APPENDIX H

Standard Operating Procedures

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SOP-01

Note Taking and Field Log Books

SOP-01: NOTE TAKING AND FIELD LOG BOOKS

1.0 Purpose

This standard operating procedure (SOP) provides programmatic criteria for the content of field log books.

2.0 Scope

This procedure applies to all CH2M HILL personnel and subcontractors engaged in note taking and data collection to be recorded in field log books for Galena Forward Operation Location (FOL) project tasks. The field documentation will be recorded per the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance (ADEC, 2010)*
- *Site Characterization Work Plan and Reporting Guidance for Investigation of Contaminated Sites (ADEC, 2009)*
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures (ADEC, 2002)*

3.0 General

An essential part of any environmental field project is proper documentation. The primary documentation used to record site data is field log books, which describe the history of field activities and summarize field measurements. This is necessary to demonstrate that the data are representative and have been obtained according to required procedures. The log books may be used as evidence in legal proceedings to defend procedures and techniques employed during site investigations. Therefore, it is important that documentation be factual, complete, accurate, consistent, and clear.

4.0 Document Sources

Field documents consist of the following hardcopy or electronic types:

- Field Notebooks
- Field Datasheets
- Soil Boring/Test Pit Log Sheets
- Field Calibration Sheets
- Photographs and Photographic Logs
- Global Positioning System (GPS) and Geographic Survey Coordinate Data
- Field Instrument Data (such as water-quality instruments, photoionization devices, and test kits)
- Laboratory Chain of Custody Forms

- Shipping Waybill and Manifest Documents
- Any other field activity and/or field data documentation

5.0 Responsibilities

5.1 Field Team Leader

Each Field Team Leader (FTL), in conjunction with the Project Manager (PM) and Field Manager (FM), is responsible for overall compliance with this technical procedure. The FTL, or designee, is responsible for verifying that the data entries made in the field log books comply with this technical procedure.

5.2 Site Personnel

All site personnel who make log book entries are required to read this procedure before engaging in this activity. The FTL will inform personnel who will be responsible for log book entries, care, and maintenance.

6.0 PROCEDURE

6.1 Field Notebooks

Front Cover

Field Notebooks will be bound with lined, consecutively numbered pages. Record the following information on the outside front cover of all Field Notebooks:

- Project name (Galena FOL Site Investigation)
- Client name and contract number (AFCEE Contract Number FA8903-08-D-8769, Task Order 0184)
- Log book activity title (such as Drilling and Soil Sampling, Groundwater Sampling, or Aquifer Testing
- CH2M HILL project number (394439)
- Date of first and last entries in the log book (for example, July – September, 2010)

Project Reference Pages

Reserve the first couple of pages (pages 1-2) of the Field Notebook for important project reference information, including project-related contacts (such as contact names and phones for subcontractors, site access, project assistance, field team, and emergency use), special instructions, and/or any other valuable reference information.

Table of Contents

The next few pages (pages 2-5; fewer for smaller Field Notebooks) will be reserved and will consist of a Table of Contents. The following is a suggested example of the first page of the Table of Contents.

<u>TABLE OF CONTENTS</u>

Description of Field Activities and Start Date:	Page
Drilling and Soil Sampling at Site ST005 – 06/12/2010	*1 – 5*

Site ST005 Groundwater Sampling: Wells 05-MW-05 – 06/30/2010 *6 – 7*

The TOC is to be updated on a regular basis at the conclusion of current activities and beginning of new activities.

Daily Entries

Following the Table of Contents, detailed entry of all field activities, events, data, and other relevant project task information will be documented daily (at minimum) throughout the course of field activities. The following minimum requirements must be followed when entering daily activities within Field Notebooks:

- The field activity and date must be recorded at the top of each page.
- The top page corner of each page will be consecutively numbered
- Entries in the field log book should be preceded with the time (written in military units). The time should be recorded frequently and at the point of events or measurements that are critical to the activity being logged.
- All changes must be made with a single, strike-out line through the deletion. Changes must be initialed and dated. Scribbling or blotting out deletions is unacceptable.
- Entries should be made in waterproof ink (unless inclement weather prevents pens from working).
- Entries must be written clearly and legibly enough so that any reviewer can read and understand the entry.
- A diagonal line or similar must be drawn through any space left at the bottom of the last page of field entries at the conclusion of daily site activities.
- The bottom of each page should be signed and dated by the author.
- No pages are to be removed from the Field Notebook.

Events and observations that should be recorded should include, but are not limited to, the following:

- The field activities/tasks with date and time.
- The location(s) and field conditions in which the field task will be conducted.
- The names and organization(s) of all task field staff and/or visitors, including the FTL, subcontractors, clients, and regulators.
- Site conditions (upon arrival and departure) and any changes in site conditions.
- Current weather and any changing weather conditions that might impact field activities.
- All relevant field observations, major task decisions, comments, or other valuable site investigation information will be documented throughout the course of site activities. Entries will be as specific and detailed as possible and practical.
- If field datasheets, soil boring log sheets, photographs, sample location coordinates, or other documentation types are specified by a procedure, the information need not be duplicated,

but the relevant documentation type and/or forms must be referenced in the Field Notebook.

- Documentation of field instrument calibration or reference to any appropriate field calibration sheets.
- Field map sketches will be drawn with a North arrow and approximate scale. Boring or sample locations with measurements (swing ties) to at least two fixed objects to locate points for mapping.
- Changes and/or deviations from task protocols (such as sampling procedures) outlined in any governing planning documents.
- Reason(s) for any noted deviations, and whom the deviation was discussed with and authorized by.
- Any problems, downtime, or delays and the reasons for the problem or delay.
- Upgrade or downgrade of personal protective equipment.
- All equipment make, model, and property numbers or serial numbers used at the site.
- Health and safety monitoring equipment, including calibration procedures and results and actual and background readings.
- Start and end times of sampling.
- Sampling steady-state parameters.
- Decontamination times and methods.
- Type, amount, and disposal methods used for any investigation-derived wastes.

When samples are collected, the following should be recorded in the log book or laboratory Chain of Custody form:

- Sample location and depth
- Sample identification number
- Sample date and time
- Sample methodology
- Sample type and media
- Field sampler initials
- Sample analyses requested
- Sample preservation type
- Quality control sample numbers and types
- Chain-of-custody number
- Name of individual to whom the samples are relinquished
- Laboratory service provider in which samples are to be relinquished
- Shipping Service(s) or method(s) used for sample delivery
- Date and time of shipment
- Shipping waybill or manifest number

6.2 Field Datasheets and Forms

Other unbound data documentation types (including Field Datasheets, Soil Boring/Test Pit Log Sheets, Field Calibration Sheets, Photographic Logs, Laboratory Chain of Custody Forms, Shipping Waybill and Manifest Documents, and similar documents) are part of the field form records. Generally the use of these documentation types are task-specific and when used should be referenced within the field log books. However, specific data entered on these types of documents will not typically be documented in the log books, so document handling and archiving must be performed in the same manner as the log books.

6.3 Electronic Data Documents

Electronic data documents consist of photographs, GPS and survey coordinate data, field instrument data, and other electronic data files. Investigation field instruments and tools such as digital cameras, GPS units, water-quality meters, photoionization detectors (PIDs), pressure-transducers, and hand-held computers all store investigation data in electronic formats that can be later downloaded and stored electronically for future reference. Take care when retrieving, storing, and managing these electronic data. The FTL or designee will be consulted for electronic data management instruction before using any unfamiliar electronic instrument or tool requiring electronic data retrieval and storage. At minimum, Electronic Data Documents will be managed as suggested below:

- After collection, retrieve (download) all electronic data from the field instrument daily or as determined necessary by the FTL.
- After successful electronic data document retrieval, store all electronic data files at a digital location specifically reserved for that data document type. The data storage device must be reliable and secure. The data will be stored at a location that can be readily accessed by multiple team members (that is, network project server or file transfer protocol [FTP] site).
- Back up all electronic data documents or use in the event of data loss. Backup formats may include, but are not limited to, CDs, DVDs, flash memory cards, USB storage devices, and external hard drives. Whatever data backup format is used, the data backup must be managed for retrieval by the PM, FTL, and other responsible team members, if necessary.
- Name data files appropriately to easily identify the content and date of collection or download.
- It possible, include the following identifying information in data files:
  - Contractor name (CH2M HILL)
  - Client and project name
  - Investigation area name
  - Date and time
  - Project number
  - Location(s) of data collection
  - Any other information unique to the kind of data collected

7.0 Document Control

At the conclusion of a task or when a field log book, datasheet, and/or electronic data document has been completed, it will be submitted for records retention. Project files will be maintained by the PM, FM, or designee. Documents will be securely kept in the project files. Project personnel may keep their own duplicate files; however, all original documents will be

placed in the official project file. Field logs of boring, sampling, and well installation activities will be maintained by the FM and submitted to the project manager after the field effort.

8.0 Records

Documentation should follow all guidelines contained in this technical procedure.

9.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). September 23, 2009. *Site Characterization Work Plan and Reporting Guidance for Investigation of Contaminated Sites*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

10.0 Definitions

None.

11.0 Attachments

None.

SOP-02

Site Reconnaissance, Preparation, and Restoration

SOP-02: SITE RECONNAISSANCE, PREPARATION, AND RESTORATION

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to set programmatic criteria to support proper planning for sites before field activities, and to establish expectations for restoring sites to satisfactory conditions upon completion of field activities.

2.0 Scope

This procedure applies to all CH2M HILL personnel and subcontractors engaged in site reconnaissance, preparation, and restoration for Galena Forward Operating Location (FOL) projects and tasks.

3.0 General

An essential component of the fieldwork portion of any environmental project is proper planning before field activities. Site reconnaissance (when possible) should be conducted during the planning stages of a project to ensure that there are no site specific conditions that will need to be addressed before or during field activities. In addition, the site reconnaissance visit should be used to consider staging areas and to notify potentially impacted community members before starting field activities.

4.0 Responsibilities

4.1 Field Team Leader

Each Field Team Leader (FTL), in conjunction with the Project Manager (PM) and Field Manager (FM), is responsible for overall compliance with this technical procedure. The FTL is responsible for verifying that field preparation activities comply with these procedures.

5.0 Procedure

5.1 Pre-planning Activities

Secure all necessary clearances and approvals before beginning fieldwork; if necessary, obtain written clearances and approvals. Determine vehicle access routes and keys or gate combinations to sampling locations and staging areas before any field activities. Survey areas designated for intrusive sampling for the presence of underground utilities. Conduct utility locations according to *SOP-03, Utility Clearance for Intrusive Operations.*

Complete the following tasks before field activities:

- Prepare Field Safety Instructions or a site-specific Health and Safety Plan (HSP)
- Perform a brief site reconnaissance
- Plan personnel and equipment mobilization
- Locate nearby essential facilities, such as communication and emergency facilities

- Verify that archaeological monitoring and endangered species work approvals have been secured, if necessary
- Mark and map proposed sampling locations
- Obtain all fieldwork permits
- Anticipate and document potential real property damage that could result from fieldwork, and how permanent damage will be mitigated
- Conduct physical clearance for utilities and, if necessary, unexploded ordnance
- Coordinate site access with operations such as Security, Liquid Fuels, Base Operations, and Emergency Response (as necessary)
- Establish that fieldwork plans are in compliance with the most current client policies

5.2 Site Reconnaissance

Each field team member should bring the following items:

- Waterproof log book
- Ink pens
- Digital camera
- Suitable clothing for rain or freezing weather

When conducting the site reconnaissance, it is important for the project team to pay particular attention to physical site features, such as locations and dimensions of buildings, and current site uses. For residences, schools, and daycare facilities, inquire about or estimate the number of people who may use each site. Record any observations that differ from available site maps (for example, demolished buildings).

Record all observations in a log book. Use the logbook to record such things as:

- Visual observations of the site and its surroundings
- Descriptions of photographs taken
- Conversations with site personnel or neighbors
- Visits to local authorities and information obtained
- House counts and other observations related to potential exposure assessments
- Freehand site sketches

Record the time of day for each activity or observation entered. The log book should be completed in waterproof ink (unless inclement weather prevents pens from working). Each person who enters information into the log book must sign and date after the last entry on the page.

At each site, document potential source areas, including location of tanks, floor drains, stained soil, or stressed vegetation, using color photographs. Take a series of photographs showing a panoramic view of the entire site. Document other aspects of the site such as fencing, proximity of residences, signs of current usage, and proximity to surface water.

Document all photographs in sequential order in the log book. For each site, generate a table with photograph number, time taken, description of subject, and direction the photograph was taken. Mark the location and direction of each photograph on the site sketch or map.

Document site features pertinent to contamination migration on the site sketch or map. Document location and distance to nearby residences. Discuss typical use patterns with local authorities. Determine drinking water supply sources and location of any private wells.

5.3 Housekeeping

Maintain the site with good housekeeping at all times in all project work areas. Establish common paths of travel and keep them free from spills and the accumulation of equipment and materials. Keep access to aisles, exits, ladders, stairways, scaffolding, and emergency equipment free from obstructions and slip hazards and adequately illuminated during work activities. Store tools, equipment, materials, and supplies in an orderly manner. Designate specific areas, as appropriate, for the proper storage of materials. Clean up spills and leaks quickly.

5.4 Traffic and Public Safety Management

If fieldwork is going to be conducted where traffic may pose a hazard (for example, in or on parking lots, roadways, flight lines), implement traffic controls. Discuss traffic controls with the Project-specific Health and Safety Officer before mobilizing to the field, and prepare a CH2M HILL Traffic Control Checklist (see *SOP-02, Attachment 1: HSE-216 Traffic Control*). If possible, identify traffic controls and include them in the project-specific HSP during the planning phase of the project. Stage barricades, safety cones, and personnel as necessary to direct traffic in an orderly and safe manner.

Be sure to address public safety during the planning phases of any field activities. If fieldwork is going to result in a temporary increase of noise in an area, notify residents and workers before the start of field activities. Mitigate public safety by setting up exclusion zones during field activities to protect the public from inadvertently becoming exposed to field equipment or potentially hazardous materials.

5.5 Restoration of Work Areas to Pre-fieldwork Conditions

Return each work site or sampling location as close to its original condition as possible. Make efforts to minimize impacts to work sites and sampling locations, particularly those in or near sensitive environments, such as wetlands or high-security areas. Following the completion of work at a site, remove and manage all investigation-derived waste (IDW) (such as drums, trash, and other waste) according to *Appendix B, Project-specific Waste Management Plan.*

6.0 Records

Documentation should follow guidelines contained in this technical procedure and noted in the Field Log (see *SOP-01, Note Taking and Field Log Books*).

7.0 References

None.

8.0 Definitions

None.

9.0 Attachments

Attachment 1: *HSE-216 Traffic Control*

SOP-03

Utility Clearance for Intrusive Operations

SOP-03: UTILITY LOCATES AND CLEARANCE

1.0 Purpose

This standard operating procedure (SOP) describes procedures to be used to positively identify and verify the location of above ground and buried utility lines in and around work areas. The purpose of this SOP is to establish operating requirements that will permit personnel to work safely in the vicinity of electrical, gas, steam, fuel, water/sewer and other utilities and utility installations. A secondary purpose is to prevent damage and disruption to existing utilities.

2.0 Scope

This procedure applies to all CH2M HILL personnel and subcontractors engaged in utility clearance to support the Air Force Center for Engineering and the Environment (AFCEE) Galena Forward Operating Location (FOL) project. Utilities covered under this SOP include overhead, surface and subsurface, and utilities imbedded in floors, walls and ceilings. The term “clearance” indicates:

- The positive locating of utility systems in or near the work area.
- A signed statement by an appropriate representative attesting to the location of underground utilities and the positive de-energizing (including lockout) and testing of electrical utilities that may be encountered.
- In some cases, utility representatives may deem it appropriate or necessary to use insulating blankets to isolate a power line; this is an acceptable alternative to positive de-energizing, however only the utility representatives can make that determination.

Utility clearance is required before conducting any of the following work:

- Intrusive work of any nature, including, but not limited to, excavation, drilling, trenching, installing drive points, or penetrating the components of a building structure.
- Use of heavy equipment, or undertaking raising or hoisting operations.
- Work in the vicinity of electrical lines or utility installations.

All utility clearance should at minimum be conducted in accordance with Alaska Statute Title 42, Chapter 30 Public Utilities and Carriers; and if in Anchorage, Anchorage Municipal Code, Chapter 26 Damage to Underground Utility Facilities (Alaska Statutes, 2009; Anchorage Municipal Code, 2010)

3.0 General

Identify all utilities that may be affected by the project in advance so the presence and physical location of the utilities may be incorporated into project planning documents. Be sure to collect sufficient information to verify that field operations maintain the required separations from utilities and that site safety requirements are reflected in project planning documents. This approach will also prevent data gaps that may result from utility conflicts.

The potential for encountering unknown utilities is a hazard to be recognized. This SOP is to be used in conjunction with the project-specific Health and Safety Plan (Appendix A) and the *GFI Utility Clearances Safety Management Standard* listed in Section 7.0 and provided as Attachment 3.

Utilities associated with US Air Force facilities and operations have reverted to the City of Galena. The City of Galena has not assumed responsibility for providing utility locates and clearances. The use of as-built drawings to locate subsurface utilities for clearance will require independent confirmation by land survey or geophysical methods.

Whenever possible, an appropriate representative of the utility owner should provide utility clearance. Be sure to allow advance coordination and identification of lead time requirements, because not all utility owners have the required onsite representatives in Galena.

Make all inquiries regarding electric utilities in writing, and wait to receive written confirmation of the utility clearance before the start of work. Clearly mark the location and orientation of all subsurface utilities on the closest surface, and maintain those markings during performance of site work.

4.0 Responsibilities

4.1 Project Manager

The Field Manager (FM) verifies that utility clearances are obtained for all areas before field activities commence. The FM is also responsible for ensuring that crews are trained in this procedure.

4.2 Field Team Leader

The Field Team Leader (FTL), or their designee, verifies that utility clearances are obtained for any work described in Section 2.0 of this SOP before field activities begin. In addition, the FTL or designee will confirm that all utility clearance documentation is complete, the documentation is available onsite during field activities, and all site personnel have been briefed daily on the location of site utilities.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for providing guidance and approval for all activities involving utility clearance.

5.0 Procedures

5.1 Preparation and Initial Notification

1. Call the Alaska Digline. This is the initial notification. Alaska law requires that locates be completed in within two working days or within 10 working days in remote areas from the date of request. Within Galena, Alaska Digline must be notified at least 10 business days, but not more than 28 days, before any intrusive activities on public or private property. Note that not all public utilities and often most private utilities are not included in the Alaska Digline notification list of utility organizations. Membership in the Alaska Digline Utility Locates is voluntary. When an Alaska Digline request is initiated, the

operator will list the member utilities that will be notified. If not, ask for a copy of the member utility list. Therefore, depending on the locate location, it may be necessary to independently contact individual non-member utility service providers in the area to conduct utility locates.

Alaska Digline Contact Information
Telephone numbers: 811 or 800-478-3121 or (907) 278-3121
Fax: (907) 334-1480 or (907) 278-0696
Email: lcc@akonecall.com
Website: http://www.akonecall.com/index.htm; Visit their Alaska Dig Line website and complete an E-ticket.

2. Initiate a Utility Locate Form (Attachment 1) for each site or contiguous group of sites. The Utility Locate Form should be completely filled out to include the following:

   a. A description of the areal extent of the work area
   b. A sketch or map of the areal extent of the work area (if possible)
   c. The type of work being conducted
   d. For intrusive work the proposed location and depth
   e. Notes regarding the review of as-built drawings
   f. Notes of interviews with facility owners, occupants or employees.
   g. The name of the Facility Manager/Owner or other points of contact
   h. The owner of any utilities at or adjacent to the work site.

   The Utility Locate Form is to be routed to the Alaska DigLine and the owner, manager and users of affected facilities. The date of an onsite locate is to be established and shared with the facility manager and owners.

5.2 Points of Contact

Known points of contact include the following:

ADOT/FAA: Colette Foster	(907) 451-5201 (copy Becky Calhoon Iles)
ADOT Galena Airport Manager	(907) 656-1236 (Fax 656-1898)
FAA Airway Facility Field Office	(907) 656-127
City of Galena: Tom Corrigan	(907) 656-1256
Telalaska – Customer Service	(800) 478-3127
Louden Tribal Council	(907) 656-1711 (Fax 656-1716)

5.3 Initial Utility Locate and Survey

With utility representatives, complete an initial utility locate and survey to physically locate known utilities. Participants may include the facility owners, managers, employees, representatives of site utility owners, subcontractors and others. Review site activities and the extent of intrusive activities. While onsite, review as-built drawings and identify surface features.

As needed, discuss potential utility outage requirements and complete an inventory of affected facilities. Identify outage notification requirements and lad times.

Identify and document potential Lockout/Tagout locations, procedures, outage notification and lead time requirements. When information is insufficient, it is important that the potential for concealed utilities are in the area be identified, and actions necessary to protect the affected systems be discussed and identified in the Utility Clearance Form (Attachment 2).

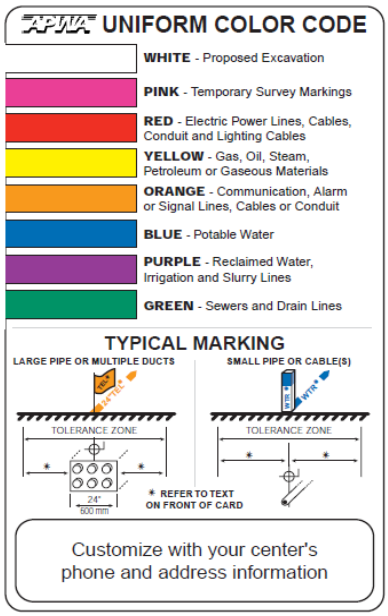
5.4 Third Party Verification

Third-party verification by geophysical and/or a survey by a licensed Land Surveyor is required when utility location information is limited to as-builts or the location of features such as valve boxes, manholes/handholes, conduit, and electrical components observed in the field. Geophysical methods may include toning, ground-penetrating radar, pipe and cable location, electromagnetic survey, and magnetometry. The FTL or designee should be present during work conducted for the purposes of third party verification.

A Licensed Land Surveyor will survey the location of subsurface or concealed utilities indicated on as-built drawings or apparent only through visual observations of surface features.; the survey should achieve a horizontal and vertical accuracy of 0.1 feet. Plot survey locations on a drawing of the site, along with notes and other data regarding burial depths. Input survey coordinates and notes into the project GIS database.

5.5 Field Markings

Mark the presence and type of buried utilities on the ground according to American Public Works Association (APWA) color coding:



White – Proposed excavation/work location

Pink – Temporary survey markings

Red – Electric power lines, cables or conduits, and lighting cables

Yellow – Gas, oil, steam, petroleum or other hazardous liquid or gaseous materials

Orange – Communications, cable TV, alarm or signal lines, cables, or conduits

Blue – Potable water

Purple – Reclaimed water, irrigation and slurry lines

Green – Sewers, storm sewer facilities, or other drain lines

It is the contractors responsibility (CH2M HILL or subcontractor) to protect and preserve the markings of approximate locations of facilities until the markings are no longer required for safe and proper excavations or survey. If the markings of utility locations are destroyed or removed before activities commence or is completed, the Project Manager must notify the utility company or utility protection service to inform them that the markings have been destroyed. Note that under Alaska State Law, there is no charge to the excavator for the first underground facility marking before excavation on a project. However, Alaska Statutes allow a utility provider to receive compensation from the excavation contractor for costs incurred responding to subsequent requests to locate the same facility during an excavation project.

5.6 Positive Response

Utilities in Alaska do not have "positive response" and therefore the Alaska Digline or utility service providers may not confirm that the locate has been completed. Locates are required by law to be completed in two working days, or within 10 working days in remote areas. It is

CH2M HILL's responsibility to maintain the markings and confirm that the utility locates have been conducted if necessary.

5.7 Surface and Overhead Utilities

Note the presence of surface and overhead utilities and potential limitations and impact to site operations, as well as potential impacts to site operations and equipment requirements which may result. For planning purposes, the minimum clearances from energized overhead lines are shown in the table below.

MINIMUM DISTANCES FROM POWERLINES

Powerlines Nominal System kV	Minimum Required Distance, Feet
0-50	10
51-100	12
101-200	15
201-300	20
301-500	25
501-750	35
751-1000	45

The minimum clearances for working near overhead power lines are as follows:

Nominal Voltage	Minimum Clearances
0 - 50 kV	10 feet or one mast length, whichever is greater
50 kV +	10 feet plus 0.5 inch for every 1 kV over 50 kV or 1.5 mast lengths, whichever is greater

5.8 Site Operations

Before initiating site operations the FTL will verify a Utility Clearance Form (Attachment 2) is completed and includes signatures from appropriate representatives. In addition, the Utility Locate Form and Utility Clearance Form must be available onsite during work activities.

Brief personnel working onsite on the location and status of utilities that may potentially be affected by site activities. The briefing should include the hazards associated with working near the utilities and the means by which the operation will maintain a safe working environment.

The FTL should verify that work is planned and conducted according to the project-specific Health and Safety Plan (Appendix A) and the *GFI Utility Clearances Safety Management Standard* (Attachment 3).

6.0 Records

The following records are to be maintained in the project file and onsite during work activities:

- Utility Locate Request Form (Attachment 1)
- Utility Clearance Form (Attachment 2), with signatures of the required parties

- A completed Building Penetration Permit (Attachment 3), if work includes attaching fasteners to, or otherwise penetrating any building components such as floors, walls, decks, and ceilings.

7.0 References

Alaska Statutes. 2009. *Alaska Statutes Title 42, Chapter 30 Public Utilities and Carriers.*

Anchorage Municipal Code. 2010. *Anchorage Municipal Code, Chapter 26 Damage to Underground Utility Facilities.*

CH2M HILL. 2007. *GFI Utility Clearances Safety Management Standard. April 30.*

CH2M HILL. December 2009. Galena Air Station Project Health and Safety Plan.

Occupational Safety and Health Organization (OSHA) 1910.333 – Selection and Use of Work Practices in Subpart S – Electrical

Occupational Safety and Health Organization (OSHA) 1926.650 through 1926.652 – Excavations

Occupational Safety and Health Organization (OSHA) 1926.955 – Provisions for Preventing Accidents Due to Proximity to Overhead Lines

8.0 Definitions

None.

9.0 Attachments

Attachment 1 *Utility Locate Form*

Attachment 2 *Utility Clearance Form*

Attachment 3 *Building Penetration Permit (Attachment 3) (GFI Utility Clearances Safety Management Standard, Attachment 1)*

SOP-04

Organic Vapor Monitoring and Air Monitoring

SOP-04: ORGANIC VAPOR MONITORING AND AIR MONITORING

1.0 Purpose

This standard operating procedure (SOP) provides guidance for conducting organic vapor monitoring of environmental media, and air monitoring procedures to identify when potentially hazardous atmospheres are encountered during field activities. Appendix A, Project-specific Health and Safety Plan (HSP), and Appendix H, Field Standard Operation Procedures, will specify the type(s) and frequency of vapor and air monitoring requirements at each work area.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in organic vapor or air monitoring activities on Galena Forward Operating Location (FOL) projects, and was developed per the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance (ADEC, 2010)*
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures (ADEC, 2002)*

There are many instruments available for organic vapor and air monitoring; this SOP focuses only on the most commonly used instruments and applications. Monitoring requirements that are not identified in this SOP will be discussed with the Health and Safety Manager (HSM) before starting field activities, such that proper requirements, procedures, and monitoring instruments are identified. Should instrumentation or procedures be added to a project task that is not included in this SOP, they must be defined in the project specific Quality Assurance Project Plan (QAPP), Appendix A, Project-Specific Health and Safety Plan (HSP), and/or Appendix H, Field Standard Operating Procedures. Field changes to field procedures and/or equipment should be implemented using *SOP-20, Field Procedure Change Management.*

In addition, the CH2M HILL enterprise Health and Safety SOP *(SOP-04, Attachment 2: Exposure Assessment for Airborne Chemical Hazards Enterprise Standard Operating Procedure HSE-207)*, should be referred to for further details on the types of monitoring, monitoring requirements, calibration, troubleshooting, exposure levels, and air monitoring terminology.

3.0 General

Organic vapor monitoring and air monitoring serve two primary functions:

1. To evaluate organic vapor concentrations in site media to assist site characterization
2. To monitor potential airborne chemical contaminant exposures to site workers according to the HSP (Appendix A)

The rapid detection of volatile organic compounds (VOCs) at field sites allows onsite analytical screening of air, water, sediment, and soils. Screening results can also be used to

anticipate potential petroleum and other VOC contamination and select locations for sample collection for laboratory analysis. In addition to monitoring for VOCs during sample collection, air monitoring for explosive atmospheres, oxygen levels, toxic gas, and airborne dust may be necessary to identify potentially hazardous atmospheres encountered during field activities.

Air screening measurements can be used to evaluate the exposure risk and be used as a basis for setting health and safety levels of protection. Instrument calibration and air monitoring should be conducted according to, and at the frequency specified in, the approved project-specific HSP. At a minimum, air monitoring instruments will be calibrated daily, before obtaining measurements. Air monitoring results compared to specifications in the project-specific HSP provide documentation that overexposure has not occurred, compliance with legal standards has been achieved, and most importantly, the real-time determination of whether engineering controls or personal protective equipment (PPE) are needed to control exposure.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources, and verifying that field staff has adequate experience and training for project-specific implementation of the health, safety, and environment (HS&E) management process and project SOPs. The PM and HSM cooperatively have overall HS&E program responsibility; however, specific tasks may be delegated to other project staff. The PM retains ultimate HS&E responsibility for the project.

4.2 Safety Coordinator

The Safety Coordinator (SC) is responsible for verifying that vapor and air monitoring is conducted according to the project-specific HSP. Under most circumstances, the SC is typically the same person as the Field Team Leader (FTL). However, the SC role may be delegated to another project team member by the FTL, if appropriate. The SC and FTL cooperatively supervise the collection and documentation of all field data generated, and verify that the equipment used by the operator(s) is calibrated at the appropriate frequency and maintained correctly at all times.

4.3 Field Team Leader

Each FTL, in conjunction with the SC, is responsible for overall compliance with this technical procedure. The FTL is responsible for following these procedures or delegating tasks to team members to perform vapor and air monitoring tasks. The FTL should verify that subcontractors are adequately complying with this technical procedure and that air monitoring is adequately conducted by or provided to subcontractors per the HSP.

4.4 Health and Safety Manager

The project HSM is responsible for identifying the need for organic vapor monitoring or the potential for hazardous atmospheres during the planning stages of the project and development of the HSP describing monitoring requirements. In addition, the HSM is responsible for developing or authorizing alternative monitoring requirements if notified that conditions encountered in the field have changed from those identified in the HSP.

5.0 Procedures

Many instruments are available for organic vapor monitoring, as well as monitoring of explosive atmosphere, oxygen levels, toxic gas, and airborne dust. Because it is beyond the scope of this SOP to describe all of these alternatives, this SOP will focus on conducting air monitoring and headspace soil vapor monitoring using the following most commonly used equipment types:

- Photoionization detector (PID)
- Flame ionization detector (FID)
- Combustible gas indicator (CGI) and oxygen level indicator
- Combination Meters and Multi-gas Meters (such as PID, CGI, oxygen, and hydrogen sulfide)
- Passive dust monitor

The organic vapor and air monitoring instruments most commonly expected to be used include the following:

- MiniRae 2000 PID
- Photovac MicroFID
- Thermo Scientific 580B OVM Datalogger PID
- Thermo Scientific TVA 1000A FID/PID
- MultiRae Plus Multi-gas Meter
- RKI Eagle 6 Gas Multi-gas Monitor
- Thermo Scientific pDR1000AN Dust/Aerosol Meter

The MiniRae 2000 PID and Photovac MicroFID are the most commonly used instruments for organic vapor monitoring. A Thermo Scientific 580B OVM Datalogger PID is a common PID that has been historically used before development of the MiniRae 2000 PID. A Thermo Scientific TVA 1000 FID/PID combines the detection capabilities of both a FID and a PID in a single instrument. A MultiRae Plus meter combines a PID, with detection of oxygen levels, combustible vapor, and toxic hydrogen sulfide. Similarly, the RKI Eagle 6 Gas Monitor detects up to six custom gas types simultaneously, including lower explosive limit (LEL), oxygen, carbon dioxide, hydrogen sulfide, methane, and other toxic gases. The Thermo Scientific pDR1000AN is direct-reading, personal, aerosol monitor designed to provide accurate, real-time measurement of airborne dust and particulate concentrations. *SOP-04, Attachment 3: Instrument Data Sheets* provides manufacturer instrument data sheets for the MiniRae 2000 PID, Photovac MicroFID, and the other common organic vapor and air monitoring instruments.

5.1 Equipment Calibration

To ensure that field air monitoring equipment will be properly calibrated and remain operable in the field, calibrate all field air monitoring equipment daily before use and at least once every day during use. Other project-specific requirements may require calibration of air monitoring equipment at a greater frequency. Calibratee all field air monitoring equipment onsite and verify that all calibration standards used meet the minimum requirements for source and purity recommended by the instrument manufacturer. PIDs and FIDs are typically calibrated with 100 parts per million (ppm) isobutylene and 500 ppm methane

calibration standards, respectively; however, other project-specific calibration standard concentrations maybe required. Calibrate PIDs and FIDs to detect “total organic vapor” concentrations in ppm benzene equivalent. Both PIDs and FIDs must be capable of ionizing the expected contaminants of concern.

Calibrate all field air monitoring equipment within calibration acceptance criteria, based on contaminants of concern potentially encountered and within the instruments operational limits. If instrument readings appear to be irregular or drifting, attempt to recalibrate instruments before collecting additional data. Flag apparent instrument drift or erratic instrument readings on any field datasheets used to record data and in the *Field Notebook* (see *SOP-01, Note Taking and Field Log Books*). If the instrument cannot be recalibrated, take the instrument out of service and replace it with a different unit that is capable of being calibrated and used with reliability.

Before starting any air monitoring, document the following calibration information in the *Field Calibration Sheet* provided as *SOP-04, Attachment 1,* for routine instrument calibration:

- Calibration Date and Time
- Instrument Type, Name, Serial Number, and Owner
- Lamp Type (PID only)
- Type of regulator
- Type of tubing (such as direct tubing or T-connection)
- Calibration gas type, canister lot number, and expiration date
- Zero gas calibration reading
- Calibration gas (span gas) reading
- Ambient weather condition (for example, temperature and wind direction)
- Operators initials
- Other notes and comments

5.2 Organic Vapor Monitoring with a Photoionization Detector

The following procedures are specific to the MiniRae 2000 PID instrument; however, they are generally applicable to other manufacturer’s instruments, and the precautions to consider are the same. Manufacturer specific manuals should be consulted, before instrument use. As described in Section 5.2.1 below, the photo ionization potential (PIP) of the expected site contaminant(s) may determine that an FID is needed instead of a PID. If an FID is required, the procedure for using it is essentially the same as a PID; therefore, this section will not separately address FID procedures.

The MiniRAE 2000 PID is a portable, non-specific vapor/gas detector employing the principle of photoionization to detect a wide variety of VOCs. Use a PID during intrusive activities (for example, borehole drilling, excavating, or confined space entry) where there is a potential for the presence of petroleum or VOC contamination.

Calibrate the PID each day, following the calibration specifications of the manufacturer and before the start of field activities. If the PID is in continuous operation, verify daily calibration. Perform instrument calibration using isobutylene calibration gas of known concentration; 100 ppm isobutylene calibration gas is preferred.

The following provide additional details about the PID:

- The MiniRae 2000 PID will typically operate continuously for up to 8 hours before requiring battery recharging.

- Elevated water vapor concentrations experienced in high humidity will foul the PID and may result in a negative or erroneous reading. If high humidity problems persist, use of *Rae Systems Humidity Filtering II Tubes* may be necessary (see Attachment 3).
- MiniRAE 2000 PID readings are always relative to the calibration gas. After calibration with 100 ppm isobutylene, the MiniRAE 2000 PID will respond directly in units equivalent to isobutylene.
- Most VOCs will be detected by the Mini RAE 2000 PID. However, it cannot distinguish between isobutylene and other ionizable compounds. A reading of 10 ppm indicates all ionizable compounds that are present have generated an ion current equivalent to 10 ppm of isobutylene. The reading is actually 10 ppm isobutylene equivalent units.
- The lamp window must be periodically cleaned according to the instructions in the manual provided with the instrument to ensure ionization of the volatized contaminants.

5.2.1 Organic Vapor Monitoring of Site Media

Monitoring of organic vapors in site media can help identify potentially contaminated areas to assist with site characterization. Organic vapor monitoring is typically conducted using a PID or FID for analytical screening of soil by screening soil cores, small test pits, or soil headspace. The PID or FID can also be used to evaluate organic vapors inside monitoring wells and excavations.

For volatile and semi-volatile compounds, knowing the PIP is critical in determining the appropriate instrument to use when organic vapor screening. Consult the QAPP and manufacturer's manual to determine that the proper instrument has been selected for the contaminate vapors of interest. If an expected compound at a site has a PIP less than 11.7 electron volts (eV), it is possible to use a PID. If the ionization potential is greater than 11.7eV, an FID is required.

Perform operation, maintenance, and calibration according to with the manufacturer's specifications and this SOP. Document results of instrument calibrations on the *SOP-04, Attachment 1: Field Calibration Sheet* as outlined in Section 5.1 and SOP-01.

5.2.2 Soil Core Screening for Organic Vapors

Soil cores are typically obtained during drilling activities and should be screened for the presence of organic vapors using a PID or FID. Immediately following extraction and opening of a lithologic core sample during drilling, screen the core by slowly passing the tip of the PID or FID along the lithologic core (very close to the core, but not touching it). Record readings along the soil core in 1 foot increments and additionally target any zones of high odor or staining. Record readings on the Soil Boring Log Field Datasheet according to SOP-07 and SOP-01.

5.2.3 Small Test Pit Soil Screening for Organic Vapors

Surface soil, newly exposed soil, soil stockpiles, and excavation surfaces can be screened for the presence of organic vapors using a PID or FID. Before screening newly exposed soil, soil stockpiles, and excavation surfaces, dig a small sample test pit at least 6 inches deep into the soil using a clean, decontaminated sampling tool such as a stainless-steel spoon and/or shovel. For surface soil or other soil directly exposed to the atmosphere for greater than 1 hour, dig an at least 18-inch test pit before soil screening. Observe soil screening from freshly exposed soil. When digging, minimize the diameter of the test pit, if possible, to

reduce advection of soil vapors out of the test pit. Immediately following digging, insert the sample tip of the PID or FID into the test pit, approximately 1 to 2 inches from the bottom of the test pit, taking care not to foul the sample tip with soil particulates or uptake water droplets. Record the maximum detector reading as the final sample concentration on the Soil Sampling Field Datasheet or in the Field Notebook (see SOP-07 and SOP-01).

5.2.4 Soil Headspace Screening for Organic Vapors

Headspace organic vapor monitoring involves the measurement of petroleum vapors emitted from soil samples in a sealed container. The headspace of the container is typically warmed and then tested for volatile organic vapors using PID or FID techniques. The results generated by this method are qualitative to semi-quantitative and are limited to organic compounds that readily volatilize.

Soil can be collected for headspace screening from various sources including lithologic soil cores during drilling, soil stockpiles, or from excavations and test pits. For soil cores, soil headspace should be screened from 1-foot intervals at zones of where contamination is expected.

The following procedures should be followed when conducting soil headspace screening for organic vapors:

- Calibrate the headspace screening instrument(s) according to the manufacturer's specifications and requirements and as discussed in Section 5.1.
- Headspace screening will typically be analyzed using clean, resealable 1-quart Zip-loc™ (or similar) plastic bags.
- To begin collection of headspace screening samples, collect a small amount of soil (about the equivalent of a softball) and immediately place it inside a clean, resealable 1-quart Ziploc™ (or similar) plastic bag until the plastic bag is about one-third to one-half full; then immediately seal the bag completely. Larger plastic bags should not be used to prevent vapor diffusion and stratification effects to significantly affect the sample. Samples from soil cores, excavations, or soil piles must be immediately transferred into the sample bag once the soil core is opened or the soil sample is uncovered and exposed to the atmosphere.
- Shake the bag for 15 seconds and let it rest for at least 10 minutes but no longer than one hour. The temperature of the headspace must be warmed to at least 40 degrees Fahrenheit (°F) (5 degrees Celsius [°C]) before testing. If the soil and/or outdoor temperature is low (<40°F) or is frozen/freezing, placing the headspace sample in a warm location at approximately room temperature (that is, indoors) may be necessary to slowly warm the sample to an acceptable temperature.
- Before testing, shake the bag for another 15 seconds to further assist volatilization.
- Insert the sample tip of the PID or FID into the bag at a point approximately one-half the headspace depth, taking care not to foul the sample tip with soil particulates or uptake water droplets. The sample bag insertion opening must be minimized to minimize vapors from escaping.
- After probe insertion, record the maximum detector reading as the final sample concentration on the Soil Boring Log Field Datasheet or in the Field Notebook (see SOP-07 and SOP-01).

- The maximum detector reading normally occurs between 2 and 5 seconds after probe insertion.
- If erratic instrument response occurs at high VOC concentrations or conditions of elevated headspace moisture, record the instrument behavior along with the maximum detected reading(s). Under these conditions, headspace data may be discounted.

5.2.5 Screening for Organic Vapors in the Monitoring Well Casing

When conducting groundwater monitoring and/or sampling, the air inside the monitoring well casing will be screening for organic vapors using a PID or FID. To screen for organic vapors inside or exiting the monitoring well casing, stand next to and not over the well approximately arms reach away from the well. Slowly open the well cap and immediately checking for organic vapors in the well casing by positioning the tip of the PID or FID at the top of the open well casing. Record this reading on the Groundwater Monitoring/Sampling Datasheet or in the Field Notebook according to SOP-10, SOP-12, and SOP-01.

5.3 Air Monitoring for Potential Contaminant Exposure

Air monitoring for potential exposure to airborne contaminants is typically conducted using a PID, FID, CGI (measuring oxygen level and explosive atmosphere), MultiRAE Plus meter (measuring oxygen level, explosive atmosphere, PID, and hydrogen sulfide), or Thermo Scientific pDR1000AN dust/aerosol meter.

Air monitoring is typically conducted at one or more of the following areas for the reasons given below:

- At the source. Monitoring at this location gives a worst-case assessment of the situation. If concentrations at the source are below the action levels, then a potential exposure problem is unlikely.
- In the employee breathing zone. Monitoring should be conducted in the employees' breathing zones to determine the actual conditions that they may potentially be exposed to. Since employees doing different tasks may have different potential exposures, monitoring should be conducted for the worst case scenario for each task.
- At the perimeter. Perimeter monitoring is used to document any background condition and that the surrounding community is not being adversely affected by the operations. This type of monitoring is typically only conducted if elevated levels are seen in the employees' breathing zones or at the perimeter of the exclusion zone, or if it is warranted as a means of documenting that no offsite releases occur.

Conduct monitoring before entering any potentially hazardous area, according to requirements in the HSP (Appendix A).

5.3.1 Monitoring of Oxygen, Combustible, Hydrogen Sulfide Gas, and Airborne Particulates

Instruments typically used to monitor oxygen levels, combustible atmosphere, hydrogen sulfide, or airborne dust include the MultiRAE plus meter (measuring oxygen level, explosive atmosphere, PID, and hydrogen sulfide), CGI (measuring oxygen level and explosive atmosphere), or Thermo Scientific pDR1000AN dust/aerosol meter.

Depending on the requirements made in the HSP (Appendix A), oxygen, combustible, hydrogen sulfide gas, and airborne dust measurements may be made during field activities to ensure that breathing atmospheres do not become hazardous.

Entry into any confined space or any other area where hazardous atmospheres may possibly be a concern must be conducted under direct consultation with the project HSM and according to the requirements in the HSP. Always consult the project PM and/or HSM with any questions or concerns regarding instrument monitoring and work situations involving confined spaces and/or potentially hazardous atmospheres.

5.3.1.1 Monitoring of Oxygen Level

The oxygen level in a confined space or other area of little to no air circulation is of prime concern to anyone about to enter that space. Removal of oxygen by combustion, reduction reactions, or displacement by other gases or vapors may be a hazard. Likewise, elevated levels of combustible or toxic gases may also pose a hazard to health. Elevated levels of oxygen may also result in an explosive hazard.

MultiRAE Plus meters are commonly used to monitor oxygen levels. Perform operation, maintenance, and calibration of oxygen monitoring instruments according to the manufacturer specifications and the HSP. Calibrate oxygen monitoring instruments before starting work each day. Document the calibration check (Section 5.1) in the Field Calibration Sheet provided as SOP-04, Attachment 1.

Because some instruments do not operate properly without sufficient oxygen and others can cause explosions, the monitoring of oxygen will be the initial concern when working in an environment where there is potential for oxygen levels to be below 19.5% or greater than 25%. The normal oxygen concentration at sea level is 21%.

5.3.1.2 Monitoring for Explosive Atmosphere

The MultiRAE Plus meter is commonly used to monitor for a flammable and explosive atmosphere. Perform operation, maintenance, and calibration of explosive atmosphere monitoring instruments according to the manufacturer specifications and the HSP. Calibrate explosive atmosphere monitoring instruments before starting work each day. Document the calibration check (Section 5.1) in the Field Calibration Sheet provided as SOP-04, Attachment 1.

Conduct monitoring for flammable or explosive environments at the same locations as monitoring of oxygen levels (described in Section 5.3.1.1). Work can proceed as normal if the air conditions are less than 10% of the LEL. If the conditions are between 10% and 20% of LEL, proceed with extreme caution and continuous monitoring. If the atmosphere is greater than 20% LEL, stop work immediately. Evacuate the site or implement engineering controls to reduce the LEL to acceptable levels.

5.3.1.3 Monitoring for Toxic Gases

The MultiRAE plus meter and Drager colorimetric tubes are commonly used to monitor for toxic gases. Perform operation, maintenance, and calibration of toxic gas monitoring instruments according to the manufacturer specifications and the HSP. Calibrate or inspect toxic monitoring instruments (as required) before starting work each day. Document the calibration check (Section 5.1) in the Field Calibration Sheet provided as SOP-04, Attachment 1.

Toxic gases include organic and inorganic vapors and gases. The MultiRAE Plus meter is capable of monitoring the odorless and colorless toxic gas hydrogen sulfide, which is a common gas found at contaminated sites.

5.3.1.4 Monitoring for Airborne Dust

A Thermo Scientific pDR1000AN dust/aerosol meter is typically used to monitor for airborne aerosol particles and dust. Perform operation, maintenance, and calibration of airborne dust monitoring instruments according to the manufacturer specifications and the HSP. Calibrate airborne dust monitoring instruments (as required) before starting work each day. Document the calibration check (Section 5.1) in the Field Calibration Sheet provided as SOP-04, Attachment 1.

Non-volatile contaminants (such as metals or polychloride biphenyls [PCBs]) can become airborne as particulates and typically require monitoring at sites where there is a potential for dusty environments. A passive aerosol monitor can be used to monitor for airborne dust as a proxy for the contaminant. Total dust action levels will be determined in the HSP (Appendix A).

6.0 Records

Record all field measurements in the Field Notebook, Field Datasheet, Field Calibration Sheet or similar, according to *SOP-01, Notetaking and Field Log.* Implement changes to field procedures and/or equipment using *SOP-20, Field Procedure Change Management.*

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

CH2M HILL. 2008. *Exposure Assessment for Airborne Chemical Hazards Enterprise Standard Operating Procedure HSE-207.*

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Thermo Fisher Scientific Inc. 2009b. *PID Analyzer, Model 580B* http://www.thermo.com/com/cda/product/detail/1,,22549,00.html. Accessed January 26, 2010.

Thermo Fisher Scientific Inc. 2009c. *FID/PID Toxic Vapor Analyzer, TVA1000B* http://www.thermo.com/com/cda/product/detail/1,1055,22546,00.html. Accessed January 26, 2010.

U.S. Environmental Protection Agency (EPA). 1988. *Field Screening Methods Catalog.* Office of Emergency and Remedial Response. EPA/540/2-88/005.

U.S. Environmental Protection Agency (EPA). 1986. *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document*. Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response.

8.0 Definitions

Combustible Gas Indicator (CGI): used to screen for flammable and explosive vapors and gases. Often combined with an oxygen level indicator.

Continuing calibration verification: an analytical standard run periodically to verify the calibration of an instrument.

Flame Ionization Detector (FID): detects organic gases and vapors. Determines relative total concentration of selected organic air contaminants, which is used to specify engineering controls and PPE requirements.

Headspace gases: the accumulated gaseous components found above solid or liquid layers in closed vessels.

Initial calibration: an analysis of standard gases at a series of different specified concentrations; used to define the linearity and dynamic range of the response of an instrument to the target compounds.

Photoionization detector (PID): detects total concentrations of many organic and some inorganic gases and vapors. Molecules are ionized using ultraviolet radiation. A current is produced in proportion to the number of ions present.

Photoionization potential (PIP): the potential difference through which a bound electron must be raised to free it from the atom or molecule to which it is attached. In particular, the ionization potential is the difference between the initial state, in which the electron is bound, and the final state, in which it is at rest at an indefinite distance from the molecule.

Volatile organic compounds (VOCs): organic compounds that evaporate when exposed to air (>100 millimeters of mercury [mm Hg]).

9.0 Attachments

Attachment 1: *Organic Vapor and Air Monitoring Field Calibration Sheet*

Attachment 2: *Exposure Assessment for Airborne Chemical Hazards Enterprise Standard Operating Procedure HSE-207*

Attachment 3: *Instrument Data Sheets*

SOP-05

Hollow Stem Auger and Direct Push Drilling Methods

SOP-05: HOLLOW STEM AUGER AND DIRECT PUSH DRILLING METHODS

1.0 Purpose

This standard operating procedure (SOP) provides guidance for selecting and implementing the proper drilling methods for collecting subsurface soil, soil gas, and groundwater samples and for installing groundwater monitoring wells using hollow stem auger (HSA) and direct push system (DPS) drilling.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in drilling activities at Galena Forward Operating Location (FOL) projects and was developed according to Alaska Department of Environmental Conservation (ADEC) and other reference documents, including the following:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Monitoring Well Guidance* (ADEC, 2009)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used drilling tasks and applications anticipated at Galena FOL and should be used in conjunction with other project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-02, Site Reconnaissance, Preparation, and Restoration*
- *SOP-03, Utility Clearance for Intrusive Operations*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-06, Boring Log Completion, Soil Classification, and Logging*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-08, Monitoring Well/Piezometer Installation*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-21, Well Decommissioning and Abandonment*
- *SOP-24, Direct Push Groundwater Sampling*
- *SOP-25, Direct Push Soil Gas Sampling*

Should field tasks and procedures be added to a project that is not included in this SOP, they must be defined in Appendix H, Field Standard Operation Procedures and/or Appendix A, Project-specific Health and Safety Plan (HSP), before implementation. Changes to field procedures and/or equipment should be implemented and documented according to *SOP-20, Field Procedure Change Management.*

3.0 General

Selecting the proper drilling equipment for environmental and geotechnical sampling and monitoring well installation is a critical part of field investigations. This SOP describes HSA

and DPS drilling methods generally used for subsurface soil sampling and groundwater monitoring well installation and the commonly used tools for these techniques. HSA and DPS drilling methods may also be used to collect groundwater and soil gas samples, as described in *SOP-24, Direct Push Groundwater Sampling* and *SOP-25, Direct Push Soil Gas Sampling*.

In addition to selecting the proper type of drilling technology, drilling activities should conform to state regulations and be supervised by a qualified geologist or engineer. Either the drilling contractor or CH2M HILL will obtain all permits, applications, and other documents required by state and local authorities and the client. In addition, the following general guidelines should be thoroughly considered during planning and implementation of all drilling investigations:

- Review background information for the investigation area. This includes identifying and understanding the type(s) of contaminant(s) released, the manner of release, and the affected media.
- Select the proper drilling technology and drill rig. Drilling activities should conform to state regulations, including 18 *Alaska Administrative Code* (AAC) 75 and 18 AAC 78.
- Coordinate boring locations at Air Force installations with the appropriate Restoration Program Manager (RPM) before drilling begins.
- Determine the inside diameter of the soil borehole needed to accomplish the drilling objectives and provide adequate sample volume.
- Before mobilization to each boring location, determine that the location is free of subsurface or overhead utilities according to the procedures described in *SOP-03, Utility Clearance for Intrusive Operations*.
- Take appropriate precautions during drilling to avoid introducing contaminants into the borehole.
- Drill boreholes in areas of no or low anticipated contamination by first progressing toward areas of increasing contamination. Under ideal conditions, upgradient areas without contamination should be drilled first.
- When drilling boreholes through more than one water-bearing zone or aquifer, take measures to prevent cross-connection or cross-contamination of the zones or aquifers, such as using telescoped casing.
- Before mobilization to each boring location, decontaminate the drill rig and all drilling equipment placed into the borehole by steam cleaning, using high-pressure hot water, or similar methods according to *SOP-14, Equipment Decontamination Procedures*. The drill rig must not leak any fluids that may enter the borehole or contaminate equipment placed in the borehole.
- Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary. If their use is necessary, drilling fluids must not introduce or mask contaminants. Provide material safety data sheets (MSDSs) for all drilling fluids proposed for downhole use before field work and describe procedures for containment and disposal of fluid in the project work plan. If it is necessary to add drilling mud to the borehole during drilling to stabilize the

hole or control down-hole fluid losses, use only high-yield sodium bentonite clay free of organic polymer additives.

- If it is necessary to add water to the borehole during drilling to control flowing and heaving soils, use only potable water from a documented clean source. All potable water volume added to a borehole must be developed from the well. If potable water is added to the borehole, an equal volume of water must be developed from the borehole in addition to the standard well development volume.
- To the extent practical, restore the site to its pre-investigation conditions.

Record all information pertinent to documenting the above requirements in the field log book and the Soil Boring Log Datasheet according to *SOP-01, Note Taking and Field Log Books*.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff have adequate experience and training for project-specific implementation of the health, safety, and environment (HS&E) management process and project SOPs. The PM and Health and Safety Manager (HSM) cooperatively have overall HS&E program responsibility; however, specific tasks may be delegated to other project staff. The PM retains ultimate HS&E responsibility for the project. The PM will solicit the appropriate technical expertise to adequately identify the best drilling and sampling technology for the job given the current understanding of the site lithology.

4.2 Health and Safety Manager

The HSM is responsible for site-specific HS&E and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP (Appendix A), coordinates with the Field Manager (FM) and/or Safety Coordinators (SCs) to complete and certify the PPE program, and conducts project audits on the effectiveness of HS&E program.

4.3 Safety Coordinator

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

4.4 Field Team Leader

Each FTL, in conjunction with the SC, is responsible for overall compliance with this SOP. The FTL is responsible for following these procedures or delegating drilling tasks to team members. The FTL should verify that subcontractors adequately comply with this SOP and that air monitoring is adequately conducted by or provided for subcontractors according to the HSP.

4.5 Field Geologist

The Field Geologist supervises the drilling and collection of lithologic samples, and records all field data as described in this SOP, the HSP, and *SOP-01, Note Taking and Field Log Books*.

5.0 Drilling

5.1 Hollow Stem Auger Drilling

HSA drilling is a form of rotating auger drilling, consisting of continuous-casing, segmented auger sections with screw-flights that are rotated into the subsurface under downward pressure. The auger section is typically equipped with a drill bit and cutting teeth. Drill cuttings are brought to the surface by a conveyor action created by the rotating screw flights and drill bit. The auger sections maintain borehole stability even in unconsolidated material. Generally, HSA drilling is limited to depths less than 100 feet where lithology is unconsolidated. Multiple auger sections are connected in series to create a “drill string” with clamping pins or screw fittings. HSA drilling usually requires a larger drill rig than is used with DPS drilling, and the entire rig can stand between 20 and 40 feet high, requiring high overhead clearance.

At sites where groundwater is relatively shallow (less than 50 feet) and DPS drilling is not feasible because of lithology (that is, cobbles and boulders are present), or where a larger-diameter boring is required, it is common to use HSA drilling. *SOP-05, Attachment 1: CME-75 Features and Specifications* further discusses the capabilities of the CME-75 drill rig, which is typical equipment for HSA drilling.

In situ soils may be sampled through the center of the HSA drill stem. An advantage of HSA drilling is that the auger sections can be left in place to hold the borehole open and reduce slough in unconsolidated soils.

HSAs are specified by the internal diameter of the hollow stem, not by the size of the hole they drill. Augers with a minimum inner diameter of 4 inches will be required to install a 2-inch monitoring well, to give clearance around the well for filter pack sand and bentonite seals. It is preferable to use a larger inner-diameter auger (5 or 6 inches) to install a 2-inch monitoring well; however, the benefits should be weighed against the additional investigation-derived waste (IDW) volumes that will be generated. If a 4-inch monitoring well is required, the inner auger diameter must be 6 to 8 inches.

Boreholes should be advanced using pre-cleaned and decontaminated augers and sampling equipment, according to *SOP-14, Equipment Decontamination Procedures*. Boreholes that are not converted to wells should be abandoned according to *SOP-21, Well Decommissioning and Abandonment*.

5.2 Direct Push System Drilling

DPS technologies involve a category of drilling equipment that hydraulically pushes or drives small-diameter, hollow steel rods into the subsurface without rotating the drill rods. Some drill rigs may be “combo rigs,” capable of conducting both direct push and rotating HSA drilling operations. DPS drilling uses a combination of a hydraulically powered percussion hammer, a downward hydraulic push, and the weight of the vehicle on which the system is mounted to drive rods into the subsurface. DPS methods push a continuous tube sampler into the subsurface by laterally displacing soil to make a path for the sampler, so no cuttings

are generated. DPS drilling is commonly used for shallow applications (less than 50 feet); however, depending on the lithologic conditions, it may be used as deep as 120 feet. *SOP-05, Attachment 2: Geoprobe® Model 66 Series Features and Specifications* further discusses the capabilities of the Geoprobe® 6620DT, a typical DPS drilling rig.

DPS technology is typically limited to unconsolidated formations that are relatively free of cobbles or boulders. Refusal may occur if there are too many cobbles, boulders, or other consolidated formation materials. However, since DPS drilling is relatively fast, refusal at a desired location because of cobbles may be mitigated by abandoning the hole, moving to a nearby location, and re-drilling.

DPS boreholes generally cannot be sampled deeper than the water table because unconsolidated materials cave in once the drive rods are removed. However, caving may be mitigated by advancing a casing with an inner drill rod used for sampling, allowing for sampling and well installation far below the water table.

Outside diameters of samplers and boring tools generally range from 0.75 to 3.5 inches. If installation of monitoring wells is planned, the inside diameter of the boring should typically ranges from 1.5 to 3.5 inches (for 1- to 2-inch wells).

DPS technologies provide the following advantages over conventional drilling methods:

- Minimal ground disturbance, with a small-diameter boring that is easy to abandon
- No cuttings, which eliminates the need for handling, containerizing, sampling, and disposing of potentially contaminated IDW (unless samples are brought to the surface)
- Faster boring advancement
- Faster monitoring well installation if small-diameter wells (0.75 to 1 inch in diameter) with pre-packed screens are installed

Boreholes should be completed using pre-cleaned and decontaminated drive points, rods, and sampling equipment according to *SOP-14, Equipment Decontamination Procedures*. Boreholes that are not converted to wells should be abandoned according to *SOP-21, Well Decommissioning and Abandonment*.

6.0 Drilling and Sampling Procedures

6.1 Drilling Subcontractor Responsibilities

Working around drill rigs is dangerous. As a result, increased consciousness and vigilant oversight of drilling activities are critical, to reduce the risk of injury to workers involved with drilling. Safe work requires that good communication is maintained between the driller and the Field Geologist during drilling activities. Encourage the driller to notify the Field Geologist routinely of the depth(s) at which changes in drilling rates become evident and immediately of any other drilling observations that may indicate subsurface obstructions or utilities.

At a minimum, the following activities should be conducted as part of the drilling program:

- Conduct a project kickoff meeting. Describe tasks to be conducted and a tentative schedule for the project at the beginning. As the project progresses, discuss the remaining tasks and revised schedule with the drill crew daily. Communicate progress and issues with the PM.

- Hold a health and safety tailgate meeting using a CH2M HILL pre-task safety plan.
- Review or have the drill rig operator discuss the task-specific activities identified in the driller subcontractor Job Hazard Analysis (JHA).
- Wear proper PPE at all times.
- Conduct air monitoring as specified in the project-specific HSP and according to *SOP-04, Organic Vapor Monitoring and Air Monitoring*.
- Visit the site and drilling locations with the driller to identify all potential site hazards and obstacle before mobilization and setup.
- Obtain underground and overhead utility clearance and verify that the drilling location has been cleared according to *SOP-03, Utility Clearance for Intrusive Operations.* Maintain proper clearance with aboveground utilities and obstructions.
- Set up proper traffic controls if working in an area where there are traffic hazards, according to *SOP-02, Site Reconnaissance, Preparation, and Restoration*.
- Establish an exclusion zone using barriers, flagging tape, or other methods to prevent unauthorized access to the drilling location according to the HSP.
- Inspect the drill rig for leaking lines or other hazards and have the driller test safety switches and demonstrate that they work. No fluids should leak from the rig.
- Verify that all personnel working around the drill rig are properly trained and instructed, familiar with drill rig operation, and understand the task to be performed.
- Identify the locations of the fire extinguisher(s) and first aid kit(s), and verify that they are readily available for use.
- Maintain good housekeeping on and around the rig at all times.
- Complete *SOP-05, Attachment 3: Drilling Self Assessment Checklist* according to requirements in the HSP.
- Establish a staging area for storing IDW and decontaminating augers and sampling equipment.
- Establish a core logging and sample collection area at a safe location within sight of the drill rig.
- Place sampling equipment and soil recovered from the subsurface on plastic sheeting or similar dedicated material to avoid potentially contaminating the ground surface.
- Carefully log any downtime that occurs because of subcontractor equipment failure, weather, site access, or other issues, and any time where CH2M HILL is causing a delay in field activities, in the field log book, according to *SOP-01, Note Taking and Field Log Books.*

6.2 Hollow Stem Auger Drilling

Stage the drill rig over the desired drilling location and attach the first auger section. Rotate the auger so that soil cuttings are brought to the surface. The driller's helper will use a shovel to scoop cuttings into a pile near the borehole as they emerge at the surface. As the

auger section is drilled into the subsurface, add new auger sections to achieve greater depths. Along the way, leave auger sections in place while a spilt-spoon sampler, open-barrel sampler, or similar tool is used to collect a sample.

