samples will be stored in coolers, in which ice will be placed in plastic zip-lock bags to contain ice water. Samples will be adequately layered in ice to prevent breakage of glassware. Samples will be positioned upright in the cooler except in the case of 40 milliliter VOA samples. All 40-milliliter VOA vials will be sealed in thick or heavy-duty plastic zip lock bags. If samples are to be shipped to a laboratory for analysis, a Chain of Custody record, custody seals, fragile markers, and reinforced nylon tape will be affixed to the sample cooler. If samples are to be delivered to the contract lab directly, then only the Chain-of-Custody record is required.
 - Chain-of-Custody Form - enclose in large plastic zip lock bag and either tape to inside top of cooler lid or set on top of vermiculite inside of cooler.
 - Custody Seals - place custody seal over cooler gasket separating the cooler bottom at all sides except hinged side.
 - Nylon Tape - tape completely around cooler at two locations. Tape reinforcing should prevent cooler from opening should lid locking mechanism fail.
 - Fragile Markers - fragile markers and upright stickers should be affixed to each side of the cooler.
- Verify that all required documentation entries have been made to the Chain of Custody.

FIELD NOTES

A number of field measurements and observations should be made in the field at the time of sampling. This information is listed below and will be recorded in a project Field Log Book or Sampling Record Form (Haley & Aldrich Form 3202), whichever is more appropriate. For large sampling programs both documentation reports may be completed. For smaller sampling assignments the Project Manager will identify which reporting format is to be used by field personnel. The following list of measurements and observations represents a minimum requirement for surface water samples:

- Field Log Book Entry for Surface Water Samples
 - Surface Water Location Number
 - Time
 - Date Collected
 - Sample Characteristics (measured in separate transfer container not in sample glassware), if requested by the Project Manager - pH, Conductivity, Dissolved Oxygen, Temperature
 - Preservative(s)
 - Samplers (names of individuals who actually collected samples)
 - Sample Destination (Analytical Laboratory)
 - Description (in detail) of the Sample Location
 - Photograph Number and Roll Used, if applicable
 - Approximate dimensions of Stream or Water Course at Sampling Point (measured after sampling) including depth and width
 - Velocity of Water (estimated from floating object)
 - Flow Rate of Water Course (in cubic feet/second; using the following formula)

Where -

Q = discharge in cubic feet/second (cfs)

A = area in square feet

u = velocity in feet/second (ft/sec)

w = width in feet

d = depth in feet

$Q = Au = wdu$

The cross sectional area (A) can then be multiplied by the velocity to derive a rough flow rate. Using a watch, measure the time it takes a floating object to travel a measured distance (two or three feet) to calculate the velocity of the water course.

- Observable Physical Characteristics - Odor, Color, Turbidity, Immiscible Layers, Formation of Precipitates

- Evidence of Stressed Vegetation, Wildlife, or Dumping
- Ambient Weather Conditions during Sampling - Air Temperature, Sky Condition, Recent Precipitation or Drought
- Samples Collected (enter all sample numbers collected at this location)
- Chain-of-Custody and Request-for-Analysis Forms
 - All samples submitted to the laboratory will be accompanied by a Chain-of-Custody as described in the QAPP.
 - Appropriate Chain-of-Custody procedures will be followed at all times during a sampling event and subsequent transport to the laboratory.

EQUIPMENT

- Decontamination fluids, rinse water and equipment (brushes, towels)
- Appropriate sampling containers
- pH meter, Conductivity meter, Dissolved Oxygen (DO) meter, Temperature gauge
- Sampling Materials (containers, log book/forms, coolers, chain-of-custody)
- Work Plan
- Health and Safety Plan
- Gloves, polyethylene sheeting

DECONTAMINATION

- Sampling equipment such as spatula, measuring tape and trowel will be cleaned prior to and between each use according to procedures outlined in the QAPP. Transfer containers will be decontaminated before disposal.

REFERENCE

1. Environmental Protection Agency (1991), Compendium of ERT Surface Water and Sediment Sampling Procedures, OSWER-9360.4-03.

5.5 SEDIMENT SAMPLING

INTRODUCTION

The field procedures presented in this attachment were developed for obtaining representative samples of sediment.

Sediment samples as referenced herein mean sediment soils or soil-like material below surface water. These samples may contain contaminants that are insoluble in water, persistent in the environment, relatively immobile in the soil, or have low volatility.

These procedures are intended specifically to minimize problems associated with variability in sample collection.

PROCEDURES REFERENCED

- 1.2 Field Data Recording
- 5.6 Sample Handling and Shipping
- 7.0 Equipment Decontamination

SAMPLE COLLECTION

- Label and number required sample bottles. Fill out the label in indelible ink and carefully and clearly address all categories and parameters.
- Sample analyses will be specified in the RFI. Based on the selection of analyses, appropriate containers are identified in the QAPP.
- Decontaminate sampling device and/or container immediately prior to use according to procedures in the QAPP.
- If surface water samples are to be collected from same area as the sediment samples, the surface water samples should be taken first.
- Samples should be collected from downstream (flow) to upstream (flow) so disturbance from sampling does not affect sample quality at other sample locations.