Collect lithologic samples at intervals specified in the site-specific sampling plans in Appendix D. Soil cuttings seen at the surface represent a blend of material from the borehole and the current auger depth, so logging or sampling cuttings is of limited use. In addition, soil cuttings seen at the surface have to travel the length of the auger flights to reach the surface, so these cuttings do not correlate exactly with the lithology that the auger is currently drilling through. The best indication of lithology, when not sampling, is to carefully examine the rate in which the auger is advancing. There is commonly a discernable sound when the drilling rate changes. Note changes in lithology and drilling rate on the Soil Boring Log Datasheet (*SOP-01*).

A split-spoon sampler is typically used to collect representative soil samples at depth during HSA drilling. A split-spoon sampler is a soil coring device that consists of a length of carbon or stainless steel tubing split longitudinally and equipped with a sample shoe and a drive head. These are available in a variety of lengths and diameters and are typically advanced by blows of a hammer dropped from a drill rig mast. The soil sample is contained within the split-spoon sampler as it is advanced into the ground. Depending on the sampling purpose, separate liners made out of plastic, stainless steel, or brass may also be used within the split spoon to collect soil samples.

When sampling using HSA drilling, advance the drill string to the desired sample depth. Attach a split-spoon sampler to the end of a series of drive rods and lower it down the center of the hollow auger sections (drill string). Hammer the split-spoon sampler ahead of the drill string to collect a relatively undisturbed, representative soil sample. Depending on the size of split spoon employed, 18 to 24 inches of soil typically should be recovered in advance of the drill bit. Remove the sampler from the borehole and open it to expose the soil for examination and sampling. The Field Geologist will examine the lithologic sample. The sample will be screened for volatile organic compounds (VOCs) using a photoionization detector (PID) or flame ionization detector (FID) (see *SOP-04, Organic Vapor Monitoring and Air Monitoring*) and logged for lithology as described in *SOP-06, Boring Log Completion, Soil Classification, and Logging*. Decontaminate the entire split-spoon sampler and sample shoe between each sample retrieval depth, according to *SOP-14, Equipment Decontamination Procedures*. Once the sample is collected, advance the drill string to the top of the next desired sampling depth. Reinstall the decontaminated split-spoon sampler on the HSA drill string to collect another split-spoon sample.

Problems with split-spoon sampler soil recovery are encountered when unconsolidated, non-cohesive soils fall out of the end of the split spoon upon retrieval and when large gravel lodges in the end of the sampler, preventing further soil from entering the sampler during advancement. Both issues may result in less than full sample recovery. Note the percentage recovered, and what portion of the sample is missing, on the Soil Boring Log Datasheet as described in *SOP-06, Boring Log Completion, Soil Classification, and Logging.*

A Standard Penetration Test (SPT) can be completed during advancement of the split-spoon sampler into the in situ formation, to evaluate the relative density of unconsolidated soil. To complete the SPT, drive the split-spoon sampler into the formation using a hammer mounted on the drill rig. Repeatedly raise and drop the hammer over a 30-inch height until the entire length of the split-spoon sampler is driven into the formation over the discrete sampling interval or there is sampler refusal. Record the number of blows necessary to drive

the sampler every 6-inch interval on the Soil Boring Log Datasheet (see *SOP-06*). Also record the weight of the hammer used on the Soil Boring Log Datasheet.

Upon reaching total borehole depth, remove the drill string from the borehole by withdrawing and disconnecting each auger section. Before advancing another soil boring, decontaminate all used auger sections, drive rods, drill bits, and split spoons according to *SOP-14, Equipment Decontamination Procedures.*

6.3 Direct Push System Drilling

Stage the drill rig over the desired drilling location and advance a solid-point drive string to the top of the desired discrete sample interval. When the desired sampling depth is achieved, withdraw the center rods and solid-drive tip from the probe drive string (outer drive casing) and lower a sampling tool (for example, a Geoprobe® DT325 Dual Tube Sampling System sampler with polyvinyl chloride [PVC] liners) down the inside probe drive string to the end of the cutting shoe. Hydraulically push the probe drive string and sampler down through the discrete sample interval to obtain an undisturbed sample of the soil formation. Once the probe drive string and sampler are fully advanced, withdraw the sampler and center rods from the probe drive string and remove the recovered soil core in the PVC liner from the sampler. After the soil core is removed, the solid-point drive point can be either reinserted and driven to another desired discrete sample interval or another sampler with a PVC liner can be lowered down the inside of the probe drive string to the end of the cutting shoe to conduct continuous-core soil sampling. *SOP-05, Attachment 4: Geoprobe® DT325 Dual Tube Sampling System SOP* further describes this method and associated tools. Soil sampling using DPS drilling may be conducted from the surface until groundwater is encountered or until sample recovery becomes poor as specified in the site-specific sampling plans in Appendix D.

After soil core recovery, extract the PVC liner encasing the soil core from the sampler's sample sheath and cut open the PVC liner to expose the core. The Field Geologist will examine the soil core for lithology. The soil core will be screened for VOCs using a PID or FID (refer to *SOP-04*), logged as described in *SOP-06*, and sampled according to *SOP-07, Discrete Surface and Subsurface Soil Sampling*. Decontaminate the sample collection equipment between each sample depth, according to *SOP-13*.

Problems with sampler soil recovery are encountered when unconsolidated, non-cohesive soils fall out of sampler upon retrieval and when large gravel (that is, stone) lodges in the end of the sampler, preventing further soil from entering the sampler during advancement. Both issues may result in less than full sample recovery. Note the percentage recovered, and what portion of the sample is missing, on the Soil Boring Log Datasheet as described in *SOP-06 Boring Log Completion, Soil Classification, and Logging.*

To install a well, install an expendable cutting shoe on the probe drive string. Install the well through the probe drive string upon reaching the desired total depth. Push out the expendable cutting shoe and withdraw the probe drive string. Construct the resulting well with sand and bentonite according to *SOP-08, Monitoring Well/Piezometer Installation*.

7.0 Heaving and Flowing Soils

The presence of heaving and flowing soils within the saturated zone are a known issue at the Galena FOL. When encountered, use appropriate drilling techniques to minimize potential impacts; these includes using drilling fluids or a drill-stem plug. Minimize the use of

drilling fluids if possible. However, when necessary, it is permissible to add potable water from a documented, clean source and/or drilling mud to the borehole to control heaving and flowing soils as long as identification of the saturated zones during drilling is not compromised and the drilling fluid can be removed during development so that representative water levels can be obtained. All drilling fluid volume added to a borehole must be developed from the well. If potable water is added to the borehole, develop an equal volume of water from the borehole, in addition to the standard well development volume. If a drill-stem plug is used, slowly release the plug from the end of the drill-string while at total borehole depth.

8.0 Records

Record all field activities in the Field Notebook and/or Soil Boring Log Datasheet according to *SOP-01, Note Taking and Field Log Books*. Log all borings lithologically according to *SOP-06, Boring Log Completion, Soil Classification, and Logging*.

9.0 References

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10.0 Definitions

Auger section: a segment of hollow auger outer casing with helices (flights) welded around the exterior that conveys soil cuttings from the drill bit to the surface when rotated.

Borehole: the downward hole in the subsurface lithology created by drilling activities.

Combo drill rig: drill rigs capable of conducting both DPS and rotating HSA drilling operations.

Cutting shoe: the cutting end of a DPS drill string.

Direct Push System (DPS): a drilling technology that hydraulically pushes or drives small diameter, hollow steel rods into the subsurface without rotating the drill rods.

Down time: non-productive time on the part of the drilling contractor or their subcontractors related to scheduling, breakdown, or other operational delays

Drill bit: the cutting end of a drill string that typically has cutting teeth.

Drill string: multiple auger or casing sections connected in series with a drill bit or cutting shoe connected at the driving end of the drill string.

Flame ionization detector (FID): a detection tool that measures organic vapor concentrations in air using the flame-ionization potential of the contaminant.

Heaving or Flowing Soils: loose medium- and fined-grained soils in a confined, water-bearing zone or aquifer that tend to rise up into the drill stem when the unit confining the aquifer is breached by the drill bit. This happens because the water in the aquifer has a pressure head great enough to cause upward flow into the drill stem with enough velocity to overcome the weight of the sand, creating a quicksand condition and carrying sand into the drill stem. Usually associated with hollow stem auger drilling.

Hollow Stem Auger (HSA): a form of rotating auger, consisting of continuous-casing, segmented auger sections with helices (screw-flights) that are rotated into the subsurface under downward pressure.

Investigation-derived waste (IDW): any contaminated waste generated during investigation activities, including wash water, purge water, personal protective equipment, sampling tools and supplies, and soil cuttings.

Photoionization detector (PID): a detection tool that measures organic vapor concentrations in air using the photoionization potential of the contaminant.

Probe drive string: the outer casing and drive string used during DPS drilling.

Sample shoe: a retaining device, typically made of polyethylene, that allows soils to enter a sampler but does not allow them to exit through the end of the sampler.

Solid-point drive point: a solid point placed within the open, hollow end of a DPS cutting shoe so that soil may not push up and into the probe drive string.

Split- spoon sampler: a soil coring device that consists of a length of carbon or stainless steel tubing split longitudinally and equipped with a sample shoe and a drive head.

Standard Penetration Test (SPT): a soil test used to evaluate the relative density of unconsolidated soil by counting the number of times a weighted hammer is repeatedly raised and dropped over a 30-inch height for every 6 inches of soil penetration.

Unconsolidated formation: a subsurface soil formation that is unstable or loose with a low ability to remain cohesive without retainment. Soils that easily slough or erode back into an open borehole without an outer casing to keep the borehole open.

11.0 Attachments

Attachment 1: *CME-75 Features and Specifications*

Attachment 2: *Geoprobe® Model 66 Series Features and Specifications*

Attachment 3: *Drilling Self Assessment Checklist*

Attachment 4: *Geoprobe® DT325 Dual Tube Sampling System SOP*

SOP-06

Boring Log Completion, Soil Classification, and Logging

SOP-06: BORING LOG COMPLETION, SOIL CLASSIFICATION, AND LOGGING

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to establish the methodology to be used by CH2M HILL field technicians and subcontractors to classify and record soil lithology, and complete Soil Boring Log Datasheets and Test Pit Log Datasheets with pertinent geological, geotechnical, physical, and chemical field observations of the soil. Adherence to a standard format for recording data will help streamline project efforts and allow a consistent presentation of subsurface data.

2.0 Scope

This procedure applies to CH2M HILL field geologists, field personnel, and subcontractors who oversee the advancement of soil borings and excavation of test pits, classify soil, and prepare lithologic logs describing those borings and test pits on Galena Forward Operating Location (FOL) projects and tasks. All personnel new to the project who will be involved in such activities must be trained in the protocols described in this SOP by a competent person with program-specific experience.

3.0 General

SOP-06, Attachment 1: Soil Boring Log Datasheet and *SOP-06, Attachment 2: Test Pit Log Datasheet* are intended for use in the field during drilling, sampling, soil classification, and soil boring/test pit logging activities. The purpose of the *Soil Boring Log Datasheet* and *Test Pit Log Datasheet* is to clearly document the findings of the drilling and test pit excavation activities. Complete datasheets according to *SOP-01, Note Taking and Field Log Books* and retain in the project files.

Complete the Soil Boring Log Datasheets and Test Pit Log Datasheets in the field according to the procedures outlined below. If completed by hand, fill datasheets out neatly and completely. Datasheets may also be filled out electronically in the field. For geotechnical needs, it is important to check field classifications against laboratory test results. Corrections should be noted in red, initialed, and dated on the datasheet.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise so that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying that all paperwork and forms

developed during lithologic classification and soil boring/test pit logging are in compliance with this SOP, and are executed throughout the whole data collection process. The FM is also responsible for verifying that all field staff engaged in this activity are trained in this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) will verify that soil is classified and logged according to this procedure and other SOPs in Appendix H, Field Standard Operation Procedures. The FTL should also ensure that the applicable requirements of Appendix A, Project-specific Health and Safety Plan (HSP), and Appendix B, Project-specific Waste Management Plan, are followed.

4.4 Field Geologist

The Field Geologist performing lithologic classification and logging is responsible for completing consistent, accurate, and uniform lithologic descriptions on the Soil Boring Log Datasheet or Test Pit Log Datasheet provided as Attachments 1 and 2. The Field Geologist will verify that entries have been appropriately reviewed and that any corrections have been made. The Field Geologist also must check that field activities are properly documented per requirements of this procedure, other applicable procedures, and the site-specific sampling plans (Appendix D).

5.0 Procedure for Lithological Logs

This section covers several aspects of the soil characterization: instructions for completing soil boring and test pit logs, field classification of soil, and standard penetration test procedures. The *SOP-06, Attachment 1: Soil Boring Log Datasheet* and *SOP-06, Attachment 2: Test Pit Log Datasheet* indicate the information required for observation and logging of soils. The heading information should be completely filled out on each log sheet, and the technical items in each column must be addressed in the field. Field personnel should review completed logs for accuracy, clarity, and thoroughness. It is important that information be correctly recorded on both the sample container and the datasheets. The information required in each column is discussed in more detail below. An example of the soil boring log template is provided in Figure 1.

5.1 Heading Information

Complete the heading block with all available information. If the item requested is not applicable (NA), then record NA in that box. The heading block portion of the soil boring field forms contains general information regarding the soil boring or test pit. Record the following information in the heading block for each soil boring or test pit as appropriate.

Project Number. Use the standard six-digit project number and appropriate point numbers.

Boring/Test Pit Number. Enter the boring or test pit number. A numbering system should be chosen that does not conflict with information recorded for previous exploratory work done at the site. Number the sheets consecutively for each boring. If rock core log sheets are also used, continue the consecutive numbering.

Project. Fill in the name of the project or client.

CH2MHILL

PROJECT NUMBER: BORING NUMBER:

Sheet: 1 of 1

SOIL BORING LOG

PROJECT: LOCATION:

ELEVATION: DRILLING CONTRACTOR:

DRILLING METHOD AND EQUIPMENT:

WATER LEVELS: START: FINISH: LOGGER:

DEPTH BELOW	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	NUMBER	TYPE	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0					Ground Surface	
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						

Figure 1. Example of the Winlog CH2M HILL Soil Boring Log Template.

Location. Identify the area of concern, building, or other landmark the boring or test pit is associated with. Also indicate the stationing, coordinates, mileposts, or similar project layout information, if available. Indicate the position of the boring to that system using modifiers

such as approximate or estimated, as appropriate. If this information is not available, identify the client facility (for example, Galena FOL SE Runway) and provide a brief description of location. Record swing-tie information if valuable and/or necessary.

Elevation. Enter the estimated elevation. If it is estimated from a topographic map, or if it is roughly determined using a hand level, use the modifier approximate. It is important to tie the boring elevation to a recoverable reference point (such as a fire hydrant or floor slab) if no other elevation data are available. Such points can be picked up later in a site survey and boring elevations can be determined. In the event that no survey is done, the relative boring elevation with respect to pertinent project facilities will be known, at the least.

Drilling/Test Pitting Contractor. Enter the name of the drilling or test pit excavation subcontractor, and the city and state where the company is based.

Drilling/Test Pitting Method and Equipment. Identify the drilling method (such as hollow-stem auger [HAS] or direct-push system [DPS], or other), drilling equipment (such as CME-75, Geoprobe 6620D), bit size and type, and drilling fluid (if used). Information on the test pit excavation equipment (such as Caterpillar 303C excavator) should also be included.

Water Level and Date. Enter the depth below ground surface (bgs) to the static water level in the borehole, if encountered. If multiple water level measurements are taken for the boring, this field should list the last or most representative measurement. Frequent water measurements are recommended to capture differences between water-bearing zones, and to capture the stable water level. Record the information in the Comments column. If free water is not encountered during drilling, or cannot be detected because of the drilling method, make a note of this information. Generally, water levels should be measured each morning before resuming drilling and at the completion of each boring. Record the date and time of day (for such things as tides or river stage) of each water level measurement.

Date of Start and Finish. Enter the dates and times the boring was begun and completed.

Logger. Enter the first initial and full last name of the geologist or engineering recording the soil log.

5.2 Technical Data

Depth Below Surface. This column refers to the depth bgs. Depths should typically be recorded in feet, unless very shallow soil borings are expected. The scale of the log may be adjusted as needed by the Field Geologist for the best and most accurate representation of the data. Depth intervals should be recorded at consistent depths (such as 10, 15, 20, 25 feet; or 0.5, 1.0, 1.5, 2.0 feet). Use a depth scale that is appropriate for the sample spacing and for the complexity of subsurface conditions.

Sample Interval. The sample interval refers to the depth interval that each lithologic sample is collected using a split spoon or core sampler. The depth interval that each lithologic sample is collected from should be recorded in the Interval column corresponding to where it was collected. Draw horizontal lines at the top and bottom depth of each sample interval. These lines should extend to the soil description column. For a very short sample interval, the bottom line can be lowered after the interval column to provide room for writing the information (see Figure 2). Enter the depth at the top and bottom of the sample interval.

CH2M HILL

PROJECT NUMBER D22371.65 | BORING NUMBER B-3 | SHEET 1 OF 3

SOIL BORING LOG

PROJECT Howard Ave Landslide LOCATION Howard & 24th Ave, Centennial, CO

ELEVATION 5136 Feet DRILLING CONTRACTOR Kendall Explorations, Ashcan, Colorado

DRILLING METHOD AND EQUIPMENT 4-inch H.S. Augers, Mobil B-61 rotary drill rig

WATER LEVEL AND DATE 3.2 feet, 8/5/86 START August 4, 1986 FINISH August 8, 1986 LOGGER J. A. Michner

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0					Surface material consists of 4 inches AC underlain by 6 inches of 3/4-inch minus base rock		Start Drilling @ 3:00
	2.5						
	4.0	S-1	1.5	2-3-4 (7)	POORLY-GRADED SAND WITH SILT, fine, light brown, wet, Loose (SP-SM)		Driller notes water at 4 feet
5	5.0						Driller notes very soft drillin 4 ft. dark gray, wet silty cuttings
	6.5	S-2	0.9	WOH/12" – 1	ORGANIC SILT, very dark gray to black, wet, very soft (OL); strong H_2S odor; many fine roots up to about 1/4 inch		
	8.0						
	10.0	ST-3	1.3	—	ORGANIC SILT, similar to S-2, except includes fewer roots (by volume)		
10	11.5	S-4	1.3	2-2-2 (4)	SILT very dark gray to black, wet, soft (ML)		water level @ 3.2 feet on 8/5/86 @ 0730
							Driller notes rough drilling action and chatter @ 13 ft
15	15.0						
	15.5	S-5	0.5	60/6"	SILTY GRAVEL, rounded gravel up to about 1 inch maximum observed size, wet, very dense (GM)		
							Driller notes smoother, firm drilling @ 19 ft
20	20.0						
	21.0	S-6	1.0	8-12-50/6"	LEAN CLAY WITH SAND, medium to light green moist, very stiff (CL)		same angular rock chips @ bot tip of S-6; poss boulders? rock? Driller notes very hard, slow grinding, smooth, drilling action from 21 to 23 ft, possibly bedrock
	23.0						
	23.1	S-7	0	50/1"	NO RECOVERY		
					END SOIL BORING @ 23.1 Feet		
					SEE ROCK CORE LOG FOR CONTINUATION OF B-3		

Figure 2
EXAMPLE OF COMPLETED LOG FORM

Figure 2. Example of a Completed CH2M HILL Soil Boring Log Form.

Sample Recovery. The recovery column shows the amount of sample recovered per lithologic sample attempt. The lithologic sample recovery should be recorded as the length

in inches of sample recovered. Often, there will be some wash or caved material above the sample; do not include the wash material in the measurement.

Sample Type and Number. The sample number refers to the consecutive number of lithologic samples collected throughout the depth of the soil boring. Each consecutive lithologic sample number should be recorded in the "#/Type" column at the depth interval corresponding to where it was collected. Enter the sample number and type. For instance, 1-SS = first split-spoon sample or 1-DP = first direct-push sample. Number samples consecutively regardless of type. Enter a sample number even if no material was recovered in the sampler.

Standard Penetration Test Results. In this column, enter the number of blows required for each 6 inches of sampler penetration and the "N" value (the sum of the blows in the last two 6-inch penetration intervals) if the standard penetration test is being used with a hollow-stem auger drill rig. A typical standard penetration test involving successive blow counts of 2, 3, and 4 is recorded as 2-3-4 and (7). The standard penetration test is terminated if the sampler encounters refusal. Refusal is a penetration of more than 6 but less than 12 inches, with a blow count of 100, or a penetration of less than 6 inches with a blow count of 50. A partial penetration of 50 blows for 4 inches is recorded as 50'4". (See Section 6.0 for additional discussion.) In order for the standard penetration test to be useful, the hammer weight and split-spoon size must be recorded.

Soil Description. Soil classification should follow the format described in Section 5.3, Field Classification of Soil. The Soil Description column is completed using the standard Unified Soil Classification System (USCS) Group Symbol code that corresponds to the lithology encountered. An entry should be made at each lithological change or at the top of a new page if the same lithology is encountered. The Field Geologist should determine and record the correct USCS group symbol classification according to Section 5.3. Lithologic descriptions must be determined before the assignment of the appropriate group symbol.

Comments. Include pertinent observations including soil core or soil headspace photoionization detector (PID) or flame ionization detector (FID) readings, analytical samples collected with identification (ID) and depths, changes in drilling difficulty, equipment malfunctions, any driller observations and comments, and any other valuable observations. The driller will be instructed to alert the geologist when changes in drilling are encountered. Such information should be attributed to the driller and recorded in this column.

Others specific information might include the following:

- The date and the time drilling began and ended each day
- The depth and size of casing and the method of installation
- The date, time, and depth of water level measurements
- Rod chatter, rod drops, and depth of occurrence
- Depth and percentage of drilling fluid loss
- Depth of hole caving or heaving
- Depth of change in material
- Drilling interval through a boulder

- The results of pocket penetrometer or torvane test reported as: “PP = _____ TSF” or “TV = _____ TSF,” respectively
- Depth of piezometers and the results of in situ tests

Soil core PID or FID screening results or headspace screening results for volatile organic compounds (VOCs), collected according to procedures outlined in *SOP-04, Organic Vapor Monitoring and Air Monitoring*, should be recorded in the Comments column. The specific PID/FID reading depth should also be recorded.

5.3 Field Classification of Soil

This section describes the format for the field classification of soil. In general, the approach and format for classifying soils should conform to the most current version of the American Society for Testing and Materials (ASTM) standard ASTM D2488, *Visual-Manual Procedure for Description and Identification of Soils*.

The USCS is based on numerical values of certain soil properties measured by laboratory tests (ASTM D2487). It is possible, however, to estimate these values in the field reasonably accurately with visual-manual procedures (ASTM D2488). Also, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of soil types in a bedded deposit, can be obtained only in the field. Corrections and additions to the field classification can be provided, when necessary, through laboratory testing of the soil samples.

Soil descriptions should be precise and comprehensive without being verbose. The correct overall impression of the soil should not be distorted by excessive emphasis on insignificant details. In general, similarities between consecutive samples, rather than differences, should be stressed.

Soil descriptions must be recorded in the Soil Description column for every soil sample collected. The format and order for soil descriptions should be as follows:

1. Soil name (synonymous with ASTM D2488 Group Name) with appropriate modifiers
2. Group symbol
3. Color
4. Moisture content
5. Relative density or consistency
6. Soil structure, mineralogy, or other descriptors

This order follows, in general, the format described in ASTM D2488. Examples of soil descriptions are provided in Table 1.

Table 1. Example Soil Descriptions.

POORLY GRADED SAND (SP), light brown, moist, loose, fine sand size
FAT CLAY (CH), dark gray, moist, stiff
SILT (ML), light greenish gray, wet, very loose, some mica
WELL-GRADED SAND WITH GRAVEL (SM), reddish brown, moist, dense, sub-angular gravel to 0.6 inches max
POORLY GRADED SAND WITH SILT (SP-SM), white, wet, medium dense
ORGANIC SOIL WITH SAND (OH), dark brown to black, wet, firm to stiff but spongy undisturbed, becomes soft and sticky when remolded, many fine roots, trace of mica
SILTY GRAVEL WITH SAND (GM), brownish red, moist, very dense, sub-rounded gravel to 1.2 inches max
INTERLAYERED SILT (60%) AND CLAY (40%): SILT WITH SAND (ML), medium greenish gray, moist, non-plastic, sudden reaction to shaking, layers mostly 1.5 to 8.3 inches thick; LEAN CLAY (CL), dark gray, firm and brittle undisturbed, becomes very soft and sticky when remolded, layers 0.2 to 1.2 inches thick
SILTY SAND WITH GRAVEL FILL(SM), light yellowish brown, moist, medium dense, weak gravel to 1.0 inch maximum, very few small particles of coal
SANDY ELASTIC SILT (MH), very light gray to white, wet, stiff, weak calcareous cementation
LEAN CLAY WITH SAND (CL/MH), dark brownish gray, moist, stiff
WELL-GRADED GRAVEL WITH SILT (GW-GM), brown, moist, very dense, rounded gravel to 1.0 inches max

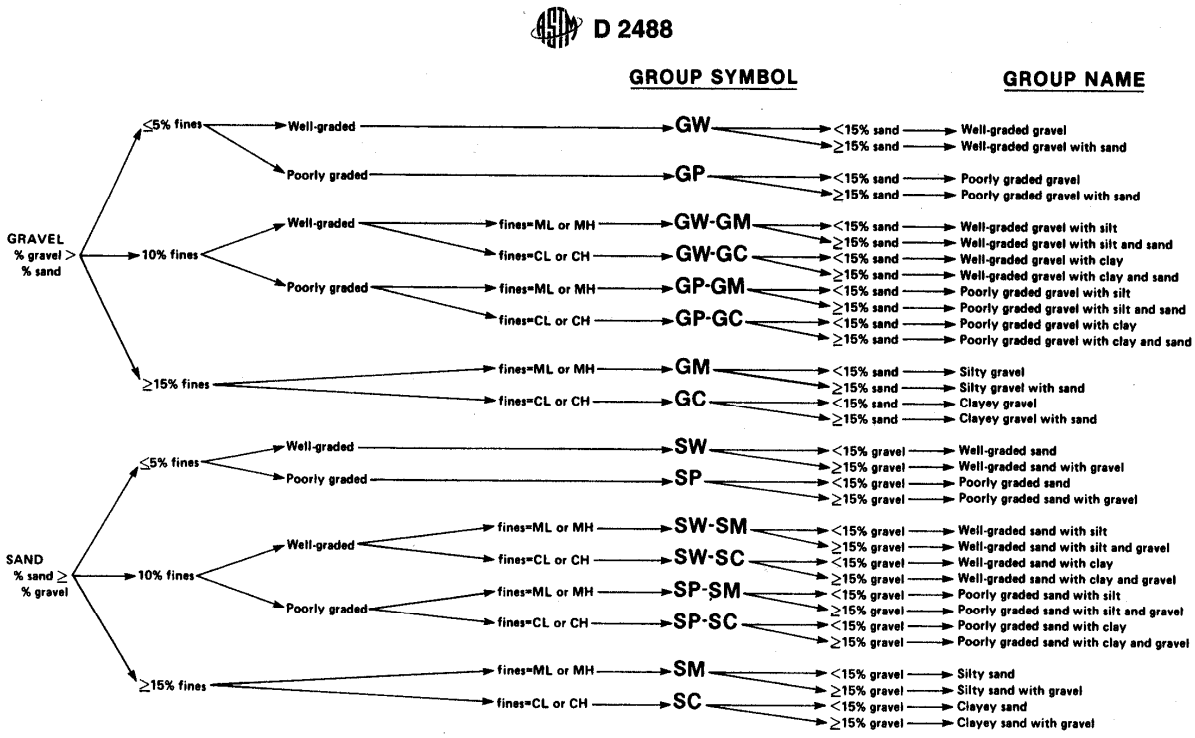
5.3.1 Soil Name

The basic name of a soil should be identical to the ASTM D2488 Group Name, based on visual estimates of gradation and plasticity, and should be capitalized. The only acceptable soil names are those listed in Figures 3 and 4, from ASTM D2488.

Examples of acceptable soil names are illustrated by the following descriptions:

- A soil sample is visually estimated to contain 15% gravel, 55% sand, and 30% fines (passing No. 200 sieve). The fines are estimated as either low or highly plastic silt. This visual classification is SILTY SAND WITH GRAVEL, with a Group Symbol of (SM).
- Another soil sample has the following visual estimate: 10% gravel, 30% sand, and 60% fines (passing the No. 200 sieve). The fines are estimated as low plastic silt. This visual classification is SANDY SILT. The gravel portion is not included in the soil name because the gravel portion was estimated as less than 15%. The Group Symbol is (ML).

The gradation of coarse-grained soil (more than 50% retained on No. 200 sieve) is included in the specific soil name in accordance with ASTM D2488. For a coarse-grained soil, note whether the soil is well-graded or poorly graded. If poorly graded, note whether it is fine-, medium- or coarse-graded. Also record the maximum size and angularity or roundedness of gravel and sand-sized particles. Note that samples from split spoons and small-diameter core tools are not always representative of coarse-grained strata (those with grain sizes of a diameter greater than that of the diameter of the particular coring apparatus used). Be sure to check driller's logs and soil cuttings for boulders, cobbles, gravels, and similar that were encountered during advancement of the boring, and note their presence on the Soil Boring Log Datasheet.



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

Figure 3. Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines); USCS (ASTM, 2009).

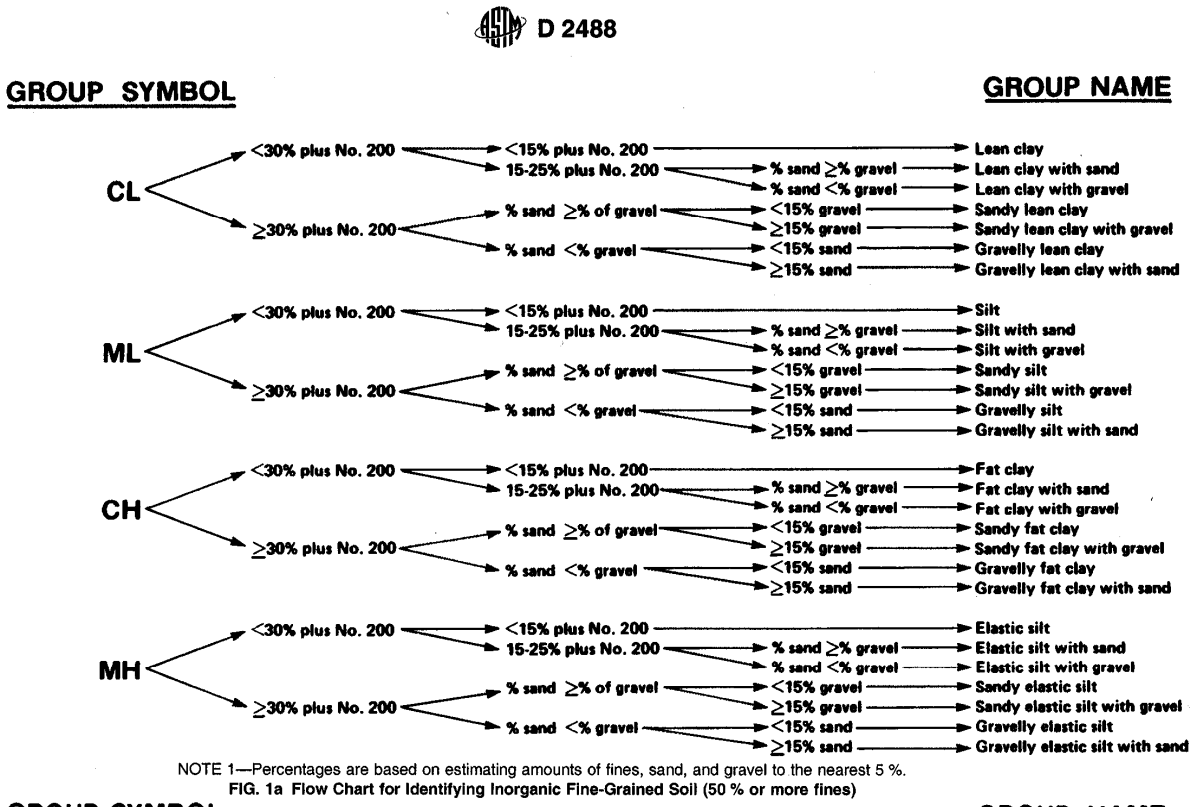


Figure 4. Flow Chart for Identifying Inorganic Fine-Grained Soils (50% or more fines); USCS (ASTM, 2009).

For fine-grained soil (50% or more passing the No. 200 sieve), modify the name by the appropriate plasticity/elasticity term, in accordance with ASTM D2488. Take special consideration when dealing with soil samples in which the predominant grain size is fine grained (that is, CLAY or SILT). Because of the fine size of clay and silt, physical properties other than grain size must be used as criteria for identification in the field. The property of plasticity is characteristic of clays and may be determined using a simple field test. If a sample of moist fine-grained soil can be rolled into a long thin thread in the palm of the hand, it contains a significant amount of clay. Silt can seldom be rolled into a thread without severe cracking. If a sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation before rolling. The dilatancy or “shaking test” may be also be used to distinguish between the fractions of clay and silt. To perform this test, mix a small amount of soil with water to a very soft consistency in the palm of the hand. Lightly tap the back of the hand. If the sediment is silty, water rises quickly to the surface of the mixture and gives it a glistening or shiny appearance. Because of the difficulty in

distinguishing between silt and clay, it is not necessary to provide the relative percentage of each. Where helpful, the evaluation of plasticity/elasticity and dilatancy can also be justified in the Comments section of the log by describing the results from any of the visual-manual procedures for identifying fine-grained soils, such as reaction to shaking, toughness of a soil thread, or dry strength.

For interlayered soils, describe each, starting with the predominant type. Use an introductory name, such as Interlayered Sand and Silt. Also indicate the relative proportion of each soil type and layer thickness (see Table 1 for example).

5.3.2 Group Symbol

The appropriate group symbol from ASTM D2488 (see Figure 3) must be given after each soil name. Place the group symbol in parentheses to indicate that the classification has been estimated.

In accordance with ASTM D2488, dual symbols (for example, GP-GM or SW-SC) can be used to indicate that a soil is estimated to have about 10% fines. Borderline symbols (for example, GM/SM or SW/SP) can be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. Borderline symbols should not be used indiscriminately. Every effort should be made to first place the soil into a single group.

Fill is often encountered when drilling. Fill comprises any materials that people have placed on the naturally occurring ground surface. Fill material can be determined from historical information or from the discovery of human-made materials, such as concrete, brick, glass, plastic, and wood. If the soil being described is determined to be fill material, “fill” should be included in the soil description. If appropriate, provide additional details in the Comments column.

5.3.3 Color

Give the basic color of a soil, such as brown, gray, or red; the color term can be modified, if necessary, by adjectives such as light, dark, or mottled. Especially note staining, iron staining, or mottling. This information might be useful for establishing water table fluctuations or contamination. As an alternative, consider using the Munsell soil color chart designation in addition to the color designation.

5.3.4 Moisture Content

The degree of moisture present in a soil sample should be defined as dry, moist, or wet. Moisture content can be estimated from the criteria listed in Table 2.

Table 2. Criteria for Describing Moisture Conditions.

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

5.3.5 Relative Density or Consistency

Relative density of a coarse-grained (cohesionless) soil is based on N-values from the Standard Penetration Test. (ASTM D1586). If the presence of large gravel or disturbance of

the sample makes determining the in situ relative density or consistency difficult, then omit this item from the description and explain it in the Comments column of the soil boring log.

Consistency of fine-grained (cohesive) soil is properly based on results of pocket penetrometer or torvane results. In the absence of this information, consistency can be estimated from N-values from the Standard Penetration Test. Relationships for determining relative density or consistency of soil samples are given in Tables 3 and 4.

Table 3. Relative Density of Coarse-Grained Soil (Developed from Sowers, 1979).

Blows/Ft	Relative Density	Field Test
0-4	Very loose	Easily penetrated with 12-in. steel rod pushed by hand
5-10	Loose	Easily penetrated with 1/2-in. steel rod pushed by hand
11-30	Medium	Easily penetrated with 1/2-in. steel rod driven with 5-lb. hammer
31-50	Dense	Penetrated a foot with 1/2-in. steel rod driven with 5-lb. hammer
50	Very Dense	Penetrated only a few inches with 12-in. steel rod driven with 5-lb. hammer

Table 4. Consistency of Fine-Grained Soil (Developed from Sowers, 1979).

Blows/Ft	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	<0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumb, but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

5.3.6 Soil Structure, Mineralogy, Particle Shape, and Other Descriptors

Discontinuities and inclusions are important and should be described. Such features include joints or fissures, slickensides, bedding or laminations, veins, roots, root holes, and wood debris.

Record significant mineralogical information. Describe cementation, abundant mica, or unusual mineralogy, as well as other information, such as organic debris or odor.

Include other descriptors if they are important for the project or for describing the sample. These descriptors include particle size range and percentages, particular angularity, particle shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to hydrochloric acid (HCl), and cementation.

Residual soils have characteristics of both rock and soil and can be difficult to classify. Describe relict rock structure and identify the parent rock, if possible.

5.3.7 Potentially Impacted Subsurface Media

Record observations of any potentially impacted subsurface media in the soil description or as comments. Notable observations of impacted media include staining, sheens, unusual discolorations, unusual crystals, and odors. Make a note about odor and describe the characteristics of the odor (for example, hydrocarbon odor) but do not try to guess what chemical smell is observed. Also describe non-aqueous phase liquids (NAPL) if they are present. Describe *how* they are present, such as sheen, staining along joints or root casts, residual, or free NAPL seeping from the sample. Do not try to guess what fluid is present. Use terms such as phase-separated hydrocarbons if you know a fluid is a fuel, but do not use terms such as diesel, unless you have tested and know that the fluid is diesel. For larger investigation projects, it is advisable to prepare guidelines for describing site contamination in the soil samples.

6.0 Standard Penetration Test Procedures

Standard Penetration Tests (SPT) are conducted to obtain a measure of the resistance of the soil to penetration of the sampler and to recover a disturbed soil sample. They should be conducted in accordance with ASTM D1586, *Penetration Test and Split Barrel Sampling of Soils*. These tests are most commonly performed on geotechnical projects. On environmental projects, a larger split spoon often must be used to collect the amount of soil required for analytical sampling. Recording blow counts can be useful for understanding variations in soil density or consistency on environmental projects, but typically is not done for an SPT. Refer to *SOP-05*, *Hollow Stem Auger and Direct Push Drilling Methods* for addition details regarding SPT testing during drilling.

6.1 Equipment and Calibration

Before testing is started, inspect equipment for compliance with the requirements of ASTM D1586. The split-barrel sampler outer diameter (O.D.) should measure 2 inches, the inner diameter (I.D.) should measure 1-3/8 inches, and the split tube should be at least 18 inches long. The dimensions should conform to those shown in Figure 1 of ASTM D1586. The minimum size sampler rod allowed is the “A” rod (1-5/8-inch O.D.). A stiffer rod, such as the “N” rod (2-5/8-inch O.D.), is required for depths greater than 50 feet. The drive weight assembly should consist of a 140-pound hammer weight, a drive head, and a hammer guide that permits a free fall of 30 inches.

6.2 Procedures

Ideally, conduct SPTs at every change of stratum, or within a continuous stratum, at intervals not exceeding 5 feet. Before driving the split-barrel sampler, remove loose and foreign material from the bottom of the borehole. It might be helpful to measure the rod stickup to ensure that the sampler is being driven from the bottom of the borehole. Perform the SPT by driving a standard split-barrel sampler 18 inches into undisturbed soil at the bottom of the borehole with a 140-pound guided hammer or ram that falls freely from a height of 30 inches.

Observe the number of blows required to drive the sampler for three 6-inch intervals (for a total of 18 inches) and record that number on the soil boring log. The sum of the number of blows required to drive the sampler for the second and third 6-inch intervals is considered the Standard Penetration Resistance (N) or the *blow count*. If the sampler is driven less than 18 inches, but more than 1 foot, the penetration resistance (N) is the blow count for the last

1 foot of penetration. If less than 1 foot is penetrated, the log must state the number of blows and the fraction of 1 foot penetrated. It is important that the field logger observe the sampler being driven and count the blows for each sample attempt.

6.3 General Considerations

Consider the following suggestions when you perform SPTs:

1. The borehole should be cleaned out before every sample attempt. Because a minor amount of caving can be expected, the borehole can be considered adequately clean if no more than 4 inches of loose or foreign material has collected at the bottom. If there is a greater amount of caving, clean the borehole again.
2. The ball check valve in the split-barrel sampler should be cleaned and working properly for each sample. Bent, chipped, or damaged shoes should be replaced. The split-barrel halves should not be warped. In case of zero sample recovery (that is, if the sample is lost during the first attempt), a spring catcher should be used during subsequent attempts to facilitate recovery.
3. During SPT sampling, it is important that all rod connections be tight and that the hammer guide be connected securely to the drill rods. If the hammer guide connection becomes loose, much of the hammer energy can be lost because of deflection of the hammer coupling. The lifting rope should not rub against the mast. Each hammer fall should be 30 inches.
4. During SPT sampling, it is important that the drill rods be positioned at the center of the drill hole to preclude the development of friction between drill rods and the walls of the borehole or casing.
5. If the hammer weight is raised by means of a cathead, generally two wraps on the cathead should be used. The optimal number of wraps varies with the condition of the rope and cathead, and with the weather. Most importantly, the driller should exercise care to prevent friction of the rope on the cathead during the fall of the hammer.
6. Nonstandard procedures or equipment occasionally are used for obtaining samples (for example, 3-inch O.D. split-barrel samplers, or 300-pound hammers). Any nonstandard practice should be described on the boring log form. Also, the blow counts should be clearly marked as not conforming to SPT values.

7.0 Sample Labeling and Packaging

This section addresses only those sample labeling and packaging requirements that apply to *physical* testing of soil samples. For guidance on requirements for samples destined for *chemical* testing, refer to *SOP-18, Packing and Shipping of Environmental Samples*. If the work is being conducted at a site containing hazardous waste (not simply hazardous constituents, but either listed or characteristic hazardous waste) or toxic waste (such as polychlorinated biphenyls), contact the PM, FM, or FTL regarding appropriate sample handling procedures consistent with hazardous or toxic waste management regulations and *SOP-19, Sample Handling and Custody*.

The samples recovered from the borehole are an important part of the boring record and must be properly packaged and labeled, if further testing is required. The following description outlines the minimum requirements for packaging and labeling the samples.

1. Place disturbed samples in Ziploc™ bags or jars. If using jars, mark the jar lids and affix labels to the sides of the jars. Labels are usually available from the analytical laboratory. Mark the following information clearly on the bags or jars:

   a. Project number
   b. Boring number
   c. Sample number
   d. Sample depth
   e. Date

   Use a permanent marker. If moisture content tests are anticipated, use jars, which should be tightly sealed, then sent to the laboratory. Testing should be initiated as soon as possible (within 1 week). Alternatively store the samples in double-bagged Ziploc™ bags of an appropriate size. Do not expose samples to hot or freezing temperatures which might alter the moisture content of the sample.

2. Label boxes containing the jars, on top and on one end, with the following information:

   a. Project name
   b. Project number
   c. Boring number
   d. Sample numbers
   e. Sample depths
   f. Date
   g. Name

   It is helpful to start a new box for each new boring if the boxes are at least half full.

3. Clean Shelby tubes of mud and moisture. When they are dry, use a permanent marker to label them with the following information:

   a. An arrow indicating which way is up
   b. Project number
   c. Boring number
   d. Sample number
   e. Sample depth
   f. Amount of recovery
   g. Date

   Circumscribe the top and bottom of the sample on the outside of the tube with a marker.

4. Sealing of Shelby tubes is essential if sample testing is not to occur within a few days. In all cases, place lids on the ends and tape them with airtight tape. Be sure to seal the holes in the top of the tube. Pack the open portion of the tube above the sample to prevent shifting of the soil. Dampened newspaper is generally adequate for this purpose, but it should be separated from the soil sample with a wax seal or an inverted cap.

5. Maintain Shelby tubes in upright position at all times. Ship is a manner that will minimize disturbance (vibration) to sample.

8.0 Field Equipment Checklist

The following equipment and supplies are necessary or useful for soil boring and test pit exploration:

8.1 Site Setup

- Lath, flagging, orange spray paint, grease pencil, survey stakes
- 100-foot tape measure
- Magnetic compass or Global Positioning System (GPS) receiver

8.2 Logging Equipment

- SOP-06, Boring Log Completion, Soil Classification, and Logging
- Clipboard
- Soil boring Log Datasheet or Test Pit Log Datasheet, on all-weather paper
- Pens/pencils
- Engineer's pocket tape measure with tape lock (with tenths of foot instead of inches)
- Field notebook on all-weather paper
- Squirt bottle with water
- Spatula or large spoon
- Munsell Soil Color chart
- Hand lens

8.3 Sampling and Packaging

- Jars with lids and labels
- Ziploc™ bags
- Shelby tubes and plastic end caps
- Airtight tape (such as electrical)
- Newspaper
- Sealing wax, stove, melting pot, and matches
- Indelible fine felt-tipped markers (such as Sharpie brand)

8.4 Test Equipment

- Pocket penetrometer
- Torvane
- Water Interface Meter

For potentially contaminated projects, follow the site-specific sampling plan (Appendix D) and HSP (Appendix A) for field monitoring and PPE.

9.0 Records

Fill out Soil Boring Log Datasheets and Test Pit Log Datasheets according to this SOP. The field geologist will check that entries have been appropriately reviewed and that any corrections have been made properly.

To guard against loss of data because of damage or misplacement of datasheets, make regular copies of completed pages and securely retain them in the project-specific files. Upon completion of field activities, save the datasheet to the project folder on the local area network (LAN).

Enter information on soil boring log field forms into a boring log software program such as WinLoG, gINT, or CH Boring Logger. If boring log software is used, do so according to the software instructions.

10.0 References

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11.0 Definitions

Angularity: pertaining to the sharpness of edges and corners of individual grains. A grain is angular if most of the edges or corners are sharp, and rounded if most are smooth.

Cohesiveness: measure of the strength, when air-dried, of an unconfined soil or sediment, or a measure of the cohesion of a soil or sediment when submerged.

Lamination: the state of being laminated, specifically the thinnest recognizable layer in a sediment differing from other layers in color, composition, or particle size.

Lithologic: pertaining to the physical characteristics of a rock or sediment.

Plasticity: measure of the tendency of a soil or sediment to be deformed without rupturing.

Relative Density: the ratio of (1) the difference between the void ratio of a cohesionless soil in the loosest state and any given void ratio, to (2) the difference between the void ratios in the loosest and in the densest states.

Sample ID: the unique identifier that CH2M HILL assigns to a specific environmental sample.

LOCID: the unique identifier that CH2M HILL assigns to a specific sampling location.

Sorting: a measure of the uniformity of particle size(s) in a particular soil or sediment.

Texture: the general appearance or character of rock or sediment, including the geometric aspects of, and mutual relations among, its component particles, for example, the size, shape, and arrangement of the constituents of sediment.

12.0 Attachments

Attachment 1: *Soil Boring Log Datasheets*

Attachment 2: *Test Pit Log Datasheets*

Attachment 3: *Soil Characterization Field Reference Materials*

SOP-07

Surface and Subsurface Soil Sampling

SOP-07: SURFACE AND SUBSURFACE SOIL SAMPLING

1.0 Purpose

This standard operating procedure (SOP) provides the methodology for collecting discrete surface and subsurface soil samples to characterize the nature of soil contamination, the areal and vertical extent of contaminated soil, and to determine the geotechnical, physical, and chemical properties of the soil.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in collecting or otherwise handling surface or subsurface soil samples on Galena Forward Operating Location (FOL) projects and tasks, and was developed per the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used soil sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-06, Boring Log Completion, Soil Classification, and Logging*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*
- *SOP-20, Field Procedure Change Management*
- *SOP-22, Multi Increment® Sampling for Surface Soil*

3.0 General

Selecting the proper methods and tools for surface and subsurface soil sampling is a critical part of field investigations. This SOP describes the methods generally used for surface and subsurface soil sampling, as well as the tools commonly used.

All soil sample collection activities should adhere to the note-taking, decontamination, labeling, packaging, shipping, storage, and chain-of-custody requirements applicable to the soil sampling activities being conducted according to the SOPs discussed in Appendix H, Field Standard Operation Procedures. Refer to technical procedure *SOP-19, Sample Handling and Custody* for details on sample container labeling, handling, and chain-of-custody requirements. Sample packaging and shipping requirements are outlined in technical procedure *SOP-18, Packing and Shipping of Environmental Samples*.

All personnel who collect or handle the soil samples should wear, at a minimum, disposable nitrile gloves to prevent cross-contamination and provide personal protection. New gloves should be donned for sample collection at each location, or whenever gloves are torn or otherwise compromised. The *Project-Specific Health and Safety Plan* (HSP) (*Appendix A*) provides information on site-specific personal protective equipment (PPE) requirements.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to ensure that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and ensure overall compliance with project HS&E requirements. The HSM conducts PPE evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP (*Appendix A*), coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and certify the PPE program, and conducts project H&S audits on the effectiveness of the HS&E program.

4.3 Safety Coordinator (SC)

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

4.4 Field Team Leader

The FTL should ensure that soil samples are collected according to this procedure and other SOPs in *Appendix H*. The FTL should also be required to make rational and justifiable decisions when deviations from this procedure are necessary because of field conditions or unforeseen problems. The FTL should consult the FM if significant deviations from the sample and analysis plan are necessary because of field conditions. The FTL should also ensure that the applicable requirements of *Appendix A,* the HSP, and *Appendix B, Project-specific Waste Management Plan,* are followed.

5.0 Procedures

5.1 General Guidelines

The following procedures should be used to collect soil samples for laboratory analysis:

- Unless otherwise specified, all laboratory soil samples must be discrete samples and may not be composited before analysis.

- Soil samples must be collected according to the method specifications appropriate for the laboratory parameters to be analyzed.
- All soil samples must be collected with disposable or clean tools that have been decontaminated as outlined in *SOP-14, Equipment Decontamination Procedures*.
- Disposable nitrile gloves (at a minimum) must be worn and changed between sample collections.
- Soil samples must be placed in containers quickly and in the order of volatility; for example, volatile organic aromatic samples must be taken first, gasoline range organics next, heavier range organics next, and soil classification samples last.
- All sample containers must be quickly and adequately sealed, and rims must be cleaned before tightening lids; tape may be used only if known not to affect sample analysis.
- Sample containers must be labeled and handled as outlined in *SOP-18, Packing and Shipping of Environmental Samples* and *SOP-19, Sample Handling and Custody*.
- Samples must immediately be preserved according to the method specifications appropriate for the laboratory parameters to be analyzed. And unless specified otherwise, at a minimum, the samples must be immediately chilled to 4 ±2 degrees Celsius (°C) and this temperature must be maintained through delivery to the laboratory for analysis.
- Sample holding times must conform to the method specifications of the required analytical methods.
- Alternative methods to obtain soil samples may be used only if the alternative methods have been approved by the PM and/or FM and documented in the QAPP according to *SOP-20, Field Procedure Change Management* and/or in the *Field Notebook*.
- Because of their volatile nature, samples collected for analysis of volatile organic compounds (VOCs), gasoline range organics (GRO), and/or volatile petroleum hydrocarbons (VPH) will be collected with special precautions as detailed below in Section 5.7.
- Each soil sample fraction collected for analyses other than VOCs, GRO, or VPH will be thoroughly homogenized using a sampling spoon or trowel. The homogenized material will then be divided equally among the appropriate sample containers. The sample containers will then be sealed tightly. Care should be taken to ensure that the sampling tools and containers (such as a spoons and bowls) used for sample collection and homogenization do not interfere with the analytes of interest.
- Multi-incremental samples (MIS) should be collected by placing equal amounts (or aliquots) of soil collected from multiple locations into a decontaminated, dedicated collection container. The aliquots will then be homogenized using a sample collection tool such as a scoop or spoon. The homogenized material will be divided equally among the appropriate sample containers, and the sample containers will be sealed tightly. Refer to *SOP-22, Multi- Increment® Sampling for Surface Soil* for further details regarding collection of MIS samples.

5.2 Sampling Tools and Equipment

Equipment that may be used to facilitate the collection of surface or subsurface soil samples includes, but is not limited to, the following items:

- Photoionization devices (PID) or Flame-ionization device (FID)
- Stainless-steel trowel, scoop, or spoon
- Stainless-steel hand (bucket) auger
- Stainless-steel split spoon, split barrel, or continuous sampler
- Shovels, pickaxes, pick mattocks, or similar excavating tools
- Soil core samplers (En Core® sampler, TerraCore®, or equivalent)
- Stainless-steel bowls or pans
- Field notebook
- *Soil Boring Log Datasheet* or other field datasheet
- Waterproof and permanent pens and markers
- Digital camera
- Paper towels
- Aluminum foil
- Decontamination equipment (buckets, brushes, detergent, etc.)
- PPE
- Sample cooler
- Ice or gel-ice
- Sample jars and labels
- Chain-of-custody forms
- Soil classification charts
- Ziploc® (or similar) resealable bags
- Survey stakes or flags
- Hammer

5.3 Decontamination

Before collecting any soil samples, all reusable, nondisposable sampling equipment should be decontaminated. Decontamination supplies must be on hand so that equipment can be decontaminated in the field if sampling equipment is to be reused. Each piece of reusable sampling equipment should be decontaminated between each sample location or interval. Spent decontamination fluids will be managed according to the *Appendix B, Project-specific Waste Management Plan*. Procedures presented in *SOP-14, Equipment Decontamination Procedures*, will be followed for decontamination of re-usable field equipment and for personnel decontamination.

Disposable sampling equipment will be used whenever feasible to minimize decontamination and the potential for cross-contamination. All disposable sample equipment will be inspected before use to confirm that it is clean and free of potential contaminant.

5.4 Surface Soil Sampling

Under Alaska regulation 18 Alaska Administrative Code (AAC) 75.990(127), surface soil is defined as soil that extends to 2 feet below ground surface (bgs). However, the depth that is considered surface soil may vary depending on project DQOs and investigation approaches, as defined in *Worksheet 17.*

Surface soil samples can be collected in paved and unpaved areas. In paved locations, surface asphalt or concrete will need to be removed mechanically or by hand, as will any

pavement base material located beneath the paving. In unpaved locations, surface vegetation such as a muskeg layer may need to be removed before sampling.

Surface soil samples may be collected as either discrete or MIS samples. Each surface soil sample will be collected using a stainless steel scoop, spoon, or other appropriate tools. Samples for VOC analysis will be collected directly from the soil column at the specified sampling depth interval bgs if possible (see Section 5.7). For non-VOC samples, the sampler, wearing clean disposable nitrile gloves, will remove materials, including pebbles and roots, from the mixture as the sample is collected. Each non-VOC sample will be collected by thoroughly homogenizing material from the appropriate depth interval bgs (as stated in the site-specific sampling plans in *Worksheet 17* and *Appendix D*) from the respective sampling location. A clean, decontaminated stainless-steel scoop or spoon will be used to collect the soil sample and fill all laboratory-supplied analytical sample containers.

5.5 Subsurface Soil Sampling

Under Alaska regulation 18 AAC 75.990(123), subsurface soil is defined at as soil that is more than two feet bgs. Before subsurface soil sampling, each sample location should be checked and cleared for buried utilities before intrusive activities begin, according to *SOP-03, Utility Clearance for Intrusive Operations*.

5.5.1 Shallow Subsurface Soil Sampling with Hand Tools

Shallow subsurface soil samples will be collected as discrete samples. Shallow subsurface soil samples can be collected by hand using a wide variety of sampling equipment and devices. Common equipment used to collect shallow subsurface soil samples include soil coring devices, various types of hand augers (bucket-type, continuous-flight, and posthole), and other common hand tools such as shovels and pickaxes. Depending on field conditions or sampling objectives, several types of sample collection equipment maybe used to collect soil samples at a single location. Of the equipment listed, only soil coring devices collect an undisturbed soil sample and thus are recommended for sampling of volatile organic (that is, for VOCs, GRO, and/ VPH). Bucket augers and other common hand tools are not recommended when an undisturbed soil sample for volatile organics is desired. Sampling personnel should choose the sampling equipment that is best suited for project requirements and task needs.

Using a decontaminated hand auger (or similar equipment), the soil borehole will be advanced to the depth immediately above the sampling interval, and all cuttings will be removed from the borehole. Before advancing a borehole, remove all unnecessary rocks, twigs, and other non-soil materials from the selected sampling location. Assemble the sampling equipment, if necessary, per the manufactures specifications and place the sampler in position with the bit or cutting shoe touching the ground. Begin turning the auger with a clockwise motion or driving the soil core device with the slide hammer until the desired sampling depth is obtained.

During advancement of the auger or coring device, cuttings from within and around the borehole will be periodically removed and placed next to the borehole. If the sample is to be collected using the same hand auger or soil coring device, the auger bucket or core sampler will be decontaminated (or replaced with a decontaminated bucket or sampler) before collecting the soil sample. The discrete sample will then be collected by advancing the sampling equipment to the appropriate depth interval and retrieving the soil sample. When

collecting samples at depths greater than 12 inches, it is advisable to discard approximately the upper 1 inch of material in the top portion of the auger or sampler because of borehole slough and cave-in. The sample will then be immediately transferred into laboratory-cleaned sample containers using a decontaminated stainless steel spoon or trowel.

5.5.2 Deep Subsurface Soil Sampling

Deep subsurface soil samples are typically collected using split-spoon samplers. A split-spoon sampler is a soil coring device that consists of a length of carbon or stainless-steel tubing, split longitudinally and equipped with a sample shoe and a drive head. Split-spoon samplers are used in conjunction with a power auger or drill rig, and are usually either hammered or hydraulically pushed into the interval to be sampled. The interval(s) to be sampled may be either predetermined or determined according to criteria observed during advancement of the drilling equipment as specified in the site-specific sampling plans in *Worksheet 17* and *Appendix D*. The following procedures focus on sampling soil for chemical analysis, using a split-spoon or DPS continuous tube sampler. Soil samples obtained for physical characterization are typically collected using similar procedures.

Hollow-Stem Auger Drilling

Using hollow-stem auger (HSA) drilling equipment, the soil borehole will be advanced to the depth immediately above the sampling interval as described in *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*. During advancement of the auger, cuttings from around the augers will periodically be removed and shoveled into a pile near the borehole or into appropriately labeled drums. A split-spoon sampler then be attached to the end of a series of drive rods and lowered down the center of the hollow auger drill string. The split-spoon sampler will then be advanced ahead of the drill bit in order to collect a relatively undisturbed, representative soil sample. Standard Penetration Test (SPT) blow counts for that sample, as well as the interval from which the sample was obtained, will be recorded in the *Soil Boring Log Datasheet* according to *SOP-01* and *SOP-06*. Depending on the size of the split-spoon employed, typically 18 to 24 inches of soil should be recovered in advance of the drill bit. The split-spoon sampler will then be removed from the borehole and opened exposing the soil core for sample collection and examination. Soil samples for laboratory analysis should be collected from the undisturbed, middle portion of the soil core and soil from the very ends of the soil core must be discarded as they often contain disturbed soils. The sample will then be immediately and quickly transferred into clean, laboratory sample containers using a decontaminated stainless steel spoon or scoop as described in previous Section 5.1. The soil core will be examined by the field geologist, screened for VOCs using a PID or FID (see *SOP-04, Organic Vapor Monitoring and Air Monitoring*), and logged for lithology (see *SOP-06, Boring Log Completion, Soil Classification, and Logging).* Soil cores may also be photographed and recorded per *SOP-01*.

Direct Push System Drilling

Direct push system (DPS) soil samples are typically collected using a continuous tube sampler with polyvinyl chloride (PVC) liners such as Geoprobe's® DT325 Dual Tube Sampling System sampler, using the DPS drilling procedures described in *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*. At the top of each sample interval, the continuous tube sampler will be driven into the substrate to a depth equal to the length of the sampler. After the sampler has been advanced, it is retrieved from the borehole and the PVC liner containing the soil core is placed on a firm, horizontal surface, for opening, inspection, and sampling. The PVC liner for each sample core is then cut open to expose the soil sample core for soil sampling and examination. Samples for laboratory analysis will

be immediately transferred into clean laboratory sample containers using a decontaminated stainless-steel spoon or scoop, as described previously in Section 5.1. The soil core will then be examined by the field geologist, screened for VOCs using a PID or FID (see *SOP-04*), and logged for lithology (see *SOP-06*). Soil cores may also be photographed and recorded per *SOP-01*. Special attention must be paid to labeling and storage of individual core samples when continuous soil samples are collected from a single boring. In many instances, soil cores can be produced faster than they can be opened, logged, screened and sampled by a technician. In those instances when a backlog of cores is being generated, care must be made to protect the cores from direct sunlight, excessive ambient temperatures, and rain. These conditions may have an adverse effect on highly sensitive volatile organics within the core or the instruments used for screening. Always keep the cores labeled so that the up/down orientation is not lost. Proceed carefully, but quickly when field screening. If necessary, log soils for lithology information after sample collection.

5.6 Excavation and Stockpile Sampling

Soil sampling of excavations and stockpiles should be conducted using similar techniques as described in Sections 5.4 and 5.5.1.

5.6.1 Excavation Sampling

When collecting soil samples from excavations including test pits, soil samples should generally be collected from freshly uncovered soil. Remove 4 to 6 inches of soil immediately before sample collection. If the excavation has been open for longer than 1 hour, remove at least 12 inches of soil immediately before collection. Do not collect samples from disturbed soil that has fallen into the bottom of the excavation pit. If the depth of the excavation is such that sampling cannot be safely conducted within the excavation, soil samples may be collected directly from the excavator bucket. When collecting soil samples from an excavator bucket, samples should be collected from the center of the bucket and away from the bucket sides. Refer to *Appendix A, Project-specific Health and Safety Plan,* and/or consult the project HSM regarding excavation safety before entering any open excavation.

5.6.2 Stockpile Sampling

Stockpiled soil must be field screened (see *SOP-04*) before sample collection. Field screening and analytical soil samples must be collected at least 18 inches beneath the exposed surface of the stockpile, unless additional shallower field screening samples are needed to represent soil contaminant heterogeneity. Contamination can be persistent near the bottom of long-term stockpiles, so it is important that some samples be collected near the base. Soil samples from the surface, within, and near the bottom of a stockpile will be collected using the methods previously discussed in Sections 5.4 and 5.5.1.

5.7 Volatile Organic Soil Sampling

If VOCs are among the analytes to be investigated at a particular site, discrete soil samples will be collected as soon as possible following exposure of the soil core. Special precautions must be taken when collecting samples for VOC analysis, which includes VOCs, GRO, VPH, and/or benzene, toluene, xylenes, and ethylbenzene (BTEX). All soil samples for VOC analysis must be collected in a way that minimizes sample volatilization through excessive atmospheric exposure, mixing, and/or other disturbance. It is recommended that VOC samples be collected using core-type samples such as split-spoons, continuous tube samplers, and soil coring devices that reduce the loss of volatiles during sampling. Soil

core samplers must be constructed of non-reactive materials that will minimize the loss of volatile organics from the sample.

GRO and VOC soil samples analyzed using ADEC analytical method AK101 and U.S. Environmental Protection Agency (EPA) Method SW8260B will be collected as follows:

- Collect a minimum of 25 grams of soil (a piece approximately 1 inch in diameter) with minimum disturbance directly into a 4-ounce (oz) or larger jar with a Teflon-lined septum fused to the lid. Interim storage/containers (such as resealable plastic bags) are not allowed.
- Immediately after collection, carefully add 25-milliliters (mL) of methanol (for method AK101, methanol must include a surrogate) until the sample is submerged. This step must be completed within approximately 10 seconds of placing the soil in the sample jar. VOC samples by Method SW8260B will be collected in TerraCore® kits that will include the 4-oz jar preserved with methanol described in this section, and non-methanol preserved containers described in the next section. All containers must be collected at the same time.
- After sealing, gently agitate the sample so that entire sample is submerged.
- Do not place tape, including evidence tape, on the sample container directly.
- Cool and retain samples at 4°C ± 2 degrees Celsius (°C).
- Collect a sample of the same material from the same location in an unpreserved jar for percent moisture determination.
- Collect appropriate field and laboratory quality control samples including field duplicates and matrix spike/matrix spike duplicate (MS/MSD) samples.
- Analytical samples should be collected in the following order:
  - VOCs, GRO, VPH, and BTEX
  - Semi-volatiles organic compounds (SVOCs); including pesticides, herbicides, diesel range organics (DRO), residual range organics (RRO), and polychlorinated biphenyls (PCBs)
  - Total organic carbon (TOC)
  - Metals
- All VOC samples should be accompanied by an appropriate trip blank from the time of collection until analysis at the project laboratory.

VOC samples analyzed using EPA SW-846 Method 5035A will be collected as follows:

- The discrete soil sample must be collected using a 5-gram soil core sampler with a new, dedicated, and disposable sample syringe or tip as described in American Society for Testing and Materials (ASTM) standard D6418-09. These devices are used to collect a specific soil sample mass for volatile organic analysis in a manner that minimizes loss of contaminants because of volatilization or biodegradation. Frequently accepted soil core samplers are listed below and details of these soil core samplers are provided in *SOP-07, Attachment 1: Soil Core Sampler Information.*

  - En Core® sampler
  - TerraCore® sampler
  - EasyDraw Syringe® with PowerStop Handle® sampler
  - Core N' One™ sampler
  - Lock N' Load™ sampler

- Soil samples will be collected from a specified location and soil depth as determined by field screening or as determined in the project-specific field sampling plan (*Worksheet 17* and *Appendix D*). After determining the sample location, the soil core sampler will be plunged into the soil core to collect a sample.
- To collect a sample, have ready a pre-weighed, pre-preserved, and labeled 40 mL volatile organic analysis (VOA) vial containing sodium bisulfate/water preservative. With the syringe or plunger seated in the handle, push the soil core sampler into freshly exposed soil until the sample chamber is filled. Do not pull the syringe or plunger back before use.
- Wipe all soil or debris from the outside of the soil core sampler and remove any excess soil that extends beyond the end of the sampler, so that the soil plug is flush with the end of the sampler. A filled chamber will deliver approximately 5 grams of soil.
- Place the mouth of the soil core sampler into the 40-ml VOA vial containing sodium bisulfate/water preservative and extrude the 5-gram sample into the VOA vial by pushing the syringe or plunger down. These VOC samples will be collected in TerraCore® kits that will include the 4-oz jar preserved with methanol described in the previous section. All containers must be collected at the same time.
- Quickly seal the lid back on the 40-ml VOA vial.
- Take care not to leave any soil grains along the threaded cap area of the VOA vial so that the lid can be screwed on tightly forming a tight seal. Be sure to remove any soil or debris from the top and/or threads of the vial.
- Immediately following collection, samples will be labeled with a unique sample identification, packaged appropriately, and kept at a temperature of approximately 4 degrees Celsius inside a cooler for preservation.
- VOA containers should be padded so that the glass walls of the containers do not come into direct contact with ice or other samples, thereby reducing the risk of cracking the glass containers.
- All volatile organics samples should be accompanied by an appropriate trip blank from the time of collection until analysis at the project laboratory.
- All sample collection details should be noted in the *Field Notebook* and *Soil Boring Log Datasheet*, according to *SOP-01*.

5.8 Quality Assurance/Quality Control Procedures and Samples

Quality Assurance/Quality Control (QA/QC) samples should be collected during soil sampling according to the *Field QC Sample Summary* and *Site-specific Sampling Plans* in *Worksheets 17 and 20* and in *Appendix D*. QA/QC samples should be assigned unique sample identification and handled and submitted to the laboratory the same as field samples.

5.8.1 Equipment Blanks

Equipment blanks should be collected at a frequency specified in *Worksheets 17 and 20* and in *Appendix D*. An equipment blank sample is collected in the field by running ASTM Type II Reagent-Grade water (or deionized water with less than 15 microSiemens conductivity) across the surface of re-usable, decontaminated sampling equipment (typically the split-spoon or drive shoe of the DPS continuous tube sampler) and into appropriate sample containers.

5.8.2 Field Duplicate Samples

Field duplicates will be collected at a frequency specified in *Worksheets 17 and 20* and in *Appendix D*. Field duplicate samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.8.3 Matrix Spikes and Matrix Spike Duplicates

MS/MSD samples will be collected at a frequency specified in *Worksheets 17 and 20* and in *Appendix D*. MS/MSD samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.8.4 Sample Identification, Handling, and Documentation

Samples should be identified, handled, and recorded as described in this SOP and according to *SOP-01, Note Taking and Field Log Books*, *SOP-18, Packing and Shipping of Environmental Samples,* and *SOP-19, Sample Handling and Custody.*

6.0 Records

All records should be documented in a bound *Field Notebook* according to *SOP-01, Note Taking and Field Log Books* and/or the *Soil Boring Log Datasheets* provided in *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*.

7.0 References

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8.0 Definitions

Discrete soil sample: a discrete aliquot from a distinct sampling interval (of a specific sample size) that is representative of one specific location at a specific point in time.

Surface soil: generally considered to be the top 6 inches of a soil horizon profile (that is, soil from 0 to 6 inches bgs), soil down to depths of 2 feet bgs may be considered surface soil. For the purposes of this procedure, surface soil represents the soil in the 0- to 6-inch depth interval bgs.

Subsurface soil: the soils, silts, sands, and clays below surface soil.

9.0 Attachments

Attachment 1: *Soil Core Sampler Information*

SOP-08

Monitoring Well/Piezometer Installation

SOP-08: MONITORING WELL/PIEZOMETER INSTALLATION

1.0 Purpose

This standard operating procedure (SOP) provides the methodology for installing and constructing groundwater monitoring wells and piezometers.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in installation and construction of groundwater monitoring wells and piezometers at Galena Forward Operating Location (FOL) projects and tasks. This SOP was developed in accordance with the following guidance documents:

- *Monitoring Well Guidance* (Alaska Department of Environmental Conservation [ADEC], 2009)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)
- *Standard D5092: Standard Practice for Design and Installation of Ground Water Monitoring Wells* (American Society for Testing and Materials [ASTM], 2004).

This SOP focuses on the most common monitoring well installation tasks anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-09, Monitoring Well Development*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*

3.0 General

Data collected from monitoring wells and piezometers at investigation sites support various site characterization objectives, including delineation of the nature and extent of a contaminant plumes, development of a conceptual model of the subsurface lithology, assessment of aquifer properties, and development of a long-term monitoring network to detect trends in site groundwater elevations and contaminant concentrations. Wells installed for each of these purposes must satisfy different requirements, and may require different strategies for well design and installation. Representative groundwater samples and groundwater level measurements depend upon proper monitoring well design and construction, which should reflect anticipated contaminant types and concentrations, project objectives, and site conditions. Selection of monitoring well type, construction materials, and drilling method is commonly a site-specific determination and often site logistics and economics influence well design and installation choices.

Well design and installation must prevent the introduction of surface contaminants into the groundwater and prevent the transfer of groundwater or contaminants between stratigraphic intervals within the well borehole or along the well annulus. Do not install monitoring wells in locations where they are subject to periodic or seasonal inundation by floodwaters, unless the well has special watertight construction. Protect monitoring wells integrity from soil erosion, soil settlement, shrink-swell soil conditions, frost heaving of soils, damage by vehicles or heavy equipment, or other site specific hazards. Monitoring wells should not be completed at-grade or below-grade.

Drilling techniques anticipated for use at Galena FOL projects and tasks include hollow-stem auger (HSA) and direct push systems (DPS):

- HSA drilling will be used to install 2- to 4-inch diameter (or greater) permanent groundwater monitoring wells or when consolidated geologic conditions are expected. The drill rig will be mounted on a heavy-duty truck, or it will be self propelled by an all-terrain mechanized track system.
- DPS drilling will be used for soil sampling in unconsolidated lithology and to install 0.75- to 1.0-inch-diameter microwells or piezometers. The drill rig will be mounted on a heavy-duty truck, or it will be self propelled by an all-terrain mechanized track system.

Microwells and piezometers will have a 0.75- to 1-inch-diameter casing with an attached screen; they are used primarily to temporarily monitor the static water level or obtain a finite number of water samples for water quality or contaminant screening purposes. Microwells use pre-packed screens for installations in small-diameter DPS boreholes.

Successful installation of a well requires that the procedures for installing each component of the well are followed and well documented. There are nine essential components of a well installation:

- Well casing
- Well screen
- Filter pack
- Annular seals (lower and upper surface seals)
- Surface completion
- Well protection
- Field notebooks
- Well completion report
- Records Management

References and definitions are provided in Sections 8.0 and 9.0, respectively. Figure 1 illustrates the design of a typical groundwater monitoring well.

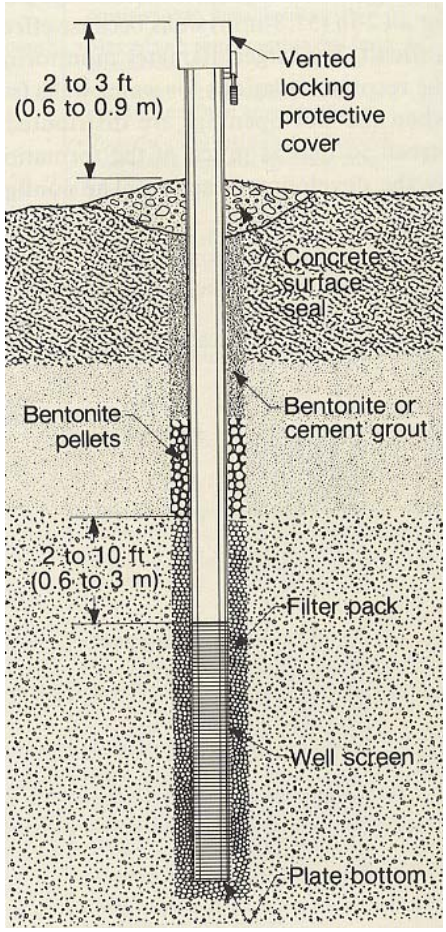


Figure 1. Typical Monitoring Well (Driscoll, 1986)

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) verifies that monitoring well and piezometer installation procedures comply with this SOP and the requirements of the enforcing agencies. Alternate installation requirements and procedures required by local agencies or other modifications must be documented and approved by the PM.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities and for ensuring that monitoring wells and piezometers are installed in compliance with this SOP and all field staff engaged in this activity are trained in this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) will develop or direct the development of a detailed sampling plan that includes the specifics of the well design and installation, particularly the materials and procedures to be used. The FTL, or their designee, should know the requirements for well installations and should maintains adequate documentation of the installation process and materials used to demonstrate that the well has been properly installed.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) oversees site-specific health, safety, and environment (HS&E) protocols and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE, lists the requirements in the *Project-specific Health and Safety Plan* (HSP) (Appendix A), coordinates with the FM and Safety Coordinators (SC) to certify the PPE, and conducts project health and safety audits to evaluate the effectiveness of the HS&E program.

4.5 Safety Coordinator

The role of SC is fulfilled either by the FM or the FTL(s). The SC assists in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements, and receives feedback from project staff regarding the effectiveness of the PPE and HS&E procedures.

5.0 Procedure

Installation of monitoring wells will be performed under the direct supervision of a qualified geologist, engineer, or other professional. Permanent monitoring wells should be constructed in accordance with the *Monitoring Well Guidance (*ADEC, 2009*)* and ASTM Standard D5092 (see Attachment 1).

A monitoring well is generally composed of a well casing, well screen, filter pack, and sanitary or grout seal. Permanent monitoring wells will be installed in open boreholes advanced by an HSA drill rig. Soil borings should be advanced until the desired depth is obtained and the subsurface soil demonstrates saturated soil conditions. Once the desired borehole depth is obtained, all drill tooling will be removed from the borehole and the monitoring well will be installed. The diameter of the HSA boreholes will be at least 4 inches larger than the outside diameter of the blank casing and screen. This allows for proper installation of materials within the annular space to create an adequate annular seal.

The following general guidelines will be followed to properly complete each monitoring well to the desired depth:

1. Properly decontaminate well construction materials before installation.
2. Prevent contamination when joining casings and attaching the screen.
3. Pour the filter pack into the annulus to a minimum of 2 feet above the top of the screen and 1 foot beneath the well end cap.
4. Use bottom caps or end plugs.
5. Use permanent or temporary surface casing if contamination or sloughing is a potential issue.
6. Apply filter packs with a tremie pipe or similar method (unless using a pre-packed filter).
7. After installation, “sound” the filter pack for proper placement.
8. Place a fine-grain sand filter 0.5 to 2 feet thick at the top of the filter pack and below the annular seal to help prevent infiltration of bentonite into the filter pack.

9. Apply bentonite pellets or granules to seal the annular space by pouring them freely or through a tremie pipe.
10. If the well is 40 feet or greater in depth, pump grout or slurry into the annular space by using a tremie pipe.
11. For wells less than 40 feet deep, pour grout or slurry freely into the annular space, with or without the use of a tremie pipe.
12. If more than 10 feet of standing water is present, use a tremie pipe to install neat cement and bentonite-cement grouts.
13. Submerge the end of the tremie pipe in the sealing material when installing a slurry or grout.
14. When using a slurry or grout, allow 24 hours between installation of the annular space seal and installation of the protective pipe cover. Fill any settlement in the annular space seal before installing the protective cover.
15. Install a cement surface seal at the ground surface.

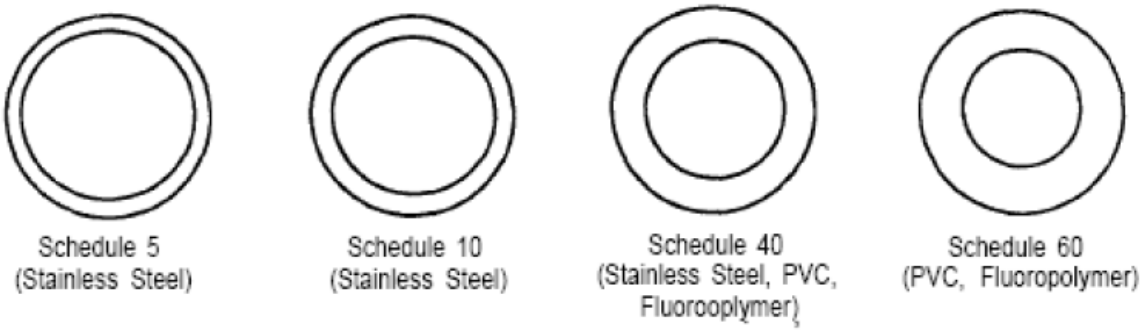
5.1 Well Casing and Well Screen

5.1.1 Well Casing

The well casing allows access to groundwater from the ground surface. To eliminate the introduction of contaminants when sampling, join casing sections together with threaded couplings rather than glues, in order to eliminate the introduction of adhesive contaminants into the groundwater. Threaded couplings should have O-rings to complete the seal, and the well casing should be flush, on the inside.

The inside diameter of the well casing should be at least 1.9 inches, with the exception of microwells and piezometer installations. Monitoring wells in Alaska commonly use Schedule 40 polyvinyl chloride (PVC), nominal 2-inch-diameter casing. Deeper wells, or wells that need large, dedicated pumps or tubing, may require 4-, 6-, or 8-inch-diameter casing. However, most monitoring wells will use a smaller casing (2 or 4-inch-diameter) to minimize the amount of water generated during sampling events. Table 1 lists the inside diameters of various well casings.

Table 1. Casing Thickness and Diameter for Monitoring Well Materials (EPA, 1991b)



Wall Thickness (Inches)	Sch 5	Sch 10	Sch 40	Sch 80	Outside Diameter (Standard)
Nominal 2	0.066	0.109	0.164	0.218	2.375
Nominal 3	0.063	0.120	0.216	0.300	3.500
Nominal 4	0.083	0.120	0.237	0.337	4,500
Nominal 5	0.109	0.134	0.258	0.375	5.563
Nominal 6	0.109	0.134	0.280	0.432	6.625
Inside Diameter	**Sch 5**	**Sch 10**	**Sch 40**	**Sch 80**	
Nominal 2	2.245	2.157	2.067	1.939	
Nominal 3	3.334	3.260	3.068	2.900	
Nominal 4	4.334	4.260	4.026	3.826	
Nominal 5	5.345	5.285	5.047	4.813	
Nominal 6	6.407	6.357	6.065	5.761	

5.1.2 Well Screen

The well screen is the part of the well that allows groundwater to enter into the monitoring well and allows access to the aquifer. Determining the slot size and well screen length characteristics of a well screen depends on the purpose of the monitoring well and aquifer characteristics. The proper slot size of the well screen should be determined based upon the filter pack selected for the monitoring well and the formation material. Monitoring wells typically installed in Alaska within unconsolidated soil use a 20-slot (0.020-inch) well screen with a No.10-20 silica sand pack, or 10-slot (0.010-inch) well screen with a No.20-40 silica sand pack. Screen slots will be sized to prevent 90% of the filter pack from entering the well. The standard screen slot size anticipated for newly installed wells at Galena FOL is 10-slot (0.010-inch), unless field conditions indicate otherwise and approval of the PM has been obtained. Monitoring wells must use commercially manufactured, machine-slotted well screens. Table 2 lists the recommended screen slot size and filter pack characteristics.

Table 2. Recommended Filter Pack Characteristics for Common Screen Slot Sizes (ASTM D5092)

Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Powers Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these cases.

The type of well screen and slot size controls the amount of open area in a well intake (EPA, 1991b). In addition, the depth of the screened interval and the well screen length can affect the water quality and hydraulic characteristic results. Minimize the length of the well screen to avoid dilution during sampling. Increased open area in the monitoring well screen allows effective development and easy flow of water from the formation into the well. The well screen depth and length are determined on a site-specific basis in consideration of water table variations, site stratigraphy, expected contaminant behavior, and groundwater flow. Typically, well screens are 1 to 10 feet in length, and only rarely equal or exceed 20 feet (EPA, 1991b). Conventional monitoring well screens at petroleum-contaminated sites in Alaska are typically 10 feet long and are installed with a portion of the screen above the high water table to allow for seasonal water table fluctuations. However because of the large thickness of the smear zone at the former Galena FOL, screens longer than 10 feet may be required.

Clustered monitoring wells are often installed to determine vertical hydraulic or contaminant concentration gradients. Clustered wells should consist of individual wells installed in separate boreholes in close proximity to each other and screened at varying depth intervals. Nested wells that consist of multiple aquifer completions in a single borehole should not be installed. Figure 2 illustrates both clustered and nested well designs. When installing clustered wells, drill the deepest well first. Refer to borehole sampling information to determine what formation interval to screen or where to place seals to prevent communication between the aquifers.

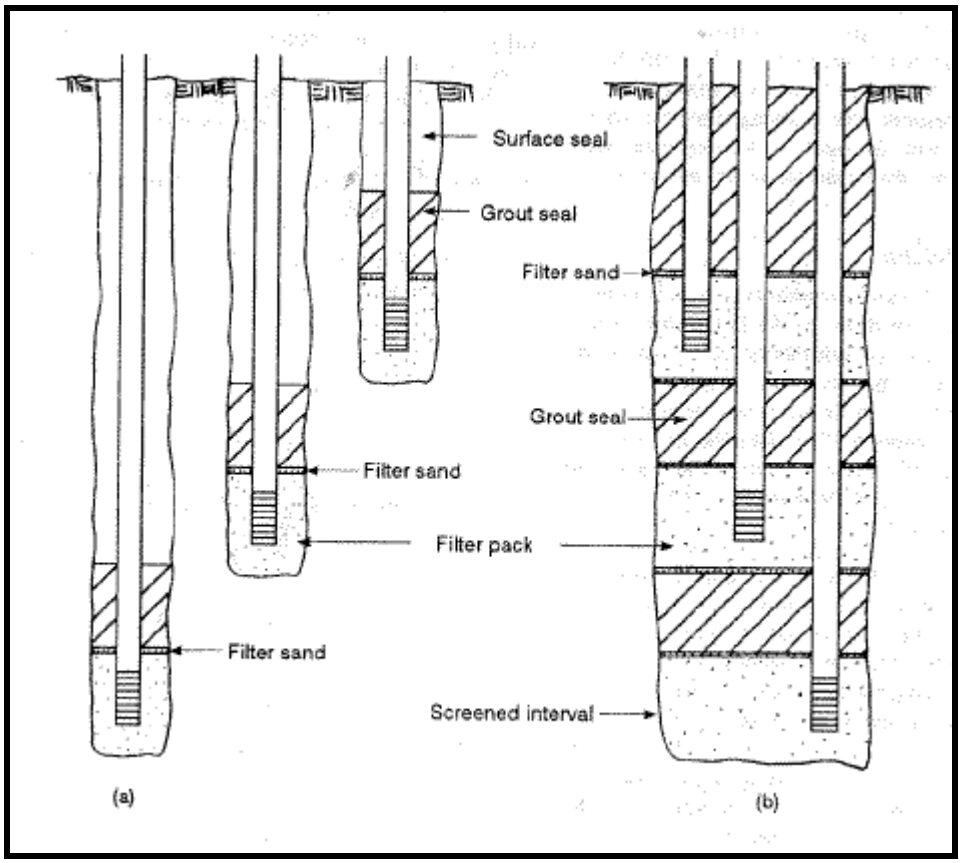


Figure 2. Piezometers Installed as (a) Clusters, or (b) Nested (EPA, 1991b).

5.1.3 Materials

A variety of construction materials are used for the well casings and well screens. The material used for well screens is generally selected based on the same guidelines used for selecting well casing. There are many different casing materials used in design of a monitoring well; thermoplastic materials (such as PVC) and stainless steel are the most widely used. Typically in Alaska, PVC well screens are used because they provide a strong monitoring well with good chemical resistance (EPA, 1991). The type of well casing and well screen material to be used, screening intervals, screen slot sizes, and specific material decontamination procedures are provided in the site-specific field sampling plan in Appendix D.

5.1.4 Installation Procedures

The following general procedures should be followed when installing well casings and well screens:

- Keep the well casing sealed in plastic until it is ready to be installed into the borehole.
- Carefully assemble and install well casings and screens to prevent damage to the sections and joints.
- Sections of well casing and screen must be mechanically connected, such as flush threading. Use of glue or solvents to connect or seal casing is prohibited.

- Secure an end cap at the bottom of the well screen before installing section(s) of well screen into the well boring.
- If using pre-pack well screens, take care to not tear or damage the outer fabric or screen holding the pre-pack filter sand to the well screen.
- Install the well casing and well screen straight and plumb and centered within the middle of the borehole.
- Install the filter pack from the bottom of the borehole to at least 2 feet (up to 5 feet) above the top of the well screen. At locations that have shallow groundwater, the filter pack can be placed to extend to at least 1 foot above the top of the screen.
- During installation, place a cap on top of the casing to prevent well materials from entering the well casing.
- A completed monitoring well should be sufficiently straight to allow passage of pumps or sampling devices.
- Document the calculated and actual quantities of materials used in the well installation and the condition of well materials in the Field Notebook in accordance with *SOP-01, Note Taking and Field Log Books*.

5.2 Filter Pack

The well screen of each monitoring well should be surrounded by a permeable, course-grained sand known as the filter pack. Fill the annular space surrounding the well screen with a filter pack of uniform-grain-size sand that is coarser and has a higher permeability than the natural, surrounding formation. The filter pack should allow groundwater to flow freely into the well from adjacent formation material and minimize or eliminate fine-grain material from entering the well. The use of natural formation material as the only filter pack is not acceptable.

In Alaska, most monitoring wells within unconsolidated soils are installed with either a No.10-20 or 20-40 silica sand filter pack. The filter pack should extend above the well screen to a length of 20 percent of the well screen length, but no less than 2 feet (ASTM D5092). The thickness of the filter pack between the borehole and the well screen should be at least 2 inches but no greater than 8 inches (EPA, 1991).

5.2.1 Materials

Filter pack materials must be poorly graded (well sorted) to provide good permeability and hydraulic conductivity of the materials near the screen. The filter pack material should be clean, chemically inert, and well-rounded siliceous material and should be slightly coarser than the surrounding formation. Using coarser material increases the effective well diameter. The sand or gravel used for filter packs should be of uniform size, be hard and durable, and have an average specific gravity of 2.50 or greater. The filter pack material should be obtained from known clean sources and should be well washed and free of clay, dust, and organic matter. No more than 5 percent of the sand or gravel should be soluble in hydrochloric acid.

Filter pack material should meet the National Sanitary Foundation (NSF) standards and be packaged in properly sealed and marked packages. Record the NSF label information and any associated lot or identification numbers in the Field Notebook.

The filter pack is designed for the anticipated and tested grain size distribution in the screened formation and the size of well-screen openings (see Table 2). The filter pack should have a grain size distribution and uniformity coefficient compatible with the formation materials and the screen (Driscoll, 1986). The filter pack must not extend across more than one water-bearing unit (or aquifer). Install the filter pack in all wells (deep or shallow) in a manner that minimizes bridging and void spaces in the filter pack.

Any open annular space outside of a pre-pack filter should be filled to the maximum extent practical with additional filter pack material, as previously described. Natural collapse can also be allowed to fill annular space around a pre-pack filter.

5.2.2 Installation Procedures

The following procedures should be followed to optimize the installation of the filter pack and the quality of the well:

- Calculate the volume of the well annulus (that is, the filter pack required), and document in the Field Notebook the type and volume of the filter pack material installed.
- Record in the Field Notebook the NSF label information and any associated lot or identification numbers from the filter pack material.
- Periodically measure the filter pack during installation by using a sounder or weighted measuring tape to confirm uniform placement and prevent bridging.
- Measure the depth of the top of the filter pack to verify the thickness of the pack and to confirm proper depth placement above the well screen (at least 2 feet above the screen.
- Under no circumstances should the filter pack extend into any aquifer other than the aquifer to be monitored.

5.3 Annular (Bentonite) Seal

Annular seals prevent vertical movement of water or contaminants between the filter pack, the adjacent soil formation, and the natural backfill material above the screen.

There should be two annular seals in standard monitoring wells, one above the filter pack (lower seal) and one at the ground surface (upper seal). All permanent monitoring wells should be constructed with a lower annular seal at the top of the filter pack to confine the well screen within the desired sampling interval. The lower annular seal should be installed at least 2 feet thick on the top of the filter pack to prevent seal material from leaching into the filter pack. Pelletized bentonite is preferred for this application; however, a bentonite slurry or similar material may also be used, if appropriate.

Install the upper annular seal near the ground surface to protect the well from infiltration of surface runoff and potential aboveground contaminants The upper annular seal should be installed at least 2 feet thick and extend from approximately 1 to 2 feet below ground surface (bgs) to 3 to 4 feet bgs. This annular seal should be bentonite pellets, bentonite slurry, or similar material.

For shallow wells constructed with approximately only 5 to 6 feet between the top of the filter pack and the ground surface, it is acceptable to combine the upper and lower annular seals into a single annular bentonite seal approximately 3 to 4 feet thick from the top of the filter pack to approximately 1 to 2 feet bgs. For deeper wells, the annular space between the two seals should be filled with a bentonite slurry or coarse bentonite chips.

When using bentonite pellets to seal the filter pack, install the pellets in sequential, 1-foot-thick layers. Hydrate each layer by pouring an approximately equal volume of clean, potable water into the borehole before placing the next layer of pellets. Continue this process until the required minimum 2-foot seal thickness is installed. Use a weighted tape measure, measuring rod, or similar measurement device to check that the filter pack seal is installed in the proper depth interval. Bentonite grout is suggested when freeze–thaw processes may affect the well.

5.3.1 Materials

Pelletized bentonite is preferred for this application; however, the following may also be used:

- Neat cement grout (not recommended for use with schedule 40 PVC well casing or where there might be shrinkage that would allow leakage along the casing)
- Sodium-based bentonite slurry with a mud weight of at least 10 pounds per gallon
- Sodium-based bentonite granules
- Sodium-based bentonite pellets
- Bentonite-cement grout.

Measure the thickness of the bentonite before hydration. The permeability of the seal must be one to two orders of magnitude less than that of the surrounding formation. The seal must be chemically compatible with the anticipated contaminants and chemically inert so that it does not affect the quality of ground-water samples.

Use fine-grain bentonite, such as granules and powder, for seals placed above the existing water level. A bentonite slurry should be used for the bentonite seal below the existing water level. Coarse bentonite, such as pellets and chips, can also be used for bentonite seals located just below the groundwater water level.

5.3.2 Installation Procedures

The following procedures should be followed for placement of the annular seals:

- When installing an annular seal, determine the type and volume of annular seal material needed by referring to the information in the well borehole log. Record the type, calculated volume, and actual volume of annular seal material used in the Field Notebook.
- Install at least 2 feet of lower annular seal material above the filter pack.
- Install at least 2 feet of upper annular seal material at least 1 to 2 feet bgs.
- At locations where there is shallow groundwater, the upper and lower annular seal may be combined so that there is 2 feet of filter pack above the well screen and 3 to 4 feet of annular seal. Document alternative procedures like this in the Field Notebook.
- Install the annular seal in 1-foot layers or less and hydrated with clean, potable water between layers.

- Water used for bentonite hydration or for mixing bentonite slurry should be from an approved potable source, of suitable quality, and free of pollutants and contaminants. Document the volume of water used in the Field Notebook.
- Measure the depth to the seal by using a weighted tape measure, measuring rod, or similar measurement device to confirm that the thickness and depth of the seal meets the design requirements.
- Allow the bentonite to completely hydrate in accordance with the manufacturer's instructions before filling the remainder of the annular space with bentonite/cement grout (described below).
- For deep wells, install the seal material by using a tremie pipe to prevent bridging. When using cased borehole drilling methods (such as HSA), the annulus between the monitoring well casing and drill stem may serve as the tremie pipe.
- Record the actual volumes of bentonite and grout used during well construction in the Field Notebook and explain any discrepancy between the calculated and actual volume.
- Record the details of the well construction including annular seal depth, thickness, seal material type, and installation methods in the Field Notebook.

5.4 Surface Completion and Well Protection

Two types of surface completions are typical to monitoring well installations:
(1) aboveground completion and (2) flush-mounted completion. Surface completion and well protection prevent surface runoff from infiltrating the well annulus and protect the well from accidental damage or vandalism. Properly survey the well installation after completion and document the survey measurements.

5.4.1 Surface Seals

There must be a surface seal of concrete around the protective well casing at each well that fills the upper annular space. A surface seal is a separate upper annular seal installed above, but not connected to, the bentonite seal (except in very shallow monitoring wells). Because of the temporary nature of microwells, surface seals other than hydrated bentonite are not necessary. For further information regarding surface seals (upper annular seals) refer to Section 5.3.

5.4.2 Surface Completion and Monuments

Construct each monitoring well with a surface monument to protect the well casing from damage. Depending on site conditions, concrete may be used to create a secure monument foundation and provide an additional surface seal. Constructed concrete monument foundations (slabs) should be sloped away from the well so that it sheds rain and surface water. On a site-specific basis, alternative well construction designs may be used if approved by the PM (for example, in areas of permafrost, frequent frostjacking, or shallow groundwater).

If an aboveground monitoring well monument is installed, construct the well monument with a protective casing, preferably made of steel. Extend the protective casing at least 6 inches above the top of the well casing, and at least 2 feet into the ground. In areas that experience frost heaving, extend the protective casing from below the depth of frost penetration (3 to 5 feet below grade, depending on local conditions) to approximately 6 inches above the top of

the well casing. Install the protective casing before the upper annular seal sets. Seal and immobilized the protective casing within the concrete monument foundation. To accommodate sampling equipment, make sure there is sufficient clearance, usually 6 inches, between the lid of the protective casing and the top of the riser. Drill an approximately ¼-inch-diameter weep hole in the protective casing approximately 6 inches above ground surface to permit water to drain out of the annular space between the protective casing and the riser. In winter, this hole will also prevent water freezing between the protective casing and the well casing. Place dry bentonite pellets, granules, or chips in the annular space from 3 to 4 inches below the weep hole within the protective casing. Place coarse sand or pea gravel (or both) in the annular space above the dry bentonite pellets and within 6 to 12 inches below the top of the well casing to allow water to drain from within the protective casing and prevent insect habitation.

If a flush-mount monitoring well monument is installed, construct the well monument with a steel protective cap with a subsurface casing that extends approximately 2 feet bgs. The top of the steel protective cap and protective casing must be flush with the ground. Drill an approximately ¼-inch-diameter weep hole in the protective casing approximately 18 to 24 inches from the top of the protective casing to permit water to drain out of the annular space between the protective casing and the well casing. Install the protective casing before the upper annular seal sets, making sure that the weep hole is above the top of the upper annular seal. Seal and immobilized the protective casing in a concrete, flush-mount foundation, if possible. To accommodate sampling equipment, make sure there is sufficient clearance, usually 6 inches, between the steel protective cap and the top of the well casing. Place coarse sand or pea gravel (or both) in the annular space within the protective casing to within 2 to 3 inches below the top of the well casing to allow water to drain from within flush-mount monument and prevent insect habitation.

Regardless of the type of monument, each well will be fitted with a locking well casing cap that easily fits below the protective well monument cap. Install a leak-proof, locking well casing cap on the top of each well casing to prevent vandalism and to prevent water from entering the well casing. The protective well monument cap should be leak-proof and secured with multiple bolts for additional protection.

Document all construction details and materials used in the Field Notebook. Clearly mark monitoring wells with a unique well identifier on the inside and outside of the protective casing.

Aboveground Completions

The following basic procedures will be followed for aboveground completions:

- Extend the well casing approximately 2 to 3 feet above the ground surface.
- Install a protective casing around the aboveground well casing. Install the protective casing in a plumb, vertical position. Place concrete (surface seal) above and around the base of the protective casing up to and becoming part of the surface concrete pad. The concrete seal should not extend below the base of the protective casing; this will allow trapped water during installation and sampling events to drain.
- The protective casing may be painted if requested by the client.
- Install a weatherproof, locking well monument cap on the top of the protective casing so there is adequate clearance between the top of the well casing cap and the bottom of the well monument cap.

- A concrete surface pad may be placed around the well protective casing. The pad should be approximately 3 feet square by 4 inches thick and sloped away from the protective casing.
- Install bollards around wells where traffic might threaten the integrity of the well (see Section 5.5.3 for detailed instructions).
- When possible, attach a stainless steel, well identification tag to the outside of the protective casing.

Flush-mounted Completions

The following procedures will be followed for flush-mounted completions:

- Cut off the well casing below grade, leaving enough space to install an leak-proof, locking well casing cap.
- Install a subgrade, protective casing with a steel protective cap around the top of the well casing. Install the protective casing to approximately 2 feet bgs. The top of the steel protective cap and protective casing must be flush with the ground.
- Drill an approximately ¼-inch-diameter weep hole in the protective casing approximately 18 to 24 inches from the top of the protective casing to permit water to drain.
- To accommodate sampling equipment, make sure there is sufficient clearance (typically 6 inches) between the steel protective cap and the top of the well casing.
- Place coarse sand or pea gravel (or both) in the annular space within the protective casing to prevent water infiltration and insect habitation.
- A concrete flush-mount foundation may be placed around the well protective casing. The concrete foundation must slope away from the protective casing.
- For flush-mounted completions located in high-traffic areas, follow the procedures outlined above except that traffic-rated cement or a steel vault should be used and cemented flush with the traffic surface.
- For flush-mounted completions, be careful to construct watertight bonds between the protective structure and the cement surface seal.
- Install a weatherproof, locking well monument cap on the top of the protective casing and weatherproof, locking well casing cap on top of the well casing.
- Where significant amounts of runoff occur, additional protection measures may be required.
- When possible, attach a stainless steel, well identification tag to the inside of the protective casing.

5.4.3 Well Protection

Monitoring wells can have either aboveground or flush-mount completions. If the well casing is composed of metal and completed above the ground surface, attach a lockable cap to the top of the protective well casing and lock the cap with a padlock. If the well is not cased with metal and is completed above the ground surface, install a metal protective casing around the well. For flush-mount wells, install a protective well monument vault (or equivalent)

around the well with a lockable or bolt-on cover that has a waterproof seal. Install the cover level with the ground surface to help prevent the inflow of surface water.

Construct flush-mount well covers to withstand the maximum expected loadings (such as vehicular traffic or material staging). Install bollards around aboveground wells where traffic might threaten the integrity of the well. Install three or four bollards in a triangular or rectangular array at least 2 feet from the casing. Use 3-inch-diameter steel or wooden bollards that extend at least 4 feet above and 3 feet below the ground surface; the bollards must be tall enough to be easily visible to traffic. Bollards should not be placed in the concrete surface pads around the wells.

Paint the aboveground portion of the bollards with bright paint (such as yellow or orange), and place photo-reflective tape on the bollards if they are potentially hazardous during low-light conditions. In areas where there is a high probability of damage to the well (such as where there is high traffic, heavy equipment, or poor visibility), it may be necessary to also install posts, markers, signs, or other safety features, as described in ASTM D5787. The level of protection should adequately mitigate the potential risk of damage to the well.

5.5 Installation of Microwells

Microwells are small-diameter monitoring wells. Microwells are generally installed in boreholes driven by DPS and are typically less than 2 inches in diameter. Microwells installed by the DPS method use pre-packed well screens. Microwells have the same installation requirements as conventional wells except that a sand barrier is installed directly above the pre-packed well screen to prevent grout from entering the screens. Other than the following modification, installation of a microwell is the same as a monitoring well:

- Place a sand barrier directly above the pre-packed well screen in the annulus between the well casing (riser pipe) and the borehole wall as the probe rods are retracted.
- The sand barrier must not extend more than 2 feet above the top of the pre-packed well screen.
- Install an annular seal from the filter pack to the top of the well in general conformance with Section 5.3.
- The annular seal must prevent vertical migration of liquids into the borehole annular space.

5.6 Monitoring Wells in Frozen Ground

Monitoring wells are designed and constructed to minimize the effects on subsurface thermal behaviors and to withstand freeze-thaw forces creating frost heaving or frost jacking. Frost heaving or frost jacking is the upward movement of a well, caused by freezing and upward expansion of the soil. Frost heaving can change the height of the well casing, and, in some cases, separate casing sections. Monitoring wells installed into seasonally frozen ground (for example, screened in the seasonal active layer) must be designed and constructed so that representative groundwater samples can be collected throughout the year, including during periods of thaw. Screen wells in seasonally frozen soil deeper than the greatest expected depth of thaw to prevent them from going dry in the thawing season. Wells installed in a permafrost layer require special attention. Use caution when installing a well through permafrost that may act as a confining unit because flowing artesian conditions may occur. Firmly seal the thawed annulus between the pipe and the permafrost to prevent upward seepage from the confined aquifer. Minimize well damage by installing a surface

outer casing to a depth of 5 to 10 feet bgs and a steeply inclined cement cap around the surface protective casing (Driscoll, 1986). When frost heaving occurs and pressure is exerted on the cement cap, the surface protective casing must be able to rise without affecting the monitoring well casing (Driscoll, 1986). More information about frost heave and frost-heave-susceptible soils is available in ASTM D5918.

6.0 Records

All materials and procedures used during installation of wells should be documented in the Field Notebook, the Well Construction Datasheets, or both, in accordance with *SOP-01, Field Note taking and Field Logbooks*. Submit well completion reports to regulatory agencies as required and maintain all copies of field notes and well completion reports in the project files.

7.0 References

Alaska Department of Environmental Conservation (ADEC). February 2009. *Monitoring Well Guidance*.

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8.0 Definitions

Annular space or annulus: the space between the borehole wall and the well casing, or the space between the casing pipe and well casing.

Bentonite seal: a seal with expansion potential that is placed above the filter pack to provide a positive seal above the filter pack.

Filter pack: a chemically inert, uniform, well-rounded material (sand or gravel) that is placed in the annulus between the well screen and the surrounding formation to prevent formation material from entering the screen.

Monitoring well: a well constructed to extract groundwater for physical, chemical, or biological testing, or for measuring water levels.

Piezometer: a small diameter (typically well 0.75 to 1 inch) well installed to measure hydraulic head.

Surge block: a plunger-like tool consisting of rubber or Teflon® discs sandwiched between steel discs that may be solid or valved; used to alternate flow from the well casing into the surrounding formation.

Tremie pipe: a pipe (usually small diameter) that carries materials to the bottom of the borehole and allows placement of materials upward from the bottom without introducing appreciable air pockets or caved material formations.

Well casing: an impervious durable tubular product that is a permanent feature of a well that is designed to provide access from the ground surface to some point in the subsurface and to serve as a passage for groundwater level measurements and sample collection devices.

Well screen: a section of casing that has been slotted to allow the free movement of water into the well.

Well sorted: clastic sediment or rock that consists of particles having approximately the same size.

Annular seal: the material placed between the borehole wall and the well casing.

Surface seal: the material placed above the annular seal from 2 feet bgs to the ground surface.

9.0 Attachments

Attachment 1: *ASTM Standard D5092*

Attachment 2: *Well Construction Datasheet*

SOP-09

Monitoring Well Development

SOP-09: MONITORING WELL DEVELOPMENT

1.0 Purpose

This standard operating procedure (SOP) provides guidance for developing temporary and permanent monitoring wells after their installation and before their designated use.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in well development procedures in monitoring wells at Galena Forward Operating Location (FOL) projects and tasks and was developed according to Alaska Department of Environmental Conservation (ADEC) and other reference documents, including the following:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Monitoring Well Guidance* (ADEC, 2009)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures (ADEC, 2002)*

This SOP focuses on the most commonly used monitoring well development tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01: Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-12, Field Water Quality Measurements and Calibration*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*
- *SOP-21, Well Decommissioning and Abandonment*
- *SOP-24, Direct Push Groundwater Sampling*

3.0 General

The primary function of a monitoring well is to provide a representative sample of groundwater as it exists in the formation (ADEC, 2009). The overall objectives of monitoring well development are as follows:

- Restoring the aquifer properties near the well boring disturbed during drilling or direct push emplacement
- Removing the finer-grained materials from the surrounding filter pack that may otherwise interfere with water quality analyses
- Improving the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the well screen
- Removing all water introduced into the borehole while drilling

Formation characteristics change during drilling and well installation, and usually include the compaction of unconsolidated particles surrounding the annulus. In fine-grained soils, this can result in a mudwall around the boring annulus, which can impede free flow of formation water into the well (ADEC, 2009). Monitoring well development physically agitates the formation around the well boring by pushing and pulling water through the filter pack and surrounding formation. Thus flushes fine-grained soils into the well, where they either settle within the filter pack or are removed from the well during development and purging.

Common well development methods include combinations of surging, pumping, and bailing. The most effective well development method is alternating between using a surge block and pumping or bailing, so that multidirectional flow occurs through the filter pack and native formation around the well.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and engaging field staff with adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The Field Manager (FM) is responsible for coordinating and scheduling daily field activities. In addition, the FM is responsible for training field staff engaged in this activity in this SOP and for compliance with this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) should direct well development activities. The FTL, or their designee, should know the requirements and procedures for well development, and should maintain adequate documentation of well development activities.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for site-specific HS&E and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the *Project-Specific Health and Safety Plan* (HSP) (Appendix A), coordinates with the FM and/or Safety Coordinator (SC) to complete and certify the PPE program, and conducts audits on the effectiveness of the HS&E program.

4.5 Safety Coordinator

The role of SC is either taken by the FM or is designated to FTLs by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and ongoing HS&E procedures are effective.

5.0 Procedures

5.1 Equipment

Well development commonly involves using equipment to surge, pump, and/or bail a monitoring well. Typical equipment includes the following:

- Surge block on a cable or line
- Peristaltic sampling pump or similar pump (bladder and gear pumps are not recommended because of pump damage from fine sediments)
- Water quality monitoring instrument(s) capable of measuring dissolved oxygen (DO), oxidation-reduction potential (ORP), conductivity, pH, turbidity, and temperature
- Water level indicator
- Groundwater purge container, tank, or drum
- Field notebook and Well Development Datasheet
- PPE

5.2 Conventional Monitoring Well Development

Newly installed conventional monitoring wells will be developed no sooner than 48 hours after well installation, according to *SOP-08, Monitoring Well/Piezometer Installation* and ADEC *Monitoring Well Guidance* (ADEC, 2009). Use a surge and purge method to develop conventional monitoring wells whenever feasible. The entire vertical screened interval should be developed using surge blocks, bailers, pumps, or other equipment, which frequently reverse the flow of water through the well screen and prevent bridging of formation or filter pack particles. Use the following instructions to develop monitoring wells:

1. Measure and record the water level and total depth of the well using a water level indicator. Note any accumulated sediment thickness, and record all information in a field notebook and on the Well Development Datasheet provided as Attachment 1.
2. Remove approximately 1 to 2 pints of water from the well using a decontaminated groundwater sampling pump or disposable bailer. Measure pH, temperature, conductivity, DO, ORP, and turbidity.
3. Begin well development by surging the bottom of the monitoring well and removing any sediment from the bottom of the well. To do this, slowly lower a decontaminated surge block into the well so that the surge block is within approximately 0.5 to 1 foot from the bottom of the well or measured sediment accumulation. Slowly raise and lower the surge block approximately 1 to 2 feet to create a mild surging effect at the bottom of the well; this will suspend any sediment that has settled at the bottom. Do not agitate the water violently. A general rule for well development is to start slowly and gently, and gradually increase agitation as the well is developed. After several surge strokes, remove the surge block and immediately begin to pump or bail the sediment-laden water. Repeat this process until accumulated sediment has been removed from the bottom of the monitoring well.
4. Next, develop the well from the bottom of the screened interval upward by alternately using the surge block and the bailer or pump. This will account for settlement that occurs

as the filter pack is reworked through surging. Lower the surge block to the base of the well screen interval and rapidly raise and lower the surge block across a 2- to 3-foot interval above the base of the well screen for approximately 2 to 3 minutes. However, do not overdevelop the well with overly aggressive surging. Record the surge interval and duration of surging.

5. Remove the surge block and lower the pump or bailer so that the intake is at the bottom of the surged screen interval. Turn the pump on or bail the well at the development interval until the purge water begins to clear up. Measure and record the water quality parameters every 3 to 5 minutes during pumping or bailing for each developed 2- to 3-foot screen interval, according to *SOP-12, Field Water Quality Measurements and Calibration*. Record the purge intake depth and the duration of pumping.

6. Once the water is clear, repeat Steps 4 and 5, continuing to alternate between surging and purging, until measurements stabilize for at least three consecutive water quality parameter readings, according to the following criteria:

   - ± 1.0 degrees Celsius (°C) temperature
   - ± 0.1 pH
   - ± 3 percent conductivity
   - ± 10 millivolts (mV) ORP
   - ± 10 percent DO or 0.2 milligram per liter (mg/L)
   - ± 10 percent turbidity or ≤ 10 nephelometric turbidity units (NTUs)

7. After the parameters stabilize and the water clarity improves, move the surge block up in 2- to 3-foot intervals, and repeat Steps 4 through 6 until the entire screened interval has been developed. Afterward, continue purging at a rate intended to avoid dewatering the screened interval and record water quality parameters at regular 3- to 5-minute intervals. In total, the entire well screen interval should be developed and surging should be conducted for a minimum of 10 minutes.

   If the well is purged dry at any point during development, approximately one well casing of clean, potable water can be introduced into the well and surging can continue (ADEC, 2009). Add water only as a last resort and only add non-formation water as necessary. After surging, purge the well dry again to complete the development process by removing at least the amount of potable water added to the well. If the well will recover naturally, continue development with formation water only.

8. The well will be considered adequately developed and development can stop after the water quality parameters have stabilized according to the criteria in Step 6 or a minimum of 10 well casing volumes (see Attachment 1) have been removed from the well (ADEC, 1992). If none of these conditions have been achieved after 4 hours of well development, the FM will decide whether to continue development.

9. Measure and record a final depth to water and total well depth measurement after well development.

10. Record all well development data on a Well Development Datasheet and/or in a field notebook.

5.3 Direct Push Groundwater Sampler and Well Point Development

Like conventionally installed wells, direct push system (DPS) groundwater samplers and well points (see *SOP-24, Direct Push Groundwater Sampling*) may be developed if necessary,

depending on project-specific goals. Because of the way some DPS samplers and well points are constructed and used, they may not accommodate surging, and only pumping or bailing may be feasible (U.S. Environmental Protection Agency [EPA], 2005). DPS samplers and well points that require development should be developed similarly to the methods described in Section 5.2 for conventional wells; however, because of the generally smaller diameters of DPS samplers and well points, smaller-diameter pumps, bailers, and, occasionally, surge blocks will be needed. Because most DPS groundwater samplers and DPS well points do not have filter packs to prevent fine-grained formation materials from entering the well casing, obtaining low-turbidity purge water during and after development may be difficult. In addition, in fine-grained formations, attempting to develop direct push wells may not improve well yield, and may result in increases in suspended sediment, well screen clogging, and/or screen damage. Purging the DPS groundwater sampler or well point at a low flow rate (≤0.1 gallon per minute), to the point at which pump discharge is free of suspended sediment (using a peristaltic pump, bladder pump, or gas-displacement pump), is often effective for developing wells installed in fine-grained formations. If DPS samplers and well points will be developed beyond usual purging during groundwater sampling, use the development techniques described in American Society for Testing and Materials (ASTM) D5521, ASTM D6724, and ASTM D5092.

5.4 Development Water Management

Manage development water generated during well development as investigation-derived waste (IDW), according to Appendix B, Project-specific Waste Management Plan.

6.0 Records

Record all data collected during well development activities in a Field Notebook and/or on a Well Development Datasheet (Attachment 1), according to *SOP-01, Note Taking and Field Log Books.*

7.0 References

Alaska Department of Environmental Conservation (ADEC). 2010. *Draft Field Sampling Guidance*. January.

Alaska Department of Environmental Conservation (ADEC). 2009. *Monitoring Well Guidance*. February.

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8.0 Definitions

Bailer: a long, narrow tubular device with an open top and a check valve at the bottom that is used to remove water and sediment from a borehole or well.

Bailing: a well development technique using a bailer that is raised and lowered in the well to create a strong inward and outward movement of water from the formation, to break sand bridges and to remove water and fine-grained materials from the well.

Surging: a well development technique in which a surge block is alternately raised and lowered within the well casing or screen, or both, to create a strong inward and outward movement of water through the well screen.

Surge block: a weighted tool that is slightly smaller than the inside diameter of the well casing. Most surge blocks are 6 to 12 inches in length, as are some in-well pumps (Grundfos pumps) commonly used as surge blocks.

Mechanical surging: a process that uses a plunging motion (surge block) to force water to flow through a well screen. A pump or bailer is then used to remove dislodged sediment.

Mudwall: a layer of fine-grained soils formed around the boring annulus during drilling that can impede free flow of the formation water into the well.

Turbidity: cloudiness in water resulting from suspended and colloidal material.

Well casing: a durable pipe placed in a borehole to prevent the walls of the borehole from caving in, and to seal off surface drainage or undesirable water, gas, or other fluids and prevent their entrance into the well.

Well development: the act of repairing damage to the borehole caused by the drilling process and removing fine-grained materials or drilling fluids, or both, from formation materials so that natural hydraulic conditions are restored and well yields are enhanced.

Well screen: a filtering device that allows groundwater to flow freely into a well from the adjacent formation, while minimizing or eliminating the entrance of fine-grained material into the well.

9.0 Attachments

Attachment 1: *Well Development Datasheet*

SOP-10

Groundwater and NAPL Level Measurement

SOP-10: GROUNDWATER AND NAPL LEVEL MEASUREMENT

1.0 Purpose

This standard operating procedure (SOP) provides guidance on the methods and equipment used to determine water levels, depth to floating product (light, nonaqueous phase liquids [LNAPL]), or total depth in a groundwater monitoring well, production well, or piezometer.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in measuring water levels, floating product, and total depths in wells at Galena Forward Operating Location (FOL) projects and tasks.

This SOP is applicable to the sampling of monitoring wells and must be performed before any activities that may disturb the groundwater table level, such as pumping, purging, or aquifer testing. This SOP should be used in conjunction with other project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-08, Monitoring Well/Piezometer Installation*
- *SOP-09, Monitoring Well Development*
- *SOP-11, Continuous Water Level Monitoring*
- *SOP-13, Groundwater Sampling Procedures*

3.0 General

Groundwater level data can be used for several purposes during site investigations, including the following:

- To determine the magnitude of horizontal and vertical hydraulic gradients in an aquifer system
- To measure changes in groundwater levels over time
- To estimate the magnitude of surface water/groundwater interaction that occurs during various flow conditions
- To estimate aquifer properties after aquifer testing
- To calculate the purge volume of standing water in the well
- To establish whether wells have fully recharged after purging and aquifer testing

A water level meter will typically be used to measure the groundwater level and total depth in wells. If LNAPL is present in the well, an oil-water interface probe will be used.

Water level meters use a battery-powered probe assembly attached to a cable marked in 0.01-foot increments. When the probe contacts the water surface, a circuit is closed and electricity is transmitted through the cable to sound an audible and/or visual alarm. The equipment has a sensitivity adjustment switch that enables the operator to distinguish between actual and false readings caused by the presence of conductive, immiscible

components (such as LNAPL floating on the groundwater) or condensation inside the well casing. Consult the manufacturer's operating manual for instructions on adjusting sensitivity.

Static groundwater level (depth to water [DTW]), depth to product (DTP), and total depth (TD) are measured relative to an established measurement reference point. The measurement reference point is generally the top of the casing (TOC), and may be marked with a surveyor's reference mark. The reference mark should be permanent, such as a small notch cut into the TOC or a permanent ink mark at the TOC. If a reference mark is not present at the time of water level measurement, use and mark the north side of the casing. Decontaminate all equipment before and after introducing it to the well, following procedures in *SOP-14, Equipment Decontamination Procedures*.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and engaging field staff with adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for site-specific HS&E and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the *Project-specific Health and Safety Plan* (HSP) (Appendix A), coordinates with the Field Manager (FM) and/or Safety Coordinator (SC) to complete and certify the PPE program, and conducts audits on the effectiveness of the HS&E program.

4.3 Field Manager

The FM is assigned to oversee all project field operations and is responsible for verifying that the field SOPs in Appendix H are effectively communicated and appropriately implemented. The FM will assist the PM, HSM, and Field Team Leader (FTL) regarding onsite activities.

4.4 Safety Coordinator

The role of SC is either taken by the FM or is designated to FTLs by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and ongoing HS&E procedures are effective.

4.5 Field Team Leader

The FTL is responsible for determining that staff measuring water levels know the procedures in this SOP and that this SOP is implemented effectively and accurately. The FTL will also confirm that applicable requirements of the HSP (Appendix A) and Appendix B, Project-specific Waste Management Plan, are followed.

5.0 Procedure

5.1 General

Decontaminate all measurement devices according to *SOP-14, Equipment Decontamination Procedures* before and between measurements. In addition, employ air monitoring procedures according to *SOP-04, Organic Vapor Monitoring and Air Monitoring,* while opening groundwater monitoring wells and measuring groundwater and LNAPL levels.

5.1.1 Equipment

The following equipment is required for groundwater and NAPL level measurement:

- Water level meter with audible alarm and a cable marked in 0.01-foot increments. The point on the probe that triggers the alarm corresponds to the zero point. Calibrate the water level meter according to the manufacturer's instructions.
- Oil-water interface probe and a cable marked in 0.01-foot increments, if a floating LNAPL layer is suspected in the well.
- Decontamination equipment (see *SOP-14*) (one spray bottle containing Alconox or Liquinox solution, one spray bottle containing deionized water, paper towels, 5-gallon poly bucket, and absorbent pads).
- Additional weight may be necessary at depths deeper than 80 feet because of the buoyancy of the cable when the weight of the tape is approximately equal to or greater than the weight of the probe.

5.1.2 Depth to Water/Depth to LNAPL Measurement

If the well is sealed with an airtight cap, allow time for pressure to equilibrate after the cap is removed before measuring water levels. Take measurements until consecutive readings are within 0.01 foot.

Measure DTW and DTP as follows:

1. With the water level indicator switched on, wet the tip of the probe in potable water to test whether the meter is working properly. If no audible alarm is observed, the meter is not working properly.
2. Slowly lower the water level meter or oil-water indicator probe down the monitoring well until the probe contacts the groundwater or LNAPL surface, as indicated by the audible alarm. Do not let the probe tip and tape free-fall down the well. Always hold onto the meter's reel handle.
3. Raise the probe out of the water or LNAPL until the audible alarm stops. Continue raising and lowering the probe until a precise level is determined within 0.01 foot.
4. If LNAPL is present in the well, measure and record the depth from the TOC reference point to the top surface of the LNAPL layer (that is, DTP). The oil-water indicator probe alarm will sound a continuous tone when LNAPL is detected.
5. Continue to lower the probe until the meter indicates the presence of groundwater. The alarm will typically emit a beep when water is detected. Measure the first static

groundwater level and record the measurement (DTW) from the reference point to the top of the static groundwater level.

6. Record the measurements in the field log book or Groundwater Sampling Datasheet according to *SOP-01, Note Taking and Field Log Books*.

5.1.3 Total Depth Measurement

Use the following procedures to measure the TD of a groundwater monitoring well:

1. Slowly lower the water level meter until the cable goes slack. Do not let the probe tip and tape free-fall down the well. Always hold onto the meter's reel handle.
2. Gently raise and lower the water level meter probe to tap the bottom of the well.
3. Record the reading on the cable at the established reference point to the nearest 0.01 foot. If there is an offset between the bottom of the probe and the water level sensor, adjust the measurement accordingly. Record the TD measurement in the field log book or Groundwater Sampling Datasheet according to *SOP-01, Note Taking and Field Log Books*.

6.0 Records

Document all measurements in the field notebook and/or on a Groundwater Sampling Datasheet according to *SOP-01, Note Taking and Field Log Books*.

7.0 References

American Society for Testing and Materials (ASTM). 1987. *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)*. ASTM Standard D 4750, ASTM International, West Conshohocken, PA. November 27.

Driscoll, F.G. 1986. *Groundwater and Wells.* St. Paul, MN: Johnson Division.

Thornhill, Jerry T. 1989. "Accuracy of Depth to Ground Water Measurements." In *EPA Superfund Ground Water Issue*. EPA/540/4-89/002.

U.S. Department of the Interior. 1981. *Groundwater Manual, A Water Resource Technical Publication.* Water and Power Resources Services. Denver, CO: U.S. Government Printing Office.

8.0 Definitions

None.

9.0 Attachments

None.

SOP-11

Continuous Water Level Monitoring

SOP-11: CONTINUOUS WATER LEVEL MONITORING

1.0 Purpose

This standard operating procedure (SOP) provides guidelines for the use of pressure transducers and programmable data loggers for continuous water level monitoring of groundwater or surface water to support remedial investigations. The objective of this procedure is to ensure that pressure transducers are installed and used in wells or piezometers in a consistent manner.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors who install and perform continuous water level monitoring with pressure transducers and programmable data loggers at Galena Forward Operating Location (FOL) projects and tasks.