- Samples will be taken with pre-cleaned hand scoops or trowels constructed of stainless steel. A stainless steel laboratory scoop is a preferred scoop device due to its non-corrosive nature.
- Procedures for Use
 - Insert scoop or trowel into material and remove sample. Care should be exercised during removal of the sample through the surface water to minimize disturbance and loss of material.
 - Decanting the sample is not necessary. Any water present from saturated sediment is representative of sediment.
 - VOCs should be sampled with ENCORE samplers first, directly off the trowel. The remainder of sample should be homogenized using a stainless steel mixing bowl or Teflon tray and then placed into the appropriate sample bottles with a stainless steel lab spoon, wooden tongue depressor or equivalent.
- Sample glassware will be filled to the top. Refer to the QAPP for sample volume size and appropriate containers for given analyses. No preservatives are required for sediment samples. All container caps will include an inner Teflon septa or lining and must be tightly secured to contain the sample.
- Check for appropriate liner in cap and secure cap tightly. Store the samples with ice in an ice chest, following these sealing and packing procedures:
 - Ice will be placed in plastic zip-lock bags to contain ice water. Samples will be adequately layered in ice to prevent breakage of glassware.
 - Check to make sure all appropriate information is in Field Log Book or Sampling Record Form, Chain-of-Custody form and Request for Analysis form (if applicable) using indelible ink.
 - If samples are to be shipped to a laboratory for analysis, a Chain-of-Custody record, custody seals, fragile markers, and reinforced nylon tape will all be properly affixed to or on the sample cooler. If samples are to be delivered to the lab directly then only the Chain-of-Custody record is required.
 - Chain-of-Custody Form - enclose in large plastic zip lock bag and either tape to inside top of cooler lid or set on top of vermiculite inside of cooler.

- Custody Seals - place custody seal over cooler gasket separating the cooler lid from the cooler bottom at all sides except hinged location.
- Nylon Tape - tape completely around cooler at two locations. Tape reinforcing will prevent cooler from opening if the lid locking mechanism fails.
- Fragile Markers - fragile markers and upright stickers will be affixed to each side of the cooler.

FIELD NOTES

This information is listed below and will be recorded in a project Field Log Book or Sampling Record Form, whichever is more appropriate. For large sampling programs both documentation reports will be completed. For small sampling assignments the Project Manager will identify which report is to be used. The following list of measurements and observations represent a minimum requirement for sediment/soil samples:

- Field Log Book Entry For Sediment/Wetland Soil Samples
 - Sediment/Soil Location Number
 - Time
 - Date Collected
 - Samplers (names of individuals who actually collected samples)
 - Sample Destination (Analytical Laboratory) to receive samples
 - Description of Sample Location with Sketch or Map (i.e., sludge lagoon, test pit, boring, stream, etc.)
 - Sample Depth (i.e., distance in feet from ground surface)
 - Photograph Number and Roll used (if applicable).
 - Water Body Characteristics (i.e. size, depth, estimated flow rate)
 - Observable Physical Characteristics:
 - Soil Classification (i.e. silty sand, clay)
 - Odor
 - Color
 - Density, Consistency, etc.
 - Layering
 - Other
 - Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken
 - Ambient Weather Conditions during Sampling:
 - Air Temperature

Sky Condition

Recent Precipitation or Drought

- Samples Collected (enter all sample numbers collected at this location)
- Chain-of-Custody and Request-for-Analysis Forms
 - A Chain-of-Custody form, as shown in the QAPP, will accompany all samples submitted to the laboratory.
 - Appropriate Chain-of-Custody procedures will be followed at all times during a sampling event and subsequent transport to the laboratory. These procedures are described in QAPP in Appendix B.

EQUIPMENT

- Stainless Steel or Teflon Scoop or Trowel, no chrome plated or painted
- Decontamination fluids, rinse water and equipment (brushes, towels)
- Sampling Materials (containers, log book/forms, coolers, chain-of-custody)
- Work Plan
- Health and Safety Plan
- Field Notebook or Sampling Forms
- Polyethylene sheeting, gloves, waste/rubbish container

DECONTAMINATION

Soil/sediment sampling equipment brought into actual contact with a laboratory sample, other than sample containers, will be cleaned prior to an between each use according to procedures outlined in the QAPP.

REFERENCE

1. Environmental Protection Agency (1991), Compendium of ERT Surface Water and Sediment Sampling Procedures, OSWER-9360.4-03.

5.6 SAMPLE NAMING, HANDLING, AND SHIPPING

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, and not lost, broken, or exposed to conditions that may affect the sample's integrity.

All sample submissions must be accompanied with a chain-of-custody (COC) document to record sample collection and submission.

The following sections provide the minimum standards for sample management.

PROCEDURES REFERENCED

A) 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 RFI Work Plan, Quality Assurance Project Plan. 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. VOC samples 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.

B) Sample Labeling

Samples must be properly labeled as soon as practical after collection.

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.

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 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. Sample 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.

Unless otherwise instructed, labels should not contain specific names of the sample source (i.e., "Well No. 16"). Provision of such specific data on the label can produce biased lab results.

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; and

- sampler's initials.

Labels should be secured to the bottle and should be written in indelible ink. 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 RFI Work Plan.

XXXX-XXXXXX-XXXX

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

- i) XXXX – Employee four-digit identification number
- ii) XXXXXX – Sample Date – Month/Date/Year
- iii) XXXX – Time (military)

Note that for Field Duplicates, Field Blanks, Equipment Blanks, Trip Blanks, Field Replicate, Known Duplicate, and Material Blank time will NOT be used. Instead we will use a sample number (ie. 0001, 0002, 0003), reset every day. This will simplify sample naming for the QA/QC samples and avoid identifying the parent sample for blind duplicates.

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

C) 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.
- iii) Do not bulk pack. Each sample must be individually padded.
 - iv) Large glass containers (1 liter 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 that 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 QA/QC plan.
- iii) Enclose the Chain-of-Custody form in a "Zip-Lock" bag.
- 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.

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 not being used in a QA/QC role should be isolated from coolers immediately after receipt. Trip blanks should be double-bagged and kept from freezing.

D) Chain-of-Custody Records

Chain-of-custody forms will be completed for all samples collected. The form documents the transfer of sample containers.

The chain-of-custody 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 chain-of-custody document will be signed and dated by the sampler when transferring the samples.

Each sample cooler being shipped to the laboratory will contain a chain-of-custody form. The chain-of-custody 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. 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 Coordinator upon receipt of the samples by the laboratory. One copy will be returned with the data deliverables package.

Chain-of-custody (COC) records are legal documents. 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 ballpoint 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.
- 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) Do not indicate the source of the sample as this may produce a biased lab result.
- xi) Before using an acronym on a COC, define clearly the full interpretation of your designation [i.e., Polychlorinated Biphenyls - (PCBs)].

E) Shipment

In all but a few cases the QA/QC plan for the field work will require shipment of samples by overnight carrier. A great many problems can be avoided by proper advance planning. 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 pick-up is available at the Site, the nearest pick-up or drop-off location should be determined. Again, the "no-later-than" time for each location should be determined.

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.

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

5.7 Vertical Water Quality Profiling

INTRODUCTION

Environmental investigations often involve characterizing the presence of contaminant compounds in groundwater. Such characterization is accomplished a number of ways depending on the site conditions, project objectives and regulatory requirements. Traditionally, site groundwater characterization has involved the installation of monitoring wells for sampling. In recent years, more refined methods of groundwater characterization have been developed. Several studies have shown that vertical mixing of contaminants in groundwater is limited, and that contaminant concentrations can vary by several orders of magnitude within very short vertical distances, even less than one ft. As such, installation of conventional monitoring wells, which typically have screen lengths of 5 to 10 feet or more, cannot discern the presence of narrow zones of significant contamination. Moreover, high concentrations of contaminant compounds in a narrow zone can be significantly diluted by cleaner-zone water entering into the well screen from outside the high concentration zone.

As traditional rotary drilling and sampling methods have been supplemented by direct-push methods, equipment has been developed that facilitates sampling groundwater from small, discrete sampling intervals. By obtaining a series of samples in a borehole, a vertical water quality profile can be developed. Such profiling can provide a more detailed understanding of site contaminant distribution and migration than might otherwise have been practical using only standard monitoring well methodology. It can be especially helpful for sites with variable soils that contain seams or zones of greater permeability where contaminants migrate more readily. Depending on regulatory or work plan requirements, the discrete, in-situ samples may need to be combined with standard monitoring well samples.

Vertical water quality profiling is most often performed in overburden soils, however discrete groundwater sampling can also be performed in bedrock, albeit using more time-consuming and costly methods.

Although this SOP cannot include a comprehensive discussion of all available methods and equipment, it presents general guidelines for vertical water quality profiling.

PROCEDURES REFERENCED

- 2.2 Drilling Techniques
- 2.3 Soil Borings
- 2.4 Bedrock Coring
- 2.5 Borehole Abandonment and Sealing
- 5.4 Water Pressure Testing
- 6.3 Groundwater Sampling
- 9.0 Equipment Decontamination

PROCEDURES AND GUIDELINES

In order to obtain a vertical profile of water quality, several discrete samples must be obtained at a subsurface exploration location. A discrete sample contains groundwater from within a short vertical section of the formation being tested, usually less than one foot. It must be obtained in a manner that does not allow the sample to be affected by groundwater from above or below the target interval, by drilling or other fluid in the borehole or casing, or by residual fluid in the sampler from previous samples. Thus procedures and sampling equipment designed with these restrictions in mind must be used.

A variation on the method of actually obtaining a sample of groundwater involves advancing through the soil a probe containing a detector designed to continuously measure levels of volatile organic compounds (VOCs). This method was developed by Geoprobe™ and utilizes their Membrane Interface Probe (MIP). This is discussed in further detail below.

Overburden

Several products have been developed to obtain discrete groundwater samples in overburden soils. These include, but are not limited to:

- Hydropunch™, by QED
- Groundwater Profiler, by Geoprobe™
- Screenpoint 15, by Geoprobe™

- Waterloo Profiler, by the University of Waterloo, Ontario

Each of these tools is generally deployed using direct-push methods, although conventional drop hammer methods can also be used. The tools are advanced by driving them down through saturated overburden soils. Once the desired depth of sampling is reached, a sample of groundwater is obtained from a narrow depth range.

Sample collection is performed differently manner depending on the type of tool used. For the Hydropunch and Screenpoint 15, the outer driving rods are retracted after reaching the desired depth, exposing an inner screened portion of the sampler that allows entry of groundwater into the sample chamber. At that point a sample of the groundwater is withdrawn from the sampling chamber and up through the drill rods using any of the following:

- a foot valve (Waterra or similar product) and tubing,
- a peristaltic pump connected to tubing,
- a small diameter bailer,
- or other methods.

For the Groundwater Profiler, 6-inch or 12-inch sections of exposed screen are driven to the desired depth. Deionized water can be circulated down the drill rods, through the screen, and into the formation during advancement to prevent screen clogging or entry of unwanted groundwater from non-target zones. A sample is then obtained using one of the sample methods described above.

For the Waterloo Sampler, sample withdrawal tubing is connected to small screened ports in the probe. Deionized water is pumped downward through the tubing and into the formation during probe advancement to minimize clogging of the sampling ports. The tubing passes through the inside of the drive rods to the surface. Once the desired sampling depth is achieved, the tubing is connected to a peristaltic pump at the surface that extracts a groundwater sample.

In the case of the Groundwater Profiler and Waterloo Sampler, the tool is designed to remain in the borehole throughout the profiling effort. In others, the probe and screen may require removal and decontamination after each sample. SOP 9.0, Equipment Decontamination, should be referenced and followed for appropriate decontamination procedures between samples or sample locations, as necessary.