This SOP focuses on the most commonly used continuous groundwater monitoring tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-10, Groundwater and NAPL Level Measurement*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*

3.0 General

Groundwater and surface water level evaluations can be accomplished using different data collection methods. Continuous water level monitoring using dataloggers and pressure transducers have the ability to collect large amounts of data quality reliably and accurately. They may also be used to record groundwater and surface water level behavior as part of an aquifer pumping test or for long-term monitoring of aquifers, lakes, or streams.

Continuous groundwater level monitoring typically occurs in multiple monitoring wells as part of the continuous groundwater monitoring program. The specifics of a continuous groundwater monitoring program depend on the groundwater conceptual site model (including its potential relationship to surface water systems), the availability and spatial distribution of data monitoring points (monitoring well locations and depths), and the data quality objectives of the program.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and

execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to verify that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Field Team Leader

Each Field Team Leader (FTL), in conjunction with the Site Coordinator (SC), is responsible for overall compliance with this technical procedure. The FTL is responsible for following these procedures or delegating tasks to team members to perform drilling tasks. The FTL should verify that subcontractors are adequately complying to this technical procedure and that air monitoring is adequately conducted by or provided to subcontractors per the Health and Safety Plan (HSP) (Appendix A).

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP, coordinates with the FM and/or SCs to complete and certify the PPE program, and conducts project H&S audits on the effectiveness of HS&E program.

4.5 Safety Coordinator (SC)

The role of SC is either taken by the FM or is designated to FTLs by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

5.0 Procedures

5.1 Instruments

Commonly used equipment and supplies that can be used for continuous groundwater level monitoring include, but are not limited to, the following:

- Vented pressure transducer
- Datalogger
- Water level indicator
- Decontamination equipment
- Installation hardware and equipment
- Portable handheld data reader or laptop computer
- Communication data cables
- Stopwatch

5.2 Continuous Groundwater Level Monitoring Procedures

5.2.1 Pre-test and Post-test Activities

The general procedures for pre-testing and post-testing activities are as follows:

- Decontaminate all downhole equipment (pressure transducers and water level monitoring devices) before and after use, according to *SOP-14, Equipment Decontamination Procedures*.
- Calibrate and test pressure transducers and data loggers before they are deployed in the field. Test the operational integrity and the configuration of the datalogger by running an inherent self test program in the unit. Connect pressure transducers to the datalogger and check for operation by placing the pressure transducer below the water table at a known depth and taking a reading, moving the pressure transducer, and taking another reading.
- Synchronize all time-recording devices to the same clock before the test.
- Take manual water levels in all wells just before beginning any test.

5.2.2 Monitoring Well Field Installation

The procedure for installation of pressure transducers in monitoring wells is as follows:

- Measure the water level and depth to the bottom of the well relative to the top of the well casing using an electronic water level indicator before installation.
- Lower the vented pressure transducer gently down the well and install below the lowest anticipated change in water level, but not so low that the range of the transducer might be exceeded at the highest anticipated change in level.
- Do not install the pressure transducer to a depth less than 1 foot from the bottom of the well, to keep the transducer out of any fine sediment that may accumulate in the bottom of the well.
- Secure the pressure transducer in place by attaching it to the well casing or monument at the surface.
- Bundle any excess of cable connected to the pressure transducer at the surface and place it back into the well or coil and suspend from the well casing. Do not plug the end of the cable as this line also acts as a vent to the transducer. A notch may be cut in the well cap to fit over the cable. Ensure not to completely seal the well to allow the water level in the well to fluctuate with pressure variances.

5.2.3 Groundwater Level Data Collection Activities

The datalogger should be programmed according to the manufacturer's instructions and as discussed in the Work Plan to meet the investigation objectives.

- To prevent data loss because of equipment or battery failures, periodically download partial data from the datalogger (for example, monthly or quarterly).
- In addition, conduct periodic manual water level measurement throughout the continuous groundwater monitoring program to determine if there is measurement drift.

Record the date and time that the manual reading was taken and the pressure head reading of the transducer.

- Record all data collection events and continuous groundwater level monitoring activities in field log books or on field datasheets.

5.3 Surface Water Level Monitoring Procedures

5.3.1 Stream and Surface Water Gauging

Surface water level measurements are used for a variety of purposes, such as establishing a relationship between the flow rate and water level at a stream gauging location. Streams and lakes may also be monitored to understand the hydrologic connection to groundwater aquifers and precipitation or tidal effects.

5.3.2 Surface Water Field Installation and Calibration

Install the surface water pressure transducer at a location that achieves the project-specific goals of the continuous water monitoring program and is safe for installation and routine data downloading. Secure the pressure transducer to a solid object such as a dock, a steel rod driven into the stream or lake bed, or other stable structure to minimize potential movement. If possible, place the transducer within a stilling well to dampen wave motion and string and secure the pressure transducer cable to an on-shore object to provide a secondary anchoring point and allow for data downloads without the need for entering the water.

If the pressure transducer is installed in a stream to establish a relationship between the volumetric flow rate and the stream stage, the following should be conducted:

- Install the pressure transducer at a stream location using the following criteria as guidance:
  - A straight reach with similar water velocities across the stream
  - A stable stream bed free of large rocks, weeds and protruding obstructions that would create turbulence
  - A flat stream bed profile to eliminate vertical velocity components
- Measure the stream bed's profile at the position of the installed pressure transducer. The creek's profile will include depth to the creek bottom from a reference point (usually the water surface), at measured intervals from one shore line to another. These measurements will allow for a calculation of area of water flowing within the stream.
- Take stream flow measurements to correlate the stream stage to a volume of water flowing within the stream. Flow can be measured using the 6/10-depth method, by using a Pygmy current meter (or equivalent). When taking stream flow measurements, field personnel should stand in a position that least affects the velocity of the water passing the current meter. Keep the wading rod in a vertical position and the meter parallel to the direction of flow.

5.4 Decontamination

Decontaminate pressure transducer, cables, and water level indicators according to the decontamination procedures in *SOP-14, Equipment Decontamination Procedures*.

5.5 Service and Maintenance

Perform service and maintenance according to the manufacturer's instructions.

6.0 Records

Record the brand and model number, unique identification number, measurement location, date and time, installation methods, programming set-up, manual water level, and any additional information relevant to continuous water level monitoring activities in the Field Log Book or on a Field Datasheet according to *SOP-01, Note Taking and Field Log Books.* Back up all downloaded digital data and store to a project server or file transfer protocol (FTP) site as detailed in SOP-01.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). February 2009. *Monitoring Well Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

American Society for Testing and Materials (ASTM). January 1, 2004. *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. ASTM Standard D5092, ASTM International, West Conshohocken, PA.

Driscoll, F.G. 1986. *Groundwater and Wells.* 2nd edition. St. Paul, MN: Johnson Division.

Kruseman, G.P. and N.A. de Ridder. 1991. *Analysis and Evaluation of Pumping Test Data*, 2nd Edition, International Institute for Land Reclamation and Improvement. Wageningen, The Netherlands.

Lohman, S.W. 1972. *Ground Water Hydraulics.* U.S. Geological Survey Professional Paper 708.

Nielsen, D.M. 1991. *Practical Handbook of Ground-Water Monitoring.* Lewis Publishers.

Thornhill, Jerry T. 1989. *Accuracy of Depth to Ground Water Measurements.* In *EPA Superfund Ground Water Issue.* EPA/540/4-89/002.

U.S. Department of the Interior (USDI). 1981. *Groundwater Manual, A Water Resource Technical Publication.* Water and Power Resources Services. Denver, CO: U.S. Government Printing Office.

U.S. Environmental Protection Agency (EPA). 1993. *Suggested Operating Procedures for Aquifer Pumping Tests*. EPA/540/S-93/503.

8.0 Definitions

Monitoring well: a well that is constructed in various ways for the purpose of extracting groundwater for physical, chemical, or biological sampling, or for measuring water levels.

Piezometer: a well that is constructed in various ways for the purpose of measuring water levels.

Pressure transducer: a submersible probe used to monitor changes in water level. A pressure transducer senses changes in pressure, measured in pounds per square inch (psi), exerted by a column of water or other fluid. One psi is equal to 2.30667 feet of water.

Datalogger: a programmable field instrument capable of measuring and recording parameters, such as water level and pressure, at previously determined frequencies for long periods of time. Dataloggers are designed for unattended use.

9.0 Attachments

Attachment 1: *Pressure Transducer-Datalogger Information*

SOP-12

Field Water Quality Measurements and Calibration

SOP 12: Field Water Quality Measurements and Calibration

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to describe general methods for calibrating, maintaining, and operating water quality meters and probes used for groundwater sampling. This technical procedure provides general guidelines; however, the manufacturer's manual describing calibration and standard operating procedures for each field instrument should be referred to for complete calibration and operating instructions.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors responsible for collecting water quality parameters during well development, sampling, or for other purposes at Galena Forward Operating Location (FOL). The SOP was developed per the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used field water quality measurement tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*
- *SOP-22, Field Test Kit Analyses*
- *SOP-24, Direct Push Groundwater Sampling*

3.0 General

Water quality meters are typically used in the field to measure the following parameters:

- Dissolved oxygen (DO)
- Oxidation-reduction potential (ORP)
- Conductivity
- pH
- Turbidity
- Temperature

Instructions for maintenance and operation of all these field instruments are described in the operation manuals provided by the manufacturer.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to verify that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) should develop or direct the preparation of a detailed sampling plan that includes the specifics of field water quality measurement, particularly the procedures to be used. The FTL, or their designee, should know the requirements for field water quality measurement and should maintain adequate documentation of field water quality measurements and calibration activities.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the Project-specific Health and Safety Plan (HSP) (Appendix A), coordinates with the FM and/or Safety Coordinators (SC) to complete and certify the PPE program, and conducts project health and safety audits on the effectiveness of the HS&E program.

4.5 Safety Coordinator

The role of SC is either taken by the FM or is designated to FTLs by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

5.0 Procedures

5.1 Instruments and Supplies

Water quality meters and instruments vary in their manufacturer and model number. Below is a list of commonly used meters and instruments, and other related supplies that can be used for field water quality measurements:

- YSI 556 MPS Multi-parameter Instrument
- YSI 650 MDS Multi-parameter datalogger
- YSI 6-Series sonde or similar multiparameter probe

- YSI 5083 Flow Cell or similar flow-thru cell
- Hach 2100P Portable Turbidimeter
- Data transfer connector cables
- Discharge hoses (two)
- Fittings to attach sample tubing to flow through cell (barbs and master flex pump tubing)
- Distilled water
- Calibration solutions and buffers (ORP, conductance, pH, and turbidity)

5.2 Calibration

Calibrate all instruments for all field parameters daily before collecting water quality data, according to the manufacturer calibration specifications developed for the instrument being calibrated. In addition, if there are anomalous readings during sample collection, stop sample collection and re-calibrate, if possible. Document field calibration in the Field Notebook or on the Field Calibration Sheet provided as *SOP-12, Attachment 1*.

If a field instrument will not calibrate, perform troubleshooting as described in the manufacturer's manual. Check that the calibration standards have not expired. If the issue cannot be resolved, use a backup instrument. If one is not available, consult with the PM on whether data collection should continue and on any other corrective actions to be taken. Flag any data recorded from a meter with calibration problems on the Groundwater Purge and Sampling Field Datasheet as discussed and provided in *SOP-13, Groundwater Sampling Procedures.*

5.2.1 pH Calibration (2-point or 3-point calibration)

Calibrate all instruments recording pH daily, using at minimum a 2-point calibration method. A 2-point calibration uses only two pH buffer calibration solutions (for example, pH 4 and pH 7 or pH 7 and pH 10) and is valuable only if the water being monitored is known to be either basic or acidic. For example, if the pH is known to vary between 5.5 and 7, a 2-point calibration with a pH 7 and pH 4 buffer solutions is sufficient.

If the pH of water being measured is unknown, a 3-point calibration method is preferred. Using this calibration, the pH sensor is calibrated with a pH 7 buffer and two additional buffers (such as pH 4 and pH 10). The 3-point calibration method accounts for the full pH range and assures maximum accuracy when the pH of the media to be monitored cannot be anticipated. Typically, the procedure for a 3-point calibration is the same as for a 2-point calibration, but the instrument may prompt you to select a third pH buffer. Follow the recommended manufacturer pH calibration instructions for additional detailed instruction for the instrument being used. Enter all pH calibration values based on the appropriate temperature as labeled on the pH calibration solutions used or according to Table 1 below. Record the final pH calibration reading, with the corresponding temperature, on the *Field Calibration Sheet.*

Table 1. pH Buffer Solution Values Based on Temperature.

Temperature	pH Buffers			Temperature	pH Buffers		
°C	4.01	7	10.01	°C	4.01	7	10.01
0	4	7.11	10.32	26	4.01	6.99	10
1	4	7.11	10.31	27	4.01	6.99	9.99
2	4	7.1	10.29	28	4.01	6.99	9.98
3	4	7.09	10.28	29	4.01	6.99	9.98
4	4	7.09	10.26	30	4.02	6.98	9.97
5	4	7.08	10.25	31	4.02	6.98	9.96
6	4	7.08	10.23	32	4.02	6.98	9.95
7	4	7.07	10.22	33	4.02	6.98	9.94
8	4	7.07	10.21	34	4.02	6.98	9.93
9	4	7.06	10.2	35	4.02	6.97	9.93
10	4	7.06	10.18	36	4.03	6.97	9.92
11	4	7.05	10.17	37	4.03	6.97	9.91
12	4	7.05	10.16	38	4.03	6.97	9.9
13	4	7.04	10.14	39	4.03	6.97	9.9
14	4	7.04	10.13	40	4.03	6.97	9.89
15	4	7.03	10.12	41	4.04	6.97	9.88
16	4	7.03	10.11	42	4.04	6.97	9.88
17	4	7.02	10.1	43	4.04	6.96	9.87
18	4	7.02	10.09	44	4.04	6.96	9.86
19	4	7.02	10.08	45	4.04	6.96	9.86
20	4	7.01	10.06	46	4.05	6.96	9.85
21	4.01	7.01	10.05	47	4.05	6.96	9.85
22	4.01	7.01	10.04	48	4.05	6.96	9.84
23	4.01	7	10.03	49	4.05	6.96	9.84
24	4.01	7	10.02	50	4.06	6.96	9.83
25	4.01	7	10.01	51	4.06	6.96	--

5.2.2 Conductivity Calibration

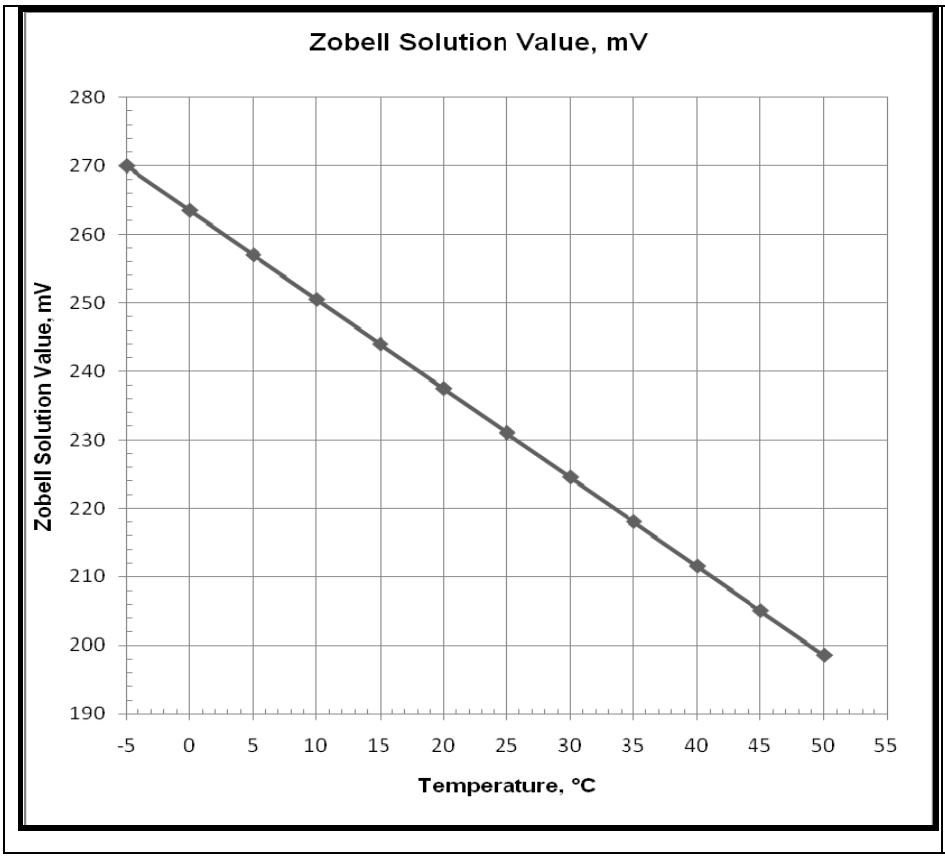
Perform daily calibration for conductivity according to the recommended manufacturer's calibration instructions. Conductivity should be calibrated for Specific Conductance and is typically entered as milliSiemens per centimeter (mS/cm) at 25 degrees Celsius (ºC). Typical conductivity standard solution has a specific conductance value of 1.413 mS/cm; which is equivalent to 1413 microSiemens per centimeter (µS/cm) or 1413 µmho/cm. Table 2 below summarizes the value relationship of a 1413 µS/cm (1.413 mS/cm) standard solution to temperature and should be referenced following calibration to verify an accurate final conductivity calibration at the appropriate temperature of the calibration solution used. Record the final conductivity calibration reading, with the corresponding temperature, on the Field Calibration Sheet.

Table 2. Conductivity Standard Solution Values Based on Temperature.

Temperature	1413 µS/cm Conductivity Standard	Temperature	1413 µS/cm Conductivity Standard
°C	(µS/cm)	°C	(µS/cm)
0	776	26	1441
1	799	27	1468
2	822	28	1496
3	846	29	1524
4	870	30	1552
5	894	31	1580
6	918	32	1608
7	943	33	1636
8	968	34	1665
9	992	35	1693
10	1017	36	1722
11	1043	37	1751
12	1068	38	1780
13	1094	39	1808
14	1119	40	1837
15	1145	41	1866
16	1171	42	1896
17	1198	43	1925
18	1224	44	1954
19	1251	45	1983
20	1277	46	2013
21	1304	47	2042
22	1331	48	2071
23	1358	49	2101
24	1386	50	2130
25	1413		

5.2.3 Calibration Check of the Oxidation Reduction Potential (ORP) Probe

A calibration check of the ORP probe can be performed by placing it into a Zobell™ solution that is within approximately 10°C of the expected groundwater temperature, or as close to groundwater temperature as practical. Groundwater temperatures ranging from approximately 3°C to 10°C can generally be expected in Alaska. This is not a calibration solution, but a check that the probe is working properly. Zobell™ solution has a short shelf life, typically lasting only 3 months. If expired, make or obtain new solution before measurement. The Zobell™ reading is dependent upon temperature and should fall within 20% of the value shown in Figure 1 below, before taking measurements. If readings are out of this range, then take a second reading with a backup electrode. If both instruments fail, replace the Zobell solution, and repeat the measurements. Record the Zobell™ solution ORP reading, with the corresponding temperature, on the *Field Calibration Sheet.*



Temperature °C	Zobell Solution Value, mV
-5	270
0	263.5
5	257
10	250.5
15	244
20	237.5
25	231
30	224.5
35	218
40	211.5
45	205
50	198.5

Figure 1. Zobell Solution ORP Dependence on Temperature for a Silver Chloride (Ag:AgCl) Electrode.

5.2.4 Turbidity Calibration (4-point calibration)

Perform routine calibration of the turbidity instrument according to the recommended manufacturer's calibration instructions. Turbidity instruments should be calibrated using a 4-point calibration method; typical calibration standards used are <0.1 NTU, 20 NTU, 100 NTU, and 800 NTU StablCal standard or formazin standard. This 4-point calibration method accounts for turbidity over a wide range from 0 to 1000 NTU. Record the calibration standard value and the calibrated turbidity value of each calibration point (< 0.1, 20, 100, and 800 NTU) on the Field Calibration Sheet.

5.3 Water Quality Instrument Field Measurement and Usage

The general procedures for measuring groundwater quality parameters and flow-through cell setup are as follows:

1. Before taking any field measurements, calibrate instruments according to the manufacturer's procedures and record the calibration on the Field Calibration Sheet.

2. Perform a saturated air check of the DO probe by placing a wet piece of cloth or paper towel in the cap that covers the probe. Check the dissolved oxygen reading against the theoretical value of saturated oxygen at different elevations using *SOP-12, Attachment 2: Solubility of Oxygen in Water and Pressure/Altitude Chart.* If the instrument is not reading in the proper range, it should be recalibrated, or the dissolved oxygen probe membrane should be replaced.

3. Secure the multi-meter sonde (or analyte specific probes) to the flow-through cell. Connect a short discharge tube to the effluent connector at the top of the flow-through cell and run the other end of the discharge tube into a 5-gallon purge water capture bucket.

4. Place the tube from the pump directly into the 5-gallon purge water bucket and start to purge (pump) for approximately 1 to 2 minutes or until the purge water begins to visually clear up. The intent is to limit any initially high turbidity water from filling and settling in the flow-through cell.

5. Once the turbidity has stabilized, briefly turn off the pump and secure the tube from the pump to the influent connector at the bottom of the flow-through cell. Turn on the pump again and then allow the flow-through cell to completely fill with water. Effort should be made to keep air bubbles from collecting in the flow-through cell. To remove any collected air from the cell, disconnect the probes from the cell while pumping until all the air escapes and then reconnect the probes.

6. Continue pumping and begin low-flow purging of the monitoring well at a flow rate of approximately 1 liter (0.25 gallons) every 3 minutes or 0.1 gallon per minute (gal/min).

7. Routinely measure and record the DO, ORP, conductivity, pH, turbidity, temperature, and current groundwater level throughout the purge at approximately every 3- to 5-minute interval. A minimum of three of these parameters should be monitored and recorded. Record the purge groundwater parameters on a *SOP-12, Attachment 3: Groundwater Purge and Sampling Field Datasheet*.

8. Continue to measure and record the groundwater parameters and current groundwater level until the parameters stabilize according to the following stabilization criteria, or until 3 well casing volumes are purged. Groundwater parameters are considered stable after purging if three successive readings are within:

   - ± 1.0 °C temperature
   - ± 0.1 pH
   - ± 3% conductivity
   - ± 10 millivolt (mV) ORP
   - ± 10% parts per million (ppm) DO or 0.2 milligrams per liter (mg/L)
   - ± 10% turbidity or ≤ 10 nephelometric turbidity units (NTUs)

9. Note the following before and during water quality measurement and groundwater purging:

   - Obtain the typical ranges for the water quality parameters at a well (or site) prior to measurement and purging, if possible, and bring these values to the field for reference during sampling. Water quality parameter ranges can often be obtained from historical groundwater purging and sampling events. These previous values should be used as clues to determine if an instrument is reading correctly and/or is drifting during water quality measurement.

   - ORP and DO measurements should always correlate with each other. Generally ORP should be negative whenever DO is near or less than 1 milligram per liter(mg/L); likewise, DO should be greater than 1 mg/L if ORP is positive.

   - DO measurement <u>should always be positive</u> and range between 0 and 14.62 mg/L.

- ORP measurements should range between -500 mV and 275 mV.
- The pH of environmental samples will typically range from 6 to 8 pH units.
- When measuring turbidity, be sure to clear any moisture or dust off of the turbidity sample cell and emplace the sample cell and light cover completely and securely. Also, be sure to put the turbidity instrument out of direct sunlight (it should be shadowed), or else light interference may provide false readings.

10. When parameters have stabilized, record final measurements and collect samples as specified in SOP-13, Groundwater Sampling Procedures.

5.4 Storage

Perform the following tasks each day upon conclusion of using any water quality measurement instrument:

1. Decontaminate the instrument(s): rinsing with distilled water, a dilute solution of Alconox or Liquinox (or similar), and rinsing with distilled water as specified in *SOP-14, Equipment Decontamination Procedures*.
2. Moisten protective caps that are made to protect the tips of probes or sensors with fresh water and replacing them back to their probes or sensors for storage while the instrument is not in use
3. Recharge or replace batteries on any instruments and meters to verify full battery charge for next use.
4. Store the instrument or meter in the protective case provided with the instrument or meter
5. Take any additional storage and maintenance steps recommended by the manufacturer as specified in the instruments operations and maintenance manual.

5.5 Service and Maintenance

Perform service and maintenance according to manufacturer's instructions.

6.0 Records

Record all instrument calibration information on a Field Calibration Datasheet, provided as *SOP-12, Attachment 1*. Calibration information that should be recorded into the field book for each instrument calibrated includes the brand and model number, unique identification number, type, lot number, expiration date of any calibration solutions, and results of the calibration. Record all field data collected during groundwater sampling on a Groundwater Purge and Sampling Field Datasheet as provided as *SOP-12, Attachment 3*.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

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8.0 Definitions

Meter (instrument): A device that presents a digital display of instrument measurements.

Probe: A device that is submerged in the flow through cell (or sample container) designed to read a specific water quality parameter such as pH or DO.

Sonde: A device that houses six field-replaceable sensors designed to measure DO, conductivity, temperature, pH, ORP, and turbidity.

Terminal: The 650-MDS Terminal is a display terminal and data logger by which the sonde communicates readings.

Flow-through cell: The flow-through cell is an attachment for the water quality probe or sonde that allows air-tight water quality measurements of small streams of water (low flow), such as water pumped from a piezometer or monitoring well.

9.0 Attachments

Attachment 1: *Field Instrument Calibration Datasheet*

Attachment 2*: Solubility of Oxygen in Water and Pressure/Altitude Chart*

Attachment 3*: Groundwater Purge and Sampling Field Datasheet*

Attachment 4*: Water Quality Instrument Information*

SOP-13

Groundwater Sampling Procedures

SOP-13: GROUNDWATER SAMPLING PROCEDURES

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to describe the methodology for planning groundwater sampling events, well purging, and collection of groundwater samples through the use of positive displacement, submersible, and peristaltic pumps, and bailers.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in who are engaged in groundwater sampling at Galena Forward Operating Location (FOL) projects and tasks and was developed per the following Alaska Department of Environmental Conservation (ADEC) documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Monitoring Well Guidance* (ADEC, 2009)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used monitoring well development tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-08, Monitoring Well/Piezometer Installation*
- *SOP-09, Monitoring Well Development*
- *SOP-10, Groundwater and NAPL Level Measurement*
- *SOP-12, Field Water Quality Measurements and Calibration*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*
- *SOP-21, Well Decommissioning and Abandonment*
- *SOP-24, Direct Push Groundwater Sampling*

3.0 General

Groundwater sampling consists of collecting a water sample that is representative of the in situ conditions and chemistry of a specific aquifer, or portion of an aquifer. Five methods for well sampling are addressed in this SOP, including the no-purge method, the low-flow method, the well-volume method, low-permeability formation method, and passive methods. The following sections include summaries and procedures for each method.

Unless otherwise approved by ADEC, newly constructed wells cannot be sampled for at least 48 hours after well development (ADEC, 2010). Disturbance of the well, water column, and samples must be minimized and only discrete grab samples may be obtained.

Composite groundwater samples are unacceptable. If multiple groundwater monitoring wells are to be sampled during the same sampling event, samples must be collected from the monitoring wells expected to be uncontaminated or to have only low levels of contamination first, and then progressing to wells expected to have higher levels of contaminant last. This practice helps reduce the potential for cross-contamination between monitoring wells.

Groundwater samples must be collected as close as possible to the vadose zone/saturated zone interface (that is, water table) unless analysis indicates that contamination is at a different depth (ADEC, 2002). If further vertical delineation of contaminant concentration(s) is necessary, groundwater samples should be collected at the interval(s) within the water column based on the physical characteristics of the contaminant (ADEC, 2010). This should be a consideration especially for light, nonaqueous phase liquids (LNAPLs) and dense nonaqueous phase liquids (DNAPLs) (such as chlorinated solvents). If multiple different contaminant analytes are to be sampled from the same well, samples must be transferred to sample containers in the order of volatility. Contaminant analytes should be collected in the following order:

1. In-field water quality parameter (see *SOP-12*)
2. Volatile organic compounds (VOCs) and volatile natural attenuation parameters including gasoline range organics (GRO), benzene, toluene, xylenes, and ethylbenzene (BTEX), methane, and carbon dioxide (CO_2)
3. Semi-volatiles organic compounds (SVOCs) (such as diesel range organics/residual range organics [DRO/RRO], polynuclear aromatic hydrocarbons [PAHs], polychlorinated biphenyls [PCBs], pesticides, and herbicides)
4. Total organic carbon (TOC)
5. Inorganic compounds (such as total metals, dissolved metals, nitrate/nitrite, and sulfide)

3.1 Equipment and Materials

Groundwater sampling may be performed using several sampling devices including submersible pumps, peristaltic pumps, inertial pumps, and bailers. The choice of sampling device will be based on site-specific considerations including the well diameter, depth of groundwater, and well sampling method. Groundwater sampling devices must compliment the intended data use and site decisions, and selected groundwater purging and sampling equipment should minimize increases in sample temperature, water column agitation, and sample agitation (ADEC, 2010).

Materials used during groundwater sampling must not absorb, desorb, or leach contaminants of concern from or into a potential groundwater sample (ADEC, 2010). The materials used must be resistant to chemical and biological degradation. If bailers are used, the bailer must be made of glass, stainless-steel, other suitable materials, or of disposable materials such as Teflon® or polyethylene (ADEC, 2002). Polyvinyl chloride (PVC) bailers are not acceptable for sampling of VOCs.

3.2 Groundwater and LNAPL Level Measurement

Before groundwater sampling, conduct a site-wide groundwater level survey to determine the current site hydrogeologic conditions. Measure the depth to groundwater in each well to within 0.01 feet according to *SOP-10, Groundwater and NAPL Level Measurement*. If the possibility of LNAPL is suspected, check the monitoring well for the presence of LNAPL

using an oil-water indicator probe (see *SOP-10*). If LNAPL is encountered in a well, measure the product thickness and record it on a *SOP-13, Attachment 3: Well Purge and Sampling Datasheet* and/or in the Field Notebook before any purging or sampling. Unless otherwise specified by the site-specific sampling plan (*Appendix D*) or the Field Manager (FM), do not collect laboratory samples from wells that contain LNAPL.

3.3 Historical Groundwater Level Information

The initial step in developing a groundwater sampling plan for a particular site is to acquire historic groundwater elevation data from monitoring wells at the site, if available. If no monitoring wells currently exist, acquire groundwater level data for wells at or as close as possible to the site, as discussed in Section 3.2. Evaluate these data to determine the range of seasonal water level fluctuations that occur at the site and the shallowest and deepest observed water levels over the period of record. This information defines the depth interval of the intermittently saturated zone, or potential “smear zone” that is created as a LNAPL layer rises and falls with seasonal water level fluctuations. Attachment 1 summarizes the range of seasonal water level fluctuations that occurs at the Galena FOL and highlights the expected smear zone and permanently saturated zones.

Collect groundwater samples from both the smear zone and the permanently saturated zone. In the case of the smear zone, the extent of the subsurface interval from which groundwater samples can be obtained will vary, depending on groundwater levels at the time the sampling event is being conducted. By definition, groundwater samples may be obtained from the permanently saturated zone throughout the year. The general groundwater sampling methodologies for each of the hydrogeologic intervals are described below.

3.3.1 Smear Zone

Collect groundwater samples within the smear zone in conjunction with soil samples using Direct Push System (DPS) methods, wherever possible, to provide direct comparison of soil and groundwater contaminant concentrations (see *SOP-05* and *SOP-24*). Collect these samples either from separate borings in close proximity to one another (soil samples from the first and groundwater samples from the second), or within a single boring using a simultaneous sampling device such as the Simulprobe Technologies Mini SimulProbe® or similar device (see *SOP-13, Attachment 2*) (BESST, 2010). The target depth intervals for groundwater sampling and analysis depend on location. Analyze all collected groundwater samples for the target analytes as specified in Appendix D, Site-specific Sampling Plan.

3.3.2 Permanently Saturated Zone

Collect groundwater samples from the permanently saturated zone beneath each suspected source area, using either conventional monitoring well installations or DPS groundwater sampling methods (see *SOP-08* and *SOP-24*). If there are multiple potential source areas within a particular site, collect groundwater samples at each location. Collect an additional groundwater sample from the permanent saturated zone at a location determined to be up gradient (based on the most recent available groundwater flow direction determination) from each source area. These samples will be used to determine the mass flux contribution from the vadose zone and smear zone to the permanently saturate zoned beneath the source area.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to verify that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The FM is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) should develop or direct the preparation of a detailed sampling plan that includes the specifics of groundwater sampling, particularly the procedures to be used. The FTL or their designee should know the requirements for groundwater sampling and should maintain adequate documentation of groundwater sampling measurements and calibration activities.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the Project-specific Health and Safety Plan (HSP) (Appendix A), coordinates with the FM and/or Safety Coordinator (SC) to complete and certify the PPE program, and conducts project H&S audits on the effectiveness of HS&E program.

4.5 Safety Coordinator (SC)

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

5.0 Procedures

5.1 Pre-sampling Tasks

5.1.1 Planning Tasks

The FTL should work with the PM and FM to obtain historical information on which wells have historically had contaminants present, so that wells with the greatest concentrations may be sampled last to minimize potential cross contamination. Site background information (historical Well Purge and Sampling Datasheets), including depth to water, well total depth, and water quality parameters from previous events (if available), should be obtained before

the field sampling event to augment data quality and allow for verification of data consistency. Expected purge volumes should be estimated before field deployment such that proper pumps may be selected and purge water management may be planned.

5.1.2 Field Equipment Decontamination

Clean (and/or decontaminate) all equipment and materials used during groundwater sampling before use, as discussed in *SOP-14, Equipment Decontamination Procedures*. Groundwater sampling equipment that typically requires decontamination before purging a well includes the water level or oil-water interface probe, water quality meters and probes, and the inside of flow-thru cells. Decontaminate submersible pumps between sampling at each well. Portable decontamination supplies (for example, decontamination water containers, spray bottles, Alconox, and deionized water containers) should be available during sampling so that all appropriate accessory equipment can be decontaminated in the field. Place used decontamination solutions in the purged well water containers and managed as investigation-derived waste (IDW), according to Appendix B, Project-specific Waste Management Plan.

5.1.3 Field Equipment Calibration

Before going into the field, the FTL or designee should verify that field instruments are operating properly and that there are no obvious defects that could prevent proper operation. Calibrate all instruments before obtaining field data to within an acceptable range, according to *SOP-12, Field Water Quality Measurements and Calibration*. Minimize field sampling time or data quality lost because of malfunctioning equipment through proper pre-event planning and by using adequate backup equipment, as necessary. Make field measurements for temperature, pH, turbidity, specific conductance, dissolved oxygen, temperature, and oxidation-reduction potential (ORP) according to SOP-12.

Air monitoring may be necessary during groundwater sampling activities as specified in the HSP (*Appendix A*). Calibration and operation of air monitoring equipment (photoionization detectors [PIDs] or flame ionization detectors [FIDs]) are detailed in *SOP-04, Organic Vapor Monitoring and Air Monitoring*. If instrument readings become erratic during normal operations, recalibrate the equipment.

5.1.4 Equipment Selection

Obtaining a representative sample is greatly dependant on the methodology and technology used to obtain the sample. Five methods for well sampling are addressed in this SOP, including the no-purge method, the low-flow method, the well-volume method, low-permeability formation method, and passive methods. Each method uses different sampling technology and equipment, as necessary to accommodate the appropriate well installation and construction, drilling and sampling methods (such as conventional or DPS methods) employed, and project objectives.

However, most sampling methods require physically withdrawing water from the aquifer by pumping or bailing. Table 1 should be used for selecting the proper pumping or bailing method for sample collection (HDOH, 2008).

Table 1. Potential for Representative Analytical Results Using Various Pumping Technologies (HDOH, 2008).

Pump Type	VOC	SVOC	Metals*	Pesticide/ Herbicide	Dioxin/ Furans	PAH	PCB	Explosives	Free Product
Positive Displacement Pump (bladder, gear, or piston pump)	E	E	E	E	E	E	E	E	NR
Submersible Pump	G	G	E	E	E	E	E	E	NR
Peristaltic Pump	P	P	G	G	G	G	G	G	G
Bailer	NR	P	P	G	G	G	G	G	G

Notes:

E = excellent, G = good, P = poor, NR = not recommended, * = for dissolved metals analysis, samples must be filtered.

VOC = volatile organic compound, SVOC = semivolatile organic compound, PAH = polynuclear aromatic hydrocarbon, PCB = polychlorinated biphenyl

The use of positive displacement pumps is highly encouraged to obtain the best sample and geochemical parameter data. These types of pumps include bladder, gear, and piston pumps. Bladder pumps are the simplest of these pumps (which makes them easiest to decontaminate) and have diameters as small as 0.625 inch, which can sample 3/4-inch inside diameter (ID) or greater wells. Submersible pumps are acceptable for most analytes; however, take care to select the proper submersible pump for the estimated sample depth so that the pump does not become overheated and alter the well chemistry. Peristaltic pumps are generally not recommended for purging and sampling for the following analyses because of potential loss of the volatile fraction because of negative pressure gradients: VOCs, SVOCs, dissolved oxygen (DO), oxidation reduction potential (ORP), CO_2, pH, and dissolved iron. If the depth to water is less than approximately 25 to 27 feet below ground surface (bgs), the monitoring well has low recovery, the sampled analyses do not include VOCs and SVOCs, and/or the well or DPS sample point is constructed such that no other pumping method is feasible or practical, you may use peristaltic pumps as specified in the site-specific sampling plan (Appendix D).

5.2 Pump Setup

Groundwater sample pumping equipment is setup slightly different depending on the method of sampling and the types of equipment employed. Different types of pumps have different requirements; therefore, pumping equipment should always be set up according to the manufacture's recommendations. However, there are general similarities in equipment set up no matter what type of pump is used. Figures 1 and 2 summarize the typical setup for a low-flow bladder pump and peristaltic groundwater sampling set.

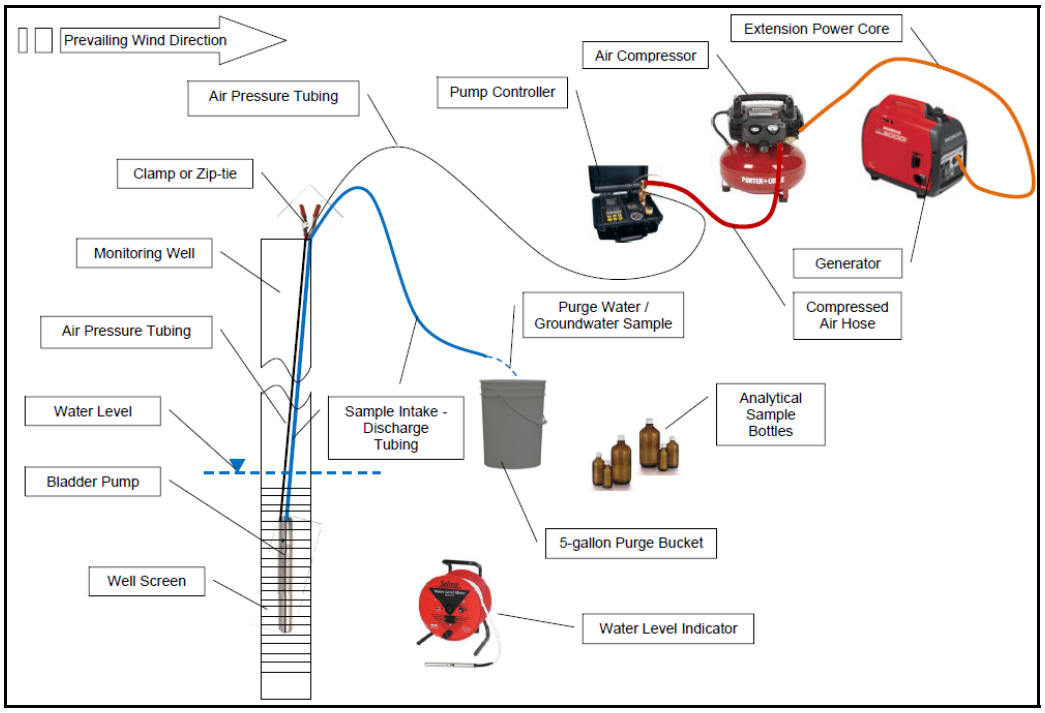

Figure 1. Typical Bladder Pump Sampling Equipment Setup.

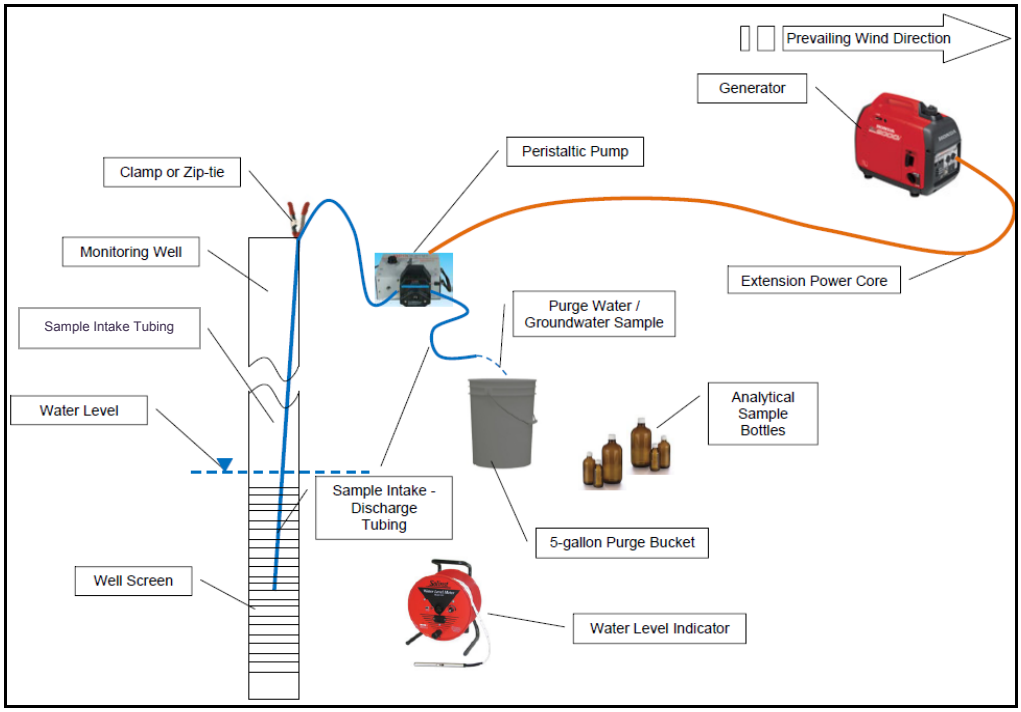

Figure 2. Typical Peristaltic Pump Sampling Equipment Setup

Follow these basic equipment setup guidelines for the most commonly used pumps, when setting up groundwater sampling equipment:

5.2.1 Bladder and Submersible Pumps

- Connect the pump to the sample intake-discharge tubing. Connect either the air pressure tubing (bladder pumps) or the pump power control cable (submersible pumps) to the pump. Tightly secure the tubing to the pump with one or two zip-tie fasteners. If the well is very deep, connect a separate deployment cable or line to the pump.
- Slowly and carefully lower the pump with tubing (and cable) into the well to the desired well depth. Lower the pump with the deployment cable (if used) or the most secure and largest diameter tubing or cable attached.
- Secure the pump and tubing to the top of the casing by the deployment cable (if used) or the most secure and largest diameter tubing or cable attached. Use with multiple zip-tie fasteners or a spring clamp if the pump is relatively light and the well is shallow.
- Connect the opposite end of the air pressure tubing or the pump power control cable to the pump controller. Both bladder and submersible pumps have some kind of pump controller.
- Clamp the other end of the sample intake-discharge tubing to the purge bucket in a way that discharging purge water will flow into the bucket.
- Connect the pump controller to either an air compressor (bladder pump) or directly to a generator (submersible pump) using a compressed air hose or extension power cord as appropriate.
- If a bladder pump and air compressor are used, connect the compressor to the generator using an extension power cord.
- Place the generator downwind of the sampling area a significant distance away (~20 feet or more). If a bladder pump is used, the generator should not be operating while a sample is being collected.
- Make sure that the generator supplying power to the pump is sufficiently fueled before purging and sampling to avoid power loss.

5.2.2 Peristaltic Pumps

- Connect an appropriate length of sample intake tubing to one end of an approximately 8- to 12-inch piece of Masterflex® or similar silicone tubing. Connect the other end of the silicone tubing to a 3- to 4-foot piece of pump discharge tubing. Try and minimize the length of sample tubing whenever possible to reduce sample turbulence and aeration during pumping.
- Slowly and carefully lower the sample intake tubing into the well to the desired sample intake depth.
- Secure the sample intake tubing to the top of the casing using multiple zip-tie fasteners or a spring clamp.
- Insert the 8- to 12-inch silicone tubing section into the peristaltic pump head and lock the tubing within the pump head.
- Clamp the other end of the discharge tubing to the purge bucket in a way that discharging purge water will flow into the bucket.

- Connect the peristaltic pump directly to the generator (or battery if available) using an extension power cord.
- Place the generator downwind of the sampling area a significant distance away (~20 feet or more). If a battery is available, it should used while a sample is being collected.
- Make sure that the generator supplying power to the pump is sufficiently fueled before purging and sampling to avoid power loss.

5.3 Well Purging

Most groundwater methods (except no-purge sampling methods) require purging of the well before groundwater sampling. The purpose of well purging is to remove stagnant water from the well and obtain a water sample representative of the aquifer being sampled with a minimum of disturbance to the water column. Using the low-flow or the well-volume approach methodology, purge the well until field parameters (such as DO, ORP, conductivity, pH, turbidity, and temperature) have stabilized, until three well casing volumes are purged, or until the well is purged dry according to *SOP-12, Field Water Quality Measurements and Calibration*. Do not collect a representative groundwater sample until the groundwater level and the groundwater parameters have stabilized according to the criteria indicated in *SOP-12*.

Sample the well immediately following purging, without moving or adjusting the position of the pump or sample intake line. Containerize purge water and manage as IDW according to Appendix B, Project-specific Waste Management Plan.

5.4 Preparation for Groundwater Sampling

The following procedures should be performed at each well in preparation for groundwater sampling:

- Ensure that all remediation systems (soil vapor extraction and bioventing) operating within 250 feet of the monitoring well to be sampled have been shut down at least 24 hours in advance of groundwater sampling activities.
- Wear PPE and take any other precautions as specified in the HSP (Appendix A).
- Monitor the ambient air and any vapors within or near a well while opening the well and during sampling according to *SOP-04* and Appendix A. Check the area around the well for organic vapors (background reading) using the PID or FID. Open the well cap and immediately checking for organic vapors in the well casing and breathing zone. Take appropriate readings in the breathing zone during purging and sampling with air monitoring equipment (PID or FID) according to the HSP (generally every 30 minutes). All air monitoring readings and observation should be recorded on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet* and/or in a *Field Notebook.*
- Inspect the condition any permanent monitoring wells for any unusual site or well conditions. Record the condition of the well monument, concrete well pad, protective posts (if present), or other well condition around the well on a *SOP-13, Attachment 4: Well Condition Inspection Datasheet* and/or in a Field Notebook. Any deficiencies encountered should be reported to the FTL and FM as soon as possible.
- Measure the depth of the static water level and the total well depth with a water level or oil-water indicator probe to the nearest 0.01 foot from the measurement reference point

on the well casing pipe as described in *SOP-10, Groundwater and NAPL Level Measurement*. This information should be recorded on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet* as well.

- If previous total well depth information is available from either well construction or previous sampling events), compare the current total well depth with the previously measured total well depth and note any differences greater than 0.5 foot on the on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.* Notify the FTL and/or FM of the observation.

5.5 Groundwater Sampling Procedures

5.5.1 No-Purge Sampling

No-purge groundwater sampling is a method for obtaining representative groundwater samples under natural flow conditions without purging the well beforehand (ADEC, 2010). This procedure is directed primarily at monitoring wells that have a screen, or an open interval of 10 feet or less. This method may be appropriate for wells that are unconfined and screened through the water table, do not contain NAPL, and have been previously sampled using conventional sampling techniques to provide data for comparison (API, 2000).

Advantages to this method include that less time is needed for sampling and elimination of purge water management and disposal costs. Samples obtained using this procedure are also suitable for the analysis of groundwater contaminants such as VOCs, SVOCs, herbicides, pesticides, PCBs, metals, and naturally occurring compounds. Disadvantages include potentially low-biased results for volatile and redox-sensitive parameters if groundwater is stagnant in the well and in contact with air.

No-purge groundwater sampling can be conducted using either bailers or pumps and is commonly used for DPS groundwater sampling as discussed in *SOP-24*. No-purge groundwater sampling is expected when using the Geoprobe® Screen Point 16 Groundwater Sampler and is potentially used during sampling of DPS well points (Kejr Inc., 2006). No-purge groundwater sampling should be conducted as follows using bailers and pumps:

No-Purge Method with a Bailer

1. Measure the water level within well using a water level meter. Record the depth to water on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*

2. Securely connect a bottom-filling bailer to a retrieval line or cord. The bailer line and any leader used that comes in contact with the water should be constructed of polytetrafluoroethylene (PTFE) -coated stainless-steel or new polyethylene cord. Fit reusable bailers with a new bailer line for each well sampled; the bailer and line may be handled only by personnel wearing clean disposable gloves. Prevent the new bailing line from contacting the outside of the well, equipment, and clothing before or during sampling.

3. Very slowly, lower the bailer down the well and below the water table, taking care to not disturb the water column or stir up sediment in the bottom of the well as the bailer fills with water from the bottom.

4. Obtain samples as close as possible to the water table, unless analysis indicates that contamination is at a different depth.

5. Lift the bailer slowly and transfer, with minimum disturbance and agitation, approximately 1 to 2 pints of water into a decontaminated sample cell; measure the pH, temperature, conductivity, DO, ORP, and turbidity as similarly described in *SOP-12, Field Water Quality Measurements and Calibration.* Record the water quality parameters on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
6. Slowly transfer the remaining water in the bailer into analytical sample containers with a minimum of disturbance and agitation to prevent loss of volatile compounds.
7. Repeat Steps 3 through 5, recording water quality parameters each time and filling analytical sample containers as discussed in Section 5.6 until complete.

No Purge Method with a Pump

1. Measure an initial water level within the well using a water level meter, if possible. Record the depth to water on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
2. Set up the sampling equipment and pump as described in Section 5.2 and according to the manufacturer's instructions.
3. Very slowly, lower the pump or pump intake tubing down the well to the desired sample intake depth. (preferably within the screened interval) Record the approximate pump or pump intake tubing depth on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
4. Start the pump on the lowest setting. Adjust the flow slowly until water begins to discharge. Continue pumping and begin low-flow sampling the well at a flow rate of approximately 1 liter (0.25 gallons) every 3 minutes or 0.1 gallon per minute (gal/min), such that the pumping rate does not lower the water level more than 0.3 foot. Initially monitor the drawdown frequently, to establish a steady pumping rate that minimizes drawdown. If the minimal drawdown exceeds 0.3 foot *but remains stable*, continue sampling. Record the drawdown, stable depth to water on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
5. First fill approximately 1 to 2 pints of water into a decontaminated sample cell and measure the pH, temperature, conductivity, DO, ORP, and turbidity as similarly described in *SOP-12, Field Water Quality Measurements and Calibration.* Record the initial water quality parameters on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
6. Next, slowly fill the required analytical sample containers with a groundwater sample, taking care to minimize disturbance and agitation of the sample and prevent loss of volatile compounds. Fill the analytical sample containers as discussed in Section 5.6, until complete.
7. After filling sample containers, repeat Step 1 and record the final water quality parameters on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
8. Remove the pump and pump intake tubing from the well and disassemble the sampling equipment and pump as necessary.

5.5.2 Low-flow Sampling

Low-flow sampling is a method of collecting samples from a well that does not require purging large volumes of water from the well and relies on natural flow of formation water

through the well. Using this method, the water flowing into and through the well is representative of the groundwater with the formation surrounding the screen and thus representative groundwater samples can be obtained by slowly pumping.

“Low flow” refers to the velocity with which water enters the pump intake and is imparted during pumping to the formation pore water adjacent to the well screen (American Society for Testing and Materials [ASTM] D6771). Low-flow does not necessarily refer to the flow rate of water discharged by a pump at the surface, which can be affected by valves, connections, and discharge tubing restrictions. However, typical low-flow surface discharger rates should be limited to less than 0.5 liters per minute (L/min) (0.13 gal/min). Low-flow sampling methods emphasize minimal stress to the groundwater by low water-level drawdown and low pumping rates in order to collect samples with minimal alterations to water chemistry (U.S. Environmental Protection Agency [EPA], 2002; ASTM D6771). This is the preferred method for natural attenuation monitoring, which requires careful measurements of DO and oxidation-reduction sensitive analytes, such as iron and manganese. Low-flow sampling is the most recommended sampling method for collecting groundwater samples and should be used whenever possible and practical, including at conventional, permanent wells, microwells, and at DPS well points if possible. Wells with low recharge rates may require special pumps capable of very-low-flow rates, such as bladder or peristaltic pumps. If the well is dewatered during purging, then it should be sampled as discussed below in Section 5.5.4 for low-permeability formations.

Low-flow sampling is typically conducted using positive displacement pumps, submersible pumps, or peristaltic pumps. Commonly used low-flow pumps include the QED Sample Pro® bladder pump, Geotech® bladder pumps, Grundfos Redi-Flo 2® submersible pump, and the Geotech Geopump™ Series II peristaltic pump (see *SOP-13 Attachment 5*).

Low-flow groundwater sampling should be conducted as follows and should be used along with *SOP-12, Field Water Quality Measurements and Calibration*:

Setup

1. Measure an initial water level within the well using a water level meter, if possible. Record the depth to water on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
2. Set up the sampling equipment and pump as described in Section 5.2 and according to the manufacturer’s instructions.
3. Secure the water quality meter to the flow-through cell and connect a short discharge tube to the effluent connector at the top of the flow-through cell and run the other end of the discharge tube into a 5-gallon graduated purge water discharge bucket. Securing the discharge tube to the 5-gallon bucket with a metal spring clamp is recommended.
4. Very slowly lower the pump or pump intake tubing down the well to the desired sample intake depth (preferably within the screened interval). Record the approximate pump or pump intake tubing depth on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
5. Run the aboveground end of the intake tube from the pump directly into the 5-gallon purge water bucket.

Purging

1. Turn on the pump and start to pump on the lowest setting. Adjust the flow slowly until water begins to discharge. Slowly pump at a flow rate of approximately 1 liter (0.25 gallons) every 3 minutes or 0.1 gal/min for approximately 1 to 2 minutes, or until the purge water begins to visually clear up. The intent is to limit any initial high turbidity water from filling and settling in the flow-through cell.

2. Once most of the observable turbidity has cleared, briefly turn off the pump and secure the tube from the pump to the influent connector at the bottom of the flow-through cell. Turn on the pump again and then allow the flow-through cell to completely fill with water. A continuous effort should be made to keep air bubbles and significant air volume from collecting in the flow-through cell. To remove any collected air volume within the flow-through cell, partially unscrew the multi-meter sonde from the flow-through cell while pumping until all the air escapes and water begins to slowly leak from the sonde/flow-through cell connection.

3. Continue pumping and begin low-flow purging the monitoring well at a flow rate of approximately 1 liter (0.25 gallons) every 3 minutes or 0.1 gal/min, such that the pumping rate does not lower the water level more than 0.3 foot. Initially monitor the drawdown frequently, to establish a steady pumping rate that minimizes drawdown. If the minimal drawdown exceeds 0.3 foot, *but remains stable*, continue purging.

4. Purge the water through the flow-through cell and into a 5-gallon graduated purge water discharge bucket. Observe the purge rate and cumulative total discharge volume based on the graduated marks on the purge bucket. Empty the purge bucket into an IDW drum or dispose of the purge water according to Appendix B, Project-specific Waste Management Plan.

5. Routinely measure and record the DO, ORP, conductivity, pH, turbidity, temperature, current groundwater level, and cumulative total purge volume throughout the purge at approximately every 3 to 5 minute interval. A minimum of three of groundwater parameter measurements should be monitored and recorded. The groundwater level should be measured frequently during purging to verify that the water level has not dropped lower than the desired 0.3 foot. Record the groundwater parameters, groundwater level, and cumulative total purge volume on a *SOP-13, Attachment 3: Well Purge and Sampling Field Datasheet*.

6. Stabilization of water quality parameters is the primary criterion for sample collection by this method. Continue to measure and record the groundwater parameters and current groundwater level until the parameters stabilize according to the following stabilization criteria. Groundwater parameters are considered stable after purging if three successive readings are within the following parameters:

   a. ± 1.0 degrees Celsius (°C) temperature
   b. ± 0.1 pH
   c. ± 3% conductivity
   d. ± 10 millivolts (mV) ORP
   e. ± 10% DO
   f. ± 10% turbidity or ≤ 10 nephelometric turbidity unit (NTUs)

7. If it does not appear that the groundwater parameters are approaching stabilization after the removal of two well volumes and *SOP-12* and *SOP-13* have been strictly followed, check the calibration of the field instrument or try using a different water quality

instrument. If the instrument check or recalibration shows that the field instruments are working properly and parameter stabilization is still not occurring, the FTL may elect to collect the sample after a minimum of three or maximum of six well casing volumes have been purged (EPA, 2002). The FTL will contact the FM when this behavior is observed and will record in the *SOP-13, Attachment 3: Well Purge and Sampling Field Datasheet* that parameter stabilization could not be achieved.

8. If and once groundwater parameters have stabilized or a minimum of 3 well casing volumes have been purged, record the final parameter measurements, water level, total purge volume, and any other purge observations on the *SOP-13, Attachment 3: Well Purge and Sampling Field Datasheet*.

Sampling

1. Following purging, collect groundwater samples without altering the flow rate or extensively interrupting the flow. Next, very briefly turn off the pump and disconnect the aboveground end of the pump intake tube from water quality meter and flow-through cell before sampling. Do not sample from the discharge of the flow-through-cell.

2. Turn the pump back on and continue to pump at a flow rate of approximately 0.1 gal/min. Re-verify the pumping rate does not lower the water level in the well by more than 0.3 foot. While sampling, discharge any groundwater pumped between filling sample containers in a 5-gallon groundwater purge bucket. Dispose of this water along with other purge water accumulated.

3. Begin filling the laboratory-supplied analytical sample containers in the order of volatility as previously described in Section 3.0. Fill the analytical sample containers as discussed in Section 5.6 until complete.

4. Record the sample ID, date and time, sampler, analytes, and other sample information on the sample bottle labels, the sample chain-of-custody, and on the *SOP-13, Attachment 3: Well Purge and Sampling Field Datasheet*, as required (see *SOP-19, Sample Handling and Custody*).

Optional – Field Filtered Samples

1. If field filtered samples are required (for dissolved metals, phosphate, nitrate/nitrite, or perchlorate, for example), briefly turn off the pump and connect the field filtering apparatus or an in-line filter capsule to the aboveground end of the pump intake tube per the laboratory analytical method and/or filter equipment manufacturer's instructions. A 0.45-micron disposable in-line filter capsule is typically used for field filtering dissolved metals. Consult the laboratory analytical method for the correct filter size and type for the analytes sampled.

5. Once connected, turn the pump back on and pre-rinse the field filter apparatus or capsule with approximately 25 to 50 milliliters (ml) of pumped groundwater. To do this, pump water through the filter for approximately 30 seconds to flush and rinse the filter media.

6. Begin filling the laboratory-supplied analytical sample containers with filtered water as discussed in Section 5.6 until complete.

7. Record the sample ID, date and time, sampler, analytes, and other sample information on the sample bottle labels, the sample chain-of-custody, and on the *SOP-13,*

Attachment 3: Well Purge and Sampling Field Datasheet, as required (see *SOP-19, Sample Handling and Custody*).

5.5.3 Well-Volume Approach

The well-volume approach method is based on purging three to six well volumes before sampling. This method can be conducted with either a bailer or pump. This method is also the default method used during low-flow sampling if groundwater parameter stabilization cannot be achieved.

One well casing volume of water (gallons) may be calculated using the following formulas:

$$V_1 = A \cdot (D_T - D_W)$$

where:

D_T = Total depth of the well (feet below top of casing [BTOC])

D_W = Depth to groundwater (feet BTOC)

D_I = Inside diameter of the well casing (inches)

A = Volume of water per linear foot of water column (gallon/foot). See Table 2.

$$A = 7.48 \cdot \pi \cdot \left(\frac{D_I}{24}\right)^2$$

Table 2. Unit Casing Volume per Linear Foot for Schedule 40 PVC Pipe.

Nominal Casing Size *(inches)*	0.75	1	1.5	2	2.5	3	4	5	6	8	10	12
Casing ID (inches)	0.82	1.05	1.61	2.07	2.47	3.07	4.02	5.04	6.06	7.98	10.0	11.9
Unit Casing Volume (*A*) (gal/ft)	0.02	0.04	0.10	0.17	0.25	0.38	0.66	1.04	1.50	2.60	4.09	5.81

Well-volume approach sampling should be conducted as follows:

1. Measure the water level within well using a water level meter. Record the depth to water on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet.*
2. Securely connect a bottom-filling bailer to a retrieval line or cord or setup the sampling equipment and pump as described in Section 5.2 and according to the manufacturer's instructions.
3. Very slowly lower the bailer, pump, or pump intake tubing to the desired sample intake depth.
4. Begin bailing or pumping the well, starting at low rate and then increasing the flow.
5. Routinely measure and record the DO, ORP, conductivity, pH, turbidity, temperature, and current groundwater level throughout the purge at approximately every 1/2 well-volume interval. Record the groundwater parameters, groundwater level, and cumulative

total purge volume on a *SOP-13, Attachment 3: Well Purge and Sampling Field Datasheet*.