The following is a list of recommendations and/or requirements for effective groundwater profiling that will produce meaningful results:

- It is best if overburden stratigraphic conditions at the site can be evaluated, at least in part, prior to groundwater profiling. This will enable targeting specific zones or strata where soil grain size (and therefore groundwater flow) is most likely to be greatest, thereby increasing the chances of obtaining sufficient sample for analysis.
- The discrete sampling devices discussed herein are designed primarily for obtaining samples from granular soils, and in general, the coarser (grain size) the formation, the more readily it will yield representative groundwater samples. Fine-grained soils (fine sandy silts, silts and clays) will often clog the intake openings of the samplers, limiting the inward flow of groundwater and necessitating significant and time-consuming efforts to remove and clean the openings. This should be taken into consideration when designing a sampling program.
- It is helpful to know the depth to the water table. Obtaining a sample at that depth will maximize the ability to evaluate the potential presence of light, non-aqueous, phase liquids (LNAPL).
- The length of sample intervals should be kept to a minimum, so that analytical results are representative of a narrow vertical range. If practical sampling intervals should be less than one foot.
- Regardless of sampling interval length, it is important to accurately determine the top and bottom limits of the interval. Accurate measurements of the sampling apparatus prior to deployment is essential. In addition, during deployment of the sampling screen, the length of rod retraction must be measured.
- Avoid overlap of sampling intervals, so that analytical results apply only to that interval. Overlap of sampling intervals will cause confusion with regard to the specific location of contaminants.
- When using a sampler that requires removal after each sample, decontamination of the screen and sampling chamber is critical. In addition, the sampler must be designed with measures that prevent infiltration of borehole fluids into the sampling chamber when returning the sampler to the borehole for additional samples. In general, this requires a system of o-rings or other sealing mechanism that keeps water out until the screen is deployed at the desired depth.
- When using the Groundwater Profiler or Waterloo Sampler it is imperative that clean deionized water be circulated down through the probe and into the formation during advancement. The water must be pumped at a rate/pressure that

will prevent infiltration of groundwater into the sample screen or ports until the desired depth is reached.

These units also require sufficient purging of the deionized water prior to obtaining the groundwater sample to insure a representative formation sample is obtained. The length and diameter of the tube must be known to calculate the minimum volume of water to purge. In addition, the water that was pumped into the formation at or near the sampling depth must also be accounted for and purged out if possible.

- If the target analytes are metals, it is recommended that a PVC screen be used in lieu of stainless steel.
- With regard to sampling, be sure that the work plan or regulatory requirements do not prohibit sampling with a tubing/foot valve assembly (e.g. Waterra) due to the potential for cavitation of gases that could affect volatile organics (VOCs) analysis results. It may be necessary to use a small-diameter bailer or other means to retrieve the sample.
- Upon exploration and sampling completion, seal the borehole with grout unless it is to be completed as a permanent well installation. This will minimize or prevent the potential for the borehole to exacerbate the spread of contaminants between zones that are otherwise separated by stratigraphic barriers.

Bedrock

Water quality profiling in bedrock is generally feasible, although obtaining discrete samples in narrow zones within bedrock is generally more time consuming and costly than in overburden. However, obtaining samples in zones as narrow and frequent as in overburden is generally not practical. Bedrock groundwater profiling is generally accomplished using a system of borehole packers (or a single packer) that allows collection of a groundwater sample from an isolated interval, albeit of a generally greater length. The sample collection apparatus may or may not be similar to the overburden equipment.

The following is a partial list of considerations when performing rock corehole water quality profiling:

- The proper description and logging of bedrock core is important in determining potential target sample intervals. The presence of pits, vugs, cavities, and other

dissolution features, as well as fractures, bedding planes, and joints should be described and the correct depths of the features assigned. Rock coring should be performed in accordance with SOP 2.4, Bedrock Coring.

- Packer pressure testing, performed as a precursor to water quality profiling in the corehole, can identify potential yielding transmitting portions of the bedrock that are likely to produce sufficient water quality samples (see SOP 5.4, Packer Pressure Testing). These tests can also generate relative hydraulic conductivity values for the tested bedrock intervals. As indicated above it is crucial to recover all lost water from the formation prior to collecting representative groundwater samples.
- Development/recovery of all drilling water lost within the target interval is critical to obtaining a representative formation sample that is not diluted or contaminated by drilling water. At least as much water as was initially lost should be recovered during purging.
- It is recommended that maximum 5-foot intervals be sampled so as not to cause overlap of potential zones of interest or to isolate intervals that are too short as to include meaningful bedrock features.
- It is especially important to know the dimensions (i.e. lengths) of the apparatus being used for proper and accurate depth targeting in the bedrock.
- A submersible pump is recommended for collecting representative samples from depth. A submersible pump can operate at a lower flow rate so as to generate minimal turbulence for VOCs sampling and analysis and can collect samples from deeper intervals. Other sampling apparatus may also be used if required, based on interval depth, etc.
- To prevent cross-contamination, proper decontamination must be performed when using non-dedicated equipment that is to be used at multiple locations or at multiple depths within a single location, including packer assemblies, reusable tubing, pumps, etc.

EQUIPMENT AND VENDORS

- Geoprobe Systems
601 N. Broadway
Salina, Kansas 67401

(800) 436-7762

- QED Environmental Systems, Inc.
P.O. Box 3726
Ann Arbor, MI 48106-3726
(800) 624-2026
- Waterloo Center for
Groundwater Research
University of Waterloo
Waterloo, Ontario, Canada, N2L 3G1
- Packer assembly apparatus, if required
- Sampling pump(s) (Grundfos, peristaltic, bladder, etc.)
- Sampling apparatus (Watterra foot valve, tubing, mini-bailers, etc.)

REFERENCES

1. Company Literature, Waterloo Center for Groundwater Research, University of Waterloo, Waterloo, Ontario, Canada.
2. Company Literature, Geoprobe Systems, Salina, Kansas.
3. Company Literature, QED Environmental Systems, Inc., Ann Arbor, Michigan.
4. Company Literature, Solinst Canada, Ltd., Georgetown, Ontario, Canada.

5.8 SOIL VAPOR SAMPLING

INTRODUCTION

This procedure is for the collection of vapor samples from temporary well points for laboratory analysis in accordance with USEPA Method TO-15. This procedure includes technique for outdoor vapor collections.

PROCEDURES REFERENCED

- 1.1 Utility Clearance
- 2.1 Drilling Techniques/Background Information
- 2.2 Soil Borings
- 2.4 Soil Classification
- 2.5 Soil Vapor Point Installation
- 3.1 Well Construction Materials
- 5.8 Soil Vapor Sampling
- 7.0 Equipment Decontamination
- 8.0 Waste Characterization

SOIL VAPOR POINT INSTALLATION PROCEDURES

Operating Procedure 2.5 – Soil Vapor Monitoring Point Installation presents description of installation requirements for soil vapor point installations.

TRACER GAS TEST AND WELL PURGING

Soil Vapor well points will be sampled in order of increasing chemical concentrations (if known or anticipated). Equipment calibration, field documentation, sampling, and shipping will be conducted in accordance with the Field Sampling Plan (FSP) and Project Quality Assurance Project Plan (QAPP). Personal protective equipment will be donned in accordance with the requirements of the Project Health and Safety Plan.

1. Begin tracer gas test procedure by laying plastic sheeting at sampling location. Seal tubing and sheeting with hydrated bentonite. Fit tracer bucket over sampling location with tubing clearing bucket. Set up purge tedlar bag and GilAir pump to collect necessary purge volume.
2. Flood the bucket with commercial grade helium from a disposable compressed gas cylinder. (commercial grade can be purchased from retail stores or provided by an industrial gas supplier (i.e. welding supply).
3. Purge the installed well by connecting the well point to GilAir pump (or equivalent device) using High Density Polyethylene (HDPE) tubing and extract at least well volumes of soil vapor from the well point.
4. Using the well point installation report to obtain well depth, calculate the volume of air present in the well point, using the formula:

$$\text{Volume} = \pi \left(\frac{d}{2} \right)^2 h$$

Where,

d = the inner diameter of the tubing

h = the overall tubing length

Note: 1 in³ = 16.39 mL

For example, ¼" O.D. tubing has an inner diameter of 0.187". Therefore a 1 foot section of that tubing has a volume of:

$$\text{Volume} = 3.14 \left(\frac{0.187"}{2} \right)^2 12" * \frac{16.39 \text{ mL}}{\text{in}^3} = 5.4 \frac{\text{mL}}{\text{foot}}$$

5. Purge the well at flow rates not to exceed 0.2 L/minute to remove three (3) volumes so that the sample collected for analysis will be representative of soil gas located in the vadose zone. GilAir pump should be calibrated to this flow rate.
6. Stop the GilAir pump and close the tedlar bag. Disconnect tedlar bag and release under He analyzer for deflection. If He is detected, modify the surface seal for the vapor sampling point and re-test. If no detection is noted, proceed with sample collection.

SOIL VAPOR COLLECTION USING SUMMA CANISTER

1. After purging, while assembling canister, close off the well point to the atmosphere using a hose clamp or similar device. The soil vapor well point is now ready to be sampled.
2. Verify the vacuum level in the passivated SUMMA[®] canister (or equivalent device) to be used for sample collection using the vacuum gauge supplied by the laboratory. Record the initial vacuum on the Soil Vapor Survey Sampling and Purge Information sheet (sampling record), close the valve.
3. Attach the calibrated orifice to the ¼" male fitting on the vacuum gauge using a stainless steel open end wrench. (Note: Do not over tighten. ¼ turn past finger tight should be adequate to create a proper seal.)
4. Attach tubing from soil well point to the end of the critical orifice. Be sure that the selected orifice is appropriate for the sample time length. Be sure to record any ID numbers from canister, gauge and critical orifices on chain.
5. Turn green knob on canister and allow sample collection time.
6. **MONITOR SAMPLE VACUUM DURING COLLECTION TO ENSURE THAT THE SAMPLING RATE IS CORRECT AND THAT THE CANISTER VACUUM IS NOT EXPENDED.**
7. At the conclusion of the sample collection, record the final time on the sampling record and close the valve.
8. Record final vacuum reading on chains, close the valve, remove the vacuum gauge and orifice and replace the ¼" cap on the canister inlet. Label the SUMMA[®] canister sample tag with proper well ID, vacuum readings and sampling time interval (e.g. 24 hours).
9. Remove the sampling train tubing apparatus for the individual well and discard. Repair soil area if possible.
10. Fill out Chain of Custody with project name, file number, sample identifications, Summa canister and related equipment serial numbers, date and time collected, and

analysis requirements. Retain copies of the Chain of Custody record and relevant shipping information. Place canisters back into their original boxes and ship them to the laboratory via an overnight courier.

- Sample number/ID
- Date and time
- Parameters to be analyzed
- Project Number
- Sampler's initials

FIELD NOTES

Field notes must document all the events, equipment used, and measurements collected during the sampling activities. *Operating Procedure 1.2* describes the data/recording procedure for field activities. The field forms should document the following for each well sampled:

- Identification of soil vapor well point location
- Soil vapor well point depth
- Static groundwater elevation and measurement technique
- Purge volume and pumping rate
- The amount of time required to purge the well point
- Purge/sampling device used
- Sample identification
- Parameters requested for analysis
- Laboratory to which samples were shipped
- Chain of custody number for shipment to laboratory
- Field observations on sampling event
- Name of sample collector(s)
- Climatic conditions including air temperature
- Problems encountered and any deviations made from the established sampling protocol.
- Sample Identification Key

EQUIPMENT AND MATERIALS REQUIRED

Soil Vapor Sampling

- SUMMA can with tag
- Critical orifice (4hr for outdoor)
- Pressure gauge
- COCs

- 40-50lbs bentonite
- Water bottle to hydrate bentonite
- Pre-made tracer test bucket
- Plastic Sheeting cut into 4 X 3 feet squares
- He canister from grocery or party store
- He detector “Ion Science Gas Check 5000is” from Ashtead rentals
- Or He detector dielectric mdg-2002 from Hazco rentals
- ¼ inch OD Tygon tubing
- Gil Air hand pump set at < .2L/min
- Tedlar bags from SKC