6. Continue to measure and record the groundwater parameters and current groundwater level until the parameters stabilize according to the stabilization criteria in *SOP-12, Water Quality Measurements and Calibration*.
7. Once the groundwater parameters have stabilized and a minimum of three well casing volumes have been purged, record the final parameter measurements, final water level, total purge volume, and any other purge observations on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet*.
8. If parameters have not stabilized within six well volumes, stop purging and record the final parameter measurements, final water level, total purge volume, and any other purge observations on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet* (EPA, 2002).
9. If using a pump, briefly turn off the pump, reduce the flow rate of the pump to approximately 0.1 gal/min, and disconnect the aboveground end of the pump intake tube from the water quality meter and flow-through cell. Do not sample from the discharge of the flow-through cell. Then turn the pump back on and continue to pump at a flow rate of approximately 0.1 gal/min. While sampling, discharge any groundwater pumped between filling sample containers in a 5-gallon groundwater purge bucket. Dispose of this water along with other purge water accumulated.
10. If bailing, very slowly lower the bailer down the well and below the water table taking care to minimize disturbing the water column or stir up sediment in the bottom of the well as the bailer fills with water from the bottom. Then lift the bailer slowly from the water column and out of the well.
11. Begin filling the laboratory-supplied analytical sample containers in the order of volatility as previously described in Section 3.0. Fill the analytical sample containers as discussed in Section 5.6 until complete. Water should be transferred to the sample containers with minimum of disturbance and agitation.
12. Record the sample ID, date and time, sampler, analytes, and other sample information on the sample bottle labels, the sample chain-of-custody, and on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet*, as required (see *SOP-19, Sample Handling and Custody*).

5.5.4 Low-Permeability Formations

If a well is screened in a low permeability zone (such silts and clay layers), natural recharge flow into the well maybe so low that there may be no way to avoid pumping or bailing the well dry. Low-flow purging and sampling are particularly useful for wells that purge dry or take 1 hour or longer to recharge (ADEC, 2010). If a well is purged dry, a minimum of 2 hours between purging and sampling should be observed and groundwater samples should not be collected until the well has recharged to approximately 80% of its pre-purge volume (EPA, 2002; ADEC, 2010). For this method, a bailer may be used, since many sampling pumps have tubing capacities that would exceed the water volume in the well and cause it to be pumped dry again. A very-low-flow device, such as a peristaltic pump, can also be used if the groundwater depth is less than approximately 25 feet.

The following procedures apply for purging low-permeability formations, where it is not possible to obtain stabilization of field parameter data:

- Purge the well dry and allow the well to recover until at least one of the following is met:
  - A minimum of 2 hours has elapsed since purging
  - There is sufficient water volume present to obtain a water sample
  - The water in the well has recovered to 90% of the pre-pumping elevation
- Begin filling the laboratory-supplied analytical sample containers in the order of volatility as previously described in Section 3.0. Fill the analytical sample containers as discussed in Section 5.6 until complete. Water should be transferred to the sample containers with minimum of disturbance and agitation.
- Record the sample ID, date and time, sampler, analytes, and other sample information on the sample bottle labels, the sample chain-of-custody, and on the *SOP-13, Attachment 3: Well Purge and Sampling Datasheet*, as required.

5.5.5 Passive Sampling Method

Passive" groundwater sampling allows a sample to be collected from a discrete location without active media transport induced by pumping or purge techniques (Interstate Technology & Regulatory Council [ITRC], 2006; ADEC, 2010). Passive technologies rely on the sampling device being exposed to media in ambient equilibrium during the sampler deployment period. For example, well water is expected to be in natural exchange with the formation water. All passive sampling devices provide a sample from a specific location (that is, point samples).

Some of these sampling technologies are relatively mature and accepted for appropriate applications by regulators. Nonetheless, they are still considered to be innovative technologies and few if any specific policies governing their use have been written into official regulations. Passive samplers are classified on the basis of the sampling mechanism and nature of the collected sample, as follows (ITRC, 2006; California Environmental Protection Agency [CEPA], 2008):

- Grab Sample Devices. Samples are an instantaneous representation of conditions at the sampling point at the moment of sample collection.
  - Simulprobe Technologies Mini SimulProbe®
  - GeoInsight HydraSleeve™ Samplers
  - ProHydro Snap Sampler™
- Diffusion-to-Equilibrium Devices. These samplers rely on diffusion of the analytes into the sampler until equilibrium with the sampled medium is obtained. Samples are time-weighted toward conditions at the sampling point during the latter portion of the deployment period. The degree of weighting depends on analyte and device-specific diffusion rates. Typically, conditions during the last few days of sampler deployment are represented.
  - Regenerated-Cellulose Dialysis Membrane Samplers
  - Nylon-Screen Passive Diffusion Samplers (NSPDS)

  - Passive Vapor Diffusion Samplers (PVDs)
  - Peeper Samplers
  - Passive Diffusion Bag Samplers (PDBs)
  - Rigid Porous Polyethylene Samplers (RPPS)

- Diffusion/Sorption Accumulation Devices. These samplers rely on diffusion and sorption to accumulate analytes into or onto the sampler. Samples are a time-integrated representation of conditions at the sampling point over the entire deployment period. The accumulated mass and duration of deployment are used to calculate analyte concentrations in the sampled medium.

  - Semi-Permeable Membrane Devices (SPMDs)
  - GORE™ Sorber Module
  - Polar Organic Chemical Integrative Samplers (POCIS)
  - Passive In-Situ Concentration Extraction Sampler (PISCES)

SOP-13, Attachment 5: Low-flow and Passive Sampling Equipment describes the types and mechanisms of the various passive sampling devices listed above.

Passive Diffusion Bag Samplers (PDBs)

ADEC suggest the use of PDBs when confronted with sampling a monitoring well that displays little or virtually no recharge capability during well evacuation or in instances where long term monitoring during the operation and maintenance phase of remediation justifies their use (ADEC, 2010). PDB samplers take advantage of semi-permeable membrane technology to gather contaminants from groundwater (EPA, 2009). When the sampler is placed in contact with an ambient medium (contaminated groundwater), the contaminants diffuse across the semi-permeable membrane into reagent-grade organic-free water contained with the sampler. The number of contaminants that PDB samplers are capable of detected are limited, therefore these devices are not recommended for initial investigations where a more complete understanding of the contaminants of concern remains to be determined (ADEC, 2010). In addition, PDB samplers are not recommended for sampling sentinel wells. Table 3 provides a list of contaminants that PDBs may or may not be useful for sample collection.

PDB samplers are typically about 18 to 20 inches in length, are made of low-density polyethylene plastic tubing (typically 4 mil) (ADEC, 2010), and are deployed as described in the paragraphs below.

Fill the sampler with between 220 ml to 350 ml of laboratory grade (American Society for Testing and Materials [ASTM] Type II) de-ionized water and seal at both ends. Suspend the sampler at the desired depth interval within the well and left to equilibrate within the well. Teflon® coated stainless-steel wire is preferable for deploying the samplers within a well; however, synthetic cord (such as white, 3/16-inch cord) may also be used as the deployment line for single-use applications. Allow the PDB sampler to equilibrate in the well for at least 2 weeks for the most representative samples (many VOCs equilibrate within 48 to 72 hours, but the sampler should be left for the full 2-week period) (ADEC, 2010). This equilibrium period is necessary to allow the formation water and well water to re-stabilize after deployment of the samplers, and to allow diffusion between the stabilized well water and the PDB sampler to occur. In low-yielding formations, take additional time for the well to re-stabilize.

Table 3. Contaminants Where Field Data Suggest that PDBs May or May Not Be Acceptable for Collection (EPA, 2009).

Contaminants Potentially Acceptable for Collection		
Benzene	1,2-Dichlorobenzene	1,1,2,2-Tetrachloroethane*
Bromobenzene*	1,3-Dichlorobenzene	Tetrachloroethene
Bromochloromethane*	1,4-Dichlorobenzene	Toluene
n-Butylbenzene	Dichlorodifluoromethane	Trichlorobenzene*
1,2,3-sec-Butylbenzene	1,1-Dichloroethane	1,1,1-Trichloroethane
1,2,4- tert-Butylbenzene	1,2-Dichloroethane	1,1,2-Trichloroethane
Carbon disulfide	1,1-Dichloroethene	Trichloroethene
Carbon tetrachloride	cis-1,2-Dichloroethene	Trichlorofluoromethane
Chlorobenzene	trans-1,2-Dichloroethene	1,1,2-Trichloro-1,2,2-trifluoroethane
Chloroethane	1,2-Dichloropropane	Vinyl chloride
Chloromethane	Ethylbenzene	m,p-Xylene
Dibromochloromethane	Hexachlorobutadiene*	o-Xylene
1,2-Dibromoethane*	p-Isopropyltoluene	Xylenes, total
Dibromomethane*		
Contaminants Potentially Not Acceptable for Collection		
tert-Amyl methyl ether*	Naphthalene	1,2,4-Trimethylbenzene
Bromoform*	n-Propylbenzene	1,3,5-Trimethylbenzene

*Note: The data set for this compound was relatively small (fewer than five instances of comparison), so the power of the classification (that is, acceptable or unacceptable) is fairly low.

If quarterly sampling is being conducted, it is acceptable to leave PDB samplers in the well for up to a maximum of three months so that samplers can be retrieved and deployed for the next monitoring round during the same mobilization; however, longer periods of deployment are not recommended (ADEC, 2010).

Once the acceptable deployment period is complete, carefully retrieve the bag from the well and slowly drain the water within the sampler in the laboratory-supplied analytical sample containers, taking care to minimize agitation or aeration, in the order of volatility as previously described in Section 3.0, until complete.

5.6 Sampling Collection

Groundwater samples should be collected as follows:

- Fill sample containers so that the sample is allowed to flow gently along the inside wall of the container. Take care to minimize turbulence, agitation, and aeration of the sample.
- Minimize the headspace in the sample container by filling the sample jar until a positive meniscus is present (ADEC, 2002)
- Quickly and adequately seal the containers. Unless otherwise specified, seal the jar using Teflon®-lined screw caps.
- Clean rims before tightening lids.
- Label and handle sample containers as outlined in *SOP-19, Sample Handling and Custody*.
- Preserve containers immediately according to the procedures in *SOP-19, Sample Handling and Custody*. Unless specified otherwise, at a minimum, immediately cool the

samples to 4±2°C and maintain this temperature through delivery to laboratory until the samples are analyzed (ADEC, 2002).

5.7 Investigation-derived Waste

If any IDW or free product is generated during purging or sampling, store and dispose of according to Appendix B, Project-specific Waste Management Plan.

6.0 Records

Record details regarding the pumping method, parameter readings, purge volumes, and samples collected in the Field Notebook and on a *SOP-13, Attachment 3: Well Purge and Sampling Datasheet*.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

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U.S. Environmental Protection Agency (EPA). 2002. *Passive Diffusion Bag Samplers.* http://www.clu-in.net/characterization/technologies/passdiff.cfm. U.S. EPA Office of Superfund Remediation and Technology Innovation, Hazardous Waste Clean-Up Information (CLU-IN). Accessed February 19, 2010.

8.0 Definitions

None.

9.0 Attachments

Attachment 1: *Seasonal Water Levels and Expected Smear and Saturated Zones*

Attachment 2: *MiniSimulProbe Standard Operating Procedure*

Attachment 3: *Well Purge and Sampling Datasheet*

Attachment 4: *Well Condition Inspection Datasheet*

Attachment 5: *Low-flow and Passive Sampling Equipment*

SOP-14

Equipment Decontamination Procedures

SOP-14: EQUIPMENT DECONTAMINATION PROCEDURES

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to provide the step-by-step procedures for field decontamination of environmental sampling equipment and personal protective equipment (PPE). Decontamination of equipment and PPE is designed to ensure that sample cross-contamination, human-health exposure, and contamination transport are minimized.

2.0 Scope

This procedure applies to all CH2M HILL personnel and subcontractors engaged in collecting environmental samples or operating in environments in which hazardous or contaminating substances are expected to be present at the Galena Forward Operating Location (FOL). All decontamination procedures will be conducted per the following guidance documents:

- *Draft Field Sampling Guidance* (Alaska Department of Environmental Conservation [ADEC], 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)
- Appendix A, Project-specific Health and Safety Plan (HSP)
- Appendix B, Project-specific Waste Management Plan

3.0 General

Decontamination consists of physically removing contaminants from the surface of sampling equipment and materials potentially exposed to those contaminants. A decontamination plan should be based on the most conservative, worst-case scenario, using all available information about the work area. The plan can be modified, if justified by supplemental information. Initially, the decontamination plan assumes that all protective clothing and equipment which leave the exclusion zone are contaminated. Based on this assumption, a system is established to wash and rinse all nondisposable equipment and dispose of all disposable equipment.

The type of decontamination procedures and solutions needed at each site should be determined after considering the following site-specific conditions:

- The type of equipment to be decontaminated
- The type of contaminant(s) present
- Extent of contamination
- Potential human and ecological risk scenarios

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for overall compliance with this procedure and for verifying that field staff are properly trained and meet project Health, Safety, and Environmental (HS&E) requirements.

4.2 Field Team Leader

The Field Team Leader (FTL) is responsible for following these procedures or delegating tasks to technicians to perform decontamination tasks. The FTL should verify that subcontractors are taking necessary precautions to decontaminate field equipment before and throughout field activities. The FTL should also verify that decontamination waste and PPE are disposed of appropriately according to Appendix B, Project-specific Waste Management Plan.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and overall compliance with project HS&E requirements. The HSM conducts PPE evaluations, selects the appropriate PPE for the project, lists the requirements in the Project-specific Health and Safety Plan (HSP) (Appendix A), coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and certify the PPE program, and conducts project health and safety audits on the effectiveness of the HS&E program.

4.4 Safety Coordinator

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

5.0 Procedure

Decontaminate all nondisposable sampling equipment used at the site both before activities begin and after each sample is collected. Decontaminate all drilling and excavation equipment both before activities begin and between each investigation location. Take care that materials and solutions used for decontamination procedures are themselves not hazardous or could potentially contaminate samples (that is, are acids and solvents).

5.1 Decontamination Area

Identify a localized decontamination area or drill rigs and other sampling equipment. Select the decontamination area so that decontamination fluids and soil wastes can be managed in a controlled area with minimal risk to the surrounding environment. The decontamination area should be large enough to allow temporary storage of cleaned equipment and materials before use, as well as to stage drums of decontamination investigation-derived waste (IDW). In the case of large decontamination areas (for example, for hollow-stem-auger decontamination), line each area with a heavy-gauge plastic sheeting and include a collection system designed to capture potential decontamination IDW. Decontamination

areas will, in all cases, be laid out in such a way as to prevent overspray while performing equipment and personnel decontamination.

Smaller decontamination tasks, such as surface water and sediment equipment decontamination, may take place at the sampling locations. In this case, all required decontamination supplies and equipment must be mobilized to the site and smaller decontamination areas for personnel and portable equipment will be provided as necessary. These locations will include basins or tubs to capture decontamination IDW, which will be transferred to larger containers as necessary.

5.2 Decontamination Equipment

The following is a list of equipment and materials that may be needed to perform decontamination:

- Concrete or synthetic material-lined decontamination pad
- Plastic sheeting/membrane to serve as secondary containment for liquids
- Brushes and flat-bladed scrapers
- Garden-type water sprayers (without oil-lubricated, moving parts)
- High-pressure washer
- Portable steam cleaner
- Sump or collection system for contaminated liquid
- Wash basins and buckets
- Spray and rinse bottles
- Potable water, deionized water, and laboratory-grade detergent (Liquinox, Alconox, or similar)
- Plastic waste bags
- Leak-tight liquid waste containers (55-gallon drums or similar)
- Bulk solid waste containers (super-sacks, 55-gallon drums, or similar)

5.3 Decontamination Procedures

5.3.1 Personnel and Personal Protective Equipment

Decontamination of personnel and PPE prevents undesired human-health exposure to contaminants via ingestion, absorption, and inhalation. All personnel and PPE will be decontaminated as outlined in the HSP (Appendix A). Any further concerns regarding personnel and PPE decontamination procedures may be addressed directly with the FM, PM, or HSM.

5.3.2 Sampling Equipment

Conduct consistent decontamination of sampling equipment to ensure the quality of the samples collected. Decontaminate all equipment that comes into contact with potentially contaminated samples. Disposable equipment intended for one-time use that is factory

wrapped generally does not need to be decontaminated before use, unless evidence of contamination is present. Disposable equipment, such as disposable bailers, spoons, TerraCore® or Encore® VOC samplers, is preferred over reusable equipment; use wherever appropriate. Decontaminate sampling equipment, including split-barrel samplers, hand-augers, reusable bailers, spoons, trowels, shovels, and pumps used to collect samples for chemical analyses before each use and before sampling at a new sampling location.

Take the following steps to decontaminate non-dedicated sampling equipment:

- Decontamination personnel will wear the appropriate PPE as required by the HSP (Appendix A).
- The sequence of actual decontamination will be as follows:
    1. Remove as much gross contamination (such as pieces of soil) as possible off equipment at the sampling site.
    2. If heavy petroleum residuals are encountered during sampling, an appropriate solvent such as methanol will be used to remove any petroleum residues from sampling equipment. If a solvent is used, it must be properly used, collected, stored, and disposed of according to the HSP (Appendix A) and the Project-specific Waste Management Plan (Appendix B). If heavy petroleum residuals are not encountered, this step should be omitted.
    3. Wash water-resistant equipment thoroughly and vigorously with potable water containing non-phosphate laboratory-grade detergent such as Liquinox, Alconox, or equivalent, and using a bristle brush or similar utensil to remove any remaining residual contamination.
    4. Rinse equipment thoroughly with potable water (1st rinse).
    5. Rinse equipment thoroughly with distilled or deionized water (2nd rinse).
    6. For sensitive field instruments, rinse equipment with distilled, deionized, or American Society for Testing and Materials (ASTM) reagent grade water (3rd rinse).
    7. Air dry at a location where dust or other fugitive contaminants may not contact the sample equipment. Alternatively, wet equipment maybe dried with a clean, disposable paper towel to assist the drying process. All equipment should be dry before reuse.
- If the equipment is not used soon after decontamination, it should be covered or wrapped in new, oil-free aluminum foil or new, unused plastic bags to protect the decontaminated equipment from fugitive contaminates before reuse.
- Store decontaminated equipment at a secure, unexposed location out of the weather and any potential contaminant exposure.
- Depending on site conditions and the number of samples collected at each location, rinse and detergent water will normally be replaced with new solutions between borings or sample locations.

NOTE: See Section 5.3.3 for information on groundwater sampling pumps.

5.3.3 Groundwater Sampling

Proper decontamination between wells is essential to avoid introducing contaminants from the sampling equipment. For sampling with decontamination of peristaltic pumps, all that is necessary is to replace the pump head tubing after sampling each well. If sampling with pumps such a submersible, bladder, or similar pump in which mechanisms of the pump come in direct contact with contaminated water, or sampling with a reusable stainless steel bailer, decontaminate the pump or bailer. The following steps will be used for pumps and bailers contaminated with dissolved phase contamination only:

- Wash the exterior of the pump or bailer and any associated cable thoroughly and vigorously with potable water containing non-phosphate laboratory-grade detergent such as Liquinox, Alconox, or equivalent, and using a dedicated wash bristle brush or similar brush.
- Place the pump into a potable water wash basin/reservoir containing non-phosphate laboratory-grade detergent making sure that the pump intake is fully submerged and the pump outlet is allowed to flow directly back into the wash reservoir. Set the pump to a very low flow rate and turn the pump on, allowing the wash water to recirculate through the pump mechanism for a minimum of 5 minutes. Disregard this step for reusable bailers.
- Initially, rinse the pump or bailer by repeating Steps 1 and 2 using potable water, a dedicated rinse bristle brush, and a rinse basin/reservoir containing only potable water (1st rinse).
- Final rinse the pump or bailer by duplicating Step 3 using distilled, deionized, or ASTM reagent grade water (2nd rinse).
- Dry off any excess water with a clean, disposable paper towel and allow to air dry at a location where dust or other fugitive contaminants may not contact the sample pump or bailer.

If the pump or bailer is used to sample groundwater containing non-aqueous phase liquid (NAPL) or other heavy petroleum contamination, field-dismantle (field-stripp) the equipment per the manufacturer's guidelines and decontaminate the interior and exteriors surfaces of the pump or bailer using the wash, double rinse, and dry steps outlined in the previous Steps 1, 3, 4, and 5. If significant heavy petroleum residue is encountered during decontamination, use an appropriate solvent such as methanol to remove any petroleum residues from pump or bailer surfaces. If a solvent is used, it must be properly used, collected, stored, and disposed of according to the HSP (Appendix A) and the Project-specific Waste Management Plan (Appendix B). If heavy petroleum residuals are not encountered, omit this step.

5.3.4 Measurement Devices and Monitoring Equipment

For water quality instruments, oil-water interface indicators, water level indicators, continuous water level dataloggers, and other field instruments that have the potential to come into contact with site media, at a minimum, washwith dilute laboratory-grade detergent (Liquinox or similar) and double rinse with potable and distilled/deionized water before and after each use using a similar procedure as discussed in Section 5.3.2. If heavy petroleum residuals are encountered during sampling, use an appropriate solvent such as methanol to remove petroleum residues per the manufacturer's maintenance guidelines.

5.3.5 Drilling and Subsurface Soil Sampling Equipment

Drilling equipment and associated materials will be decontaminated by the drilling contractor prior to any drilling operations and between borings. Decontaminate tools used for soil sampling (for example, split spoon samplers) before and between collecting any analytical samples, as outlined in Section 5.3.2. Thoroughly clean external and internal surfaces of drilling equipment (that is, drill bits, auger, drilling stem, and hand tools) before beginning any drilling operations and between borings using the following basic sequence:

- Remove as much gross contamination as possible off equipment at the sampling site.
- Wash equipment thoroughly and vigorously with high-temperature potable water using a high-pressure washer and/or steam cleaner. A bristle brush is also suggested to remove any persistent gross contamination.
- Rinse equipment twice thoroughly with potable water (1st and 2nd rinse).
- Air dry at a location where dust or other fugitive contaminants may not contact the sample equipment. All equipment should be dry before reuse.
- Store decontaminated equipment at a location away from any potential exposure from fugitive contamination.

5.3.6 Decontamination of Earthwork Equipment

Wash earthwork equipment (such as excavators, back-hoes, and trucks) with high-pressure potable water, if possible, before leaving a contaminated area, using similar steps as outlined in Section 5.3.5. Portable steam-cleaners and hand washing with a brush and detergent, followed by a potable water rinse, can also be used. In some instances, tires and tracks of equipment maybe only need to be thoroughly brushed with a dry brush. Take particular care with the components in direct contact with contaminants, such as tires and backhoe buckets. Any part of earthwork equipment that may come in direct contact with analytical samples (that is, sampling from the excavator bucket) must be thoroughly decontaminated before excavation activities and between sample locations.

5.4 Investigation-derived Wastes

Depending on the contaminant, potentially hazardous IDW (such as wash water or rinsate solutions) will be accumulated in 55-gallon drums and subsequently transported to a waste storage area designated by the client, according to project-specific and installation-wide procedures for management of IDW as described in Appendix B, Project-specific Waste Management Plan and in accordance with all federal, state, and local waste regulations (ADEC, 2010).

6.0 Records

Sampling personnel will be responsible for documenting decontamination of sampling and drilling equipment. Record documentation in the Field Notebook or on a Field Datasheet as discussed in *SOP-01, Note Taking and Field Log Books*. The information entered in the Field Log Book concerning decontamination should include the following:

- Decontamination personnel
- Decontamination solutions used (such as Alconox or distilled water)

- Date and time (start and end)
  - Location of decontamination
- General decontamination methods, tools used, and observations
  - Any deviations from the decontamination methods outlined in SOP-14
- Equipment identification numbers
- Manufacturer names and lot numbers of decontamination solutions
  - Location and amount of decontamination IDW collected, stored, and/or disposed
  - Identification number, date, sampling area, and information of stored decontamination IDW
  - Any decontamination IDW spills or releases and associated corrective actions

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

American Society for Testing and Materials (ASTM) International. 2008. Standard D5088-02: Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites.

Nielsen, D.M. 1991. *Practical Handbook of Ground-Water Monitoring*. Lewis Publishers. Pages 625-636.

U.S. Environmental Protection Agency (EPA). February 1999. *Procedures to Schedule and Complete Sampling Activities in Cooperation with EPA Region VII Environmental Services Division*.

U.S. Environmental Protection Agency (EPA). Region VII. February 1, 1991. *Environmental Services Division Operations and Quality Assurance Manual.*

U.S. Environmental Protection Agency (EPA). August 1987. *A Compendium of Superfund Field Operations Methods.* Volumes I and II. EPA/540/P 87/001a & b.

8.0 Definitions

Decontamination Area: an area that is not expected to be contaminated and is upwind of suspected contaminants

Decontamination Equipment: any equipment used during the process of decontamination of personnel or sampling equipment.

Drilling and Subsurface Soil Sampling Equipment: any equipment and tools used during the process of drilling or subsurface soil sampling.

Galena Forward Operating Location (FOL): the overall location of Air Force site investigations in Galena, Alaska.

Health and Safety Plan: a plan developed to ensure that all hazards associated with a site are evaluated prior to site entry

Measurement\Monitoring Equipment: any equipment used to check or evaluate site conditions

Personal Protective Equipment (PPE): personal health and safety equipment used to protect the individual from contaminant exposure, physical injury, or death.

Potable: water acceptable for drinking and washing

Sampling Equipment: any equipment used during the process of sample collection

Earthwork Equipment: Heavy earthmoving equipment typically used for excavation and test pit investigations.

9.0 Attachments

Attachment 1: *HSE-218 Hazardous Waste Operations*

SOP-15

Soil Gas Probe Installation and Active Soil Gas Sampling with a SUMMA Canister and Helium Leak Testing

SOP-15: SOIL GAS PROBE INSTALLATION AND ACTIVE SOIL GAS SAMPLING BY USING A SUMMA CANISTER AND HELIUM LEAK TESTING

1.0 Purpose

This standard operating procedure (SOP) describes the general methodology for installing soil gas and sub-slab gas probes and collecting soil gas and sub-slab gas samples for laboratory analysis by using a SUMMA Canister. Leak testing procedures for active soil gas sample collection are also described.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in soil gas probe or sub-slab gas probe installation and gas sampling with SUMMA Canisters. All of the soil gas and sub-slab gas probe installation and sampling procedures included in this SOP are intended to meet the requirements of the following documents:

- *Draft Field Sampling Guidance* (Alaska Department of Environmental Conservation [ADEC], 2010)
- *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009)

In addition, the sub-slab gas probe installation and sampling procedures must be conducted per Appendix A, Project-specific Health and Safety Plan (HSP).

3.0 General

There are two basic types of soil gas surveys typically performed during site assessments. The first type is an active soil gas survey, where soil gas is typically pumped into a sample container or directly into an analyzer; if sample results of higher data quality than field screening are desired, the sample containers are shipped to the laboratory for analysis. The second type is the passive soil gas survey, where absorbent material is buried in the vadose zone so that the contaminant vapor can be selectively absorbed over time (typically over a 1- to 2-week period). Passive soil gas surveys are often used during site characterization to identify source areas and localized hotspots.

This *SOP-15* covers only procedures for obtaining active soil gas samples with SUMMA Canisters (or similar devices). Procedures for installation and retrieval of passive soil gas samplers are covered in *SOP-27*.

Active soil gas sampling that does not involve direct measurement of samples (by field screening methods) is typically conducted by using SUMMA Canisters. SUMMA Canisters are stainless-steel vessels that have inert inner surfaces to prevent potential reaction with organic contaminants in air. The SUMMA Canisters are pre-cleaned and prepared for sampling by repeated pressurization with humidified air, heat, and evacuation at the laboratory. Gas samples are typically analyzed by U.S. Environmental Protection Agency Method TO15. Actual analyses are project specific and specified in this work plan.

Active soil gas samples (also known as integrated samples) can be collected over a 5 minute to 24-hour period by connecting the SUMMA Canister to a flow controller that is pre-calibrated to the sampling time required to fill up the canister.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) supervises the development of the project planning documents; assigns trained, qualified personnel to supervise the installation of soil gas probes and acquire soil gas samples as described in this SOP, and confirms that the necessary equipment and supplies are used to obtain representative soil gas samples.

4.2 Field Team Leader

The Field Team Leader (FTL) supervises the installation of soil gas probes and the collection of gas samples. The FTL documents all field-related activities and checks that equipment is calibrated and correctly operated and maintained.

4.3 Project Chemist

The Project Chemist identifies qualified laboratory services, monitors the results of gas analyses, and confirms that the work meets project data quality objectives.

4.4 Field Sample Collector

The Field Sample Collector collects samples following procedures outlined in this SOP, and follows directions given by the FTL.

5.0 Procedure

The following sections describe typical materials, equipment, and procedures for soil gas probe installation and soil gas sampling.

5.1 Site-specific Considerations

Site-specific conditions to consider for soil gas surveys include the following:

- Sampling depth: Soil gas samples should be collected in the vadose zone and above the capillary fringe. Generally, soil gas samples should not be collected actively at depths above 5 feet below ground surface (bgs) because of the risk of leakage and dilution of the sample with ambient air. Sampling at multiple depths should be considered.
- Soil permeability**:** It might not be feasible to collect soil gas from tight-grain soil with little pore volume, such as clay. If there are clay layers in the subsurface, these intervals should be avoided. During purging and sampling, the vacuum in the sampling system should never exceed 7 inches of mercury (inches Hg) (100 inches of water). High vacuums can be caused by tight-grain soil, wet soil, or an unreleased expendable probe tip (see *SOP-15*, Attachment 3 for detailed troubleshooting instructions).
- Precipitation: Soil gas sampling should generally not be performed for 48 hours after a significant precipitation event (more than 1 inch of precipitation). Soil moisture can displace the soil gas, dissolve volatile organic compounds, and increase the vacuum

during sampling. Generally, at depths greater than 3 feet bgs, soil gas is unlikely to be affected by precipitation. If soil gas samples are taken at less than 3 feet bgs, then the percent of moisture in the soil should be measured.

- Seasonal changes: Soil gas concentrations can vary significantly with fluctuating groundwater table elevation, soil moisture, temperature, and barometric pressure. Consideration should be given to the season and weather conditions during sampling. Multiple sampling events during the annual cycle may be needed to characterize the soil gas adequately.
- Contaminant types: Some contaminants (such as hydrocarbons) are readily biodegradable. Field measurements of natural bioattenuation field parameters (carbon dioxide [CO_2], oxygen [O_2], and methane [CH_4]) should be considered for sites where biodegradable contaminants are present and natural bioattenuation may be active.

5.2 Equipment, Supplies, and Suppliers

Soil gas and sub-slab gas installation and sampling equipment should be verified by the source supplier to be pre-cleaned before use to eliminate the potential for cross contamination. The following list of supplies and equipment may be needed during the course of conducting a soil gas investigation:

- SUMMA Canister(s) (typically obtained from the analytical laboratory).
- Teflon® tubing or stainless-steel tubing for collecting samples from the desired sampling zone (Tygon® tubing should NOT be used).
- Stainless steel soil gas implants, certified clean silica sand or glass beads, and bentonite for completing semi-permanent subsurface soil gas probe installations. Appropriate surface completions to protect probes if probes are at risk of being disturbed before sampling.
- Stainless-steel sub-slab probes for sub-slab gas probe installation. Sub-slab probes can be assembled before field mobilization, as described in *SOP-15*, Attachment 3. The following parts may be needed: tube cutter, 1/4-inch stainless steel tube, Swagelok® nut and ferrules, probe union (1/4-inch male Swagelok® to 1/8-inch female national pipe thread [NPT]), probe seal (1/8-inch NPT slotted brass plug), and sampling union (1/4-inch male Swagelok® or equivalent to ¼-inch male NPT).
- Beeswax, Fix-It-All™, or bentonite/cement mixture for sub-slab probe surface seal (see Table 1 in *SOP-15*, Attachment 3 to determine appropriate seals for task).
- 1/4-inch Swagelok® nuts and ferrules, and T-connections for connecting to SUMMA Canisters and leak testing equipment during leak testing.
- Oil-less, low-flow vacuum pump for leak testing, and purging of soil gas probe lines and annular space.
- Helium detector/meter (*SOP-15*, Attachments 1 and 3) for leak testing if conducting active sampling.
- MiniRAE or MultiRAE photoionization detector (PID) instrument if field measurements of total volatile organic compounds (VOCs) are necessary.
- GEM™ 2000 Landfill Gas Monitor if field measurements of CO_2, O_2, CH_4 are necessary.

- Rotometer to measure flow rates during purging and leak testing before sampling.
- Filters (to prevent particulate matter from entering the canister). The required filter size is 2 microns. Usually attached upstream from the flow controller.
- Vacuum gauge (0 to 30 inches Hg) (to measure the initial and final vacuum of the canister and to monitor filling rate when collecting an active soil gas sample).
- Flow controller (required for an active soil gas sample).
- Generator or battery to run the vacuum pump. If generator is used, check that there is enough extension cord to place generator downwind and away from sampling location.
- Nitrile gloves.
- Camera.
- Flags and flagging.
- Shipping container/storage box for canisters.
- Field Sampling Log and Field Data Collection Forms.
- Permanent markers (care should be taken any time markers are used around active gas sampling equipment because there are VOCs in most markers).

Equipment necessary for soil gas and sub-slab gas investigations may be obtained by contacting:

- SUMMA Canister(s) provided by the analytical laboratory.
- Gas fittings and leak testing equipment. Applied Sciences Laboratory or Ben Thompson in the Corvallis, Oregon, office (telephone 541-768-3132).
- The CH2M HILL Denver Field Equipment Warehouse has field equipment available for project use (Terry Foxworthy, telephone 720-286-2525).

After receipt of SUMMA Canisters from the laboratory, the canisters should be inspected for physical deformities and sufficient negative pressure. Canisters with negative pressure readings less than ˜28 inches Hg are acceptable sampling containers.

5.3 Soil Gas Probe Installation

Soil gas probes should generally be deployed by using these procedures. Modifications to these procedures might be necessary depending on project objectives. Detailed installation procedures for temporary soil gas probes are included in *SOP-15*, Attachment 1. Detailed installation procedures for permanent and semi-permanent soil gas probes are included in *SOP-15*, Attachment 2.

- Every probe must be at least 5 feet away from any other drilled or pushed location to avoid short circuiting.
- Soil gas samples should generally not be collected from depths shallower than 5 feet bgs to avoid dilution of samples with ambient air.
- All down hole equipment (for example, soil gas drive rods and continuous core soil sampling equipment) must be decontaminated before use as described in *SOP-14*. After

the equipment is decontaminated, the probes must be free of contaminants. At a minimum, a suitably sensitive organic gas meter (such as a PID) should be used for this purpose. Any probe that does not pass a decontamination inspection should not be used.

- Install temporary post-run tubing (PRT)-style soil gas probes by using a direct push drill rig to push the PRT to the desired sampling depth, making sure that this depth a couple feet above the highest expected water levels (see *SOP-05* and *SOP-15*, Attachment 1). In limited-access locations, a fencepost hammer potentially can be used to push the PRT to the desired sampling depth for shallow locations in relatively soft soil. Retract 6 inches to create an annular space for sampling
- Soil samples cannot be collected from the exact same location when installing temporary probes.
- The inner soil gas pathway from probe tip to the surface should be continuously sealed (for example, with a sampling tube attached to a screw adapter fitted with an O-ring and connected to the probe tip) to prevent infiltration (see *SOP-15*, Attachment 1).
- During sampling of temporary soil gas probes, hydrated bentonite or some other surface seal may be used around the drive rod at ground surface to prevent ambient air intrusion from occurring.
- Install permanent or semi-permanent soil gas probes by using a direct push drill rig (see *SOP-05* and *SOP-15*, Attachment 2) or a hand auger. Push down to the desired sampling depth, making sure that this depth is approximately 2 feet above the highest expected water levels.
- Install permanent or semi-permanent, stainless-steel soil gas implants into the borehole. The inner soil gas pathway from the soil gas implant to the surface should be sealed continuously with tubing to prevent infiltration (see *SOP-15,* Attachment 1).
- Backfill with clean silica sand to at least 0.5 foot above the soil gas probe. Add enough bentonite powder to create a 2 inch ‘dry’ layer followed by hydrated bentonite grout. At least 2 feet of the mixture are recommended to adequately seal the hole and prevent contribution from ambient air during sampling.
- After installation, allow at least 20 minutes for temporary wells and at least 30 minutes for permanent wells for equilibration before purging with leak test followed by sampling.
- Prepare soil gas probe manifolds. Attach Teflon® sampling tubing to soil gas probes by using a 1/4-inch Swagelok® fitting with a ferrule at the surface end of the tubing. Tubing diameter should be small (1/8 or 1/4 inch) to avoid turbulent flow. A few feet of extra tubing coming out of the borehole is necessary to place the SUMMA Canister and stage leak testing equipment at the sampling location.
- Soil gas sample integrity is verified by using a real time helium leak checking procedure before taking each sample. This leak checking procedure must be done after installation of each probe and before sampling as well as before each subsequent sample collected from permanent probes. Follow leak testing (*SOP-15*, Attachment 3) and SUMMA Canister deployment procedures outlined below. Low-flow purge rates, between 100 and 200 milliliters per minute, should be used during purging to limit stripping, creation of preferential pathways, and dilution with ambient air.

- If an adequate seal cannot be obtained (as determined by *SOP-15*, Attachment 3), an additional soil gas probe should be installed in a new borehole and the leak test conducted again. Unless the leak test is passed, the SUMMA Canisters should not be deployed.

- Soil samples can be collected from ground surface down to the desired soil gas sampling depth when drilling a borehole for installation of semi-permanent soil gas probes. Soil sample collection beyond the soil sample probe depth in the same borehole is not recommended because of the risk for leakage of soil gas from deeper in the borehole. If soil samples are to be collected at greater depths, a separate soil boring can be drilled a minimum of 5 feet away from the soil gas probe. The soil boring should be sealed with grout or hydrated bentonite chips to avoid leakage of ambient air to the soil gas probe.

5.4 Sub-slab Gas Probe Installation

Sub-slab gas probes generally should be deployed following these procedures, though alterations to these procedures may be necessary depending on project objectives. Detailed installation procedures for sub-slab soil gas probes are included in *SOP-15*, Attachment 3.

- Drill through the sub-slab by using a hammer drill as described in *SOP-15*, Attachment 4. First, drill a 7/8-inch- or 1-inch-diameter hole to a depth of 1 3/4 inches (measured to the center of the hole) to allow room for installing the probe nut and probe union.

- Remove the cuttings and dust from the hole by using a vacuum cleaner (shop-vac type or handheld). Be careful not to compromise the integrity of the slab during drilling (for example, cracking it), although note if this occurs. It is important that the slab and the probe hole remain airtight for sampling and that cracks are noted.

- Drill a 5/16-inch- or 3/8-inch-diameter hole through the remainder of the slab and approximately 3 inches down into the sub-slab material by using the hammer drill.

- Clean out the drilled hole by using the vacuum cleaner (equipped with a micro tip), Q-tips®, and paper towels.

- Remove concrete dust from the drilled hole with a vacuum cleaner or Shop-Vac®.

- Construct sub-slab gas probes of appropriate length and install in the sub-slab hole (*SOP-15*, Attachment 4).

- Seal around probe with beeswax, Fix-It-All™, or bentonite/cement (*SOP-15*, Attachment 4). Allow 10 minutes for beeswax, 30 minutes for Fix-It All™, or 24 hours for bentonite/cement to dry.

- Sample integrity is verified by using a real time helium leak checking procedure before taking each sample. This leak checking procedure must be done after installation of each probe and before sampling. Follow leak testing (*SOP-15*, Attachment 4) and SUMMA Canister deployment procedures as outlined in this SOP.

- If the leak test fails, fortify the probe seal by adding more sealing material, and repeat the purge and leak check procedure.

- If an adequate seal cannot be obtained (as determined by *SOP-15*, Attachment 4), an additional sub-slab probe should be installed and the leak test conducted again. Unless the leak test is passed, the SUMMA Canisters should not be deployed.

5.5 Purging and Leak Testing before Active Soil Gas or Sub-Slab Gas Sampling

SOP-15, Attachments 3 and 4 provide detailed procedures for conducting purging of dead volume and leak testing before starting soil gas or sub-slab gas sampling. These procedures must be followed before any active gas sampling where probes are installed for the purpose of obtaining a discrete sample from below the ground surface or sub-slab.

The dead volume is determined as the sum of the internal volume of the sample tubing and the annual space at the end of the probe tip. Purging of three dead volumes is necessary to remove ambient air before sampling.

Leak testing is necessary to determine if the soil gas probe or sub-slab gas probe will provide a discrete sample from the desired sampling depth (as opposed to obtaining an air sample from the ground surface above the borehole or sub-slab where it was installed). This may be caused by short circuiting around the soil gas probe tubing or by cracks in the surrounding formation or slab.

5.6 Active Soil Gas and Sub-Slab Gas Sample Collection

SOP-15, Attachments 3 and 4 provide detailed procedures for conducting active soil gas or sub-slab gas sampling. An active sample should be collected by using a flow controller for a period from 30 minutes to 24 hours. A gauge is used to record the initial and final vacuum and to monitor the vacuum as the canister fills. Final vacuum, canister number, and flow controller number are to be recorded on the sample tag, chain-of-custody form, and form provided in *SOP-15*, Attachments 3 and 4.

Active sampling results provide data that indicate the average concentration present in soil gas, which is useful for determining exposure hazards.

Soil gas samples will be analyzed for parameters determined in the work plan. The general field sampling procedures for sampling are as follows:

- The SUMMA Canisters are certified clean and evacuated by the laboratory to near absolute zero pressure. Care should be used at all times to prevent inadvertent loss of canister vacuum.
- Never open canister valves unless collecting a sample or checking canister pressure.
- Check the initial vacuum of the canister with the “vacuum gauge” provided by opening the canister valve; record the vacuum reading on the sample tag attached to the canister and the form provided in *SOP-15*, Attachment 3 & 4.
- Place the SUMMA Canisters in a relatively secure location, away from vehicle traffic or other sources of gas or fumes unrelated to the sampling objective.
- Connect the flow controller and pressure gauge to the SUMMA Canister. The flow controller should be set to closed (no flow) position.
- Attach the flow controller by using a 1/4-inch female Swagelok® fitting to the inlet of the canister (which is a 1/4-inch male Swagelok® fitting); tighten the threaded nut until it is hand tight. Do not cross the threads.
- Use a 9/16-inch wrench to completely tighten the flow controller to the canister inlet. After tightening, the flow controller should not be able to be turned on the top of the canister by hand.

- To start sampling, turn the canister valve clockwise, one and one-half to two turns. Note the start time on the sample tag attached to the canister.
- The flow controller is preset for sample collection at the desired sampling rate. No field adjustments are possible.
- Record the sampling date, time, canister identification (ID), flow controller ID, and any other observation pertinent to the sampling event on the Field Sampling Log (*SOP-15*, Attachments 3 and 4).
- After sampling for the appropriate amount of time (see project instructions), close the sample valve and the canister valve. After closing the valves, remove the flow controller from the canister, replace the dust cap, and package all equipment in the box in which they were received.
- The final pressure should be close to 1 and 3 inches Hg (nearly atmospheric pressure). If the canister is at atmospheric pressure when the field final pressure check is performed, the sampling period will be uncertain; this information should be noted in the Field Sampling Log; also record the time of day.
- Attach an identification tag to the canister. The canister serial number, sample number, sampling location, and sample completion date and time are recorded on the tag (the start date and time were already recorded).
- Record the final vacuum measurement, canister number, and flow controller number on the laboratory chain-of-custody form.

6.0 Records

All field measurements will be recorded in the Field Sampling Log (*SOP-01*), and the Field Sampling Log in *SOP-15*, Attachments 3 and 4. Field measurements should include the coordinates of the sampling location, sample probe depth, initial and final canister pressure, sample collection start and end time, serial numbers of sample canisters and flow meters, and information on any other equipment used. In addition, if active soil gas sampling is conducted, leak testing parameters will be recorded on the leak testing form provided in *SOP-15*, Attachments 3 and 4. PID readings will be recorded at sampling locations where total VOC measurements are necessary. Other field parameters (such as CO_2, O_2, and CH4) will be recorded at sampling locations where bioattenuation may be significant.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). July 2009. *Draft Vapor Intrusion Guidance for Contaminated Sites*.

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Winberry, William T. May 1987. C*ompendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. EPOA-600/4-84-041 Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 1987. *Compendium of Methods for the Elimination of Toxic Organic Compounds in Ambient Air*. EPA-6-094-84-04 (Methods T0-1 to T0-14).

8.0 Definitions

SUMMA Canister: a stainless-steel vessel used to collect air gas samples for laboratory analysis. The canister's inner surfaces are passivated to prevent reaction with contaminants in gas samples.

Volatile organic compounds (VOCs): organic compounds that evaporate when exposed to air (the gas pressure is greater than 100 mm Hg)

9.0 Attachments

Attachment 1: *Standard Operating Procedure for the Installation of Temporary Shallow Soil Gas Sampling Probes in Conjunction with Indoor Gas Vapor Intrusion Assessments (Post-run Tubing Soil Gas Probes)*

Attachment 2: *Standard Operating Procedure for the Installation of Permanent Soil Gas Sampling Implants*

Attachm*ent 3: Standard Operating Procedure for the Collection of Soil Gas Samples from Temporary and Permanent Soil Gas Probes by Using SUMMA Canisters and a Helium Leak Check*

Attachment 4: *Standard Operating Procedure for Installing Sub-slab Probes and Collecting Sub-slab Soil Gas Samples by Using SUMMA Canisters and a Helium Leak Check*

SOP-16

Global Positioning Satellite System (GPS) Surveying

SOP-16: GLOBAL POSITIONING SATELLITE SYSTEM (GPS) SURVEYING

1.0 Purpose

This standard operation procedure (SOP) outlines the protocols and general procedures for operating a mapping grade global positioning satellite system (GPS) handheld instrument.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in environmental investigation activities at Galena Forward Operating Location (FOL) projects and tasks. This SOP focuses on the most commonly used environmental surveying and sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-15, Active Soil Gas Vapor Sampling*
- *SOP-27, Passive Soil Gas Vapor Sampling*
- *SOP-24, Direct Push Groundwater Sampling*
- *SOP-31, Multi Increment® Sampling for Surface Soil*

3.0 General

It is CH2M HILL's position that establishing standardized protocols for collecting environmental data in the field using Global Positioning System (GPS) technology is imperative to the success of any project. The guidelines in this section have been developed to ensure consistent GPS data collection and post-processing techniques across projects, staff, and geographic locations. Please refer to *Attachment 1, CH2M HILL GPS Management SOP,* for an overview of the most important GPS management activities. The methods described are based on Trimble submeter mapping grade GPS devices and Trimble Pathfinder Office software. These procedures are to be used as a reference tool in conjunction with specific GPS and job procedure training.

3.1 GPS Basics

GPS is divided into three fundamental aspects: control, space, and user (Trimble, 2006).

- Control is the central "brain" of the GPS system. A GPS controller monitors the satellites' transmission of navigation messages and sends adjustments, if necessary. The U.S. Department of Defense (DoD) operates this segment from Falcon Air Force Base in Colorado Springs, Colorado. Control also includes four monitoring and upload stations distributed throughout the world, with each satellite passing over a monitoring station twice a day.

- Space is the Navigation Satellite Timing and Ranging (NAVSTAR) constellation of satellites that broadcast GPS signals. When the system is at full operational capacity, there are 24 operational satellites. This number changes constantly as satellites are commissioned and decommissioned. These satellites orbit 20,200 kilometers (km) above the earth and make one complete revolution approximately every 12 hours.
- Users include all civilian and military personnel worldwide, who use GPS to calculate global spatial positions using many applications. Civilian users currently outnumber military users worldwide for applications such as agriculture, aviation, emergency services, recreation, and vehicle tracking.

GPS is based on satellite ranging, which is the measurement of how much time it takes a radio signal to reach the GPS receiver from a satellite and then a calculation of distance using that time. In satellite ranging, the GPS receiver compares digital codes generated at precisely the same time by a GPS satellite and the GPS receiver (Trimble, 2006). Identical “pseudorandom” codes are generated by all GPS equipment (satellites and receivers) every millisecond. Time is calculated as the difference between when the satellite generated the code and when the receiver receives the code. Trilateration is then used to measuring the distance from at least three satellites to establish a position on Earth. However, the accuracy of a measurement based on three satellites may be diminished because of non-synchronization of clocks in the GPS satellites and the receiver (Trimble, 2006).

An accurate position is calculated by using four satellites. Four imperfect measurements can eliminate timing offsets and microprocessors in the GPS receiver recognize timing offset when it receives a series of measurements that it cannot intersect at one point (Trimble, 2006). The GPS receiver then automatically starts subtracting the same amount of time from all of the measurements until a position on Earth is determined. Trimble GeoXT and GeoXH receivers have at least twelve parallel channels to receive radio transmissions from up to twelve GPS satellites simultaneously.

The orbits of all GPS satellites are measured constantly by the DoD, which determines satellite ranging and calculates the exact location of each satellite as ephemeris data (Trimble, 2006). The ephemeris information is a data file that contains orbit information for one particular satellite. The DoD then transmits the ephemeris data to the satellites, which then transmit it to GPS receivers. This information is used by the GPS receivers along with their internal almanac to establish precisely the position of the satellite.

Differential GPS is used to determine the precise measurement of the relative positions of two receivers tracking the same GPS signals (Trimble, 2006). This requires a receiver to be placed as a base station over a known coordinate benchmark. The base station determines what errors the satellite data contains and then that of other GPS rovers then uses this corrected information to eliminate error in their measurements. Differential GPS measurements are much more accurate than standard GPS measurements and when taking measurements in the differential mode, GPS spatial accuracy of less than one meter can be achieved. However, the ultimate accuracy of a GPS position is determined by the sum of several sources of error, the contribution of which varies depending on atmospheric and equipment conditions (Trimble, 2006). Sources of error that affect the results of GPS data collection include atmospheric conditions and physical objects causing obstructions and reflected signals. Source errors can be minimized by applying rigorous data collection techniques to equipment setup and obtaining satellite lock.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources, and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if any complications arise with following these critical sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the Project-Specific Health and Safety Plan (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.4 Field Team Leader

The Field Team Leader (FTL) is responsible for maintaining compliance with GPS data collection, data downloading, and file maintenance (that is, backing up data on a server and mailing data files to GIS personnel), in particular, for maintaining consistency in the procedures to be used. The FTL, or their designee, must know the GPS data collection, data downloading, and file maintenance techniques and should maintain adequate documentation of GPS data collection activities. The FTL should take responsibility for collecting, downloading, and regular storage of collected GPS data in the project data files. The FTL will also coordinate with the FM and Geographical Information System Manager (GISM) to appropriately plan GPS data collection task and post-process collected data. The FTL or FM will provide the GISM with the collected data for post-processing and data usage on a scheduled basis (such as daily, every other day, or weekly).

4.5 Geographical Information System Manager

The GISM will facilitate and coordinate with the FTL and FM regarding GPS data planning and data post-processing. The GISM will acquire the required GPS technology, facilitate development of all data dictionaries, and conduct all data post-processing. The GISM will work closely with the FTL and FM to conduct all GPS surveying tasks.

4.6 Field Sampler

The Field Sampler, under the supervision of the FTL (who may be the same person), will collect the GPS survey data according to this SOP. The Field Sampler will be adequately trained in the use and data recovery of the GPS tools provided. The Field Sampler will

document all GPS surveying activities in a Field Notebook according to *SOP-01, Note Taking and Field Log Books*.

5.0 Procedures

5.1 Equipment and Software

A GPS system has three components: data collector, GPS receiver, and TerraSync™ or similar control software. A GPS handheld device that combines the GPS receiver and data collector is known as a "Rover" (Trimble, 2006). A rover with the Trimble TerraSync™ software makes up a complete GPS data collection system. A Trimble GeoXT combines all these elements into one unit.

5.1.1 Hardware

There are a number of different GPS system configurations available; this SOP focuses on the handheld Trimble GPS Pathfinder receivers such as the Trimble GeoXT and GeoXH GPS rovers. These 12-channel devices allow for 2D RMS sub-meter accuracy (within 1 meter of the indicated position 95 percent of the time) following post-processed differential correction. *SOP-16, Attachment 2: Trimble GPS Receiver Comparison* provides a comparison of the various Trimble GPS rovers. *SOP-16, Attachment 3: Trimble GPS Hardware and Software* provides details on the Trimble GeoXT and GeoXH GPS rovers.

5.1.2 TerraSync Software

Trimble GeoXT and GeoXH GPS rovers running Trimble TerraSync™ software are designed for collecting and updating GIS and spatial data by transferring files between a GPS rover and an office computer. The TerraSync™ software acts as the controlling software (user interface) and communicates with the Trimble GeoXT or GeoXH to set GPS parameters in the receiver, record GPS positions on the data collector, and maintain existing GIS data (Trimble, 2006). Transferring TerraSync™ software files between a GPS rover and an office computer requires the Microsoft® ActiveSync® software and either GPS Pathfinder Office Software (version 3.10 or later) or the Trimble Data Transfer utility, which is available for free download from the Trimble website (Trimble, 2010b; Microsoft, 2007). Additional details regarding setting up and using TerraSync™ Software are discussed in Sections 5.2 and 5.3 and in *SOP-16, Attachment 4: TerraSync™ and GPS Pathfinder® Office Software and Orientation Guide. SOP-16, Attachment 3: Trimble GPS Hardware and Software* provides details on about the TerraSync™ Software.

5.1.3 GPS Pathfinder Office software

After GPS data is collected and transferred to a computer, the information can be processed and exported using the GPS Pathfinder Office software (Trimble, 2006). The GPS Pathfinder Office software provides the tools needed to effectively do the following:

- Use task planning software to find the best times of day to collect data
- Create data dictionaries that describe the features you want to collect
- Edit attributes and offsets and delete erroneous positions
- Importing data updates from GIS
- Transfer data files between a field computer and your office computer

- Differentially correct data
- Export data to a Computer Aided Design (CAD) system or Geographic Information System (GIS).

Sections 5.2 and 5.3 and *SOP-16, Attachment 4: TerraSync™ and GPS Pathfinder Office Software and Orientation Guide* provide additional instructions on using the GPS Pathfinder Office Software. *SOP-16, Attachment 3: Trimble GPS Hardware and Software* provides details about the GPS Pathfinder Office Software.

5.2 Pre-Field Planning

Project planning is critical to a team's success in GPS data collection. Several steps should be completed before deployment to the field. Many items need to be considered before field data collection, including the incorporation of existing data resources and the preparation of field tools towards appropriate integration into future data deliverables. Before field data collection the following data requirements should be considered and planned. *SOP-16, Attachment 5: CH2M HILL GPS Project Planning and Requirements SOP* should be consulted during the pre-field planning stages of any environmental investigation requiring GPS data collection.

5.2.1 Data Standards

Determine the GPS data collection data standards before using the GPS in the field. The Spatial Data Standard for Facilities, Infrastructure and Environment (SDSFIE) is the common standard for U.S. military and other federal clients and is a template for creating standardized geospatial information.

5.2.2 Data Dictionaries

Develop data dictionaries before field data collection to help increase data collection efficiency and integrity of the data. Data dictionaries can supply order to GPS data collection tasks. As an example, they use dropdown menus with defined attributes to standardize data collection. Other examples include required fields, automated fields for date and time generation, standardized symbology, and standard logging (recording) intervals to meet specific accuracy requirements. SDSFIE data dictionaries can automatically be generated using the SDS2DDF application. The SDS2DDF application imports data into the Trimble Data Dictionary Editor, which can then be uploaded into a Trimble GPS unit for field collection.

The proper data dictionary file must be transferred from a computer to the GPS device before any data collection. Whenever possible, do not use the default data dictionary on a GPS rover. CH2M HILL has standardized data dictionaries for environmental investigation projects in addition to customized dictionaries that can be tailored to project or client specific requirements. Use of the correct and current data dictionary will directly affect the entire data collection process. In addition, it is important to note that if multiple field teams will be collecting data on a project, it is critical for each team to be using the identical data dictionary. If all teams are not using identical data dictionaries, it will substantially increase the post data collection processing time and delay project deliverables. Because of this, it is highly recommended to coordinate GPS needs with the GISM early during the planning stages of a GPS data collection task. <u>All data dictionaries should be developed by or with the assistance of the GISM before field data collection</u>. Refer to *SOP-16, Attachment 6:*

CH2M HILL GPS TerraSync™ Data File SOP for more information about data dictionary development and how that is used with “background map information.”

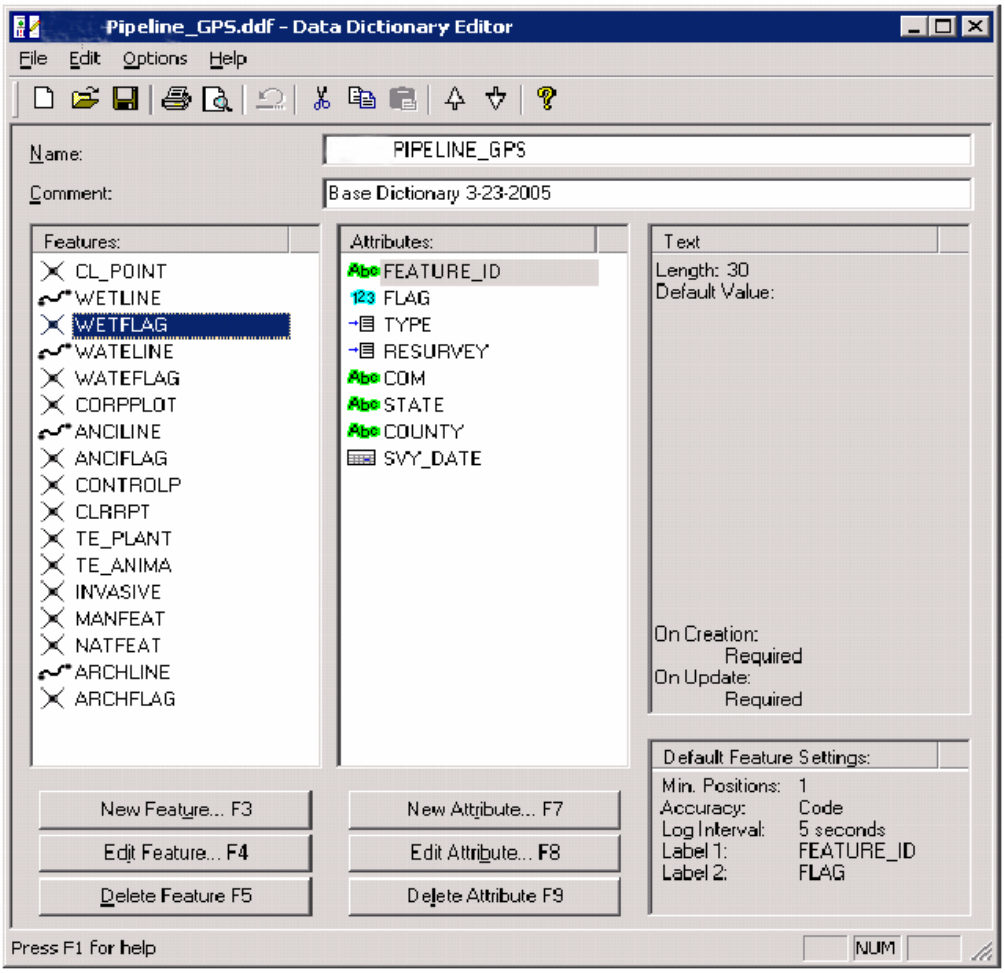

Figure 1. Example Data Dictionary (CH2M HILL, n.d.).

5.2.3 Photograph Collection

Based on the project needs, photographs can be linked to the corresponding spatial data locations via both X and Y coordinates, as well as by time. There are a variety of GPS/software/camera combinations available; consult the GISM before field data collection if this feature is necessary. *SOP-16, Attachment 7: CH2M HILL GPS Photo-linking SOP* provides additional details regarding procedures for photograph-GPS data collection.

5.2.4 Data Management Guidelines

Reliable and secure data management practice is essential to quality data collection and future data use and should be maintained during all preparation, data collection, and post-processing stages. If quality data management practices are not followed, significant amounts of valuable and often irreplaceable data can be lost or significant effort may be required to post-process data.

GPS data management includes managing data within the standardized directory structure, setting up the GPS device, and verifying data backup as well as data flow from project planning though correction and export to GIS production data. Generally, proper data management includes daily downloading and delivery of GPS files to the GISM. The GISM should be consulted regarding any data management procedures or issues. In addition, the following SOP-16 Attachments should be referred to by field staff for procedures and guidelines for quality GPS data management.

- *Attachment 8, CH2M HILL GPS Data Management SOP*
- *Attachment 9, CH2M HILL File Transfer SOP*
- *Attachment 10, CH2M HILL Device Setup SOP*

5.2.5 Configuring Critical Settings in the TerraSync software

There are some critical settings in the TerraSync software that must be configured before collecting GPS data; these critical settings include GPS settings, logging settings, real-time settings, coordinate settings, and unit settings. Critical settings can be configured in the office or in the field, and non-critical settings can be set to suit the task-specific application or needs. <u>However, it is recommended that the critical settings be configured by or with assistance from the GISM before field data collection.</u> In addition, the critical setting should remain the same throughout the project or task and should not be altered before each data collection session. *SOP-16, Attachment 4, TerraSync™ and GPS Pathfinder Office Software and Orientation Guide* provides detailed instruction on how to configure the critical settings in the TerraSync™ software.

5.2.6 Pre-Event PDOP Planning

To gain the most accurate GPS data possible, determine times for best satellite coverage before GPS data collection. Trimble Planning Software (or the Quickplan application in previous versions of the Trimble GPS Pathfinder Office software) should be used to predict if any downtime will occur, based on satellite ephemeris data (Trimble, 2008). These applications will graph the number of satellites available at any given time during the day as well as the PDOP (Position Dilution of Precision) for the satellite configuration. When the satellites are spread around the sky, the PDOP is low and GPS accuracy is higher. When the satellites are close together, the PDOP is high and GPS accuracy is lower. A PDOP below 6 is required for submeter accuracy on a Trimble GeoXT or GeoXH GPS rover; therefore, a PDOP reading of less than 6.0 will be required to collect rover data. For the most accurate planning, latest ephemeris data file should be downloaded from the Trimble website (Trimble, 2010a)

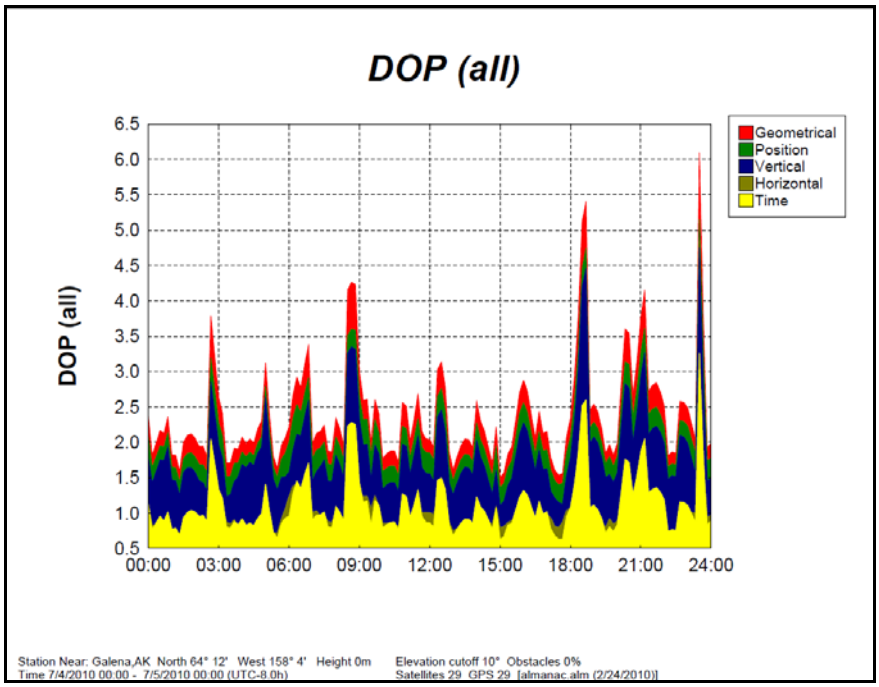

Figure 2. Predicted DOPs (including PDOP for Galena, Alaska on July 4th, 2010) using Trimble Planning Software (Trimble, 2008).

5.3 Field Use and Data Collection

5.3.1 GPS Status and Startup

Follow the below general procedures and guidelines for checking the GPS system status and starting to use the GPS rover in the field (Trimble, 2006):

1. Before data collection, check the status of your receiver. Begin by going outdoors and when ready, turn on the Trimble GeoXT or GeoXH and start the TerraSync™ software to allow it to begin satellite tracking. The GPS receiver should activate automatically. This is done using the GPS rovers stylus (plastic pen) to tap the “Windows Start” button on the Microsoft Windows® or Windows Mobile® taskbar and then selecting *Programs* → *TerraSync*. While the software is loading, the Trimble identification screen appears followed by (typically) the TerraSync™ *Skyplot* status screen.

2. Next, obtain a clear view of the sky by moving to a location where the receiver has clear line of sight to the sky. Signals can be received from any direction but can also be blocked by people, buildings, heavy tree cover, large vehicles, or powerful transmitters. Because of this, optimal locations include open fields, parking lots, or other open spaces free of obstructions above the horizon. GPS signals can go through leaves, plastic, and glass if necessary, but these signals are weakened. The receiver typically gets the best reception when facing south.

3. Next, begin to check the GPS status. Once the TerraSync™ software starts, it automatically connects to the GPS receiver and begins to track visible satellites and to calculate its current position. Use the *Satellite* icon on the *Status Bar* to check whether the receiver is computing GPS positions. The software provides information about the geometry of the satellites that are being used to compute GPS positions.

4. The *Status Bar* appears in the top row of the TerraSync™ screen. It is always visible, but the icons displayed depend on the current status of the system. The *Status Bar* provides basic information about the status of the TerraSync™ software. Figure 3 below shows the icons in the *Status Bar*. (Note this shot is the Map view).

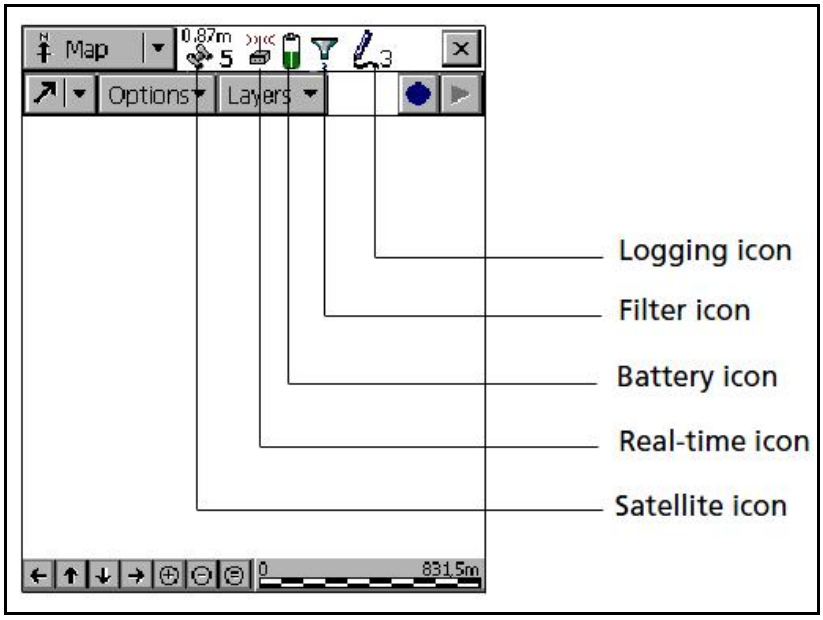

Figure 3. TerraSync™ Status Bar (Trimble, 2006).

5. Use the *Status* button to view the satellites currently tracked and those that are being used to calculate the current position. To view the GPS status, do the following:

   – The *Skyplot* screen typically is the default screen that appears when you first run the TerraSync™ software. If this screen is not visible, tap the *Section* list button (upper left corner), select *Status*, tap the Subsection list button and then select *Skyplot*. Figure 3 shows the parts of the *Skyplot* screen.

   – Use the Skyplot screen to check the satellites that are being tracked and to see your current position. Filled black boxes represent satellites that the receiver is using to compute its current GPS position. White boxes represent satellites that the receiver is getting signals from but is not using because the signals are too weak. If an SBAS satellite is being tracked, its location is indicated by the “Airplane” icon as shown in Figure 4. The current GPS position is displayed at the bottom of the screen.

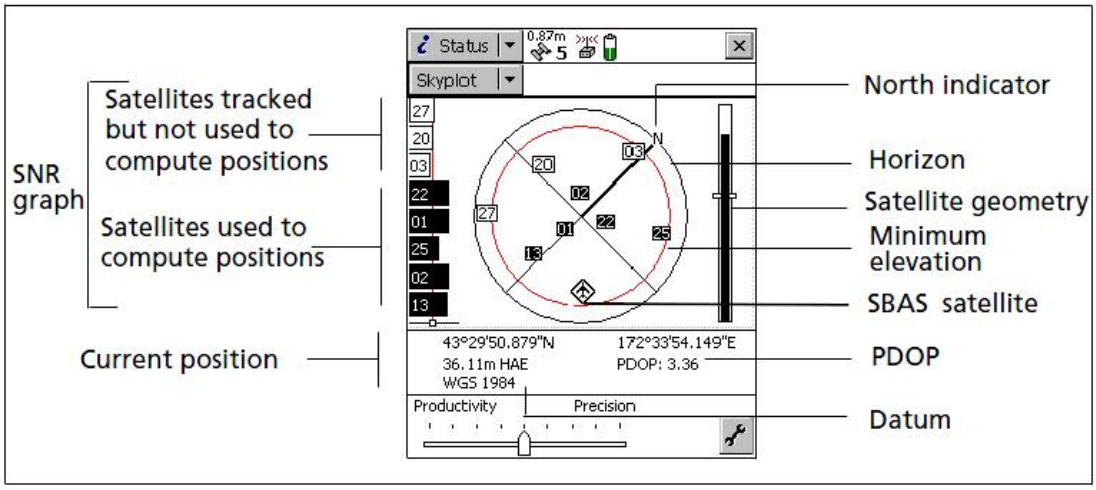

Figure 4. Example Skyplot screen showing eight GPS satellites, of which five are being used to compute the current GPS position (Trimble, 2006).

A minimum of four satellites with good geometry are required to compute a three-dimensional GPS position and collect X, Y, and Z spatial data. Note that Z data is not submeter accuracy with a mapping grade GPS unit such as the GeoXT. Use the Satellite icon in the status bar to check whether the receiver is computing satellite positions. If the Satellite icon and the number below it are solid (not flashing), the receiver will allow data to be collected. The number above the Satellite icon shows the CEA (Current Estimated Accuracy), which is an indication of the horizontal accuracy (RMS) of the current GPS position. If the satellite geometry is poor or if there are too few satellites available to compute GPS positions, adjust the GPS Slider as described in the critical settings configuration in Attachment 4 or wait until conditions are more favorable.

More advanced instructions are provided in the SOP-16, *Attachment 4: TerraSync™ and GPS Pathfinder Office Software and Orientation Guide.*

5.3.2 Basic Data Collection

The following general procedures and guidelines provide basic instruction for GPS data collection using a Trimble GeoXH or GeoXT GPS rover in the field (Trimble, 2006). Additional data collection instruction is available in Attachment 4 and Attachment 6.

Creating a New Data File

Before starting the data collection session, use the *Data* screen to create a new data file (know as a Rover File) to store the new features and attributes collected. Create a new Rover File by doing the following (Trimble, 2006):

1. Tap the *Section List* button and then select *Data*.
2. Tap the *Subsection List* button and then select *New*. The *New File* screen appears and the TerraSync™ software automatically enters a default name in the *File Name* blank. If desired, create a new File Name by using the TerraSync™ keyboard. Typically a filename including the date and initials of field collector should be used (for example, 03112010-gt).

Figure 5. New File screen (Trimble, 2006).

3. In the *Dictionary Name* field, select a data dictionary.
4. Tap *Create*. The *Collect Features* screen appears. This screen shows a list of all the features in the data dictionary. A new data file has now been created and data features can start to be collected.

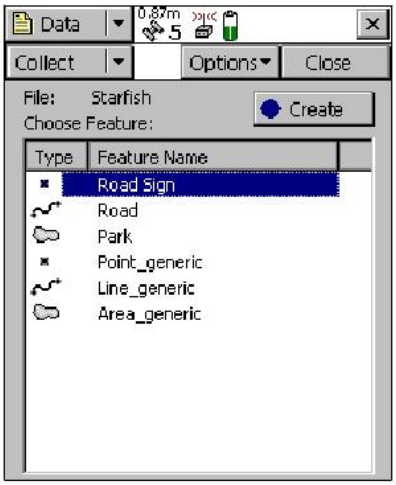

Figure 6. Collect Features screen (Trimble, 2006).

Collecting a Point Feature

When you record a point feature, you must remain stationary for the duration for which the TerraSync™ software logs a number of GPS. These positions are averaged together to compute the final GPS position of the point feature. When the TerraSync™ software is logging GPS positions, the *Logging* icon appears in the *Status bar*. The number beside the icon indicates how many positions have been logged for the selected feature. Record a point feature by doing the following:

1. Make sure the *Collect Features* screen is open. If it is not, tap the *Section List* button and select *Data*. Then tap the *Subsection List* button and then select *Collect Features*.

2. In the *Choose Feature* list, highlight an appropriate point feature and then tap *Create*. The point attribute entry form for the feature type appears.

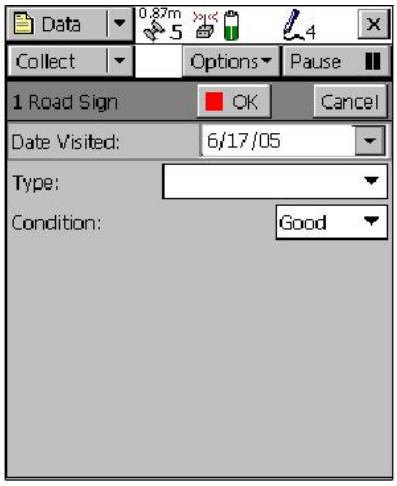

Figure 7. Point Attribute Entry Form (Trimble, 2006).

3. Fill in the attribute fields with the appropriate values. As the software logs GPS positions, the counter beside the logging icon increases incrementally. It is suggested that at least 15 count increments using a 1-second interval are collected for reliable and efficient data collection; 30 count increments are recommended for the most accurate data collection.

4. When recording the point feature has finished and all attributes have been entered, tap, *OK* to close the point feature. The attribute entry form closes and you are returned to the *Collect Features* screen.

Collecting a Line Feature

To record a line feature, you need to travel along the line. As you do so, the TerraSync™ software records a GPS position at the configured interval, which was set when the feature was created in the data dictionary. These positions are joined together to form a line. Create a new line feature by doing the following (Trimble, 2006):

1. Make sure the *Collect Features* screen is open. If it is not, tap the *Section List* button and select *Data*. Then tap the *Subsection List* button and then select *Collect Features*.

2. In the *Choose Feature List*, highlight an appropriate line feature.

3. Tap *Create*. The line attribute entry form for the feature appears.

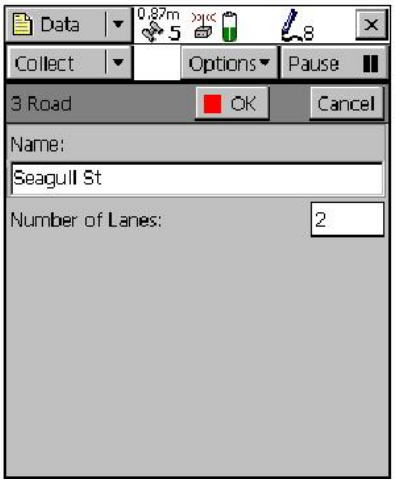

Figure 8 - Line Attribute Entry Form (Trimble, 2006)

4. Begin slowly traveling along the line feature to be collected making sure the GPS is logging positions. When you reach the end of the line feature being logged, tap *OK* to close the line feature. The attribute entry form closes and you are returned to the *Collect Features* screen.

Collecting an Area Feature

To record an area (polygon) feature, the GPS rover will need to travel around the perimeter of the area to be surveyed. As the GPS rover travels, the TerraSync™ software will log the GPS positions at the logging interval set in the data dictionary during configuration of the critical settings. When travel around the perimeter of the area has been completed, the first and last GPS positions are joined together by a straight line to close the area and form the area feature. Therefore, in some instances there is no need to return to the exact starting point to complete the feature. Create a new area feature by doing the following (Trimble, 2006):

1. Make sure the *Collect Features* screen is open. If it is not, tap the *Section List* button and select *Data*. Then tap the *Subsection List* button and then select *Collect Features*.
2. Tap *Options* and then select *Log Now*.
3. In the *Choose Feature* list, highlight an appropriate area feature.
4. Tap Create. The attribute entry form for the area feature opens, and the TerraSync software starts to log positions.

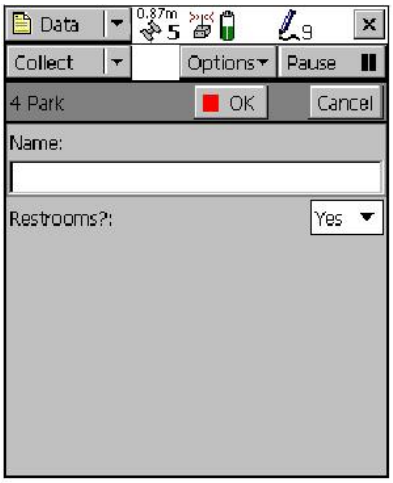

Figure 9. Area Attribute Entry Form (Trimble, 2006).

5. Logging can be paused at anytime. For example, if you are traveling around the perimeter of an area and you want to stop and examine an object some distance away; you would pause logging positions for the area perimeter boundary while you investigate the object. Logging can also be paused if time is needed to enter attribute values. To pause logging, tap *Pause*. The TerraSync™ software stops logging positions and a pause icon flashes in the *Status Bar*. To continue collecting the area feature, tap *Resume* to resume logging again. The pause icon will disappear.

6. A map of the area feature can also be viewed while collecting features. To do this, tap the *Section List* button and then select *Map*. The features that have been collected will appear on the map, along with the area perimeter that you are currently collecting.

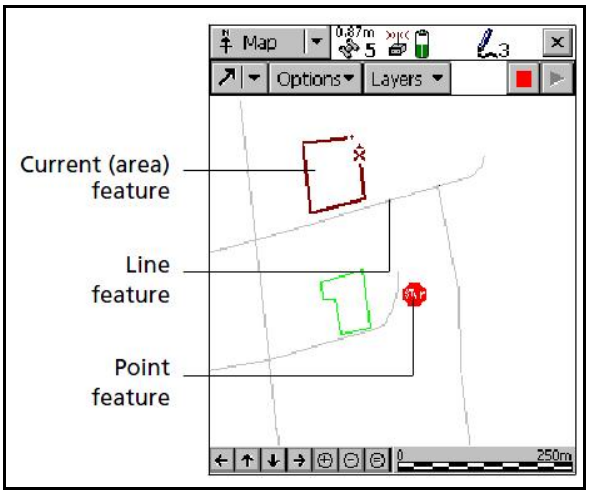

Figure 10. Map View will collecting features (Trimble, 2006).

7. In addition, the map can be viewed at different scales. To do this, tap the *Zoom In* or *Zoom Out* button on the Command Bar. Or alternatively, tap the *Map Tools List* button, select *Zoom In* or *Zoom Out*, and select the point on the map that you want to zoom in or out from.

8. To go back to the *Data Section*, tap the *Section List* button and select *Data*. The attribute entry form will still be active and the TerraSync™ software will still be logging positions for the area feature.
9. When you have traveled around the perimeter of the area, tap *OK* to close the area feature. The attribute entry form closes and you are returned to the *Collect Features* screen.

Ending the Data Collection Session

Once complete, a data collection session can be ended by closing the data file and exiting the TerraSync™ software. Close your data collection session by doing the following (Trimble, 2006):

1. Once in the *Collect Features* screen, tap *Close,* making sure you are not in the process of collecting a feature.
2. A message will appear, asking you to confirm that you want to close the open file. To close the current data file and return to the *New File* screen, tap *Yes*.
3. To close the TerraSync™ software, tap the Microsoft Windows close-out “X-box” button in the top right corner of the screen. A message will appear, asking to confirm that you want to exit the TerraSync™ software.
4. Tap *Yes* to confirm.
5. Press to power button on the GPS unit to turn off. Make sure you do not hold the power button in for any length of time as this will reboot the unit and potential loss of data can occur.

5.4 Data Download, Post-Processing, Validation, and Correction

5.4.1 Data Download

Collected GPS data including data files, base data, data dictionaries, and almanacs can be transferred from a Trimble GeoXT or GeoXH GPS rover to the GPS Pathfinder Office software via a desktop or laptop computer (Trimble, 2006).

Connecting the GPS rover to an office computer

1. Turn on the desktop or laptop office computer and verify that Microsoft ActiveSync technology software and GPS Pathfinder Office software are installed (Microsoft, 2007).
2. Place the GPS unit in the provided cradle and make sure power is being supplied to the cradle via a power outlet. Turn off the GPS rover and connect the GPS rover cradle to the office computer using the USB data cable supplied with the GPS rover. The Microsoft ActiveSync software should automatically establish a connection with the GPS rover and the GPS rover will also automatically turn on at this time. When connected, the message *Connected* appears in the main Microsoft ActiveSync window, and its taskbar icon turns green. Make sure to not sync the GPS unit with the office computer or laptop when the ActiveSync synchronization setup wizard dialog box shows. Select the cancel button and the GPS unit will be connected via a guest connection and will not sync the two devices. See screenshot below.

3. If the Microsoft ActiveSync software does not connect automatically, connect to the GPS rover manually. For more information, refer to the Microsoft ActiveSync software *Help*. The screenshot below shows a properly connected Microsoft ActiveSync icon (Green circle with arrows). The icon is grey when the GPS is not connected to the computer.

Transfer Rover Files to the Office Computer

1. Open the GPS Pathfinder Office software on the office computer.
2. In the GPS Pathfinder Office software, select *Utilities* → *Data Transfer*. The Data Transfer dialog screen appears.
3. From the *Device* list, select the device called *GIS Datalogger* on the Microsoft Windows CE operating system. Alternatively, if you have set up a device name for the GPS rover, select that device name from the list. The Data Transfer utility automatically connects to the GPS rover.
4. Select the *Receive* tab, and click *Add* and then select *Data File* from the drop-down list The *Open* dialog screen appears. Note that the files that appear are those in the TerraSync software data folder on the GPS rover.
5. Highlight the rover file and then click *Open*. The Open dialog screen disappears and the selected file appears in the *Files to Receive* list.

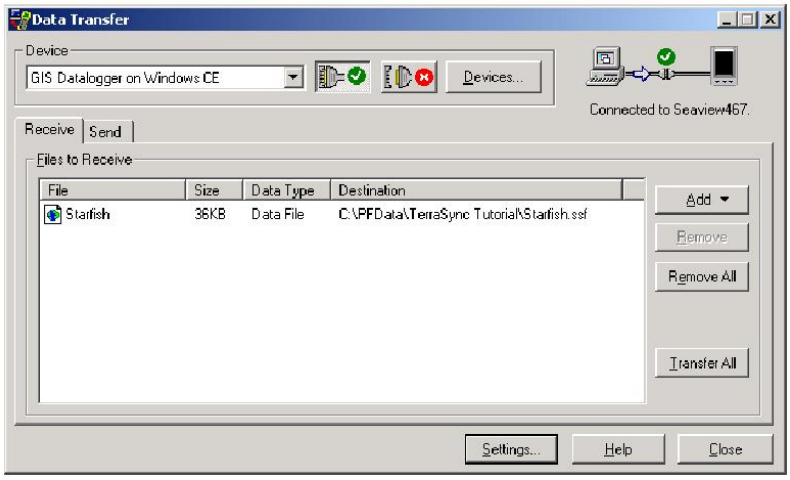

Figure 11. GPS Pathfinder Office Data Transfer Utility (Trimble, 2006).

6. Click *Transfer All*. The data file is then transferred to the office computer and a message showing summary information about the transfer appears.
7. Click *Close*.
8. To exit the Data Transfer Utility, click *Close* again.
9. For more information, refer to Attachment 9 and/or the GPS Pathfinder Office Help.

5.4.2 Post-Processing

Post-processing includes differential correction of the collected GPS data collected. Differential correction in the GPS Pathfinder Office software is the most accurate way to process GPS data (Trimble, 2006). Differential correction reduces atmospheric errors and therefore is necessary for achieving the most accurate GPS position data possible. Within CH2M HILL, differential corrections are typically conducted in the office by GIS staff once the data is transferred from the GPS rover. Refer to Attachment 4 and Attachment 11 (CH2M HILL Postprocessing SOP) for additional information and instructions on conducting post-processing of collected GPS data.

5.4.3 Data Validation and Correction

All GPS data must be validated and corrected to ensure that the data is reliable and accurate before it is integrated into a CAD or GIS system. CH2M HILL uses a standardized approach to validate and correct GPS data that assesses the overall quality of the GPS data, both positional and attribute, and the approach provides a mechanism for ensuring that GPS data is processed, evaluated, reviewed, and integrated into the GIS in a uniform manner. GPS data should be validated by CH2M HILL GIS staff specializing in GPS, field staff who performed the actual data collection, or other personnel that have specific knowledge about the conditions or geographical locations of features. Data validation should be performed using both quantitative measures (for example, GPS Pathfinder Office data file utilities and generated attribute values such as average horizontal precision and standard deviation) and from map validation from base maps, aerial photography, or other know features. Refer to *SOP-16, Attachment 12: CH2M HILL Data Validation and Correction SOP* for further information on GPS data validation and correction.

6.0 Records

Document all GPS data collection activities in a Field Notebook according to *SOP-01, Note Taking and Field Log Books*. Download GPS data files daily, including rover files, and manage them according to SOP-01. Store GPS data files at a digital location specifically reserved for that data document type and name them appropriately, so that the content and date of collection or download can be easily identified.

7.0 References

CH2M HILL. n.d. *Pipeline GPS Guidelines, Field Data Collections, Post Processing and Data Dictionary Manual*. (Available online at: https://communities.int.ch2m.com/wss/icg/ems/GPS/GPS%20Practice%20Documents/GPSPipelineSOP.pdf)

CH2M HILL. 2010. EMS – GPS, CH2M HILL Standard Operating Procedures. https://communities.int.ch2m.com/wss/icg/ems/GPS/GPS%20Practice%20Documents/Forms/Standard%20Operating%20Procedures%20CH2M%20HILL.aspx Accessed February 25, 2010.

Microsoft Corporation (Microsoft). February 13, 2007. *Microsoft ActiveSync 4.5*. http://www.microsoft.com/downloads/details.aspx?displaylang=en&FamilyID=9e641c34-6f7f-404d-a04b-dc09f8141141. Accessed February 25, 2010.

Trimble Navigation Limited (Trimble). 2010a. *GPS Data Resources*. http://www.trimble.com/gpsdataresources.shtml Accessed February 23, 2010.

Trimble Navigation Limited (Trimble). 2010b. Trimble Data Transfer Utility. http://www.trimble.com/datatransfer.shtml Accessed February 24, 2010.

Trimble Navigation Limited (Trimble). 2010c. *Mapping & GIS: Field Computers with GPS*. http://www.trimble.com/mgis_fcgps.shtml Accessed February 25, 2010.

Trimble Navigation Limited (Trimble). 2010d. *Mapping & GIS: Software*. http://www.trimble.com/mgis_software.shtml Accessed February 25, 2010.

Trimble Navigation Limited (Trimble). 2008. *Trimble Planning Software Downloads.* http://www.trimble.com/planningsoftware_ts.asp Accessed February 23, 2010.

Trimble Navigation Limited (Trimble). 2006. *TerraSync™ and GPS Pathfinder® Office Software; Orientation Guide*. Version 1.00, Revision A. December

8.0 Definitions

Accuracy: An indication of how closely a measurement is to the true value.

Almanac: Data transmitted by a GPS satellite, which includes orbit information on all the satellites, clock correction, and atmospheric delay parameters. The almanac is used to facilitate rapid SV acquisition. The orbit information is a subset of the ephemeris data with reduced precision.

Attribute: Characteristics of features in a Geographic Information System (GIS) or Coordinate Geometry (COGO) package. Every identifiable feature has attributes. One common attribute of all survey features is geographic position. Other attributes depend on

the type of feature. For example, a road has a name or designation number, surface type, width, number of lanes, and so on. Each attribute has a range of possible values, called a domain. The value chosen to describe a particular feature is called the attribute value.

Attribute Value: A particular value for a feature, chosen from the domain of an attribute. For example, road is the feature. surface type is an attribute, gravel is an attribute value chosen from the domain of bitumen, gravel, and concrete.

Windows mobile device: A small, usually palm-size or handheld, computer that is capable of running the Microsoft Windows CE operating system. A Windows Mobile device usually has a small screen and limited memory and storage space.

Data collector: In TerraSync™ documentation, a data collector is any computer that has the TerraSync™ software installed. The computer must either be a computer running a supported Microsoft Windows desktop operating system (for example, a tablet computer, laptop, or notebook computer running Windows 2000 or greater) or be a supported mobile CE device.

Data dictionary : Information that describes features that will be located in the field. This description includes feature names, data type classification (point, line, or area), attribute names, attribute types, and attribute values. After being created on a computer, a data dictionary is transferred to a datalogger and used when collecting data in the field.

Differential correction: Differential correction is the process of correcting GPS data collected on a rover with data collected simultaneously at a base station. Because it is on a known location, any errors in data collected at the base station can be measured, and the necessary corrections applied to the rover data. Differential correction can be done in real time, or after the data has been collected by postprocessing.

Dilution of Precision (DOP): An indicator of the quality of a GPS position, which takes account of each satellite's location relative to the other satellites in the constellation, and their geometry in relation to the GPS receiver, A low DOP value indicates a higher probability of accuracy. Standard DOPs for GPS applications are:

- PDOP: Position (three coordinates)
- RDOP: Relative (position averaged)
- HDOP: Horizontal (two horizontal coordinates)
- VDOP: Vertical (height only)
- TDOP: Time (clock offset only)
- GDOP: Geometric

Ephemeris: The current satellite position predictions that are transmitted in the NAVDATA message.

Feature: A physical object or location of an event. A feature can be a point, a line, or an area.

Global Positioning System (GPS): Based on a constellation of 24 satellites orbiting the earth at a very high altitude.

Horizon: The line at which the earth and sky seem to meet.

NAVDATA: The Navigation Message broadcast by each GPS satellite on both the L1 and L2 beacons. This message contains system time, clock correction parameters, ionospheric

delay model parameters and the vehicle's ephemeris and health. A GPS receiver can use this information to process GPS Signals and thus obtain user position and velocity.

NAVigation Satellite Timing And Ranging (NAVSTAR): The name given to GPS satellites.

Position Dilution of Precision (PDOP): A unitless figure of merit expressing the relationship between the error in user position and the error in satellite position. Geometrically, PDOP is proportional to one divided by the volume of the pyramid formed by lines running from the receiver to four satellites observed. Values considered good for positioning are small, such as 3. Values greater than 7 are considered poor. Therefore, small PDOP is associated with widely separated satellites.

Postprocessing: The processing of satellite data after it has been collected in order to eliminate error. This involves using office software to compare data from the rover to data collected at the base station. Because the base station is on a known location, any errors can be determined and removed from the rover data

Rover: Any combination of mobile GPS receiver and data collector collecting data in the field.

Trilateration: The measurement of a series of distances between points on the surface of the earth, for the purpose of establishing relative positions of the points in surveying.

9.0 Attachments

Attachment 1: *Standard Operating Procedure for CH2M HILL GPS Management*

Attachment 2: *Trimble GPS Receiver Comparison*

Attachment 3: *Trimble GPS Hardware and Software*

Attachment 4: *TerraSync™ and GPS Pathfinder Office Software and Orientation Guide*

Attachment 5: *Standard Operating Procedure for CH2M HILL GPS Project Planning and Requirements*

Attachment 6: *Standard Operating Procedure for CH2M HILL GPS Photo-linking*

Attachment 7: *Standard Operating Procedure for CH2M HILL GPS TerraSync™ Data File*

Attachment 8: *Standard Operating Procedure for CH2M HILL GPS Data Management*

Attachment 9: *Standard Operating Procedure for CH2M HILL File Transfer*

Attachment 10: *Standard Operating Procedure for CH2M HILL Device Setup*

Attachment 11: *Standard Operating Procedure for CH2M HILL Postprocessing*

Attachment 12: *Standard Operating Procedure for CH2M HILL Data Validation and Correction*

SOP-17

Geographic Land Surveying

SOP-17: GEOGRAPHIC LAND SURVEYING

1.0 Purpose

This standard operation procedure (SOP) identifies requirements for land surveying by a certified or licensed land surveyor.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in land surveying activities at Galena Forward Operating Location (FOL) projects and tasks. This SOP focuses on the most commonly used land surveying tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures.

3.0 General

It is CH2M HILL's position that establishing standardized protocols for collecting spatial data in the field using land surveying technology is imperative to the success of any project. The guidelines in this section have been developed to verify consistent spatial data collection and post-processing techniques across projects, staff, and geographic locations. These procedures are to be used as a reference tool in conjunction with specific land surveying and job procedure training.

Surveying involves the science and techniques for accurately determining the terrestrial or three-dimensional space position of points and the distances and angles between them. These points are usually used to establish the locations of monitoring devices (including wells, soil borings), site boundaries and topography for land maps.

CH2M HILL requires the services of a Land Surveyor licensed in the state of Alaska to determine the vertical elevations and horizontal positions of wells and sampling points installed during investigation activities.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if any complications arise with following these critical sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for ensuring compliance with this SOP and that all field staff engaged in this activity are trained in this SOP. The FM will coordinate and plan accordingly for all survey activities before and after other site investigation activities.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the *Project-Specific Health and Safety Plan* (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.4 Field Team Leader

The Field Team Leader (FTL) is responsible for maintaining overall compliance with spatial data collection and post-processing requirements; in particular, for making sure that the procedures used are compliant. The FTL, or their designee, must be aware of land survey activities and should maintain adequate documentation of these activities. The FTL will also coordinate with the FM and Geographical Information System Manager (GISM) to appropriately plan spatial data collection tasks and post-process collected data.

4.5 Geographical Information System Manager

The GISM will facilitate and coordinate with the FTL and FM regarding land survey data planning and data post-processing. The GISM will work closely with the FTL and FM to conduct all land surveying tasks.

4.6 Land Surveyor

The Land Surveyor, who is most likely a subcontractor under the supervision of the FTL, will collect the land survey data according to this SOP. The subcontracted Field Surveyor must provide a Professional Land Surveyor licensed and in good standing with the State of Alaska. All work should be conducted using equipment, personnel, and procedures that will verify compliance with the accuracy standards as defined below. It is the responsibility of the supervising Land Surveyor to verify that all work under this agreement complies with all state and local regulations. The Land Surveyor will be adequately trained in the use and data recovery of the land survey tools used. The Land Surveyor will document all land surveying activities in a Field Notebook according to *SOP-01, Note Taking and Field Log Books*. All documents submitted should bear the surveyor's seal, signature, and a certificate that all work was done under the surveyor's supervision and that all information contained in the document is true and is accurately shown.

5.0 Procedures

5.1 General Surveying

A licensed land surveyor will measured all surveying locations as the distance in feet and meters from a reference location that is tied to the WGS84 coordinate system. The subcontractor will be responsible for identification of existing benchmarks and establishing

temporary control points. The subcontractor will perform elevation (vertical) and positional (horizontal) surveying according to the following guidelines:

- All survey equipment should be of the proper type and should be in good operating condition to verify that the work can proceed without interruption.
- Survey instruments should be inspected and calibrated by an authorized manufacturer's representative in accordance with the manufacturer's specifications regarding procedures and frequencies.
- At a minimum, instruments should have been calibrated no more than 6 months before the start of the survey work.
- An X, Y coordinate system will be used to identify locations.
- The latitude coordinate will be the east-west axis; the longitude coordinate will be the north-south axis.
- Coordinates of all points X, Y, and Z will be measured to the nearest 0.01 of a foot.
- The units of measure should be U.S. Survey Feet.
- Survey data should be provided in the Alaska State Plane coordinate system.
- Horizontal Positional (X,Y) data should be referenced to the North American Datum of 1983 (NAD 83, Latest Adjustment). Required precision is 0.01 foot (0.003048 meters).
- Vertical elevation data (Z) should be referenced to the North American Vertical Datum of 1988 (NAVD88 in mean sea level (msl) datum. Required precision is 0.01-foot (0.003048 meters).
- Vertical control networks should be verified between at least two published benchmarks.
- All level and horizontal traverse networks should be closed to the starting point.
- The horizontal accuracy of the control should be Second Order Class II, and the Vertical Accuracy should be Second Order, Class II, as outlined in the *FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Constructions (A/E/C) and Facility Management* (Attachment 1).

The following information should also be provided:

- Survey method
- Survey date
- Data source (organization reporting the data)
- Comments on any notable issues benchmarks used etcetera.

5.2 Surveying Monitoring Wells and Other Environmental Monitoring Points

At each well location, measure the ground elevation, the measuring point elevation, and top of casing, if the location is a groundwater monitoring well.

The measuring point elevation of all newly installed wells is the most critical measurement; survey the measuring point elevation at the water-level measuring point (notch) on the riser pipe. If the measuring point is not clearly marked, the surveyor should mark a location on the north side of the riser pipe and survey that location. The vertical accuracy of well

measuring point elevations should be 0.01 foot. The surveyors will report X, Y, and Z coordinates for the measuring point, ground surface, and top of casing at all monitoring wells. Surveying of soil gas sampling locations and subsurface soil and groundwater boring locations only requires X and Y data, unless otherwise noted.

5.3 Mobilization, Demobilization, Equipment Supply, and Storage

Before beginning surveying activities, the surveyor should coordinate with the CH2M HILL FM or PM, after which a CH2M HILL representative (for example, the FM or FTL) and the surveying subcontractor may elect to visit all or some of the locations to be surveyed. The land surveyors will then be allowed to complete the survey without further direct supervision from CH2M HILL. The surveying subcontractor should provide all the necessary labor and equipment to complete the survey.

Throughout the period of surveying, keep the worksite free and clear of all rubbish and debris; implement protective barriers and other safety protection necessary to protect the public and workers, as necessary. Conduct all surveying activities in a manner that protects all existing site fences, walls, buildings, trees, and landscape throughout the process of work. In the event of damage to such property, the surveyor(s) should notify CH2M HILL FM or PM immediately. After completion of the work, remove all materials, tools, and debris from the premises and work areas.

6.0 Records

The subcontractor should provide certification documentation to show that it is a Licensed Land Surveyor.

Document all land surveying activities in a Field Notebook according to *SOP-01, Note Taking and Field Logbook*. Include the date, names of the crew, weather conditions, and all collected survey data information in the field notes. In addition, download survey data files daily and manage them according to SOP-01. Store Global Positioning System (GPS) data files at a digital location specifically reserved for that data document type and verify that it is named appropriately to easily identify the content and date of collection or download. Submit all electronic files in Microsoft™ Excel or ASCII format listing all X, Y, and Z coordinates, and the coordinate system used for all data points, to CH2M HILL within the timeframe identified in the scope of work prepared for the surveyor purchase requisition.

7.0 References

Federal Geographic Data Committee (FGDC). 2002. *Geospatial Positioning Accuracy Standards PART 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management*. Document Number: FGDC-STD-007.4-2002.

Nielsen, D.M. 1991. Practical Handbook of Ground-Water Monitoring. Lewis Publishers. pages 343-346.

Urquhart, L.C. 1962. Civil Engineering Handbook, 4th Edition. pp. 96-97.

8.0 Definitions

<u>Accuracy</u> - An indication of how closely a measurement is to the true value.

Universal Transverse Mercator (UTM) – UTM is a coordinate system that uses a grid-based method of specifying locations on the surface of the Earth that is a practical application of a 2-dimensional Cartesian coordinate system. It is used to identify locations on the earth, but differs from the traditional method of latitude and longitude in several respects. The UTM system is not a single map projection. The system instead employs a series of sixty zones, each of which is based on a specifically defined secant transverse Mercator projection.

World Geodetic System (WGS) - is a standard for use in cartography, geodesy, and navigation. It comprises a standard coordinate frame for the Earth, a standard spheroidal reference surface (the datum or reference ellipsoid) for raw altitude data, and a gravitational equipotential surface (the geoid) that defines the nominal sea level. The latest revision is WGS 84 (dating from 1984 and last revised in 2004), which will be valid up to about 2010. Earlier schemes included WGS 72, WGS 66, and WGS 60. WGS 84 is the reference coordinate system used by the Global Positioning System.

9.0 Attachments

Attachment 1 *FGDC Geospatial Positioning Accuracy Standards*

SOP-18

Packing and Shipping of Environmental Samples

SOP-18: PACKING AND SHIPPING OF ENVIRONMENTAL SAMPLES

1.0 Purpose

This standard operating procedure (SOP) provides guidance for packing and shipping environmental samples in accordance with applicable transportation regulations and sample storage requirements.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in the packing and shipping of environmental samples at the Galena Forward Operating Location (FOL). It is intended to comply with recommended practices in the following documents:

- *Draft Field Sampling Guidance* (Alaska Department of Environmental Conservation [ADEC], 2010)
- Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures (ADEC, 2002)
- [American Society for Testing and Materials] ASTM Standard D6911, Standard Guide for Packing and Shipping Environmental Samples for Laboratory Analysis (ASTM, 2003)

This SOP focuses on the most commonly used environmental sample packing and shipping tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-15, Active Soil Gas Vapor Sampling*
- *SOP-27, Passive Soil Gas Vapor Sampling*
- *SOP-28, Sample Identification and Nomenclature*
- *SOP-24, Direct Push Groundwater Sampling*
- *SOP-31, Multi Increment® Sampling for Surface Soil*

SOP-18, Packing and Shipping of Environmental Samples, describes shipping considerations, including preparation of shipping manifests and instructions on determining if shipments are hazardous waste. CH2M HILL's enterprise SOP *HSE-417 Hazardous Materials Transportation* should be referred to for additional requirements for shipping dangerous goods (CH2M HILL, 2008) and is provided herein as Attachment 1.

3.0 General

Proper shipment of environmental samples from the field to the laboratory is a critical part of sample management. Improperly packaged samples may reach the laboratory without proper documentation. In addition, the data quality of valuable environmental samples may be diminished or the sample may become unusable if they become warm and are received at the laboratory out of temperature compliance. Improper sample packing may also result in

sample containers breaking, causing loss of data or data quality, compromising other samples within the shipment, or stopping or delaying the entire shipment because of leaking shipping containers.

Before shipping any samples, verify that the samples are not dangerous goods and that they are permitted to be transported by air (see *SOP-18, Attachment 1*). If the articles or substances are allowed to be shipped by air, they must be properly identified, classified, packed, marked, labeled, and documented according to applicable regulations.

All sample shipments to be transported by air, including those sent via Federal Express (FedEx) and Alaska Airlines Goldstreak, must meet the requirements of the International Air Transportation Association (IATA) and International Civil Aviation Organization (ICAO) for air transportation of dangerous goods. Anyone who violates the regulations for shipping articles or substances may be subject to civil or criminal penalties.

Complete an original USA manifest or air waybill to accompany each shipment. Obtain original manifests or air waybills either directly from the transporter (such as FedEx, Alaska Air Cargo, or Frontier Alaska Cargo) or from a CH2M HILL office mailroom (FedEx and DHL waybills can be found in most mailrooms). Air waybills for Alaska Airlines Cargo can also be completed online (see the Web link in Section 7.0) (Alaska Air Cargo, 2010). The shipping manifest (air waybill) serves three primary purposes:

- It serves as a tracking device to trace shipments of samples, hazardous substances, or other items.
- It provides information on the contents manifested during transport emergencies.
- It provides documentation of shipment date, priority, method, shipper information, addressee information, and often proof-of-delivery.
- It is used by the U.S. Environmental Protection Agency (EPA) and the disposal facility for recordkeeping and reporting on hazardous substance shipping.

Follow the instructions on the reverse side of the air waybill or contact the FM or transporter for assistance with completing the air waybill.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to verify that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted on decisions concerning shipping costs and any complications or uncertainties with following these procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Field Data Manager (FDM)

The Field Data Manager (FDM) is responsible for verifying that all information, including labels and chain-of-custody (CoCs) forms, are correct. The FDM should alert the laboratory that samples have been shipped, then follow up with the laboratory to verify that samples have been received in compliance with paperwork and temperature requirements and that the laboratory requested analyses have been received.

Labels and CoCs are typically generated by the Sample Tracking and Scheduling Program, which is managed by the FDM. The Sample Tracking and Scheduling Program is a database that has the sample identification and sample analytes entered into it from the site-specific attachments (Appendix D). Once entered, labels and CoCs are generated based upon specifications in the FSP.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify that overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the Project-specific Health and Safety Plan (HSP) (Appendix A), and coordinates with the Field Manager (FM) to complete and certify the HS&E program.

4.5 Field Team Leader

The Field Team Leader (FTL) directs the packing and shipping of environmental samples, particularly the procedures to be used. The FTL, or their designee, should know the requirements for packing and shipping samples and should maintain adequate documentation of sample shipping activities. The FTL, in coordination with the Sample Shipper and FDM, determines which samples are potentially hazardous and ship them accordingly. The FTL coordinates scheduling with the laboratories and the FDM accordingly, before each sampling event and before shipping samples. In addition, the FTL coordinates with the FDM to verify that the samples have arrived at the lab without complications.

4.6 Field Sampler

The Field Sampler, under the supervision of the FTL (who may be the same person), verifies that samples are correctly collected, labeled, tracked by CoC, and stored until they are delivered to the Sample Shipper. The Field Sampler should maintain custody of the samples until they are relinquished to the sample shipper.

4.7 Sample Shipper

The Sample Shipper (who may also be the FDM or Field Sampler) prepares and packs the coolers for shipping and verifies that the CoCs are correct, as described in Section 5.0. The Sample Shipper coordinates with the project expediting subcontractor to ship the samples effectively. If shipping hazardous materials, the Sample Shipper will complete CH2M HILL Dangerous Goods and Waste Management training before sample shipping. In addition, the Sample Shipper coordinates with the FDM to verify that the lab is alerted that samples have been shipped, and that other necessary follow up tasks are completed.

4.8 Sample Custodian

The sample custodian is any individual who is responsible for the custody of samples and completion of associated documentation.

5.0 Procedures

5.1 Determining Whether Samples Are Classified As Hazardous Waste

Refer to CH2M HILL's enterprise SOP *HSE-417 Hazardous Materials Transportation* for requirements on shipping and classifying dangerous goods (CH2M HILL, 2008). The Sample Shipper must complete CH2M HILL Dangerous Goods and Waste Management training, which requires that the trainee become familiar with U.S. Department of Transportation (DOT) and federal regulations for shipping dangerous goods before shipping any samples.

The *Code of Federal Regulations* (EPA 2001) describes sample shipping requirements, which are covered in SOP *HSE-417 Hazardous Materials Transportation*, as:

> "... a sample of solid waste or a sample of water, soil, or air, which is collected for the sole purpose of testing its characteristics or composition, is not subject to any requirements of this part (hazardous materials shipping requirements)... when:
>
> (i) The sample is being transported to a laboratory for the purpose of testing; or
>
> (ii) The sample is being transported back to the sample collector after testing.
>
> In order to qualify for the(se) exemption(s)..., a sample collector shipping samples to a laboratory and a laboratory returning samples to a sample collector must:
>
> (i) Comply with Department of Transportation (DOT), U.S. Postal Service (USPS), U.S. Department of Agriculture, or any other applicable shipping requirements; or
>
> (ii) Comply with the following requirements if the sample collector determines that DOT, U.S. Postal Service (USPS), or other shipping requirements do not apply to the shipment of the sample:
>
> (A) Assure that the following information accompanies the sample:
>
> (1) the sample collector's name, mailing address, and telephone number;
>
> (2) the laboratory's name, mailing address, and telephone number;
>
> (3) the quantity of the sample;
>
> (4) the date of shipment; and
>
> (5) a description of the sample.
>
> (B) Package the sample so that it does not leak, spill, or vaporize from its packing."

To establish compliance with this requirement, assess samples to determine potential hazard. Potentially hazardous samples are required by law to be properly handled and labeled. If the coolers are not to be delivered by hand to the project laboratory but shipped to the laboratory, package the samples for shipment according to DOT regulations. Label, package, and ship hazardous samples according to the requirements of the shipper (for example, FedEx, Alaska Air Cargo, or Frontier Alaska Cargo) and CH2M HILL. Verify that marking and labeling procedures are consistent with DOT regulations. Enter the method of

shipment, courier name(s), and other pertinent information on the CoC form. Properly complete air waybills, retain copies and place them in the project file.

5.2 Packing and Shipping Samples

5.2.1 Environmental Samples (Nonhazardous)

Label, pack, document, and ship environmental samples that are determined to be nonhazardous by the FTL or FM within insulated sample coolers as described below. Environmental samples do not require DOT marking, labeling, or shipping papers and there are no DOT restrictions on the mode of transportation.

Packing Samples

Photos in SOP-18, Attachment 2 illustrate the packing instructions below.

- Determine the approximate shipping duration for the sample to be sent. If the shipping duration is extensive (for example, greater than 24 hours), consider shipping the samples in extended-use 5-day or 6-day coolers.
- Determine the maximum allowable weight of each cooler (for example, the FedEx limit is 150 pounds; Alaska Air Cargo limit is 300 pounds; and Horizon Air and Frontier Alaska Air limits are 100 pounds).
- When you reuse packing, remove all inappropriate marks and labels. Old and/or non-applicable labels or markings must be removed or covered up. If the labels and marks cannot be removed, cross them out so that they are not visible.
- Each piece of the shipment must be legibly and durably marked by the shipper with the name and address of the Shipper and the Consignee. A Consignee phone is number required, if the shipment is perishable. Marking includes the application of special handling stickers, such as “THIS SIDE UP,” “FROZEN,” or “COOL.”
- Most shippers will not accept a shipment for transportation when it appears that the shipment is:
  - Improperly packed or packaged
  - Of a kind or type likely to incur damage from high or low temperature under normal air transportation conditions
  - Of an inherent nature or defect which indicates that transportation could not be furnished without loss or damage to the shipment or damage to the shippers facilities or equipment
- Check the sample container caps to make sure they are tightened properly. Samples for volatile components must be discarded and recollected if the cap is loose.
- Tape the drain plug on the inside and outside of the cooler.
- Place a minimum of approximately 2 inches of cushioning material in the bottom of the cooler, such as asbestos-free vermiculite, perlite, or bubble wrap sheets.
- Place a large plastic bag (such as a trash bag) in the bottom of cooler to contain samples. Allow the top edges of the plastic bag to hang over the outside of the cooler while filling.

- Place each sample container in a resealable Ziploc® bag or similar and seal, squeezing as much air as possible from the bag before sealing. Glass containers should be wrapped in bubble wrap.
- Place the bottles upright in the cooler so that they will not touch against each other during shipment and have enough room for ice bags and cushioning material to be placed among and around the containers.
- For the receiving laboratory to have an accurate method of assessing the temperature of samples, a temperature blank will be placed in every cooler.
- Place additional cushioning material around sample bottles, and fill voids between bottles. Insulate the samples with enough bubble wrap to deter breakage.
- To verify uniform cooling, place a minimum of 8 ice substitute bags (such as gel ice) between samples and over the containers to preserve them at approximately 4 degrees Celsius (°C). Evenly distribute the ice substitute along the walls and top of each cooler. (Note: loose bagged ice is not acceptable if coolers are transported by commercial aircraft such as Alaska Air Cargo.)
- Fill the remaining spaces within the cooler with additional ice substitute and/or cushioning material such that the contents cannot shift and move inside the cooler. Additional ice or fewer samples per cooler will be practiced in order to verify all samples arrive at the laboratory within the accepted 2° to 6° C temperature range. This practice will be of particular importance during periods of warmer weather and/or longer shipping durations.
- Pull the top edges of the large plastic bag up and together and tie the bag edges into a knot by twisting edges together while forcing out any extra air.

Shipping Samples

- If shipping via commercial carrier (such as FedEx, Alaska Air Cargo, or Frontier Alaska Cargo), write the carrier's name and air waybill number on the CoC form.
- Place the completed CoC form inside a resealable Ziploc® bag and tape the bag to the inside lid of the cooler. Each cooler must have a copy of the CoC inside the cooler. Retain an original carbon copy or photocopy of the completed CoC and submit the CoC to the FDM or FM for project archiving.
- The CoC form sent to the laboratory must be completed with all designated information and the CoC must be unique to the samples contained within each specific cooler according to *SOP-19, Sample Handling and Custody.*
- Close and seal the cooler with a strong adhesive tape. Wrap nylon-reinforced strapping tape completely around the ends of the cooler multiple times to secure it, making sure to close any open space between the lid and the cooler. Tape the cooler latch closed with strapping tape. Using only clear packing tape or duct tape to seal the cooler is unacceptable.
- Complete two custody seals and then seal the cooler by place the seals on the front and the rear of the cooler across the edge where the cooler and cooler lid meet. The signature on the custody seals should match the signature on the CoC. Tape over the custody seals with clear packing tape around the entire cooler.

- Attach the completed shipping label to the top of the cooler and print “Laboratory Samples,” with the laboratory and CH2M HILL field office addresses and telephone numbers on the top of the cooler.
- Attach “THIS SIDE UP” labels on all four sides of the cooler and place “FRAGILE” and “CHILL” or “COOL” labels on at least two sides.
- Complete the appropriate air waybill (or manifest) with all designated information, including the following:
  - Shipper service requested (for example, Express, Goldstreak, and Priority).
  - The laboratory addresses and telephone number.
  - The CH2M HILL field office addresses and telephone number.
  - The project number (as the internal reference number or PO number).
  - The sender/shipper account number and/or Customer Identification (CID) number (Alaska Air Cargo only). (The Alaska Airlines Cargo CID for the CH2M HILL Anchorage office is 5331.)
  - Special handling requests for “Notify upon Arrive” with lab contact name and phone number, “Cool - Place in Cooler,” and “Do Not Freeze.” Special handling request may need to be requested in person when dropping off shipments with the carrier.
- Attach an original copy of the air waybill to sample cooler. Retain an original carbon copy or photocopy of the air way bill and submit with the CoC to the Field Data Manager or FM for project archiving. Note that multiple coolers may be shipped under a single air waybill if each cooler is labeled with the laboratory and CH2M HILL field office addresses and telephone numbers, appropriately.
- Ship the samples and notify the laboratory that the samples have been shipped. Provide the laboratory with the name of the carrier, air waybill number, and shipment date from the retained copy or photocopy of the air waybill. The lab must be prepared to receive and check the samples and sign the CoC form. In some cases, the laboratory may need to pick up the sample shipment from the carrier directly; coordinate with the laboratory to successfully deliver the samples to the laboratory.
- The sample shipper or sample coordinator should then verify with the laboratory that samples have been received, that the requested laboratory analyses have been obtained, and that there are no compliance issues with sample labeling, packing, container and preservative, or temperature.

5.2.2 Hazardous Samples

Pack and ship hazardous samples using the same procedures as for nonhazardous samples, except for the following:

- Consult the FM and/or HSM whenever hazardous sample shipping is expected. Shipment of hazardous samples should follow the procedures outline in *SOP-18, Attachment 1: HSE-417 Hazardous Materials Transportation*.
- Place the sample container inside a 1-quart- or 1-gallon-size paint can. Fill the void space with vermiculite. Place the paint can in a cooler and pack as described above.

- Complete a carrier-approved air waybill or shipper's certification for restricted articles, providing the following information in the order listed:
  - "Flammable Liquid, No. UN 1993" or "Flammable Solid, No. UN 1325"
  - "Limited Quantity" (or "Ltd. Qty.")
  - Net weight or net volume of total sample material in cooler
  - "Laboratory Samples"
  - "Cargo Aircraft Only"
- Affix a corporate address label to the cooler with the address of the laboratory.

Note that DOT regulations do not apply to transport by government-owned vehicles, including aircraft.

6.0 Records

Log sample shipments on an Sample Shipment Log as provided in SOP-18, Attachment 3, or in a Field Notebook. Complete COC forms, air waybills, manifests, IATA Shipper's Declaration (DGD) forms, DOT shipping paperwork, and any other shipping documentation according to *SOP-01, Field Note Taking and Field Log Books,* and store them in the project files.

7.0 References

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International Air Transport Association (IATA). 2002. *Dangerous Goods Regulations.* (International Air Transport Association Regulation 618, Attachment "A"). 43rd ed.

U.S. Department of Transportation. January 2001. *Code of Federal Regulations*. Title 49, Parts 171 - 180, Washington, DC.

U.S. Environmental Protection Agency (EPA). January 2001. *Code of Federal Regulations*. Title 40, Part 261, Section 4. Washington, DC.

8.0 Definitions

Air Waybill: the shipping document that identifies the sender and addressee, transport carrier, size, and priority of a shipment transported by aircraft.

Dangerous Goods or Hazardous Materials: a substance or material, including a hazardous substance, that the U.S. Department of Transportation (DOT) has determined can pose an unreasonable risk to health, safety, and property when transported in commerce and that DOT has designated as a hazardous material.

9.0 Attachments

Attachment 1: *HSE-417 Hazardous Materials Transportation*

Attachment 2: *Sample Packing Photos*

Attachment 3: *Sample Shipment Log*

SOP-19

Sample Handling and Custody

SOP-19: SAMPLE HANDLING AND CUSTODY

1.0 Purpose

This standard operating procedure (SOP) outlines protocols for sample handling and custody. An example chain-of-custody (CoC) form is provided as part of this procedure (see SOP-19, Attachment 1); other formats with essentially identical information are acceptable.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in collecting and handling environmental samples at Galena Forward Operating Location (FOL), and was developed according to the following Alaska Department of Environmental Conservation (ADEC) documents:

- *Draft Field Sampling Guidance (ADEC, 2010)*
- Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures (ADEC, 2002)

This SOP focuses on the most commonly used environmental sample handling and custody tracking tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-15, Active Soil Gas Vapor Sampling*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-27, Passive Soil Gas Vapor Sampling*
- *SOP-24, Direct Push Groundwater Sampling*
- *SOP-31, Multi Increment® Sampling for Surface Soil*

3.0 General

An essential part of the sampling activities of any environmental project is assuring the integrity of the samples from collection through data reporting. Sample labels and CoC forms are used to document identification and handling of samples from the time of collection through the completion of chemical and/or physical analysis. Documentation of the history of a sample should be prepared and maintained to demonstrate that the data are a true representation of the environmental media. In some projects, analytical data may be used in litigation. The CoC record is used as evidence in legal proceedings to demonstrate that a sample was not tampered with or altered in any way that may bias the analytical accuracy of the laboratory results. It is extremely important that CoC records be complete, accurate, and consistent.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and verifying that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if any complications arise with following these critical sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for verifying compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Field Data Manager

The Field Data Manager (FDM) should verify that the systems are maintained to create CoC forms from the Sample Tracking and Scheduling Program. The FDM is responsible for production of CoC forms and sample labels for field samplers, and for verifying that all information, including labels and CoC forms, are correct. Labels and CoCs are typically generated by the Sample Tracking and Scheduling Program, which is managed by the FDM. The Sample Tracking and Scheduling Program is a database that has the sample identification and sample analytes entered into it from the Site-specific Attachments (Appendix D). Once entered, labels and CoCs are generated based upon specifications in the site-specific attachment.

The FDM should alert the laboratory that samples have been shipped, and follow up with the laboratory to verify that samples have been received in compliance with paperwork and temperature requirements. The FDM should also confirm with the laboratory any special analytical requests (such as rapid turnaround times).

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify that overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the Project-Specific Health and Safety Plan (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.5 Field Team Leader

The Field Team Leader (FTL) is responsible for maintaining compliance with sample handling and custody requirements; particularly the procedures to be used. The FTL, or their designee, should know the requirements of sample handling and custody, and should maintain adequate documentation of sample shipping activities. The FTL must be aware of these sampling handling procedures and will schedule accordingly, taking into account that sample packing and custody requirements for potentially hazardous samples requires more time and materials (for example, properly labeled paint cans and manifests) than does handling nonhazardous samples. The FTL should take responsibility for correctly completing

CoC forms and for coordinating with the FDM to successfully handle, package, and ship samples as described in *SOP-18*, *Packing and Shipping of Environmental Samples*. The FTL should determine or seek guidance as to which samples are potentially hazardous and handle them accordingly.

4.6 Field Sampler

The Field Sampler, under the supervision of the FTL (who may be the same person), should confirm that samples are correctly collected, labeled, tracked by CoC, and stored until they are delivered to the FTL or FDM. The Field Sampler should maintain custody of the samples until they are relinquished to the FTL or FDM. The Field Sampler should be responsible for informing the FTL and/or FDM of sampling conditions and if any of the samples are potentially hazardous.

4.7 Sample Custodian

The Sample Custodian is any individual who is responsible for the custody of samples and completion of associated documentation.

5.0 Procedures

5.1 Sample Custody

Follow procedures to preserve and verify the integrity of all samples from the time of collection through analysis. A critical aspect of sound sample collection and analysis protocols is the maintenance of strict CoC procedures, as described in this technical procedure. CoC procedures include tracking and documentation during sample collection, shipment, and laboratory processing.

A sample is considered to be in an individual's custody if any of the following apply:

1. It is in the physical possession of the responsible party.
2. It is in view of the responsible party after being in their possession.
3. It is placed in a designated, secure area that is controlled and restricted by the responsible party.

Maintain records of the custody of samples, both in the field and in the laboratory. Document custody throughout all sampling activities on the CoC record for each day of sampling, and verify that this record accompanies the samples from the site to the laboratory. Transfer sample custody according to Section 5.2.

Ship samples to subcontractor laboratories via expeditor or air courier. Use air waybills will as custody documentation during this time; they should be retained as part of the permanent sample custody documentation. If the situation warrants, hand-deliver samples to an onsite field laboratory; in these cases, note the hand delivery on the CoC form.

Place custody seals across the front and back edges of each sample cooler lid to maintain its integrity during shipping until it is opened by the laboratory, according to *SOP-18, Packing and Shipping of Environmental Samples*. In addition, seal sample coolers with a custody seal any time they are not in someone's possession or view before shipping. The responsible sampling custodian should sign and date all custody seals.

The subcontractor laboratory is responsible for sample custody once samples are received. Custody must be maintained at the laboratory once samples are received until all tests are completed. This will be accomplished using an internal custody system that requires samples to be kept in a secured and restricted area when not in use, and to be checked out and checked back in by the analysts who use them. Internal custody records must be maintained by the laboratory as part of the documentation file for each sample.