Extras/Misc

- Broom/dustpan for mess
- Paper towels
- Garbage bags
- Razors or pocketknife
- Nitrile gloves
- Stakes/spray paint to mark utilities COCs
- Thermometer
- Adjustable wrenches
- Tape measure
- Camera/batteries
- Watch
- FID/PID from Hazco rentals

REFERENCES

1. U.S.E.P.A., Soil Gas Sampling SOP# 2042, 1 June 1996, REV. #: 0.0
2. Compendium of Methods for the Determination of Organic Compounds in Ambient Air, EPA/625/R-96/010a, 2nd Edition, June 1999, USEPA ORD, Washington DC.
3. USEPA RCRA Groundwater Monitoring: Draft Technical guidance (EPA/530-R-93-001).
4. New York State Department of Health (NYSDOH) “Guidance for Evaluating Soil Vapor Intrusion in the State of New York”, October 2006.
5. USEPA “DRAFT Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion)”, 2002.

6.0 FIELD INSTRUMENTS – USE AND CALIBRATION

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.

This SOP 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

- 1.2 Field Data Recording

PROCEDURE

- All monitoring equipment will be in proper working order, and operated for the purpose for which it was intended, in accordance with manufacturer's recommendations.
- Field personnel will be responsible for insuring 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 and calibration log, if available, for each instrument used on a project will be kept on site at all times.
- 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: Calibration of instruments shall be performed once at the beginning of every day and one additional time during the day. This includes the following parameters:

- Frequency
- Use of proper calibration Gases or Chemical Standards
- Requirements for Factory Calibration

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 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. In situations where an extreme temperature differential exists, the unit should be brought to the temperature it is used in and calibrated at that temperature.

Documentation of Calibration: Instrument calibration activities and maintenance activities will be documented on the appropriate field forms. In addition, protocol for documentation outlined in the Field Data Recording Procedure will 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 Underwriter’s 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

- 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.

REFERENCE

- Underwriter's Laboratories, Inc. (<http://www.ul.com/hazloc/define.htm>) Standard UL 913.
- National Fire Protection Agency (<http://www.nfpa.org/index.html>)
- Canadian Standards Association (CSA) (<http://www.csa.ca>) Standard 22.2 No. 157

7.0 EQUIPMENT DECONTAMINATION

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

- 2.0 - Subsurface Investigations
- 4.0 - Aquifer Characterization
- 5.0 - Sample Collection for Laboratory Analysis
- 6.0 - Field Instruments – Use And Calibration
- 8.0 – Waste Characterization

PROCEDURE

A. General Procedure Discussion

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, and all monitoring equipment (rented or not) in contact with the sampling media 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 decontaminated 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

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decontaminated. At a minimum, the decontamination pad will have the following elements:

- an impermeable barrier capable of containing decontaminated 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.

B. Decontamination of Specific Sampling Equipment

The following specific decontamination procedure is recommended:

- Brush loose soil off of equipment;
- Wash equipment with laboratory grade detergent (i.e. Alconox or equivalent);
- 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; and
- Wrap equipment in aluminum foil when not being used.

C. 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 decon fluids is not possible. As such, care must be taken to wipe the instruments down with detergent-wetted wipes or sponges, and then with deionized water-wetted wipes or sponges.

D. Disposal of Wash Solutions and Contaminated Equipment

All contaminated wash water, rinsates, solids and materials used in the decontaminated process that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and disposed of in accordance with applicable regulations and Delphi 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 PCBs).

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

EQUIPMENT

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

- Polyethylene sheeting;
- Metal racks to hold 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 offsite shipping/disposal if necessary.

REFERENCE

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

8.0 WASTE CHARACTERIZATION (INVESTIGATION DERIVED WASTE)

RATIONALE/ASSUMPTIONS

This procedure applies when disposition of investigation soils and/or groundwater are required in accordance with the project Work Plan. Generally, this procedure is applicable to Facilities where the Project Manager has assessed the areas of investigation and has developed a waste handling plan. In some areas and/or sections within a Facility 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). In other areas it may not be practical to return cutting/soils to their origin, and they are better handled by this characterization/disposal procedure. These practices are consistent with USEPA procedure for investigative derived wastes (IDW) at RCRA facilities and CERCLA sites.

Typically, IDW are dealt with following "Best Management Practices"; and are not handled under RCRA regulations until proven to be listed and/or identified as characteristically hazardous waste. Investigative soils and groundwater often cannot be considered a listed waste 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 characteristic of hazardous waste. Once the IDW characterization is complete, RCRA regulations apply if determined hazardous; if determined to be non-hazardous solid wastes, best management /solid waste handling practices apply.

9.0 SUMP INSPECTION

INTRODUCTION

This procedure describes inspection of sumps. Inspection is required to reduce the risk of release of material that would compromise groundwater and soil quality. The degree of inspection will be dependent on the nature of the activity, equipment used and on the amount of material present.

BACKGROUND

1. Sumps in facilities are generally used to collect materials associated with but not limited to:
 - Machining,
 - Metalworking,
 - Coolant systems,
 - USTs
 - Wastewater
2. Sumps have no standard as to design. Engineering depends on era the sump was built. Common materials used for construction include:
 - Concrete slabs or poured in place,
 - Metal,
 - Brick,
 - Fiberglass,
 - Steel.
3. Sumps are often lined to provide additional containment of material. Common materials include:
 - Metal,
 - Plastic,
 - Coal Tar,
 - Epoxy.
4. No regulatory framework exists pertaining to general maintenance or inspection of sump integrity.

PROCEDURE

A. General Procedure Discussion

Inspection of the sumps must be performed in accordance with facility requirements pertaining to health and safety. Care must be taken to minimize the potential for transfer

of materials to the ground or onto other materials. Regardless of the size or nature of the sumps, the inspection will utilize a series of steps that involve removal of gross material (bulk liquid, solids, residue etc.), washing with high pressure, and inspection of the sump interior for cracking, staining, settling etc.