5.2 Transfer of Custody and Shipment

All personnel with sample custody are required to sign, date, and record the time on the CoC form when receiving and relinquishing samples from their immediate custody. Any discrepancies should be noted at this time. If the samples are required to be shipped, the laboratory project manager or coordinator will be notified by the FDM of when and how the samples were shipped. Notification will include the following information:

- Date of shipment
- Name of shipping company
- Air waybill number
- Number of coolers
- Name, phone number, and facsimile number of point of contact
- Estimated date of shipment arrival
- Type of samples (water, sediment, or soil)

Upon receipt of each sample cooler and after verification of the CoC records, the laboratory will provide a cooler receipt form documenting any discrepancies such as, but not limited to, the following:

- Inappropriate sample containers or preservation
- Broken sample containers
- Cooler temperature outside range of 2 to 6 degrees Celsius (°C) (where applicable)
- Missing CoC form or quality assurance (QA) sample form
- Errors on CoC or QA sample form
- Missing custody seals

The laboratory should notify CH2M HILL of any such discrepancies within 24 hours of its receipt of the samples.

5.3 Chain-of-custody Record

CoC forms document sample collection and shipment to the laboratory. CoCs are a legal document that records the transfer and disposition of collected environmental samples. The CoC form will identify the contents of each shipment and maintain the custodial integrity of the samples. Fill out CoC forms at each sampling location for each sample/analysis, to maintain a record of sample collection, transfer of samples between personnel, shipment of samples, and receipt of samples at the laboratory. The FDM will generate the CoC form using the Sample Tracking and Scheduling Program.

Information entered by the FDM includes the following:

- Project name and project number
- Name, address, and phone number of the laboratory to receive the samples
- CoC control number

- Sample type/sample collection method
- Location ID
- Unique sample ID
- Matrix type
- Analytical methods requested
- Field duplicate, if applicable
- Field quality control (QC) for matrix spike and matrix spike duplicate (MS/MSD) samples, if applicable
- Container type, size and number
- Preservatives used
- Turnaround-time (TAT) for laboratory analysis
- Air waybill number or Bill of Lading number
- Special instruction or comments to laboratory or Field Sampler, if applicable

The FTL or Field Sampler will enter the following information using indelible black or blue ink:

- Date of sample collection
- Time of sample collection (in 24-hour military format)
- Depths, if applicable
- Sampler's initials
- Void reason, if applicable
- Special instruction or comments to laboratory or Field Sampler, if applicable

The FTL and FDM should verify that the CoC record is complete, accurate in all aspects, and consistent with all other sample documentation (for example, number of samples, sample labels, and field logs). The Field Sampler or FTL will sign the "Sampled By" and "Relinquished By" fields on the CoC record, marking the date and time custody is transferred to the FDM or other authorized person.

The FDM will perform the following duties:

- Obtain the signature of the Field Sampler or FTL to transfer sample custody
- Prepare the samples for shipment from the field to the laboratory
- Record the carrier service and air waybill number on the CoC
- Sign and enter the date and time relinquished to the expeditor or air carrier.

The FDM will sign the "Received By" box, marking the date and time of receipt of the samples from the FTL, Field Sampler, or other sample custodian. Every transfer of physical custody should be documented on the CoC record.

Any corrections to the CoC form entries will be made by a single-line strike mark through the incorrect item, and then entering the correct entry adjacent to the strikeout item according to *SOP-01, Note Taking and Field Log Books*. Corrections will be initialed and dated by the person making the change. After the form has been inspected and determined to be

satisfactorily complete, the FDM will sign, date, and note the time of transferral and will reference a shipper tracking number (such as an air waybill number) on the form.

CoC forms should be completed in duplicate for each sampling event, at a minimum. The original, completed CoC form will be delivered with the sample shipping cooler, and a field copy (such as a carbon copy or photocopy) will be retained in the field project files. The original CoC form will be placed in a resealable plastic bag and placed inside the cooler according to *SOP-18, Packing and Shipping of Environmental Samples*.

5.4 Sample Labels

Attach sample labels to all sample containers at the time of sample collection. Generate the label along with the CoC form using a Sample Tracking and Scheduling Program, or similar appropriate database method, depending on the sample container. For certain types of samples (such as Summa™ gas canisters), use the blank labels provided by the laboratory when the lab provides sample containers. Verify that labels generated by the Sample Tracking and Scheduling Program are preprinted with the following information:

- Project Name and Number
- Unique Sample ID
- Site
- Sample Location
- Matrix
- Container
- Laboratory
- Preservative used
- Number of containers
- Analytical methods requested

Handwrite the same information listed above on labels not preprinted by the Sample Tracking and Scheduling Program, if necessary.

When the sample collection is complete, the Field Sampler fills in the following information in indelible, waterproof ink:

- Date and time of sample collection
- Sampler's initials

Once complete, cover the sample labels with clear tape, unless the sample container is pre-weighted for laboratory analysis (such as for gasoline range organics [GRO], volatile organic compounds [VOCs], or volatile petroleum hydrocarbon [VPH]), and prepared for shipment following *SOP-18, Packing and Shipping of Environmental Samples*. Do not tape samples collected for VOCs, GRO, and VPH, to avoid possible cross contamination from VOCs in the tape. Follow laboratory specified procedures identified by the FDM, FM, or FTL for labeling for other types of containers, such as soil gas and air samples.

5.5 Sample Identification

5.5.1 Primary Environmental Samples

Verify that all samples are identified with a unique naming convention that identifies the sample area, location type, location number, media matrix, sample depth, and any special

designation (for example, matrix spike and matrix spike duplicate samples). Identify samples using the following sample naming convention:

{SITE}VW-X_YZ

where:

- ***{SITE}*** = Name of the investigation site or area of concern (for example, ST009 or AOC023)
- ***"V"*** = Location type:
  - GP = Direct-Push Soil Boring
  - HS = Hollow-stem Auger Soil Boring
  - TP = Test Pit
  - HA = Hand Tool Soil Sample/Boring (such as hand auger, shovel, or scoop)
  - MW = Monitoring Well
  - WP = Well Point Water Sample
  - HP = Direct-Push Water Sample
  - VP = Soil Vapor Drive Point
  - MIS = Multi-Incremental Sample
- ***"W*** " = Three digit location ID number:
  - Field duplicate samples should add a "9" as the first digit.
  - MIS duplicate samples should add an "8" as the first digit.
  - MIS triplicate samples should add a "7" as the first digit.
- ***"X"*** = Matrix type:
  - SW = Surface water
  - GW = Groundwater
  - SO = Soil
  - SV = Soil vapor
  - PR = Product
  - SE = Sediment
- ***"Y"*** = Proposed sample depth interval in feet below ground surface with a two-digit numerical format. The actual sample depth intervals should be noted in the field sheets. For groundwater, product, and surface water samples from existing monitoring wells and surface water bodies, this depth designation will be omitted)
- ***"Z"*** = special designation:
  - MS for matrix spike
  - SD for matrix spike duplicates

Soil Sample Example

For example, a soil sample collected at 0 to 2 feet below ground surface (bgs) from direct-push soil borehole number 1 at Site ST009 would be identified as follows:

{SITE}VW-XYZ = ST009GP001-SO_00-02

A field duplicate sample collected at the same time would be identified as follows:

ST009GP901-SO_00-02

Matrix spike and matrix spike duplicate samples collected at the same time would be identified as follows:

ST009GP001-SO_00-02MS and ST009GP001-SO_00-02SD

Groundwater Sample Example

For example, a groundwater sample collected at monitoring MW-1 at Site ST009 would be identified as follows:

{SITE}VW-XYZ = ST009MW-1-GW

MIS Sample Example

Also, for example, a multi-incremental sampling (MIS) soil sample collected from MIS decision unit 1 at Site ST009 would be identified as follows:

ST009MIS001-SO_00-01

The associated MIS field duplicate and triplicate samples collected at the same time would be identified as follows:

ST009MIS801-SO_00-01 (duplicate) and ST009MIS701-SO_00-01 (triplicate)

5.5.2 Field Equipment Blanks and Trip

Specify field equipment and trip blank samples as follows:

{SITE}-EBY or {SITE}-TBY

where: Y = Three digit sample number (such as 001)

As an example, the first field equipment blank collected at Site ST009 would be identified as follows:

ST009-EB001

5.6 Sample Handling and Storage

Take care when handling environmental samples. Handle samples only while wearing new, disposable nitrile gloves, and keep empty sample containers and collected samples clean, dry, and away from potential cross-contaminant sources (such as vehicle exhausts, fuel sources, and contaminated equipment). Transport collected samples separately from other sampling equipment and tools, and store and transfer samples in an upright position and sealed tightly. Handle and preserve all samples according to the preservation and holding times summarized in *Worksheet #19*.

If samples cannot be shipped immediately to a laboratory and must be temporarily stored until arrangements can be made for delivery, place the samples in a secured CH2M HILL facility area with sufficient refrigeration or ice in order to maintain 2° to 6 C storage temperatures (if required for preservation of the samples). Verify that a temperature blank and CoC accompanies samples during storage. Samples may be stored in a secure, temperature-controlled refrigerator as long as reliable power is provided to the refrigerator

and the refrigerator is designated for environmental samples only. Do not store samples in refrigerators potentially used for food storage. Use storage custody seals to maintain sample security in refrigerated storage.

Samples temporarily stored overnight must be received by the custodian that placed them in storage, and may in turn be relinquished to the appropriate laboratory, the FDM, or another sample custodian. Record each transfer of custody on the appropriate CoC form(s).

6.0 Records

Record sample handling and custody information in a Field Notebook and on CoCs according to *SOP-01, Note Taking and Field Log Books*. Complete CoC forms, air waybills, and any other shipping documentation according to *SOP-01* and a copy retained in the project files.

7.0 References

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8.0 Definitions

Air Waybill: the shipping document that identifies the sender and addressee, transport carrier, size, and priority of a shipment transported by aircraft.

Custody: physical possession or control. A sample is under custody if it is in possession or under control so as to prevent tampering or alteration of its characteristics.

Sample Label: a record attached to samples to verify legal documentation of traceability.

Chain-of-Custody (CoC) Form: a legal document that records the transfer and disposition of collected environmental samples. *SOP-19, Attachment 1* provides an example of a CoC form.

Sample Tracking and Scheduling Program: a database program that the Field Data Manager uses to record and track field sample collection. The program is also used to generate CoC forms before and after sample collection.

Turnaround-time (TAT): the duration for laboratory sample analysis from the time of sample receiving to the time a laboratory data report is produced.

9.0 Attachments

Attachment 1: *Example Chain-of-Custody Form*

SOP-20

Field Procedure Change Management

SOP-20: FIELD PROCEDURE CHANGE MANAGEMENT

1.0 Purpose

This standard operating procedure (SOP) provides the process to modify field SOPs to address changing project needs and conditions.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in site investigation activities at the Galena Forward Operating Location (FOL). It is anticipated that this SOP will be used in conjunction with all existing and future project SOPs documented in Appendix H, Field Standard Operating Procedures.

3.0 General

The field SOP change management process includes the following steps:

1. Identify a potential SOP change.
2. Analyze the SOP change request.
3. Evaluate and accept, reject, or modify the SOP change request.
4. Plan and implement the approved SOP change.
5. Review and close the SOP change.

The field SOP change management process includes the following responsibilities:

Change Requestor: Requests an SOP change because of issues encountered with the current procedure or new procedural requirements; initiates the change management process by submitting an SOP Change Request Form.

Change Manager: Responsible for determining the technical feasibility, costs, and benefits of the procedural change. The Project Manager will be the Change Manager; however, the PM may delegate the Change Manager role to the Field Manager (FM), Health and Safety Manager (HSM), Field Team Leader (FTL), or other appropriate team leader.

Change Committee: Decides if an SOP change request will be implemented. The PM is the default Change Committee. At the PM's discretion, the Change Committee may include other project stakeholders (for example, CH2M HILL, the client, and regulators), depending on the nature of the SOP change request. The PM will evaluate the magnitude and impacts of the SOP change request and organize the Change Committee, as appropriate.

Change Builder: Plans, documents, and implements the change. This role will reside primarily with CH2M HILL staff, including the PM, FM, HSM, FTL, other CH2M HILL personnel, and subcontractors engaged in project activities.

4.0 Responsibilities

4.1 Project Manager

The PM is responsible for providing adequate resources and verifying that field staff have adequate experience, training, and technology to successfully comply with and implement

project-specific SOPs and the project health, safety, and environment (HS&E) program. The PM will frequently be the Change Manager; in some instances, the PM will be a member of the Change Committee and act as the Change Builder. The PM is ultimately responsible for implementing project changes.

4.2 Health and Safety Manager

The HSM is assigned to oversee site-specific HS&E issues and compliance with project HS&E requirements. The HSM develops the *Project-specific Health and Safety Plan* (HSP) (Appendix A), coordinates with the FM and SC to implement HS&E, and certifies the HS&E program. The HSM may serve as the Change Manager and actively participates as a Change Builder for issues that relate to HS&E.

4.3 Field Manager

The FM oversees all project field operations and verifies that SOPs are effectively implemented. The FM verifies that all SOP change requests are processed in accordance with this SOP. The FM assists the PM and is responsible for communicating SOP change requests to the PM for evaluation. The PM may delegate the Change Manager and Change Committee roles to the FM. The FM is a key Change Builder and implements project changes.

4.4 Field Team Leader

The FTL helps the PM and FM manage field activities. The FTL receives input from project staff regarding field task issues and communicates them to the PM and FM. The FTL may be the Change Requestor when changes are necessary. The FTL is a Change Builder for implementing SOP changes in the field.

4.5 Safety Coordinator

The SC is either the FM or FTL and implements the project-specific HSP. The SC assists the FM and HSM. The SC receives input from project staff regarding HS&E issues and communicates them to the FM and HSM. The SC may be a Change Requestor and is a Change Builder for issues that relate to health and safety.

5.0 Procedures

5.1 Identify a Potential SOP Change

Changes to the SOPs may be initiated for many reasons including unanticipated problems, changes in site conditions, new project requirements, new technology, or improved methods. All changes to the field SOPs begin with submission of a completed SOP Change Request Form to the FM, who reviews it and forwards it to the PM. The PM may serve as the Change Manager or assign that role to the FM, HSM, FTL, or other appropriate team leader.

A copy of the SOP Change Request Form is provided as *SOP-20, Attachment 1: SOP Change Request Form*. Any person or organization, internal or external, may submit an SOP change request. SOP Change Request Forms will be recorded in the *SOP Change Entry Log* (see Attachment 2). Copies of all SOP Change Request Forms and the SOP Change Entry Log must be archived in the project records.

5.2 Analyze the SOP Change Request

The Change Manager will review the SOP Change Request Form and determine the practical and technical feasibility of the proposed change and evaluate the costs and benefits relative to project goals. The Change Manager will also determine the impact that the change will have on other project SOPs, tasks, and goals. The Change Manager will present this information to the Change Committee for evaluation.

The Change Manager may ask that the requested change be tested for technical feasibility, cost, and benefit. Tests should be conducted by a Change Builder (for example, an FTL). Test results should be communicated to the Change Manager for presentation to the Change Committee.

5.3 Evaluate and Approve the SOP Change

The PM will evaluate the impacts of the SOP change and organize the Change Committee to review the information and decide if the change will be implemented. Depending on the scope and magnitude of the proposed change, the Change Committee may comprise various project stakeholders (such as CH2M HILL, client, and regulators) or it may comprise only the PM or other CH2M HILL staff. Based on the technical feasibility, costs, and benefits of the SOP change, the Change Committee will approve or disapprove the proposed change. The outcome of the SOP change request will be recorded in the SOP Change Entry Log.

5.4 Plan and Implement the SOP Change

After approval, the change will be planned and implemented by the Change Manager and Change Builders. Planning the change might include updating the existing SOP, developing a new SOP, or organizing staff, resources, and subcontractors to implement the changed SOP. All updated and new field SOPs will be added to the existing SOPs as an amendment. After the SOP change is planned and documented, the SOP change must be communicated to all affected field team members for review and implementation.

5.5 Review and Close the SOP Change

Implementation of the SOP change should be verified by the PM or his/her designee. If the change is acceptable, the SOP change request can be closed and documented as complete on the SOP Change Entry Log.

6.0 Records

A record of all submitted SOP Change Request Forms will be recorded in the SOP Change Entry Log. Copies of all SOP Change Request Forms must be maintained with the SOP Change Entry Log in the project records. All SOP Change Request Forms must be completed according to *SOP-01, Note Taking and Field Log Books*.

7.0 References

None.

8.0 Definitions

SOP Change: Any alternative field procedure, method, or process step that is different than those currently outlined in the *Appendix H, Field Standard Operating Procedures.*

SOP Change Entry Log: A log book or database that catalogs multiple SOP change requests and tracks the decision and implementation process and final decision outcome of the request.

SOP Change Request Form: A form that identifies a potential need for an SOP change and requests that the change be considered for implementation. The form provides a method to record changes during the project.

9.0 Attachments

Attachment 1: *SOP Change Request Form*

Attachment 2: *SOP Change Entry Log*

SOP-21

Well Decommissioning and Abandonment

SOP-21: WELL DECOMMISSIONING AND ABANDONMENT

1.0 Purpose

This standard operating procedure (SOP) provides guidance in the decommissioning and abandonment of monitoring wells, temporary micro monitoring wells, and boreholes that are no longer in use, or that have fulfilled their intended purposes. As referenced in 18 Alaska Administrative Code (AAC) 75.345(j) and 18 AAC 78.615(b), groundwater monitoring wells must be installed, developed, and decommissioned in accordance with the Alaska Department of Environmental Conservation (ADEC) Division of Spill Prevention and Response Contaminated Sites Program *Monitoring Well Guidance* (MWG) dated February 2009, or another approved method that is protective of human health, safety, and welfare, and of the environment. The ADEC MWG specifically addresses decommissioning of monitoring wells and for decommissioning other applications. American Society for Testing and Materials (ASTM) D5299-99 *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities* is also referenced as a guidance for the abandonment of other intrusive activities. Well decommissioning requires the prior approval of ADEC, and wells should be decommissioned within 60 days if they are abandoned or no longer used, unless an alternative schedule is approved by ADEC.

The practices described in this SOP are not applicable to all circumstances; regional, climatic, and geographic variables can influence monitoring well design and construction which will influence decommissioning methodology. While decommissioning methodologies may differ, site-specific application should be technically sound. This SOP offers an organized collection of information or a series of options and does not recommend a specific course of action. This SOP cannot replace education or experience and should be used in conjunction with professional judgment.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in the decommissioning of wells and boreholes during environmental investigations and monitoring programs for Air Force Center for Engineering and the Environment (AFCEE) projects at the Galena Forward Operating Location (FOL) in Galena, Alaska.

The procedures presented in this SOP describe the minimum acceptable practices for the abandonment of monitoring wells as outlined in the MWG (ADEC, 2009). The MWG takes precedence over the ASTM guidance.

3.0 General

Well abandonment is conducted to prevent surface water from infiltrating into the subsurface, so that the well does not become a potential conduit for contaminant dispersion. The goal in decommissioning monitoring wells is to remove the well casing and screen in a manner that ensures that the abandoned borehole is sealed to a lesser permeability than the native soils surrounding the borehole. Casing removal is important because the outside of the casing can act as a conduit through horizontal formation changes even if the inside of the casing is grouted. The well casing and screen should be removed when wells are decommissioned unless permafrost, remoteness of the well, or other unique conditions make it impracticable. If the casing cannot be completely removed, unscrew the top section

and grout from there. Otherwise, excavate the surface soil surrounding the well and cut the casing below the ground surface. ADEC approval must be obtained for all monitoring well decommissioning methods.

Decommission wells that are damaged beyond repair, abandoned, or not intended for future use. A well that is no longer maintained and secured is susceptible to damage that can prevent proper future decommissioning, and is a potential conduit for direct surface contamination to the aquifer.

Most monitoring wells are constructed of polyvinyl chloride (PVC) casing and screen with flush-threaded joints. Well casing and screen should typically never be removed unless sealing grout is concurrently placed in the vacated borehole during removal.

Before initiating decommissioning procedures, determine historical records concerning the well condition, details of construction, total depth, current water level, and the existence of any obstructions that could interfere with the process of filling and sealing the well, and obtain any well construction diagrams. For larger wells, downhole videos or photographs may be required to ascertain the current well condition and well construction details.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) should ensure that the methods used for well decommissioning are in compliance with these procedures and the requirements of the appropriate federal, state, and local enforcement agencies. The PM must document and seek approval for alternative decommissioning requirements and procedures from local agencies and modifications because of unusual conditions. The PM will ensure that decommissioning activities are approved by ADEC and that documentation of the decommissioning activities are submitted to ADEC.

4.2 Project Geologist/Engineer

The Project Geologist/Engineer should be knowledgeable of the requirements for decommissioning and will maintain adequate documentation of the procedures and materials used to ensure that the monitoring well or borehole decommissioning has been properly performed and is defensible.

5.0 Procedure

The following procedures must be followed to ensure the proper decommissioning of wells and boreholes.

5.1 General

There are six elements that generally need to be addressed before conducting well abandonment activities. These include addressing regulatory requirements, well construction design, the hydrogeological environment, the chemical environment around the well or borehole, disposal of investigation derived wastes, and determining the types of equipment and quantities of materials that will be required to complete well abandonment.

In addition, the following key principals, specifications, and precautions should be considered during monitoring well decommissioning (ADEC, 2009):

1. Decommission wells that are out of use within 60 days
2. Remove the well casing/screen
3. Pipe sealing materials directly to the point of application
4. Ensure that sealing grouts are properly mixed and prepared in accordance with manufacturer recommendations before placement.
5. Grout/slurry sealant should be used rather than bentonite/sealant pellets in order to achieve a complete and competent seal.
6. Pellets can bridge during placement, resulting in voids and an incomplete seal.
7. If using cement grout, neat cement, or puddled clay as sealing materials below the static water level in the well, introduce from the bottom up.
8. When using a tremie tube to place grout, submerge the discharge end in the grout to avoid breaking the seal while filling the annular space.
9. For artesian wells, place a cement grout or concrete plug in the confining stratum overlying the artesian zone to prevent upward seepage from the artesian zone.
10. Fill the remainder of the well with cement grout or bentonite.
11. Record decommissioning procedures and report to ADEC.

For wells with a diameter exceeding 12 inches, revised procedures (than those described in the following sections) should be submitted to ADEC for approval. A geologist or engineer should plan, supervise, and document well abandonment.

5.1.1 Well Decommissioning Materials

Materials that may be used for sealing wells and boreholes include concrete, cement grout, neat cement, bentonite, or combinations of these materials. The selection of the proper decommissioning materials must be based on the construction of the well, depth of the borehole, the nature of the formation(s) penetrated, the type and concentration of chemicals present, and the location of the well or boring with respect to possible outside sources of contamination.

Concrete is generally used for filling the upper portions of a well, sealing water-bearing formations, plugging short sections of casings, or filling large-diameter wells. It is less expensive than neat cement or grout and it makes a stronger plug or seal. However, concrete will not penetrate seams, crevices, or interstices in the screen, casing, filter pack or formation. Furthermore, if not properly placed, the aggregate is likely to separate from the cement, weaken the mixture, and more easily cause bridging within the annular space.

Cement grout, a mixture of neat cement and water, is far superior for sealing small openings in the screen and casing, penetrating any annular space outside of the screen and casing, and filling voids in the surrounding formation. Special care must be taken to ensure that upper groundwater zones are securely cased off during sealing of lower zones.

Combinations of materials are frequently required to increase the effectiveness of the seal and the workability of its placement. Plans to use combinations of materials must be

addressed with the regulatory agencies. Regardless of the type of material or combination of materials used for decommissioning, the sealant must be free of contaminants and must minimize potential chemical alteration of the quality of the groundwater and adjacent soil.

5.1.2 Grouting Requirements

Grouting must proceed from the bottom of the well up to the top of the well using a tremie pipe or dump bailer. Grout must be added to the borehole/well under pressure to ensure adequate penetration of the annular space and surrounding formation. In addition, the tremie pipe should be placed into the grout by two feet or more to prevent bridging. Free-fall placement of grout into the borehole is generally not acceptable.

When the grout has reached 5 feet below ground surface, or to a level above the water table (whichever is shallower) let it settle and cure. After 24 hours, check the grout for settling and add additional grout if necessary. Grouting is complete when the neat cement has hardened and no settlement has occurred.

If using cement grout, neat cement, or puddled clay as sealing materials below the static water level in the well, introduce from the bottom up using methods that avoid segregation or dilution of the material. A cement-bentonite grout should be used in the water bearing zone(s). A cement grout without bentonite should be used in the vadose zone to prevent shrinkage. Shrinkage may lead to cracks in the grout, which can provide a migration pathway for groundwater or surface water. For artesian wells, place a cement grout or concrete plug in the confining stratum overlying the artesian zone to prevent upward seepage from the artesian zone. Fill the remainder of the well with cement grout or bentonite.

5.2 Boring and Well Decommissioning Procedures

The following sections present the procedures that should typically be used for boring and well decommissioning, and the methods to be used for placement of the sealing material. Before beginning the decommissioning operations, ADEC must have approved the decommissioning procedures. The procedures and materials used must be properly documented to ensure defensibility.

The ADEC MWG presents three alternatives for conducting well abandonment depending on the site conditions.

- Well casing removal
- Well casing remaining in place
- Redrilling the well

Procedures for well abandonment with each of these options, and the likely rationale for selecting each option are described in the following sections.

5.2.1 Decommissioning—Well Casing Removal

Removal of well materials (casing and screen) is the preferred method for any well decommissioning. If it is believed that attempts to remove the well casing by pulling it out with jacks or a drill rig could fail and result in complications to properly decommission the well, the casing may be left in the well and abandoned by leaving the well casing in place of redrilling the well. The decommissioning method is to remove the well casing; however the casing should not be withdrawn without being first completely filled to near the ground surface, from the bottom up, with sealing grout. Removing the well casing and screen without the concurrent placement of grout sealant will lead to a collapsed and lost borehole

that may never be properly sealed. The well casing and screen serve as the conduit allowing placement of a hose or other tremie tube to the bottom of the well for purposes of grout placement. Procedures outlined in the MWG include the following:

- Obtain approval from ADEC for the well decommissioning methodology
- Puncture or separate the bottom well cap by driving a steel drill rod or steel pipe against/through the end cap. The well casing/screen/end cap assembly can be lifted from the borehole slightly before driving off the end cap, in order to raise the end cap above the underlying compacted soil and assist in breaking it off the end of the well casing/screen.
- After the end cap has been ruptured or separated, sealing grout is pumped/placed to the bottom of the well, using a hose or tremie tube installed down the casing to the bottom of the well, until a column of grout fills the casing to the near ground surface.
- The well casing can now be withdrawn; however, the grout level within the casing will lower as the casing is withdrawn and grout will flow out the base of the well casing/screen to fill the borehole void space. Grout should be periodically added as the casing is removed to keep a column of grout near the ground surface. This will prevent the sloughing of the borehole, and fill any borehole void space, should the casing break while being pulled from the borehole.
- Grout the borehole to within 5-feet of ground surface or to above the groundwater table, whichever is shallower.
- Calculate the required volume of grout based on the depth and diameter of the borehole and record. Also record the volume actually used. Explain any discrepancy between the calculated and actual volume.
- Remove the surface seal and protective surface box.
- Backfill the top of the borehole with clean soil and match the surrounding surface completion (such as asphalt, concrete, soil, or other).
- Submit documentation of well abandonment to ADEC.

5.2.2 Leaving Well Casing In-Place

Competent Annular Grout Seal. Per the WMG, if permafrost or other unique circumstances prevent the removal of the well casing and screen assembly and if the original construction of the well is known to have included a competent annular grout seal surrounding the well casing, the screen/casing should be completely grouted in-place up to the casing cutoff point located near the ground surface.

Perforate and Grout Well Casing If it is not possible to remove the casing by pulling it out or over drilling around it and pulling it out, then perforation of the casing and well screen in place is the next option. This requires a drill rig with a knife or other device that can thoroughly perforate the entire casing such that grout may be pressurized into the annular space surrounding the well casing.

The following procedures should be followed for well abandonment with the casing in-place:

- Obtain approval from ADEC for the well decommissioning methodology.
- For wells with competent annular seals, grout the well to within 5-feet of ground surface.

- For wells with unknown annular seals, use a drill rig to perforate the entire well casing.
- Grout the borehole to within 5-feet of ground surface.
- Calculate and record the required volume of grout based on the depth and diameter of the borehole.
- Record the volume actually used. Explain any discrepancy between the calculated and actual volume.
- Remove the well head including the surface seal and the uppermost 3 to 5 feet of casing.
- Backfill the top of the borehole with clean soil and match the surrounding surface completion (such as asphalt, concrete, soil, or other).
- Submit documentation of well abandonment to ADEC.

5.2.3 Re-drilling the Well

Re-drilling of the well with hollow stem augers in order to seal the borehole by placing grout down the hollow augers during auger removal can be an effective fall-back option in circumstances where the well has been damaged, broken, filled, or plugged with soil or other extraneous media, preventing successful decommissioning using either of the prior two described methods. The concern with redrilling a monitoring well borehole is there is no way to ensure that the augers will follow the original borehole to the completed well depth. For this reason, re-drilling should only be used when neither decommissioning method described above can be successfully employed. This fall-back option consists of re-drilling the borehole to the full depth of the well. The PVC casing and well screen will be destroyed and broken into multiple pieces while re-drilling the borehole. After the auger string has been drilled to the total depth of the well, place grout sealant by hose or tremie tube to the bottom of the augers until a grout column is established within the augers to near the ground surface and the top of the drill string. Then methodically withdraw the augers while adding grout to maintain the grout column within the augers to near the ground surface until all of the augers have been removed.

The following re-drilling procedures should be followed for decommissioning:

- Obtain approval from ADEC for the well decommissioning methodology.
- Remove the well head re-drill the well attempting to keep the well casing inside the auger if possible and drill to the bottom of casing.
- Place grout sealant by hose or tremie tube to the bottom of the augers until a grout column is established within the augers to near the ground surface and the top of the drill string
- Withdraw the augers and keep the grout column within the augers to near the ground surface. Backfill the borehole to within 5-feet of ground surface.
- Calculate and record the required volume of grout based on the depth and diameter of the borehole.
- Record the volume actually used. Explain any discrepancy between the calculated and actual volume.

- Backfill the top of the borehole with clean soil and match the surrounding surface completion (such as asphalt, concrete, soil, or other).
- Submit documentation of well abandonment to ADEC.

5.3 Temporary Micro Well Decommissioning Procedures

The ADEC MWG does not list procedures for abandoning these wells, which are typically 0.75- to 1.0-inch-diameter wells installed 20 feet or less. As a result, the following procedures are proposed:

- Obtain approval from ADEC for the well decommissioning methodology.
- Pull the entire casing and well screen from the borehole using a drill rig or hydraulic jacks.
- Backfill the borehole to within 5 feet of ground surface adding bentonite pellets via a tremie pipe or similar to prevent bridging.
- Regularly hydrate the bentonite pellets during emplacement once above the water table.
- Calculate and record the required volume of backfill and bentonite based on the depth and diameter of the well annulus.
- Record the volume actually used. Explain any discrepancy between the calculated and actual volume.
- Fill remainder of borehole with clean fill, and return surface conditions to natural grade.
- Submit documentation of well abandonment to ADEC.

5.4 Test Boring Abandonment Procedures

Test borings that are no longer of use must be properly abandoned and permanently sealed. Test borings are typically less than 30 feet deep and are defined as being for the immediate determination of subsurface stratigraphy, hydrologic conditions, or contamination conditions in the unsaturated or saturated zone. Test borings should be sealed properly and abandoned as soon as possible after the boring has been completed. Test borings will typically be 2-inch diameter and advanced with a vibratory drill rig which does not produce cuttings at the surface. Abandonment of test borings will be by filling the open hole with bentonite pellets. Water should be poured down the hole on a regular basis to hydrated the chips. The test boring should be sealed to 5 feet below the ground surface and the ground surface should be restored to match the pre-drilling conditions.

If the test boring is greater than 2 inches in diameter, these revised procedures cannot be followed, and alternative procedures will be proposed. All information regarding well decommissioning must be recorded and documented in the field log book.

5.5 Investigation-Derived Waste

Documentation of investigation derived waste (IDW) should be conducted throughout well decommissioning activities. Establish plans for disposal of IDW before beginning field activities (see Appendix B, Project-Specific Waste Management Plan). Potentially contaminated IDW may include soil or rock material, pumps, samplers, well casings and screens.

5.6 Reporting

Report well abandonment to ADEC and include the following information:

1. A copy of the original boring log
2. The well construction log
3. An abandonment log
4. A site map showing the location of the abandoned monitoring well
5. Disposal documentation for wastes generated during the abandonment process

6.0 Records

All decommissioning procedures will be documented at a minimum per field notes taken according to technical procedures for Field Log books.

7.0 References

Alaska Department of Environmental Conservation (ADEC). February 2009. *Monitoring Well Guidance.*

American Society of Testing Materials (ASTM) D5299-99 (Reapproved 2005). *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.*

8.0 Definitions

Annular seal: an impermeable material, such as cement grout or bentonite, placed in the annular space between the borehole wall and the permanent casing to prevent downhole movement of surface water or the vertical mixing of water-bearing zones.

Annulus: the space between the borehole wall and the well casing.

Bentonite: a hydrous aluminum silicate which increases volume (swells) upon contact with water and provides a tight seal between the well casing and the borehole. Available in powder, granular, or pellet form.

Bridging: the development of gaps or obstructions in either grout or filter pack materials during emplacement. Bridging of particles in a naturally developed or artificially gravel-packed well can occur during development.

Cement grout: a fluid mixture of cement and water, possibly with bentonite added. Consistency of the mixture is such that it can be forced through a pipe and emplaced in the annular space between the borehole and the well casing to form an impermeable seal.

Decommissioning: the complete sealing of a well or borehole with grout or other impermeable materials when the well or borehole is determined to no longer be of use. Decommissioning eliminates the potential for improper access to the subsurface.

Filter pack: a chemically inert, uniform, well-rounded material (sand, gravel, or glass beads) that is placed in the annulus of the well between the well screen and the surrounding formation to (1) prevent formation material from entering the well, (2) ensure continuous fluid flow from the formation into the well, and (3) stabilize the adjacent formation.

Monitoring well: a well that is installed for the purpose of extracting representative groundwater samples for physical, chemical, or biological analyses and can be utilized for groundwater head measurements.

Neat cement: a mixture of Portland cement (ASTM C-150) and water in the proportion of 5 to 6 gallons of clean water per bag of cement (94 pounds or 1 cubic foot).

Packer: a compressible cylinder of rubber and metal that is placed in or outside a well to plug or seal the well or borehole at a specific point.

Plugging: the complete filling of a borehole or well with an impermeable material which prevents flow into and through the borehole or well.

Pressure grouting: a process by which grout is confined within the borehole or casing by the use of retaining plugs or packers and by which sufficient pressure is applied to drive the grout slurry into the annular space or zone to be grouted.

Soil boring: a hole drilled or bored into the earth for the collection of soil samples for analysis.

Well casing: an impervious durable tubular product that is a permanent feature of a well and designed to (1) prevent caving in of the boring walls, (2) provide access from the ground surface to some point in the subsurface, and (3) serve as a passage for groundwater level measurement and sample collection devices.

Perforating the well: drill, puncture or otherwise put holes in the well casing to allow grout to infiltrate the filter pack and/or porous material surrounding the well.

9.0 Attachments

None

SOP-22

Field Test Kit Analyses

SOP-22: FIELD TEST KIT ANALYSES

1.0 Purpose

This standard operation procedure (SOP) outlines protocols for environmental field screening using field test kits and techniques.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in environmental field screening using field test kits and techniques at Galena Forward Operating Location (FOL), and was developed with reference to Alaska Department of Environmental Conservation (ADEC) *Draft Field Sampling Guidance* (ADEC, 2010).

This SOP focuses on the most commonly used environmental investigation field test kits and techniques anticipated for use at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-24, Direct Push Groundwater Sampling*

3.0 General

A valuable part of any environmental investigation is the collection of reliable, quality field data in an efficient and timely manner. When performed correctly, field test kits can provide quality investigation information rapidly in the field. Test kits are self-contained analytical kits that generally use a chemical reaction that produces color to identify contaminants, both qualitatively and quantitatively (U.S. Environmental Protection Agency [EPA], 2010). Field test kits have a wide variety of field applications and can be used to characterize many contaminant groups, including the following:

- Petroleum hydrocarbons (for example, total petroleum hydrocarbons [TPH], volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], polynuclear aromatic hydrocarbons [PAHs], diesel-range/residual-range organics [DRO/RRO], and gasoline-range organics [GRO])
- Chlorinated volatile organic compounds (CVOCs)
- Polychlorinated biphenyls (PCBs)
- Pesticides/herbicides
- Explosives
- Metals, in soil, sediment, water, air, and soil gas

Field test kit methods can be useful for estimating the nature and extent of contamination, identifying contaminate source areas and release points, and segregating excavated soils. Depending on the field test kit method employed, test kit results maybe either qualitative, quantitative, or both. Numerous different field test kits are used for environmental investigations with applications ranging from simple paper test strips used to assay various water quality parameters to sophisticated colorimetric reactions measured by ultraviolet (UV) fluorescence that give quantitative results for definitive site characterization.

There are numerous advantages to using test kits in the field, including speed, portability, ease of use, low cost per sample, and the range of contaminants that can be analyzed (EPA, 2010). Although some field test kits are based on EPA analytical methods and produce equivalent results, many kits are simple screening methods that require consideration of potentially significant analytical interferences, imprecision, and bias when interpreting test kit responses and results. For these reasons, the choice and use of field test kits used should be evaluate early during project planning to appropriately support project data use objectives. In addition, it is recommended that the correlation between on-site field test kit results and site-specific laboratory analytical results be evaluated for reliability and representativeness of the field test kit methods and techniques used (ADEC, 2009).

Many of the well-known field test kits that have been commercially available for environmental investigation of soil, groundwater, and surface water for many years often employ "microtitrations", colorimetric, turbidimetric, or "wet chemistry" methods (EPA, 2010). Colorimetric test kits for air and soil gas monitoring are also well known in the context of environmental assessment and industrial hygiene. Draeger Tubes™, for example, may be used to monitor the concentrations of contaminants in ambient air to protect site workers and aid in site characterization of soil gas and groundwater.

There are several types of field test kits available, depending on the contaminant and the matrix being investigated, and numerous suppliers that manufacture and sell field test kits. This SOP focuses on some of the anticipated field test kits and methods most likely to be used at the Galena FOL. Table 1 summarizes the most anticipated field test kits for use at Galena FOL.

Table 1. Anticipated Field Test Kits for use at Galena FOL

Section	Field Test Kit	Applicable Matrix	Target Contaminate Groups
5.1	Draeger® and GasTec® Tubes	Soil gas, air	VOCs, SVOCs, TPH, Dioxin/furans, metals
5.2	AQR Color-Tec® system	Soil, water	CVOCs
5.3	AQR Soil Gas® system	Soil gas	CVOCs
5.4	Dexsil PetroFLAG®	Soil	TPH
5.5	Dexil Clor-N-Soil®	Soil	PCBs
5.6	Dexsil L2000DX Analyzer	Soil, water, dielectric fluids, Surface Wipes	PCBs, CVOCs
5.7	Hanby Test Kits	Soil, water	Petroleum aromatic hydrocarbons, TPH, PCBs
5.8	SiteLab® UVF-3100 Analyzer	Soil, sediment, water	TPH, DRO, GRO, VOCs, PAHs, SVOCs,

Table 1. Anticipated Field Test Kits for use at Galena FOL

Section	Field Test Kit	Applicable Matrix	Target Contaminate Groups
			Asphaltenes
5.9	Hach Test Kits	Soil, water	PCB, TPH, Organics, Metals
5.10	Orion Combination pH Electrode, GX Series, Flat Surface, Thermo Electron probe	Soil	Soil Moisture, pH
5.11	Aquaterr pH-300 Digital Soil Moisture, Temperature, and pH Meter	Soil	Soil Moisture, pH, and temperature
5.12	SDIX RaPID Assay® Test Kits	Soil, water	TPH, BTEX, PCBS, PAHs, Pesticides, and PCP
5.13	SDIX EnviroGard® Test Kits	Soil, water	Specific pesticides and herbicides
5.14	SDIX EnSys® Test Kits	Soil, surface wipes	PCBs, PAHs, TNT, and RDX
5.15	SDIX PCB Rapid Strip Test Kit	Soil	PCBs

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and assuring that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if any complications arise with following these critical sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordination and scheduling of daily field activities. In addition, the FM is responsible for assuring compliance with this SOP and that all field staff engaged in this activity are trained in this SOP.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the Project-Specific Health and Safety Plan (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.4 Field Team Leader

The Field Team Leader (FTL) is responsible for maintaining compliance with field test kit methods and requirements; particularly the procedures to be used. The FTL, or their designee, should know the requirement of the field test kits being used and should maintain adequate documentation of the sampling and field testing activities conducted. The FTL should schedule accordingly to account for the requirements specific to the test kit being used. The FTL will have responsibility for correctly completing field tests and coordinating with the FDM to successfully manage field test kit results data.

5.0 Procedures

Field test kits have been designed for field analysis of soil, sediment, water, sediment, dielectric fluids (for example, transformer oil), and surface wipe samples. Some field test kits provide solvents that are used to extract analytes from soils and other solid media into a liquid medium for analysis. Most field test kits on the market contain several basic pieces of equipment, including sample containers, reagents, and calibration standards.

Most of the field test kits discussed in this SOP are dependent on colorimetric or turbidimetric reactions. Color or turbidity is developed in response to the presence of a contaminant, and the resulting color is matched to a color chart supplied with the test kit for semi-quantitative analysis. Alternatively, the color or turbidity intensity is measured using a spectrophotometer or proprietary analytical detectors that detects and analyzes the color change electronically in order to produce more precise quantitative results (EPA, 2010). Exceptions include the SiteLab® Analyzer, which uses the innate property of aromatic compounds to fluoresce in the presence of UV light and the Dexsil LD2000DX Analyzer that uses an ion selective electrode (ISE) to measure the analyte of interest (EPA, 2010). The complexity of the kit will depend on the type of test, the sample medium, and the level of data quality required.

For detailed instruction on how to setup and conduct the field test kits discussed below, see the appropriate manufacturer's test kit procedure provided in the Section 9.0 Attachments.

5.1 Draeger and GASTEC Indicator Tubes

Indicator tubes, such as Draeger® and GASTEC® tubes, are one of the most classic measurement techniques for air or gas analysis (Draeger, 2010b). Indicator tubes are thin, hermetically sealed glass tubes containing a silica gel or aluminamatrix that contains reagents sensitive to a specific target analyte or contaminant of interest (GASTEC, 2010). When a gas or vapor containing the target analyte is drawn through the tube, a colorimetric change will occur in the tube's reagent layer. Each indicator tube is printed with calibration scales on the exterior so that the measured concentrations can be directly read. The data obtained from indicator tubes are considered to be only qualitative or semi-quantitative. Indicator tubes are typically used with either a manual vacuum pump or a motor driven sample pump (Draeger, 2010a; GASTEC, 2010). Either way, the gas or vapor sample is aspirated into the indicator tube under vacuum. Draeger and GasTec indicator tubes can be easily and quickly used to qualitatively detect over 600 specific target gas analytes (Draeger, 2010b; GASTEC, 2010). Figure 1 shows an indicator tube before and after use. Further information and instructions on the use of Draeger® and GASTEC® tubes and hand pumps are available in Attachments 1 and 2.

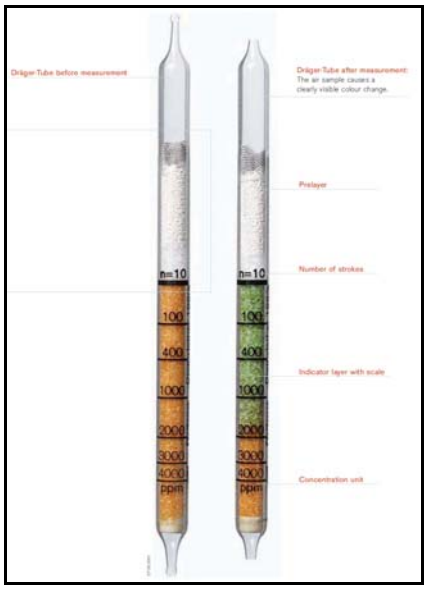

Figure 1. Example indicator tube before and after use (Draeger, 2010).

5.2 AQR Color-Tec System

The AQR Color-Tec® System is a field-based analytical method that detects total CVOCs in water and soil samples to below 3 micrograms per liter (µg/L) or micrograms per kilogram (µg/k), respectively (AQR, 2010). The following procedures are used to analyze samples using AQR Color-Tec® System:

- Collect an approximately 30-milliliter (mL) water or 30-gram soil sample within each of two 40 mL volatile organic analysis (VOA) vials (AQR Color-Tec, NDa).
- For soil samples, add deionized water to the VOA vial until it's approximately 70 percent full.
- Purge volatile compounds from the sample using ambient air and aspirate through the indicator tube. A colorimetric response occurs when chlorinated compounds are present.

Sample concentrations are obtained in the field by comparing the colorimetric tube reading to a conversion provided with the field test kit. Figure 2 illustrates the AQR Color-Tec® System. Further information and instructions for using the AQR Color-Tec® System are available in Attachment 3.

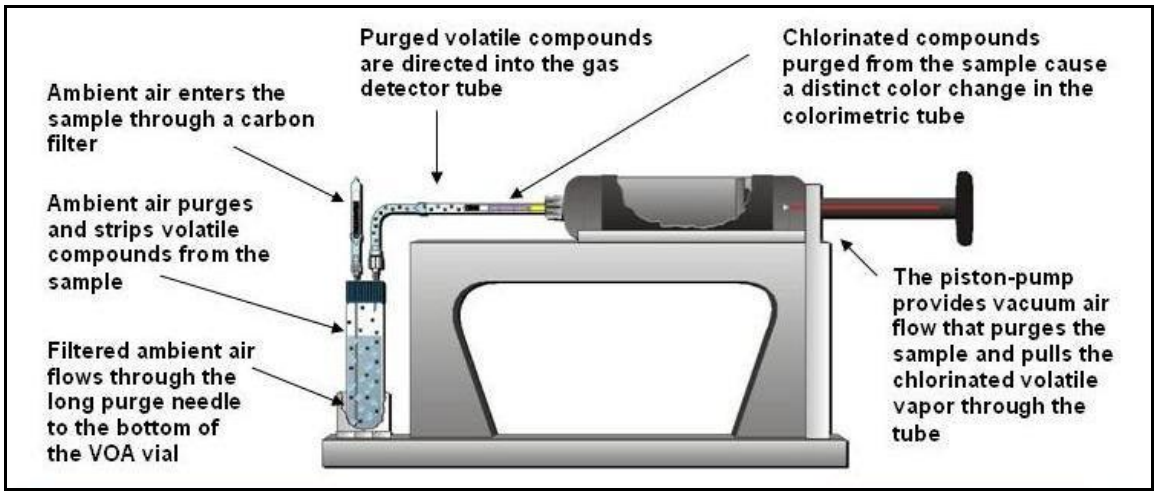

Figure 2. AQR Color-Tec® System (AQR, 2010).

5.3 AQR Soil Gas System

The AQR Soil Gas® system is an active soil gas sampling method used to detect total CVOCs in soil gas samples (AQR Color-Tec, 2010). The AQR Soil Gas method uses a soil gas sampling probe combined with a GASTEC® colorimetric indicator tube to quickly detect concentrations of total CVOCs in shallow soil gas down to 0.01 ppmV (~680 µg/m^3).

The soil gas sampling probe is comprised of a 36-inch-long, ¼-inch-diameter, stainless-steel tube fitted with a free-sliding, stainless-steel inner rod that extends 4 inches below the sampling tube. Soil gas sampling is accomplished as follows:

- Push or drive the probe into the shallow subsurface to the desired sampling depth.
- Purge the sample probe before sampling by removing the inner rod from the outer tube and attaching a disposable valve assembly to the steel sampling tube. Use a disposable syringe to purge a small volume of soil gas from the sampling depth.
- Once purging is complete, collect and analyze the soil gas sample in a single step by attaching a indicator tube to the valve assembly and drawing gas through the tube using a GASTEC® hand pump.

The resulting soil gas concentration then produces a distinct color change when exposed to CVOCs. In addition to using the AQR soil gas sample probe, the AQR Soil Gas® system is also compatible with commercial soil gas sample collection tools such as AMS® Vapor Probes and the Geoprobe® PRT soil gas sampling system (AQR Color-Tec, 2010). Figure 3 illustrates the AQR Soil Gas® System. Further information and instructions for using the AQR Soil Gas® system are available in Attachment 4.

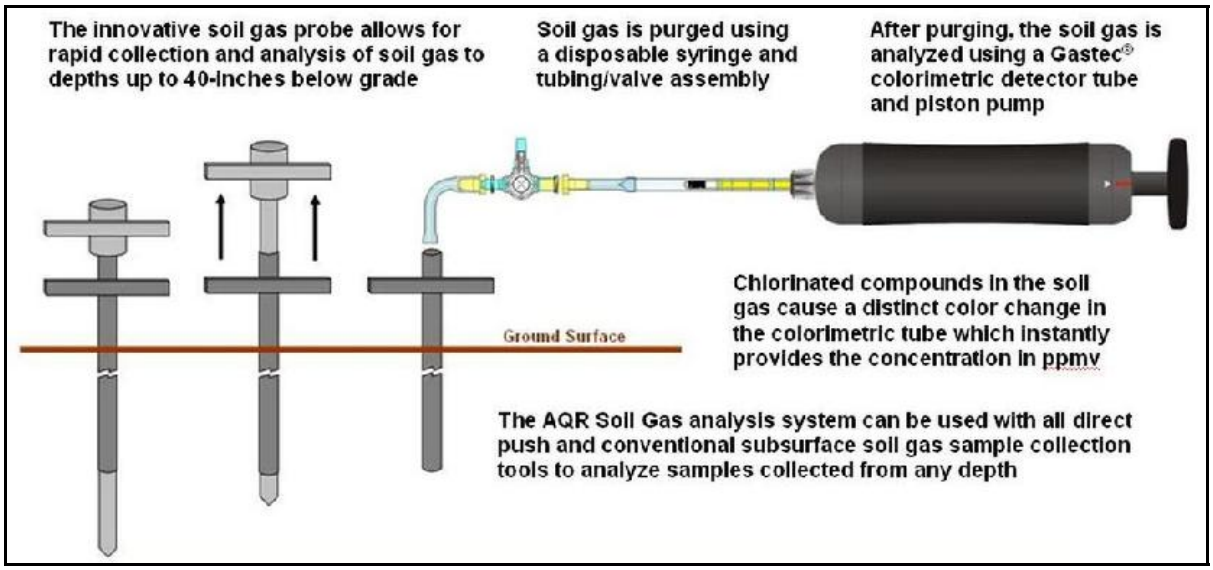

Figure 3. AQR Soil Gas® System (AQR, 2010).

5.4 Dexsil PetroFLAG

The PetroFlag™ hydrocarbon analysis system is a broad spectrum field test kit suitable for TPH contamination regardless of the source or state of degradation (Dexsil Corporation, 2010a). PetroFlag™ field test kits are manufactured by Dexsil and use a proprietary turbidimetric reaction to determine the TPH concentration of solvent extracted samples (EPA, 2010). PetroFlag™ field test kits do not distinguish between aromatic and aliphatic hydrocarbons, but quantifies all fuels, oils, and greases as TPH from 15 to 2000 ppm (Dexsil Corporation, 2010). PetroFlag™ field test kits are most sensitive to heavier hydrocarbons such as oils and greases, and less sensitive to the lighter more volatile hydrocarbon fuels (Dexsil Corporation, 2010a). Analysis of a soil sample is performed using three simple steps: extraction, filtration, and analysis. The PetroFLAG™ analysis is performed as follows (EPA, 2010):

- Place a 10 gram soil sample in a test tube.
- Add extraction solvent to the tube.
- Shake the tube intermittently for four minutes.
- Filter the extract into a vial that contains development solution
- Allow the solution to react for 10 minutes.

The filtration step is important because the PetroFlag ™ analyzer measures the turbidity or "optical density" of the final solution. Approximately 25 samples can be analyzed per hour. The vial of developed solution is placed in the meter, and the instrument produces a quantitative reading that reveals the concentration of hydrocarbons in the soil sample. The specially designed PetroFLAG analyzer allows the user to select, in the field, the response factor that is appropriate for the suspected contaminant at each site. Using the selected response factor, the analyzer compensates for the relative response of each analyte and displays the correct concentration in parts per million (ppm).

Figure 4 illustrates the Dexsil PetroFlag™ field test kit system. Further information and instructions for using Dexsil PetroFlag™ field test kits are available in Attachment 5.

Figure 4. PetroFlag™ field test kits (Dexsil Corporation, 2010a).

5.5 Dexil Clor-N-Soil

The Dexsil Clor-N-Soil field kits measure the total chlorine in PCB molecules by using an indicator solution of mercuric nitrate and diphenylcarbazone (EPA, 2010). Alone, the two compounds form a complex to create a vivid purple color; however, in the presence of chlorine, the color becomes yellow. Samples are analyzed as follows:

- Add several grams of soil into a vile and extracting the PCBs from the soil using an organic solvent.
- Treat the extract with metallic sodium to strip chlorine from the biphenyl compound as chloride ions. Any free chloride ions bind up the mercuric ions thereby disrupting the colorimetric complex.
- Add an acidic buffer to the extract to quench any unreacted sodium and to transfer the chloride ions into the aqueous phase.
- Measure chloride ions colorimetrically by an indicator solution that creates a purple or yellow color depending on the presence of chloride ions. The purple color indicates the absence of chloride, and therefore the absence of PCBs in the sample above the detection limit of 50 ppm. A yellow or clear color indicates the presence of chloride, and therefore the presence of PCBs in the sample at concentrations above 50 ppm.

The test takes approximately 10-15 minutes. Figure 5 illustrates the Dexsil Clor-N-Soil field test kit system. Further information and instructions for using Dexsil Clor-N-Soil field test kits are available in Attachment 6.

Figure 5. Clor-N-Soil® field test kits (Dexsil Corporation, 2010b).

5.6 Dexsil L2000DX Analyzer

The Dexsil L2000DX Analyzer relies on the same basic chemistry as the Clor-N-Soil field test kits; however, instead of a colorimetric reaction, the analyzer uses an ion specific electrode to quantify the contamination in the sample (Dexsil Corporation, 2010c). Sample analysis is available for dielectric fluids/oils, soils, water and surface wipes. However, if the species of chlorinated organics is known at a site (for example, PCBs), the analyzer can be programmed to convert and report quantitative results of the contaminant of interest (EPA, 2010). Samples for analysis using the Dexsil L2000DX analyzer are prepared in a similar manner to those intended for Clor-N-Soil analysis, as follows:

- Extract a 10-gram soil sample, using a solvent.
- Dry the extract and clean it, using a syringe mounted drying column, then react with metallic sodium and a catalyst.
- Extract the inorganic chloride generated by this reaction into an aqueous buffer solution, filter it, and then quantify it using the ion selective electrode.

The usable measurement range for oils and soils is 2 to 2,000 ppm, 20 parts per billion (ppb) to 2,000 ppm for water and 2 to 2,000 ug/100 square centimeters (cm^2) for wipe samples (Dexsil Corporation, 2010c). Analysis results can either be uploading to a computer or sent directly to the on-board thermal printer. Figure 6 illustrates the Dexsil L2000DX Analyzer system. Further information and instructions for using Dexsil L2000DX Analyzer system are available in Attachment 7.

Figure 6. Dexsil L2000DX Analyzer (Dexsil Corporation, 2010c).

5.7 Hanby Test Kits

Hanby Field Test Kits specifically responds to aromatic hydrocarbon compounds found in fuels, PCB, oils, solvents, crude oils and most other petroleum products. The test is based on the Friedel-Crafts reaction, in which aromatic substitution produces molecules with intense coloring. Comparisons of the intensity of color produced can be made either visually with a color chart or photometrical with a reflective photometer (EPA, 2010). Test kits are available for soil and water analysis. A Hanby Field Test Kit is used analyze a soil sample as follows:

- Weigh 5 grams of soil.
- Place it into a beaker.
- Add an ampoule of solvent to the soil.
- Stir the sample for approximately two minutes to extract the contaminant.
- Pour the extract from the beaker into a marked test tube.
- Add a catalyst is added to the test tube.
- Shake the mixture for two minutes while the color change develops.

The developed color of the precipitate is compared with a calibration photograph to obtain quantitative results (EPA, 2010). The water test is performed in the same manner, with the exception that a 500-ml water sample is extracted with solvent in a 500-ml separatory funnel, which is included in the water test kit. The detection level for the soil kit ranges from 1 ppm to 1,000 ppm and the water kit ranges from 0.01 ppm to 100 ppm. Figures 7 illustrates the Hanby Soil Field Test Kit. Further instructions for using the Hanby Field Test Kits are available in Attachment 8.

Figure 7. Hanby Soil Field Test Kit (Hanby, 2010).

5.8 SiteLab UVF-3100 Analyzer

The SiteLab UVF-3100 Analyzer uses ultraviolet fluorescence technology (UVF) to detect concentrations of petroleum and PAHs from gasoline, jet fuel, diesel fuel, heating oils, waste oils, coal tars, coal ash, creosote, crude oils, and many other petroleum products within soil, water, and sediment samples (EPA, 2010; Sitelab Corporation, 2010). This system employs the characteristic property of aromatic compounds to fluoresce in the presence of UV light. Each group of compounds specific to one of the TPH categories (for example, VOCs [C_6-C_{10}], SVOCs [C_{10}-C_{40}], and Asphaltenes [>C_{40}]) will excite under exposure to UV light, and in return emit UV energy at a specific wavelength that is measured by and quantified within the UV photometer (fluorometer) (Sitelab Corporation, 2010).

Soil analysis using the SiteLab UVF-3100 Analyzer is performed as follows (EPA, 2010):

- Weigh a 5-gram sample into a jar and then extract it with 10 ml of methanol.
- Filter the methanol extract using a syringe mounted filter, dilute, and then pour into a cuvette for fluorometer analysis.

Figures 8 illustrates the SiteLab UVF-3100 Analyzer. Further instructions for using the SiteLab UVF-3100 Analyzer are available in Attachment 9.

Figure 8. SiteLab UVF-3100 Analyzer (Sitelab Corporation, 2010).

5.9 Hach Test Kits

Hach Pocket Colorimeter II Test Kits are used for PCBs, TPH, alachlor, atrazine, and many metals including aluminum, hexavalent chromium, copper, iron, lead, managanese, nickel, cobalt, and zinc. Each Hach Pocket Colorimeter II Test Kit comes with a Pocket Colorimeter II Filter Photometer and a reagent set. The Hach pocket colorimeter II test kit can analyze TPH in soil and water, PCBs in soil, and alachlor and atrazine in water, using immunoassay methods that use an immunoassay reagent set. To analyze TPH or PCBs in soil, the soil contaminates are extracted from the sample before analysis. Water samples or soil extracts, calibrators, and reagents are added to cuvettes that are coated with antibodies specific for TPH. Color develops and is then measured with the Hach Pocket Colorimeter II Filter Photometer. The test requires about 20 to 30 minutes for complete analysis. As many as 10 cuvettes can be run simultaneously. The contaminate concentration in a sample is determined by comparing the developed color intensity to that of a TPH calibrator. The TPH concentration is inversely proportional to the color development: the lighter the color, the higher the contaminate concentration. The Hach Pocket Colorimeter II Filter Photometer provides a reading in terms of absorbance that allows comparison of the sample to the calibrators. This method provides semi-quantitative screening based on thresholds for contaminate of interest. Figures 9 and 10 illustrate the Hach Pocket Colorimeter II Test Kit and Pocket Colorimeter II Filter Photometer.

Further instructions for using the Hach Pocket Colorimeter II Test Kits are available in Attachment 10.

Figure 9. Hach Pocket Colorimeter II Test Kit (Hach Company, 2010).

Figure 10. Pocket Colorimeter II Filter Photometer (Hach Company, 2010).

5.10 Orion Combination pH Electrode, GX Series, Flat Surface, Thermo Electron probe

The Orion pH probe is designed for pH measurement in soft, moist surfaces (solid and semi-solid) such as agar gel plates, meats, bread dough, and similar samples. Appropriate for measuring small samples in micro-sample dishes (USA Bluebook, 2010).

- Dimensions: 12dia.x120Lmm.
- Cap diameter: 16mm. Lead length: 1m (BNC connector only).
- Electrode storage solution: Orion 910001 (the electrode must be placed in the storage solution at all times when the probe is not in use)

5.10.1 Instructions for Use

Two buffers are recommended for precise measurement of pH: the first, near the electrode isopotential point (pH 7), and the second near the expected sample pH (e.g., pH 4 or 10).

<u>Electrode Preparation:</u>
1. The electrode tip is covered by a cap which protects the electrode and keeps it from drying out. Pull the cap off and save for storage.
2. If bubbles are seen in the bulb area of the electrode, shake the electrode downward (like a fever Orion meter). This action will help eliminate bubbles that may have been generated during shipment.
3. Connect electrode to meter.

<u>Single-Buffer Calibration:</u>
This procedure is for routine measurements. Electrode slope should be checked periodically with a two-buffer calibration.

1. Choose a buffer which is near the expected sample pH.

2. Buffer should be at room temperature. If samples are at varying temperatures, temperature compensation is recommended.
3. Set the slope to 100% or to the percent slope determined in a two-buffer calibration. Set the temperature to the temperature of the buffer.
4. Rinse electrode with distilled water and shake off excess water.
5. Place the electrode in the buffer. Wait for a stable display. Set the meter to the pH value of the buffer at its measured temperature. (A table of pH values at various temperatures is supplied with the buffer.)
6. Rinse electrode with distilled water and shake off excess water.
7. Place the electrode in the sample. When display is stable, record pH.

Two-Buffer Calibration:

This procedure is recommended for precise measurement.