B. Initial Inspection Guidelines

The following specific inspection procedure is recommended:

1. Locate each sump using facility site plans and as-built drawings;
2. Inspect each sump and identify conditions and any differences from previous inspection if available. Inspection should identify:
 - Name
 - Location
 - Dimensions
 - Age
 - Estimate of volume and type of material present;
3. Remove bulk liquids, solids, sludge, and residue using dry mechanical methods consisting of hand scraping, shoveling, vacuuming or other similar means. Material removed should be containerized properly pending disposal;
4. Vacuum clean dust and particles as a final initial step;
5. Inspect empty sump for visible or noticeable cracks or settling. Photograph prior to and after cleaning.

C. Cleaning of Sump – High Pressure Washing

The high-pressure wash system utilized for the rigorous cleaning should be capable of operation from water temperatures ranging from 75° F to 180° F. The system should be capable of operation at a pressure of 3,000 to 10,000 PSI. The maximum jet reactive force should not exceed 20 pounds when operating at 10,000 PSI and at a maximum water usage rate of 4.0 GPM. At no time shall the water usage rate exceed 8.0 GPM. Splashback shall be held to a minimum and use of deflector shrouds or other means of control may be required for worker protection and/or liquid containment.

Water should be vacuumed out and the sump inspected for remaining residue, solids and presence of cracking, pitting, or settling. Photographs should be taken.

D. Disposal of Wash Solutions

All wash water, rinsates, solids and materials collected in the cleaning process (such as polyethylene sheeting) will be containerized and disposed of in accordance with applicable regulations and Delphi requirements. All containers

will be labeled with an indelible marker indicating contents and date of placement in the container, and any appropriate stickers required (such as PCBs).

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

EQUIPMENT

Cleaning equipment and solutions are generally selected based on ease of use and disposability.

- Polyethylene sheeting;
- Pressure Washer;
- Long-handle brushes for removing gross product and scrubbing with wash solutions;
- Plastic buckets;
- Digital Camera;
- 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 offsite shipping/disposal if necessary.

REFERENCE

SUMP INVENTORY FORM

Date: _____

Sump: _____

Time: _____

Location: _____

Personnel: _____

Shown on Plan: _____

Dimensions: _____

Depth: _____

Sump Construction:

Concrete Slab ☐

Concrete Poured ☐

Brick ☐

Steel ☐

Metal ☐

Coal Tar ☐

Other _____

Sump Liner Material:

N/A ☐

Metal ☐

Fiberglass ☐

Plastic ☐

Epoxy ☐

Other ☐

Material Handled:

SUMP DESCRIPTION

Gravity Feed (y/n) _____

Gravity Outflow (y/n) _____ Discharged to _____

Sump Type: _____

Inverts

Description

Dimensions

Location

Example: Inflow pipe

2" diameter

180° from North, 2.3' from sump rim

A: _____

B: _____

C: _____

D: _____

E: _____

F: _____



<h2 style="margin: 0;">EQUIPMENT CALIBRATION LOG</h2>

Location: :

Model Name:

Model Number: _____ **Serial Number:** _____

Cal. Standards:

[illegible]

	DAILY FIELD REPORT	REPORT NO:
		FILE NUMBER:

PROJECT NAME:	DATE:
CLIENT NAME:	PAGE:
LOCATION:	WEATHER
CONTRACTOR COMPANY	TEMPERATURE
CONTRACTOR:	MILEAGE
H&A TIME ARRIVED ON SITE:	H&A TIME LEFT ON SITE

I. CONTRACTORS ACTIVITIES:	
1	
2	
3	
4	
5	
6	
7	
II. FIELD REPRESENTATIVE ACTIVITIES:	
1	
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HALEY & ALDRICH Field Representatives (print and signature)
HALEY & ALDRICH Field Representatives (print and signature)

	DAILY FIELD REPORT	REPORT NO:
		FILE NUMBER:

PROJECT NAME:	DATE:
CLIENT NAME:	PAGE:
LOCATION:	WEATHER
CONTRACTOR COMPANY	TEMPERATURE
CONTRACTOR:	MILEAGE
H&A TIME ARRIVED ON SITE:	H&A TIME LEFT ON SITE

I. CONTRACTOR=S ACTIVITIES:


II. FIELD REPRESENTATIVE ACTIVITES:
--

HALEY & ALDRICH Field Representatives (print and signature)
HALEY & ALDRICH Field Representatives (print and signature)

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Distribution:

Form #1002

		FIELD SAMPLING RECORD							
Sample ID:					Date:		Sampler:		
Location ID:					Project Number:				
Project Name:					Project Manager:				
Comments:									
Matrix		Sampling Device/Material							
Soil		Scoop		Pump		Stainless Steel		Galvanized	
Sediment		Auger		Dredge		Poly/Plastic		Glass	
Groundwater		Split Spoon		Other		Teflon®		Other	
Surface Water		Bailer		Specify:				Specify:	
Other:									
Laboratory Analysis									
Volatile Organic Compounds			Pesticides/Herbicides			Dioxins			
Semi-Volatile Organic Compounds			Hexavalent Chromium			Other:			
TAL Metals			Total Organic Carbon						
Total			Sulfates						
Dissolved			Nitrates						
PCBs			Cyanides						
Comments: _____									
Sample Information									
Time Sampled:					QA/QC				
COC Number:					Field Blank:				
Sample Description: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____					Sample ID:				
					Field Duplicate:				
					Sample ID:				
					Trip Blank:				
					Sample ID:				
					MS/MSD:				
					Sample ID:				
					Equipment Rinsate:				
					Sample ID:				
					Regulatory Split:				
Sample ID:									
Comments: _____									
Signature									
Sampler (Print)				Sampler (signature):				Date:	



OW/PZ NUMBER

Page of

H&A FILE NO.

PROJECT MGR.

FIELD REP.

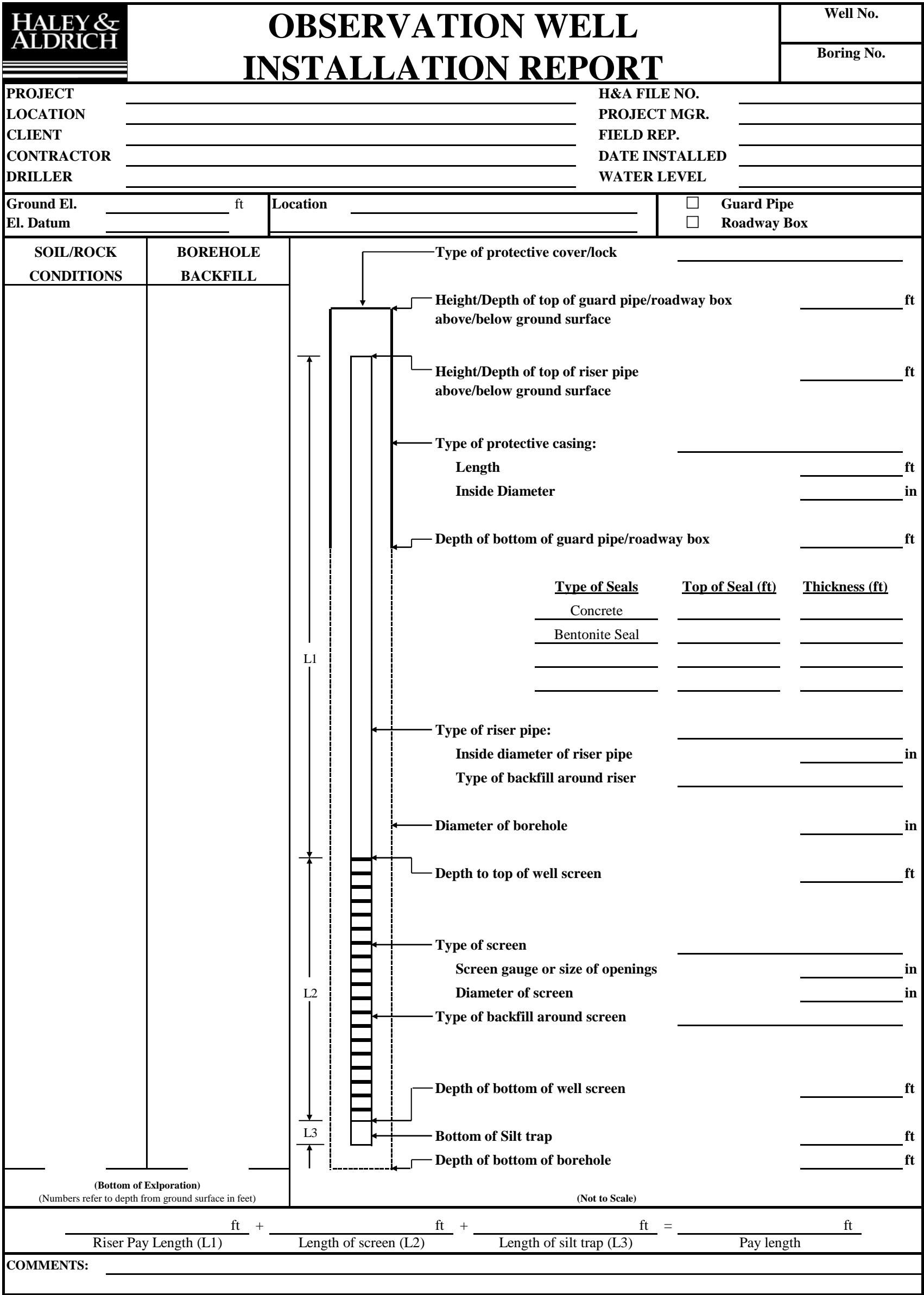
DATE _____

[illegible]



Sampler (Print)	Sampler (signature):	Date:
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[illegible]





Sand		Field
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NOTES:	FILE NO.	BORING NO.
*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.		
NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.		

	UNDERGROUND UTILITY CLEARANCE SUMMARY
--	--

Project: _____

Location: _____

Utility Clearance Organization: _____

Phone Number: _____

Date Contacted: _____ **Contacted By:** _____

Date Scheduled For Field Work Start Up: _____

On Site Meeting Called? / Date: _____

<p>Utility Company Response Summary:</p>

[illegible]

Other Comments:

<div>HALEY & ALDRICH</div>		<div>WELL DECOMMISSIONING REPORT</div>			<div>Well No.</div>					
PROJECT					H&A FILE NO.					
LOCATION					PROJECT MGR.					
CLIENT					FIELD REP.					
CONTRACTOR					REMOVAL DATE					
Well Designation					<div>Exlanation of Well Decommissioning Techniques:</div> <div>A. Shallow Wells:</div> <p>These wells may either be removed by pulling the casing out of the ground, or plugged in-place using bentonite grout. If the well is plugged in-place, the casing must be plugged above the screen using a bentonite/cement grout (see grout placement guidelines), and the casing should be cut-off a minimum of 3 feet below the ground surface. If the well is pulled, care should be taken to compact the soils to avoid significant ground subsidence.</p> <div>B. Deep Wells:</div> <p>Deep wells must be plugged using a bentonite/cement grout, which will fill the casing and annular space (see grout placement guidelines). The casing must be terminated 3 feet below the ground surface.</p>					
Well Diameter										
Decommissioning Technique										
Depth to Groundwater										
Total Depth of Well										
	Cement (Lbs. - Bags*)	Additive (Lbs. - Gals.)	Water (Gals.)	Final Quantity (Gals.)						
Type										
Manufacturer										
Quantity										
*1 Bag = 94 Lbs.										
Sketch:										
<div>Ground Surface</div> <div></div>										
COMMENTS:										