1. Choose two buffers which bracket the expected sample pH. The first should be pH 7 and the second near the expected sample pH (e.g., pH 4 or 10).
2. Ensure that buffers are at room temperature. If samples are at varying temperatures, temperature compensation is recommended.
3. Rinse electrode with distilled water and shake off excess water.
4. Place electrode in the pH 7 buffer. Wait for a stable display. Set the meter to the pH value of the buffer at its measured temperature. (A table of pH values at various temperatures is supplied with the buffer.)
5. Rinse electrode with distilled water and shake off excess water.
6. Place electrode in the second buffer. When display is stable, set meter to the actual pH value of the buffer as described in meter instruction manual.
7. Rinse electrode with distilled water and shake off excess water.
8. Place electrode in the sample. When display is stable, record pH.

Measuring Hints:

- Rinse electrode with distilled water between measurements.
- Shake off excess drops of solution to prevent solution carry over of one solution to another.
- Keep buffers and samples at approximately the same temperature. If samples are at different temperatures, perform temperature compensation, as described in the meter instruction manual.
- Check electrode operation periodically with a two-buffer standardization. If readings in the buffer drift or it slope is below 92%, follow Cleaning Procedure.
- Between measurements (up to one hour) leave the electrode in the open-air laboratory environment, not in distilled water.

Electrode Storage:

- Between Measurements (up to one hour), leave the electrode in the open-air laboratory environment, not in distilled water.
- For short-term storage (up to one week), soak electrode tip in Orion pH Electrode Storage Solution, Orion 910001. If unavailable, 200 mL pH 7 buffer with 1 g KCl

added may be used. Do not allow the solution to evaporate and crystallize on the electrode. Do not store in distilled water, as this will shorten electrode life.
- For long-term storage (over one week), cover the electrode tip with the protective cap used for shipment.

Electrode Maintenance:

- To Clean the probe, soak electrode in 0.1M HCl or 0.1M HNO3 for 15 minutes, followed by soaking in Orion pH Electrode Storage Solution for 30 minutes.
- To remove deposits:
  Protein — Digest with 1% pepsin in 0.1M HCl. *
  Inorganic — Rinse with 0.1M tetrasodium EDTA solution. *
  Grease and Oil — Rinse with mild detergent of methanol solution*.
  * After any of these cleaning procedures, soak electrode in Orion pH Electrode Storage Solution for 30 minutes.

5.11 Aquaterr pH-300 Digital Soil Moisture, Temperature, and pH Meter

Each meter is highly accurate, displays soil moisture, temperature, and pH results within seconds, may be used in a variety of soils, and is unaffected by temperature, pH, dissolved salts, or metallic ions. Includes standard pH solutions for field calibration (Forestry Suppliers, Inc, 2010).

- Soil Moisture - Range: 0 to 100%. Accuracy: ±2%. Response time: 3 sec.
- Soil Temperature - Range: 32°F to 150°F. Accuracy: ±1.5°F. Response time: 60 sec.
- Soil pH - Range: 4 to 10 pH. Accuracy: ± 0.1 pH. Response time: 5 sec.

5.11.1 Instructions for Use

Insert probe at least six inches into reasonably soft, moist area and press appropriate test button. Results appear quickly. Rapidly perform multiple tests at various depths and locations. Just wipe off probe after each test. Features 30" stainless steel probe, clay, loam and sand scales printed on meter's face panel, and soft foam handles. Informative user's guide and 9V battery included.

- Operating temperature: 40°F to 150°F.
- Power: 9V battery.
- Battery life (approx.): 3 months.
- Probe length: 30".
- Overall length: 36".
- Weight (approx.): 5 lbs.

5.10 SDIX RaPID Assay Test Kits

TSDIX RaPID Assay Test Kits apply the principles of enzyme-linked immunosorbent assay (ELISA) to determine the presense of PCBs, TPH, BTEX, PAHs, pesticides, pentachlorophenol (PCP), and related compounds in soil, water, and surface wipes samples for PCBs (SDIX, 2010). The RaPID Assay PCB Test Kit can be used as a quantitative, semi-quantitative, or qualitative process for the analysis of contaminates (SDIX, 2010). The sample to be tested is added, along with an enzyme conjugate, to a disposable test tube, followed by paramagnetic particles with antibodies specific to contaminant of interest. Both the contaminant (which may be in the sample) and the enzyme labeled contaminant (the enzyme conjugate) compete for antibody binding sites on the magnetic particles. At the end

of an incubation period, a magnetic field is applied to hold the paramagnetic particles (with the contaminant and labeled contaminant analog bound to the antibodies on the particles, in proportion to their original concentration) in the tube and allow the unbound reagents to be decanted. After decanting, the particles are washed with Washing Solution. The presence of the contaminant is detected by adding the enzyme substrate (hydrogen peroxide) and the chromogen (3,3',5,5' – tetramethylbenzidine). The enzyme labeled contaminant analog bound to the contaminant antibody catalyzes the conversion of the substrate/chromogen mixture to a colored product. After an incubation period, the reaction is stopped and stabilized by the addition of acid. Since the labeled contaminant (conjugate) was in competition with the unlabeled contaminant (sample) for the antibody sites, the color developed is inversely proportional to the concentration of the contaminant in the sample. Thus a darker color indicates a lower concentration and a lighter color indicates a higher concentration. The determination of the contaminant concentration in an unknown sample is interpreted relative to the standard curve generated from kit standards after reading with RPA-I Analyzer or equivalent spectrophotometer (SDIX, 2010). Figure 11 illustrates the SDIX RaPID Assay Test Kit and RPA-I Analyzer. Further instructions for using various SDIX RaPID Assay Test Kits for PCBs, TPH, BTEX, PAHs, pesticides, pentachlorophenol (PCP) are available in Attachment 11.

Figure 11. SDIX RaPID Assay Test Kit and RPA-I Analyzer (SDIX, 2010).

5.11 SDIX EnviroGard Test Kits

SDIX EnviroGard Test Kits use similar methodology as RaPID Assay and EnSys test kits. EnviroGard Test Kits use an enzyme immunoassay for the detection of specific pesticides and herbicides including DTT, Chlordane, and Triazine in soil, and triazine, chlorpyrifo, diazinon, isoproturon, and urea herbicides in water (SDIX, 2010). EnviroGard Test Kits are a qualitative, semi-quantative, and quantitative field tests depending on the specific pesticide or herbicide analyzed. The EnviroGard Test Kits are based on the use of polyclonal antibodies which bind both the specific pesticide or herbicide contaminate or pesticide/herbicide-enzyme conjugate. These antibodies are immobilized on the walls of the test tubes. When specific pesticide or herbicide is present in the sample, it competes with the pesticide/herbicide-enzyme conjugate for a limited number of contaminant binding sites on the immobilized antibodies. Since there are the same number of antibody binding sites

on every test tube and each test tube receives the same number of pesticide/herbicide - enzyme conjugate molecules, a sample that contains a low concentration of a specific pesticide or herbicide contaminant enables the antibody to bind many pesticide/herbicide-enzyme conjugate molecules. Therefore, a low concentration of a contaminant produces a dark blue sample. Conversely, a high concentration of contaminant will allow fewer pesticide/herbicide-enzyme conjugate molecules to be bound by the antibodies, resulting in a lighter blue sample. The determination of the pesticide or herbicide contaminant level in an unknown sample is interpreted relative to the assay calibrator levels using visual comparison or by reading with RPA-I Analyzer or equivalent spectrophotometer (SDIX, 2010). Further instructions for using various SDIX EnviroGard Test Kits for specific pesticides and herbicides are available in Attachment 12.

5.12 SDIX EnSys Test Kits

SDIX EnSys test kits use similar methodology as EnviroGard and RaPID Assay test kits. The EnSys Test Kits are a qualitative or semi-quantitative enzyme immunoassay (EIA) for the analysis of polyaromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and explosives (for example, TNT and RDX) at user specified detection levels in soil (SDIX, 2010). EnSys test Test Kits can also be used for PCB surface wipe samples as well. EnSys Test Kits are based on the use of antibodies that bind either contaminant or contaminant-enzyme conjugate. When the contaminant is present in the sample, it competes with the contaminant-enzyme conjugate for a limited number of binding sites on the immobilized antibodies. Samples are analyzed by adding a contaminated sample to a test tube containing a contaminant-enzyme conjugate. The contaminate-enzyme conjugate competes with the contaminant for the antibody binding sites. The sample is then incubated and the unbound molecules are washed away. Then a chromogenic substrate is then added to the test tube, and in the presence of bound contaminate-enzyme conjugate, the clear substrate is converted to a blue color. A low contaminant concentration produces a dark blue solution, while a high contaminant concentration produces a light blue solution. The contaminant level is then interpreted relative to the kit standard using visual comparison or by reading with the RPA-I Analyzer or equivalent spectrophotometer (SDIX, 2010). Further instructions for using various SDIX EnSys Test Kits for PAHs, PCBs, and explosives are available in Attachment 13.

5.13 SDIX PCB Rapid Strip Test

SDIX PCB Rapid Strip test kits use similar enzyme immunoassay methodology as RaPID Assay, EnviroGard, and EnSys test kits except that immunoassay chromatography occurs within a PCB Rapid Strip (SDIX, 2010). Rapid Strip test kits provide a qualitative and semi-quantitative measurement of PCBs in soil. Samples are analyzed as follows:

- First, extract the PCBs from the sample by mixing 5 grams of soil sample with 10 mL of methanol in a test tube (SDIX, 2010). Allow the sample extract to separate from the sample.
- Draw off a small amount of methanol extract from the sample, filter, and then add to a glass vial containing gold colloid conjugate and buffer solution.
- Mix the glass sample vial and apply 75 µL of the mixture to each PCB Rapid Strip test device.
- Allow the Rapid Strip to incubate for approximately 20 minutes, then measure using the PCB Rapid Strip Test Kit Reader.

Figures 12 and 13 illustrates a SDIX PCB Rapid Strip and the Rapid Strip Test Kit Reader (SDIX, 2010). Further instructions for using SDIX PCB Rapid Strip Test Kits for PCBs is available in Attachment 14.

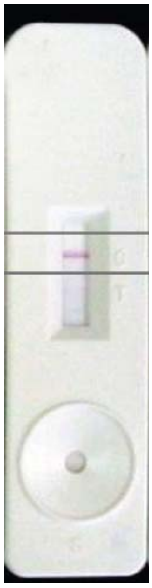

Figure 12. SDIX PCB Rapid Strip (SDIX, 2010).

Figure 13. SDIX PCB Rapid Strip Test Kit Reader (SDIX, 2010).

6.0 Records

All field test kit activities, including methods, procedures, notes, and results, should be recorded in a Field Notebook according to *SOP-01, Note Taking and Field Log Books*. Photographs should be collected to document field test kits activities. All field test kit documentation should be completed according to *SOP-01* and a copy should be retained in the project files.

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8.0 Definitions

Colorimetric: a chemical reaction where color is developed in response to the parameter of interest and compared to a color chart, or is measured using a photometer.

Enzyme Immunoassay (EIA): enzyme immunoassay, also known as enzyme-linked immunosorbent assay (ELISA) is a biochemical technique used mainly in immunology to detect the presence of an antibody or an antigen in a sample. The ELISA has been used as a diagnostic tool in medicine, plant pathology, and environmental remediation, as well as a quality control check in various industries. In simple terms, in EIA, an unknown amount of antigen is affixed to a surface, and then a specific antibody is washed over the surface so that it can bind to the antigen. This antibody is linked to an enzyme, and in the final step a

substance is added that the enzyme can convert to some detectable signal. Thus in the case of chromogenic EIA, chromogenic reporters and substrates produce some kind of observable color change to indicate the presence of the antigen or analyte.

Fluorometer: a flurometer is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. These parameters are used to identify the presence and the amount of specific molecules in a medium.

Indicator tubes: Sealed glass tubes filled with a reagent specifically sensitive to a target analyte which are designed to analyze air samples for airborne contaminants. When air containing the target analyte is drawn through the tube a colorimetric change will occur in the tube's reagent layer. The data obtained from indicator tubes are considered to be only qualitative or semi-quantitative.

Microtitrations: a chemistry test method where the titrant is added drop-wise to a small amount of sample collected in a vial containing an indicator that changes color in response to the presence of the analyte of concern.

Spectrophotometer: A spectrophotometer is a photometer (a device for measuring light intensity) that can measure intensity as a function of the color, or more specifically the wavelength, of light. Important features of spectrophotometers are spectral bandwidth and linear range of absorption measurement.

Turbidimetric: a chemical reaction where turbidity is developed in response to the parameter of interest, thereby reducing the intensity of a light beam as it passes through a solution when analyzed by a turbidimeter.

9.0 Attachments

Attachment 1: *Draeger and GASTEC Indicator Tubes*

Attachment 2*: Draeger and GASTEC Indicator Tube Pumps*

Attachment 3*: AQR Color-Tec® System Procedures Manual*

Attachment 4*:* AQR Soil Gas® *System Procedures Manual*

Attachment 5*: Dexsil PetroFLAG User's Manual*

Attachment 6*: Dexsil Clor-N-Soil Instructions*

Attachment 7*: Dexsil L2000DX Analyzer User's Manual*

Attachment 8*: Hanby Field Test Kit Instructions*

Attachment 9*: siteLAB Quick Reference Guide*

Attachment 10*: Hach Pocket Colorimeter II Field Test Kit Datasheet and Manuals*

Attachment 11*: RaPID Assay Test Kit User Guides*

Attachment 12*: EnviroGard Test Kit User Guides*

Attachment 13*: EnSys Soil Test Kit User Guides*

Attachment 14*: PCB Rapid Strip Test Kit User Guide*

SOP-23

Soil Excavation and Confirmation Sampling

SOP-23: SOIL EXCAVATION AND CONFIRMATION SAMPLING

1.0 Purpose

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used for soil excavating and confirmation sampling. This SOP serves as a supplement to the site-wide and investigation area specific work plans and field sampling plans (FSPs), and is intended to be used in conjunction with the other SOPs in this volume.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in soil excavation and confirmation soil sampling activities at Galena Forward Operating Location (FOL), and was developed per the following Alaska Department of Environmental Conservation (ADEC) regulations and guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Alaska Administrative Code* (AAC) 18 AAC 78 (ADEC, 2006)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses only on the most commonly used soil excavation and confirmation sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field LogBooks*
- *SOP-02, Site Reconnaissance, Preparation, and Restoration*
- *SOP-03, Utility Clearance for Intrusive Operations*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-06, Boring Log Completion, Soil Classification, and Logging*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sample Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-19, Sample Handling and Custody*

Should field tasks and procedures be added to a project that is not included in this SOP, they must be defined in Appendix H, Field Standard Operation Procedures and/or Appendix A, Project-specific Health and Safety Plan (HSP), before implementation. Changes to field procedures and/or equipment should be implemented and documented according to *SOP-20, Field Procedure Change Management*.

3.0 General

This SOP describes the methods generally used for soil excavation, confirmation sampling, and backfilling, as well as the commonly used tools for these techniques. All soil excavation activities should conform to state regulations and be supervised by a qualified geologist or engineer. Either the excavation contractor or CH2M HILL will obtain all permits, applications,

and other documents required by state and local authorities and the client. In addition, the following general guidelines should be thoroughly considered during planning and commencement of all excavation operations:

- Review site background information for the investigation area. This includes identifying and understanding the type(s) of contaminant(s) released, the manner of release, and the affected media.
- Select the proper excavation technology and excavating equipment. All excavation activities should conform to state regulations.
- Coordinate locations of soil excavations conducted at Air Force installations with the appropriate Restoration Program Manager (RPM) before excavation commences.
- Determine the proper excavation dimensions based on the analytical results obtained during the contaminate delineation investigation.
- Before mobilization to each excavation location, determine that the location is free of subsurface or overhead utilities according to the procedures described in *SOP-03, Utility Clearance for Intrusive Operations*.
- Take appropriate precautions during digging activities to avoid introducing contaminants into the excavation.
- Before mobilization to each soil excavation location, decontaminate the excavation equipment by steam cleaning, high-pressure hot water, or similar methods according to the procedures described in *SOP-14, Equipment Decontamination Procedures*. The equipment must not leak any fluids that may enter the excavation or contaminate equipment placed in the excavation.
- To the extent practical, restore the site to its pre-investigation conditions.

All information pertinent to documenting the above requirements will be recorded in the Field Notebook and the Soil Excavation Log according to *SOP-01, Note Taking and Field Log Books*.

Personnel overseeing soil excavation, confirmation sampling, and backfilling, and who perform logging and sampling activities should be a qualified geologist and have applicable field experience in overseeing excavation work. Other qualified personnel may include geotechnical and civil engineers or field technicians with an appropriate amount of applicable field experience and training under the direct supervision of another qualified person. Personnel overseeing excavation activities must be familiar with health and safety requirements in the project-specific HSP and local, state, and federal regulations governing excavations.

The following materials and equipment may be needed for the excavation and sampling of excavations:

- Field logbook
- Indelible black-ink pens
- Camera with film
- Tape measure

- Backhoe
- Shovels, picks, or scoops
- Teflon bailer and nylon cord
- Protective clothing and equipment, as required
- Appropriate field monitoring instruments
- Decontamination supplies and equipment (for example, high pressure sprayer/washer, wash/rinse tubs, brushes, liquinox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags, potable water, distilled or deionized water)
- Sample containers, coolers, ice (or ice substitute), chain-of-custody (COC) forms, as specified in the FSP
- Stainless-steel trowels, scoops, bowls, and knives
- Stainless steel slide hammer drive sampler with extension rods, stainless steel tubes, Teflon® sheeting, and plastic caps
- Drums and/or roll-off bins for containment of excavated material
- Drums or other approved water-tight containers for containment of water if excavation dewatering is required
- Plastic sheeting for covering excavated materials, if required
- Run-off/run-on control equipment and materials, if necessary (e.g., hay bales, silt fence, plastic sheeting)

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff has adequate experience and training for project-specific implementation of the health, safety, and environment (HS&E) management process and project SOPs. The PM and Health and Safety Manager (HSM) cooperatively have overall HS&E program responsibility; however, specific tasks may be delegated to other project staff. The PM retains ultimate HS&E responsibility for the project. The PM will solicit the appropriate technical expertise to verify that the project has identified the best soil excavation and confirmation sampling technology for the job given the current understanding of the site lithology.

4.2 Health and Safety Manager

The HSM is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP, coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and

certify the PPE program, and conduct project health and safety audits on the effectiveness of HS&E program.

4.3 Safety Coordinator (SC)

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

4.4 Field Team Leader

Each FTL, in conjunction with the SC, is responsible for overall compliance with this technical procedure. The FTL is responsible for following these procedures or delegating tasks to team members to perform soil excavation tasks. The FTL should verify that subcontractors are adequately complying with this technical procedure and that air monitoring is adequately conducted by or provided to subcontractors per the HSP.

4.5 Field Geologist

The Field Geologist supervises the soil excavation and collection of confirmation soil samples, recording all field data as described in this SOP, the HSP, and *SOP-01, Note Taking and Field Log Books*.

5.0 Procedures

Unless otherwise specified in the work plan or FSP, a soil excavation will consist of an open excavation through soil and/or buried material. Depending on the site-specific FSP (Appendix D) requirements, soil excavations will typically extend to predetermined boundaries based on analytical results obtained during the initial contaminate delineation investigation. The target depth of the soil excavation will be specified in the site-specific FSP (Appendix D). The field geologist may also determine the exact depth and extent of the soil excavation based on visual observation of soils, photoionization detector/flame-ionization detector (PID/FID) readings, and confirmation sampling results.

5.1 Preparation

The following activities will be performed in preparation for soil excavation and confirmation sampling:

- Before any intrusive digging, clear the excavation area for buried utilities in accordance with *SOP-03, Utility Clearance for Intrusive Operations*.
- Construct erosion and run-off/run-on control facilities, as required by the site-specific FSP (Appendix D).
- As specified in the HSP, verify that emergency procedures and evacuation routes are understood by all personnel.
- Review heavy equipment communication procedures and test communication tools including hand signals and hand radios.

- Don required PPE. Verify that required health and safety monitoring equipment is readily available and properly calibrated, as specified in the HSP.
- Photograph and sketch the site before excavation. Sketch the site in the Field Notebook.
- Move all equipment, machinery, and supplies to the excavation site. Verify that excavating equipment has free access and movement about the site.

5.2 Soil Excavation

Soil excavations will be completed using a backhoe unless otherwise specified by the site-specific FSP (Appendix D). Procedures for completing the soil excavation are as follows:

- Carefully excavate thin layers of soil (no more than two feet thick with each scoop of the backhoe) and stockpile a safe distance away from the test pit or deposit in the appropriate investigation-derived waste (IDW) container as specified by the PM or HSM and/or site-specific FSP (Appendix D).
- Watch carefully for the presence of buried materials, especially materials that may pose a safety hazard. If buried containers potentially containing liquids are encountered, cease excavation and notify the project manager and the health and safety manager.
- Obtain field instrument measurements during excavation as required by the Appendix D site-specific FSP or by the HSP. Record all information in the Field Notebook.
- Segregate excavated petroleum contaminated soils into different stockpiles based on field screening results.
- If pit walls cave in, lay back walls sufficiently to prevent caving.
- During excavation, log the lithology of the test pit walls and collect soil samples as specified in the site-specific FSP (Appendix D).
- Photograph all significant features exposed by the test pit. Record all pertinent photograph information on the test pit log and in the Field Notebook.
- Excavated material will be placed in designated IDW containers (for example, drums or roll-off bins) or on plastic sheeting as per the site-specific FSP (Appendix D).

5.3 Subcontractor Management

Subcontractor H&S responsibilities are expressly defined through the subcontract terms and conditions. Subcontractors must determine how to conduct their operations, in compliance with applicable H&S regulations and industry standards, and how to correct deficiencies. CH2M HILL employees should not direct the means and methods of subcontractor operations.

Subcontractors are responsible and accountable for implementing these requirements and any additional requirements established in their own safety procedures. Subcontractors retain control over their practices, and CH2M HILL's oversight does not relieve them of their own responsibility for effective implementation and enforcement of HS&E requirements.

The "Subcontractor Safety Procedure Criteria—Excavations" presented in the *CH2M HILL Excavation and Trenching Safety Enterprise Standard Operating Procedure HSE-307*

(Attachment 1) provides the minimum criteria for excavation safety procedures. These criteria may be used by CH2M HILL HS&E staff to review submitted subcontractor safety procedures when CH2M HILL is performing oversight of the subcontractor's operations.

The "HS&E Self-Assessment Checklist—Excavations" in Attachment 1 may be used to verify the subcontractor's compliance with established safe work practices, regulations, and industry standards.

5.4 Excavation Entry Requirements

CH2M HILL employees and subcontractor personnel who enter excavations must follow the requirements of this subsection, regardless of the company responsible for excavation safety (CH2M HILL, subcontractor, or third party contractor).

The party responsible for excavation safety should provide an excavation-competent person to inspect and oversee all excavation activities. CH2M HILL personnel entering an excavation controlled by a third party contractor or subcontractor must comply with the written procedures or permits governing the third party contractor's or subcontractor's excavation activities, and must document the name of the third party or subcontractor excavation-competent person in their daily log.

All personnel entering the excavation should verify that an excavation permit has been completed before entry.

- Do not enter excavations until the competent person has completed the daily inspection and has authorized entry.
- Upon entering excavations, be aware of and follow all requirements established by the excavation-competent person.
- Do not enter excavations where protective systems are damaged or unstable unless they are responsible for excavation safety and entry must be made to repair the systems. Entry should be made only after additional precautions have been taken to verify safe entry, as determined by the excavation-competent person.
- Do not enter excavations where objects (including machinery and stockpiled soils) or structures above the work location might become unstable and fall into the excavation.
- Do not enter excavations where there is the potential for a hazardous atmosphere until the air has been tested and found to be at safe levels, as determined by the excavation-competent person. It is important to remember that some chemical vapors are heavier than air and can accumulate at the bottom of excavations.
- Do not enter excavations that contain accumulated water unless precautions have been taken to prevent excavation cave-in, as determined by the excavation- competent person.

5.5 Excavation Safety Requirements

The requirements of the following subsections are to be followed by CH2M HILL personnel when self-performing excavation activities, and by subcontractors when performing excavation activities while CH2M HILL provides oversight of subcontractors activities.

5.5.1 General

- Conduct a daily safety briefing/meeting with all excavation personnel to discuss the work planned for the day and the HS&E requirements to be followed.
- Perform inspections of excavations that are to be entered daily, as needed throughout the work shift, and after every rainfall or other event that could increase the potential for excavation cave-in. This inspection should be conducted by the excavation-competent person and should include, at a minimum, indications of possible cave-in, water accumulation, failure of any component of protective systems, stability of spoil piles and adjacent structures, and indications of hazardous atmosphere. Subcontractors should document their daily excavation inspections using their excavation inspection checklist.
- If the excavation-competent person observes any deficiency or unsafe condition, deny excavation entry and remove all exposed personnel from the excavation until adequate precautions have been taken to verify safe entry.
- Provide walkways where personnel are required or permitted to cross over excavations. Walkways 6 feet (1.8 meters [m]) or more above lower levels should be equipped with standard guardrails.
- Install guardrails, fences, or barricades at excavations 6 feet (1.8 m) or deeper when the excavations are not readily visible because of plant growth or other visual obstructions.
- Provided guardrails, fences, barricades or covers for wells, pits, shafts and similar excavations 6 feet (1.8 m) or deeper.
- Operate earthmoving equipment in compliance with local regulatory agency requirements.

5.5.2 Before Excavating

- Obtain a Dig Permit at client facilities where it is required.
- Before excavating is permitted, identify the location of underground utilities such as electric, gas, fuel, water, cable, telephone, and sewer, either in service or abandoned, and of underground installations such as foundations, underground storage tanks, and any other structures. Contact utility companies and/or installation owners for exact locations of their equipment. When the exact location cannot be determined, use detection equipment or other acceptable means of locating the underground installations, before excavation.

5.5.3 Excavating Activities

- Remove or support all rocks, trees, and other surface encumbrances that are undermined or could become unstable as a result of excavating activities, to prevent them from falling into the excavation.
- Use support systems such as shoring, bracing, or underpinning to support exposed underground utilities that may become unstable as a result of excavating operations.
- Do not excavate below the base of a foundation, wall, sidewalk or other surface structure unless: 1) a support system is provided to verify the stability of the structure, 2) the excavation is in stable rock, or 3) a registered professional engineer has determined that the structure is far enough away that it will not be affected by the excavating activity.

- Employ warning systems such as barricades, hand and/or mechanical signals, or stop logs to remind the operator of the location of the edge, when mobile equipment is required to approach the edge of an excavation and the operator does not have a clear and direct view of that edge.

5.5.4 Excavation Entry

- Provide with a ladder, stairway, or ramp for trenches greater than 4 feet (1.2 m) deep, positioned so that the maximum lateral travel distance is no more than 25 feet (7.6 m).
- Verify that all structural ramps used solely by personnel are designed by a competent person. Structural ramps used by equipment should be designed by a competent person qualified in structural design (generally a registered professional engineer).
- Test the atmosphere of excavations greater than 4 feet (1.2 m) deep before entry when a hazardous atmosphere exists or could reasonably be expected to exist (such as excavating landfills, hazardous waste dumps; or areas containing sewer or gas utility systems, petroleum distillates, or areas where hazardous substances are stored nearby).
- When atmospheric testing indicates a hazardous atmosphere exists or could reasonably be expected to exist, keep emergency rescue equipment such as safety harnesses and lifelines and emergency self-contained breathing apparatus (SCBA) readily available at the work site.
- When atmospheric testing indicates that a hazardous atmosphere is present, use ventilation or appropriate respiratory protection to eliminate or reduce exposure to safe levels. If ventilation is used, conduct atmospheric testing as often as necessary to verify safe levels are maintained.
- Do not enter excavations that contain accumulated water unless precautions have been taken to prevent excavation undermining and cave-ins. Precautions may include special support systems or shield systems, water removal equipment that is monitored by the excavation-competent person to verify proper operation, or safety harnesses and lifelines.
- Use adequate precautions such as diversion ditches or dikes to prevent surface water from entering the excavation, and to provide adequate drainage of the area adjacent to the excavation when the natural drainage of surface water is interrupted.
- Protect personnel from materials falling or rolling from the face of the excavation by scaling to remove loose material, or by installing protective barricades.
- Keep spoil piles, material, and equipment at least 2 feet (61 centim) from the edge of the excavation, or use a retaining device to prevent the material from falling into the excavation.

5.5.5 Protective Systems

The excavation-competent person is responsible for determining the appropriate protective system to be used to prevent excavation cave-in. This determination may be based on the soil classification, space limitations, available materials, type of work to be performed in the excavation, and availability of tabulated data or a registered professional engineer.
CH2M HILL must rely on the expertise of the excavation-competent person with regard to excavation protective systems. The following information provides a general understanding

of the common minimum protective system requirements. For the U.S., refer to “OSHA Protective System Requirements Summary” in Attachment 1.

- Use sloping, benching, shoring, shielding, or other protective systems to protect personnel from cave-ins, except when the excavation is made entirely in stable rock or is less than 5 feet (1.5 m) deep and there is no indication of possible cave-in, as determined by the excavation-competent person.
- Slope, to 34 degrees or less, excavations that are less than 5 feet in depth where examination of the ground by a competent person provides any indication of a potential cave-in.
- Verify that protective systems for excavations deeper than 20 feet (6.1 m) are designed or approved by a registered professional engineer. If the excavation soil is not classified by the excavation-competent person, the maximum allowable slope should be 34 degrees measured from the horizontal.
- Protective system materials should be free from damage that might impair their proper function. To evaluate their suitability for continued use, the competent person should inspect damaged components as needed.
- Use protective system materials in a manner consistent with manufacturers’ recommendations; do not subject to loads exceeding their design limits.
- Connect protective system materials together to prevent sliding, falling, kickouts, or other predictable failures.
- Protect personnel from cave-ins while entering and exiting shielding systems.
- Do not allow personnel to work in shielding systems during installation, removal, or vertical movement. Personnel may remain inside the shield during horizontal movement as long as the shield is not lifted.

5.5.6 Protective Systems Removal and Backfilling

- Take precautions when removing protective system components. Start at, and progress from, the bottom of the excavation. Release components slowly so that it is possible to detect indications of possible failure of the remaining components. Temporary structural members may be required to carry the loads imposed on the protective system.
- Backfill immediately after removal of the protective system.

5.6 Confirmation Sampling

Confirmation sampling must comply with the appropriate state and federal legislation; violation of these rules could invalidate the sampling results. Alaska Administrative Code (AAC) 18 AAC 78 was used as guidance and the general basis for development of the confirmation sampling methods described in this SOP. For further information, please refer to applicable state and federal guidance documentation.

5.6.1 General Approach to Confirmation Sampling

Field indicators (including PID and FID equipment) alone are not suitable for the validation of remediated in-situ soil. The use of field measurement instruments needs to be confirmed through chemical analyses with appropriate QA/QC procedures included in the sampling

program. Judgmental sampling that does not include a systematic sampling pattern is also not appropriate for validation sampling of in-situ soils. A systematic sampling pattern is recommended for the confirmation of in-situ soils. The data obtained from the confirmation sampling program should be statistically analyzed for final compliance with the applicable soil cleanup levels using the 95 percent upper confidence limit (UCL) specified in 18 AAC 78.176 and NSW EPA *Sampling Design Guidelines* (1995) for samples collected from the same soil profile. Final compliance will be determined based on the following (ADEC, 2006):

- The number and location of samples taken
- Whether large variations in contaminant concentrations relative to the mean concentration exist
- Whether a large percentage of concentrations are below the method detection limit

Additional considerations, including if residual concentrations are present above the nominated site criteria and if a suitable population of data points have been collected to allow for statistical analysis, should also evaluated (EPA, 1995).

5.6.2 Excavation Confirmation Sampling

Soil samples will be collected from the floor and walls of each excavation to confirm that contaminated soil has been removed and evaluate if any contaminated soil remains.

At minimum, collect two soil samples at different locations from the floor of each excavation up to a surface area (footprint) of 250 square feet; then collect one additional sample for each additional 250 square feet of surface area, or portion thereof over the initial 250 square feet, at points where contamination is most likely to be present (ADEC, 2006). For example, if the total excavation area is 1,270 square feet, collect two standard samples and five additional samples.

Collect the first sample on the longitudinal axis centered between the ends of the excavation and beneath the area of the identified release, and the second sample on the longitudinal axis beneath the area of the identified release, where contamination is most likely to be present based on field screening results (ADEC, 2006). Space all additional confirmation samples beyond the first two samples throughout the excavation at points where contamination is most likely to be present based on field screening results.

When performing confirmation soil sampling of multiple excavations (that is, removal of multiple tanks or drums), collect two samples per individual excavation location (per tank or drum location) as described above for individual excavations, as applicable.

If excavation is conducted at a former dispensing area or along piping trenches, collect at least one confirmation soil sample at the location where contamination is most likely to be present, based on field screening results. Collect excavation floor confirmation samples from freshly uncovered, native soils located between 0.5 to 2 feet below the bottom of the excavation (for example, 6 inches) and/or within 2 feet below the lowest point of any dispensing equipment or buried piping (ADEC, 2006). If the excavation has been open for longer than one hour, confirmation samples should be collected at least 1 foot below the bottom of the excavation. Do not collect samples from disturbed soil that has fallen into the bottom of the excavation pit (ADEC, 2010).

Soil samples will also be collected from the walls of each excavation. At a minimum, collect one soil sample from each wall of the excavation (minimum of four wall samples per excavation) or at a frequency around the excavation perimeter as defined in the site-specific FSP (Appendix D), whichever is greater. If the excavation perimeter is greater than 40 feet and a wall sample frequency isn't defined in the site-specific FSP or the excavation perimeter is expanded, collect confirmation wall samples at a minimum excavation perimeter frequency as defined by the PM. Collect excavation wall confirmation samples from freshly uncovered, native soils located at the base (toe) of the excavation wall from at least 4 to 6 nches within the wall (ADEC, 2010). If the excavation has been open for longer than 1 hour, collect wall samples from at least 1 foot within the wall.

If groundwater is encountered within the bottom of the excavation and groundwater prevents the collection of representative soil samples, collect excavation floor confirmation samples within the first 0.5 feet of the vadose zone above the zone of seasonal water table fluctuation (ADEC, 2006). Collect these samples as close as possible to the floor sample locations described above for individual tanks. Collect excavation wall confirmation samples at the soil/water interface. If groundwater or the seasonal high water table is suspected to be within five feet of the bottom of the former tank, drum, or pipeline being excavated; a install a boring/test pit in an undisturbed area of the excavation and collect at least one soil sample from the first 6 inches of groundwater-saturated soil or the zone of seasonal water table fluctuation (ADEC, 2006).

5.6.3 Water Samples

The site-specific FSP may require sampling of groundwater that enters an excavation for chemical analysis. To collect water samples as grab samples, lower a Teflon bailer on a nylon cord into the pooled water in the excavation. Use the bailer to fill the appropriate sample containers (see *SOP-13, Groundwater Sampling Procedures*). The sample containers will be handled according to *SOP-19, Sample Handling and Custody*.

5.7 Backfilling of Soil Excavations

Backfill soil excavations using clean fill material. The source of the fill may be imported clean material or excavated material determined to be clean based on field screening or analytical results, or a combination of both. Backfill excavations the same day as excavation, immediately after completion of sampling and/or logging. If excavations are left open overnight, restrict access to the excavation using barricades or fencing.

The following steps must be followed when backfilling excavations:

- Backfill test pits on the same day as the excavation, or as soon thereafter as practical. The source of the fill will be determined before excavating the test pits.
- Place fill in the trench or pit bottom in approximately 1-foot lifts.
- Compact each lift using the backhoe bucket.
- Decontaminate all equipment according to *SOP-14, Equipment Decontamination Procedures.*

6.0 Documentation

The field geologist is responsible for documenting soil excavation observations and activities. A detailed, complete, and accurate record will be documented on the Excavation Log Form (Attachment 2) to be completed during or immediately following completion of the soil excavation, confirmation sampling, and backfilling. If an item on the form is not applicable, indicate NA on the form. Perform lithologic logging of excavation side walls according to the applicable sections of *SOP-06, Boring Log Completion, Soil Classification, and Logging.*

At a minimum the following information will be obtained and recorded on the log:

- Soil excavation location identification
- Excavation date(s)
- Excavation length, width, and depth
- Sample numbers and locations
- Lithologic material descriptions
- Photographs (numbers, locations, descriptions, and direction)
- Sketch of excavation pit location and cross section on grid on back of log

7.0 References

Alaska Department of Environmental Conservation (ADEC). 2010. *Draft Field Sampling Guidance*. January

Alaska Department of Environmental Conservation (ADEC). 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*. November 7.

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Denver Federal Center Site-wide RCRA Facility Investigation. May 2000. *Standard Operating Procedure for Test pit/Trench Excavation and Sampling.*

8.0 Definitions

Benching**:** Benching is a method of protecting personnel from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Company Responsible for Excavation Safety**:** The party that has direct control over the excavation operations is responsible for excavation safety. This could be CH2M HILL, a subcontractor, or an independent third party. When CH2M HILL self-performs excavation operations, CH2M HILL assumes responsibility for excavation safety. When CH2M HILL hires a subcontractor to perform an excavation operation, the subcontractor assumes

responsibility for excavation safety. When CH2M HILL employees must enter excavations on projects controlled by an independent third party contractor, the third party contractor assumes responsibility for excavation safety.

Competent Person: A competent person is one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them. The company responsible for excavation safety designates the excavation-specific competent person.

Excavation: An excavation is any man-made cut, cavity, trench, or depression in an earth surface that is formed by earth removal.

Hazardous Atmosphere: A hazardous atmosphere is one that by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful, may cause death, illness, or injury. Specific examples of hazardous atmospheres are include:

- Oxygen-deficient atmospheres contain less than 19.5 percent oxygen and can result in a range of symptoms, from dizziness to unconsciousness, and even death at extremely low levels.
- Oxygen-enriched atmospheres contain greater than 23.5 percent oxygen and can increase the flammability of combustible materials.
- Explosive atmospheres contain flammable gases that exceed 10 percent of the lower explosive limit (LEL).
- Carbon monoxide from the exhausts of earthmoving equipment can collect in excavations. Carbon monoxide causes oxygen starvation and can be fatal at a concentration of 1 percent [10,000 parts per million (ppm)] after a 1-minute exposure. Ventilation or respiratory protection is required when carbon monoxide levels exceed 35 ppm.
- Toxic atmospheres may develop depending on the level of contamination in the soil. Refer to the site-specific health, safety and environment (HS&E) plan or field safety instructions for more details.

Independent Third Party Contractor: An independent third party contractor has no contractual relationship with CH2M HILL and is contracted directly to the owner.

Protective Systems: Protective systems provide a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems and other systems that provide the necessary protection.

Shielding: Shielding is a structure that is able to withstand the forces imposed on it by a cave-in, thereby protecting personnel within the structure. Shields can be permanent structures or they can be designed to be portable and moved as work progresses. Additionally, shields can be either pre-manufactured or job-built in accordance with local regulatory agency requirements. Shields used in trenches are usually referred to as ”trench boxes” or ”trench shields.”

Shoring: A structure such as a metal hydraulic, mechanical, or timber shoring system supports the sides of an excavation and is designed to prevent cave-ins.

Sloping: Sloping is a method of excavating in which the sides of an excavation are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies depending on such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Stable Rock: Stable rock is natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Trench: A trench is a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). An excavation is also considered to be a trench if forms or other structures are installed or constructed in the excavation that reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation).

Type A Soil: Type A soils are cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (14,629 kilograms per square meter) or greater. Type A soils include clay, silty clay, sandy clay, clay loam, caliche, hardpan, and sometimes silty clay loam and sandy clay loam. No soil should be classified as Type A if it is fissured; if it is subject to vibration from heavy traffic, pile driving, or similar activities; if it was previously disturbed; or if it is part of a sloped, layered system in which the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or steeper.

Type B Soil: Type B soils are cohesive soils with an unconfined compressive strength greater than 0.5- ton per square foot (4,876 kilograms per square meter) but less than 1.5 tons per square foot (14,629 kilograms per square meter). Type B soils include granular cohesionless soils such as angular gravel, silt, silt loam, sandy loam, and sometimes silty clay loam and sandy clay loam; previously disturbed soils that are not Type C; fissured soils and soils subject to vibration that would otherwise be classified as Type A; dry rock that is not stable; and material that is part of a sloped, layered system in which the layers dip on a slope less steep than four horizontal to one vertical (4H:1V).

Type C Soil: Type C soils are cohesive soils with an unconfined compressive strength of 0.5-ton per square foot (4,876 kilograms per square meter) or less. Type C soils include granular soils such as gravel, sand, and loamy sand; submerged soil; soil from which water is freely seeping; submerged rock that is not stable; or material in a sloped, layered system in which the layers dip into the excavation at a slope of four horizontal to one vertical (4H:1V) or steeper.

9.0 Attachments

Attachment 1 *CH2M HILL Excavation and Trenching Safety Enterprise Standard Operating Procedure HSE-307*

Attachment 2 *Excavation Log*

SOP-24

Direct Push Groundwater Sampling

SOP-24: DIRECT PUSH GROUNDWATER SAMPLING

1.0 Purpose

This standard operating procedure (SOP) describes the methodology for collecting discrete point-in-time groundwater samples from temporary points using direct push system (DPS) techniques.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in installing temporary groundwater sample points and collecting discrete groundwater samples via DPS at Galena Forward Operating Location (FOL) projects and tasks and was developed according to Alaska Department of Environmental Conservation (ADEC) and other reference documents, including the following:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Monitoring Well Guidance* (ADEC, 2009)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used soil sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-9, Monitoring Well Development*
- *SOP-12, Field Water Quality Measurements and Calibration*
- *SOP-13, Groundwater Sampling Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-20, Field Procedure Change Management*
- *SOP-21, Well Decommissioning and Abandonment*

3.0 General

DPS groundwater monitoring points have become more common for contaminated site investigations and offer faster installation, replacement, and decommissioning. DPS groundwater monitoring points are often temporary and differ from traditional drilled wells in installation and construction. Significant advantages of DPS groundwater sampling include faster sampling and the ability to collect sequentially samples at multiple depths at the same location to characterize the vertical contaminant concentration profile within the aquifer.

DPS groundwater sampling equipment generally falls into one of two broad categories: point-in-time groundwater samplers and DPS-installed groundwater monitoring wells. This SOP focuses on point-in-time groundwater samplers. Point-in-time groundwater well points and samplers are tools and devices that are used to rapidly collect samples to define

groundwater conditions, typically during one sampling event (U.S. Environmental Protection Agency [EPA], 2005). They are usually less than 2 inches outside diameter (OD) and are generally constructed of steel or stainless steel. Direct push methods (percussion or static weight) are used to advance point-in-time samplers below the static water level in unconsolidated formations. Generally, groundwater flows into the sampler from an exposed well screen under ambient hydrostatic pressure. Groundwater may be collected from the sampler using bailers or pumps, or the sampler may be retracted to the surface to obtain the water sample. Once sampling is completed, the samplers are removed and the boring is abandoned in accordance with local regulations. Point-in-time sampling tools are typically used during site characterization to identify plume boundaries or hot spots. They cannot be used for long-term monitoring or trend analysis because the boreholes must be decommissioned when sampling is completed.

Point-in-time DPS groundwater samplers can be installed using either exposed-screen or protected-screen installation methods. In an exposed-screen installation, which is anticipated at the Galena FOL, the casing and screen surround the drive rods, or are used as the drive rod. During installation, the well screen is directly exposed to the formation, and installation is completed without a filter pack or annular seal (ADEC, 2009). With exposed-screen installation methods, the well casing and screen are driven to the target depth using a single string of rods. Because the screen is exposed to formation materials while it is advanced, proper well development is important to remove soil from screen slots. This method is not recommended for installing well screens in or beneath contaminated zones because driving the well point through contaminated soil may carry some contamination with the point, cross-contaminating the sampling zones and resulting in less-than-representative samples (EPA, 2005).

In a protected-screen installation, the casing and screen are inside the drive rod, or lowered as the drive rods are advanced (ADEC, 2009). Sealed-screen samplers typically consist of a short (for example, 6-inch to 3-foot) screen nested within a sealed, water-tight tool body. Because the screen is not exposed to the formation as the sampler is advanced into the subsurface, the screen does not become plugged or damaged. In addition, the potential for cross-contamination is greatly reduced and a true depth-discrete sample that is representative of the target sampling zone can be collected (EPA, 2005).

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and for engaging field staff with adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Field Manager

The Field Manager (FM) is responsible for coordinating and scheduling daily field activities. In addition, the FM is responsible for training field staff engaged in this activity in this SOP and for compliance with this SOP.

4.3 Field Team Leader

The Field Team Leader (FTL) should prepare or oversee preparation of a detailed sampling plan that includes the specifics of field water quality measurement, particularly the procedures to be used. The FTL, or their designee, should know the requirements for field water quality measurement and maintain adequate documentation of field water quality measurements and calibration activities.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for site-specific HS&E and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the *Project-specific Health and Safety Plan* (HSP) (Appendix A), coordinates with the FM and/or Safety Coordinator (SC) to complete and certify the PPE program, and conducts audits on the effectiveness of the HS&E program.

4.5 Safety Coordinator

The role of SC is either taken by the FM or is designated to FTLs by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and ongoing HS&E procedures are effective.

5.0 Procedures

5.1 Well Points

Well points are simple wells used for rapid collection of water level data, groundwater samples, and hydraulic test data in shallow unconfined aquifers (EPA, 2005). Well points allow for exposed-screen installation and are generally constructed of slotted steel pipe or continuous-wrap, wire-wound, steel screens with a tapered tip on the bottom. They can be driven into unconsolidated formations and either used either point-in-time sampling and decommissioned after the sample is collected, or left in place for the duration of the sampling program. If the well point will be left in the ground for any length of time, a seal will be needed to prevent infiltration of surface water.

The optimum conditions for well point installations are shallow sandy materials. Predominantly fine-grained materials, such as silt or clay, can plug the screen slots as the well point is advanced (EPA, 2005). Because well points are driven directly into the ground with little or no annular space, the formation materials are allowed to collapse around the screen, and the well point must be developed to prepare it for sampling (see *SOP-9, Monitoring Well Development*).

5.1.1 Well Point Installation

Well points can be installed using a conventional hollow stem auger rig, slide hammer, jack hammer, rotary hammer, auto-hammer, or direct push hydraulic hammer. Driving well points through contaminated unsaturated zone soils may carry some contamination with the point, resulting in less-than-representative analytical sample results. Therefore, drilling an oversized borehole is recommended before well point installation. Well points should be

installed through uncontaminated and contaminated unsaturated zone soils as described below (New Jersey Department of Environmental Protection, 1994).

Use the following procedures in areas of uncontaminated, unsaturated zone soils:

1. Make sure that all well point construction materials are clean and decontaminated before installation, according to *SOP-14, Equipment Decontamination Procedures*.
2. Place the first segment of decontaminated well point casing, constructed with a drive point and slotted well screen, in a vertical drive position beneath the direct push hammer and begin to slowly drive the well point casing into the subsurface. Once a few feet of casing have been driven and the well point has been well started, increase the drive speed, as appropriate, until most of the first casing segment has been advanced below the ground surface.
3. Weld a second segment of casing (riser) onto the first segment.
4. Drive most of the second casing segment and the remaining aboveground portion of first casing segment into the subsurface.
5. Repeat Steps 2 and 3, continuing to weld on addition well point casing sections and drive them into the subsurface until the desired subsurface well depth is achieved.
6. Once the well point has been appropriately installed, develop the well point as described in *SOP-9, Monitoring Well Development*. Because a filter pack, which is typically constructed for traditional monitoring wells, will not be used, obtaining low-turbidity groundwater samples in fine-grained aquifers during development may be difficult. If low or stable turbidity cannot be obtained, it is acceptable to disregard turbidity as long as other groundwater parameters (such as dissolved oxygen [DO], oxidation-reduction potential [ORP], pH, or conductivity) stabilize. Consult the FTL and/or FM, if appropriate, and note any development observations in a field notebook.
7. After well point development, sample the groundwater from the well according to *SOP-13, Groundwater Sampling Procedures*.
8. After groundwater sample collection, hammer or hydraulically “jack” the well point back out of the ground and abandon it according to *SOP-21, Well Decommissioning and Abandonment*.
9. If the well point will be left as a permanent installation, it must be constructed and permitted according to ADEC monitoring well requirements.
10. If the well point is used for groundwater level data, place a survey mark must on top of the casing as a reference point for water level measurements and survey the top-of-casing elevation of the well point for reference.

In areas of contaminated, unsaturated zone soils, well points may be placed with the aid of a hollow-stem auger. Use the following procedures to install well points in these areas:

1. Pre-drill an oversized borehole (20 percent larger than the well point) using hollow-stem auger drilling techniques (see *SOP-5*) to just above the target sampling zone.
2. Place the well point casing into the borehole and advance it beyond the bottom of the borehole until the desired subsurface well depth is achieved, as similarly described in Steps 2 to 5 for well point installation in uncontaminated, unsaturated zone soils.

3. Once the desired subsurface well depth is achieved, develop and sample the well according to *SOP-9, Monitoring Well Development* and *SOP-13, Groundwater Sampling Procedures.*
4. After groundwater sample collection, hammer or hydraulically “jack” the well point back out of the ground and abandon it according to *SOP-21, Well Decommissioning and Abandonment*.
5. If the well point will be left as a permanent installation, it must be constructed and permitted according to ADEC monitoring well requirements.
6. If the well point is used for groundwater level data, place a survey mark on top of the casing as a reference point for water level measurements and survey the top-of-casing elevation of the well point for reference.

5.2 Geoprobe® Screen Point 16 Groundwater Sampler

The Geoprobe® Screen Point 16 (SP-16) Groundwater Sampler is another point-in-time groundwater sampler anticipated to be used at the Galena FOL. The SP-16 Groundwater Sampler is a proprietary DPS tool that uses a protected-screen installation method and is advanced using a Geoprobe® DPS drill rig (see *SOP-05*). Basic operation uses a stainless steel or polyvinyl chloride (PVC) well screen that is encased in an alloy steel sampler sheath. An expendable drive point is placed in the lower end of the sheath while a drive head is attached to the top. O-rings on the drive head and expendable point provide a watertight sheath that keeps contaminants out of the system as the sampler is driven to depth. The protected well screen is then driven to depth and, when it reaches the sampling interval, extension rods equipped with a screen push adapter are inserted down the inside of the probe rods to hold the well screen in place while the tool string is retracted, exposing the well screen to the aquifer. The groundwater from the temporary well point is then sampled. When groundwater sampling is complete, a removable plug in the bottom of the screen allows the boring to be grouted below the sampler as the tool string is retrieved and the well point is abandoned. Figure 1 shows the SP-16 Groundwater Sampler.

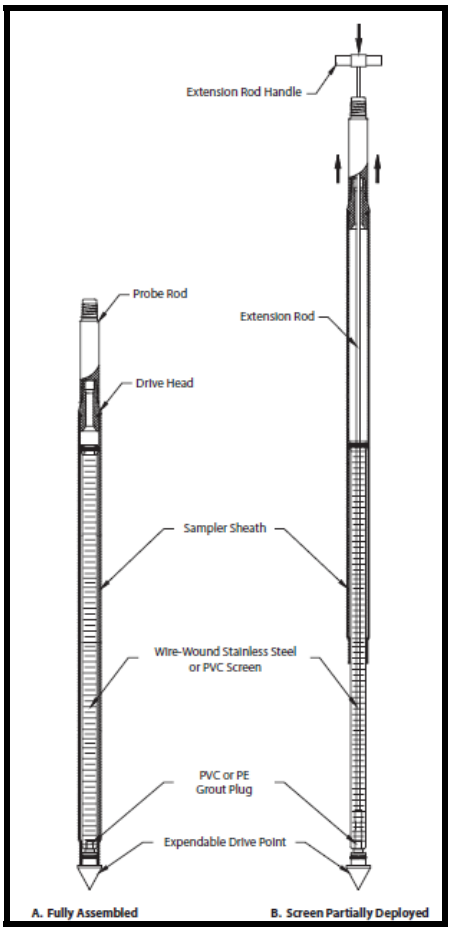

*Figure 1. Geoprobe® SP-16 Groundwater Sampler (**Kejr, Inc.**, 2006)*

The following procedures for the SP-16 Groundwater Sampler were adapted from the Geoprobe® SP-16 Groundwater Sampler SOP (Kejr, Inc., 2006). The parts of the SP-16 Groundwater Sampler are shown in Figure 2.

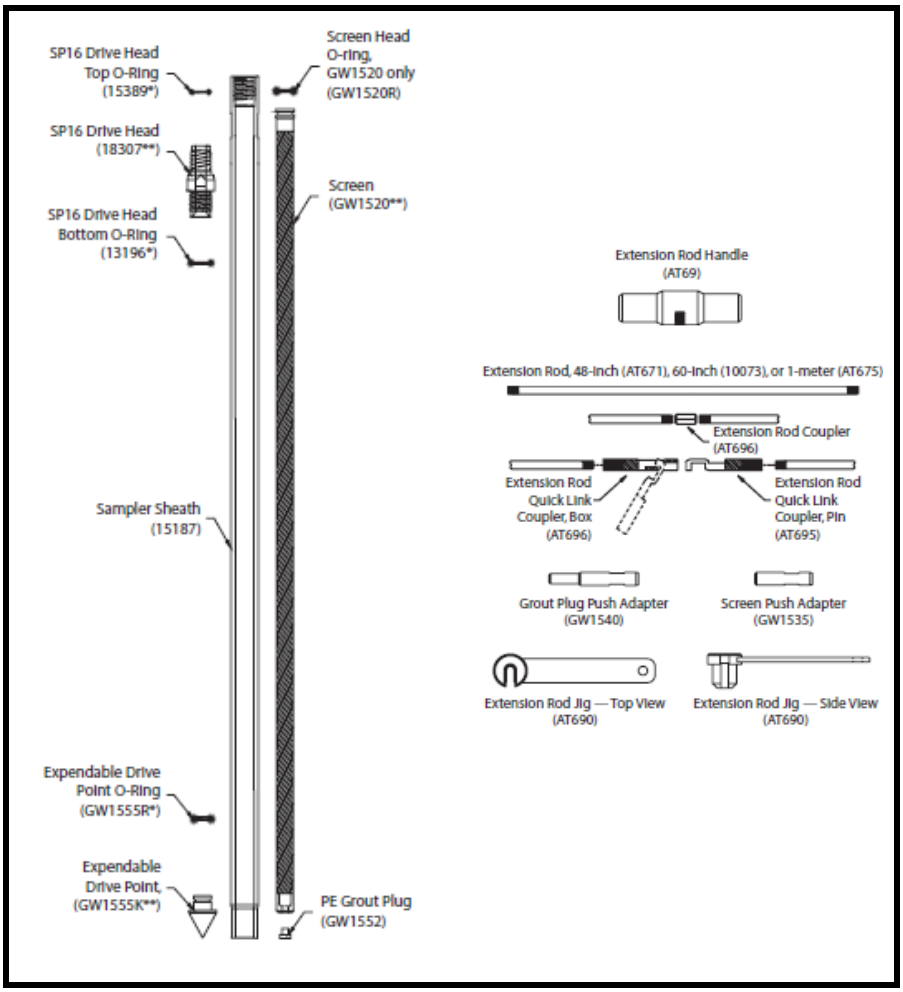

Figure 2. Geoprobe® SP-16 Groundwater Sampler Parts (Kejr, Inc., 2006)

5.2.1 Advancing the Geoprobe® SP-16 Groundwater Sampler

The drilling derrick should be extended a little more than halfway out of the Geoprobe® drill rig when positioning for operation, to provide for adequate room for screen deployment. Following are the procedures for advancing the SP-16 Groundwater Sampler:

1. Begin by placing the assembled sampler (Figure 1[A]) in the driving position beneath the hydraulic hammer of the Geoprobe® drill rig.

2. Advance the sampler with the throttle control at slow speed for the first few feet to verify that the sampler is aligned properly. Switch to fast speed for the remainder of the probe stroke.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the drive head (Figure 2). Use distilled or clean, potable water to lubricate the O-ring, if needed. Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the sampler the entire length of the new rod, with the throttle control at fast speed.

4. Repeat Step 3 until the deepest desired sampling interval at that location is reached. If multiple groundwater intervals are to be sampled from the same monitoring point, collect

groundwater samples from the deepest sample interval first, and progressively sample from deepest to shallowest interval throughout the vertical aquifer profile. Approximately 12 inches of the last probe rod (Figure 2) must extend above the ground surface to allow attachment of the rod puller assembly. Add a 12-inch rod if the tool string is over-driven.

5. Remove the drive cap and retract the drilling derrick from the tool string.

5.2.2 Well Screen Deployment

Figure 3 illustrates deployment of the Geoprobe® SP-16 Groundwater Sampler well screen. Following are the procedures for deploying the well screen:

1. Thread a screen push adapter (Figure 2) on an extension rod of suitable length. Attach a threaded coupler to the other end of the extension rod. Lower the extension rod inside the probe rod, taking care not to drop it down the tool string. An extension rod jig may be used to hold the rods.
2. Add extension rods until the adapter contacts the bottom of the screen. To speed up this step, use extension rod quick links at every other rod joint.
3. Verify that at least 48 inches of extension rod protrude from the probe rod. Thread an extension rod handle on the top extension rod.
4. Maneuver the probe assembly into position for pulling.
5. Pull up the tool string while physically holding the screen in place with the extension rods (Figure 3[B]). A slight knock with the extension rod string will help dislodge the expendable point and start the screen moving inside the sheath. Raise the hammer and tool string about 44 inches if using a GW1520 or GW1530 screen. At this point, the screen head will contact the necked portion of the sampler sheath (Figure 3[C]) and the extension rods will rise with the probe rods. Use care when deploying a PVC screen so as not to break the screen when it contacts the bottom of the sampler sheath. The disposable screen will extend completely out of the sheath if the tool string is raised more than 45 inches; measure and mark this distance on the top extension rod to avoid losing the screen during deployment.
6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top extension rod (with handle) and top probe rod. Extract all extension rods.
7. Collect groundwater samples with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small-diameter sampling device. When inserting tubing or a bladder pump down the rod string, verify that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head, giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

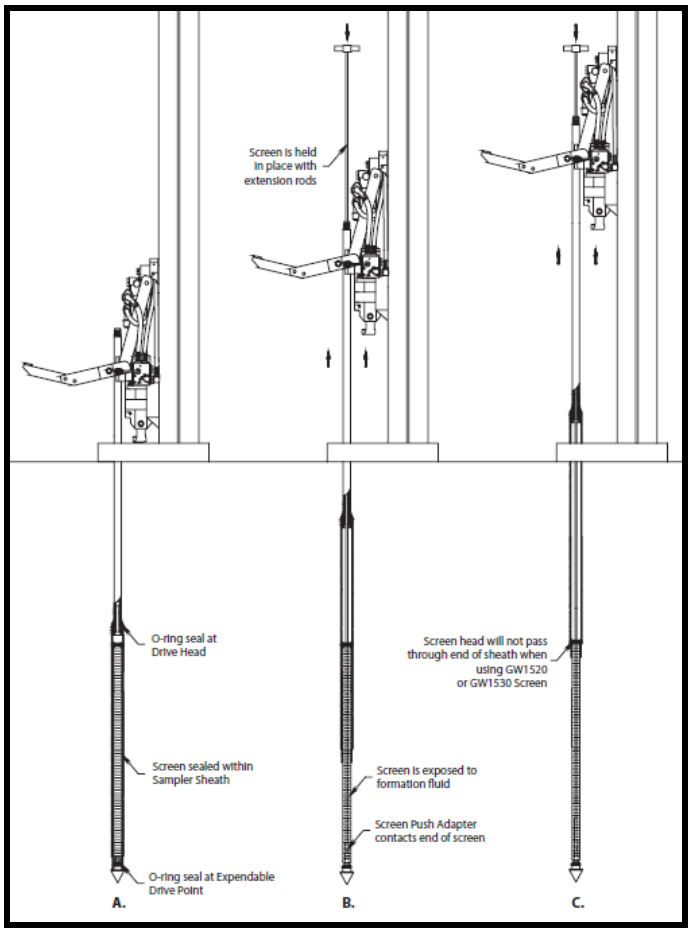

Figure 3. Geoprobe® SP-16 Groundwater Sampler Well Screen Deployment

5.2.3 Well Screen Grouting and Abandonment

The Geoprobe® SP-16 Groundwater Sampler can meet American Society for Testing and Materials (ASTM) D5299 requirements for abandoning environmental wells when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of Geoprobe® GW1520 and GW1530 well screens. A grout machine is then used to pump grout into the open probe hole as the sampler is withdrawn. Figure 4 illustrates how the SP-16 Groundwater Sampler borehole is grouted and abandoned. The following procedure is presented as an example only and may be modified to satisfy ADEC and project requirements:

1. Maneuver the probe assembly into position for pulling. Attach the rod grip puller to the top probe rod. Raise the tool string approximately 4 to 6 inches to allow removal of the grout plug.

2. Thread the grout plug push adapter (Figure 4) onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the grout plug at the bottom of the screen. Attach the handle to the top extension rod. When the extension rods are slightly raised and lowered, a soft rebound should be felt as the adapter contacts the grout plug; this is especially true when using a PVC screen.

3. Place a mark on the extension rod even with the top of the probe rod. Apply downward pressure on the extension rods and push the grout plug out of the screen. The mark on the extension rod should be below the top of the probe rod. Remove all extension rods. Note: When working with a stainless steel screen, it may be necessary to raise and quickly lower the extension rods to jar the grout plug free. When the plug has been removed, a metal-on-metal sensation may be noted as the extension rods gently “bounce” within the probe rods.

4. Connect a grout nozzle to high-pressure nylon tubing and insert the nozzle through the probe rods to the bottom of the screen (Figure 4). It may be necessary to pump a small amount of clean, potable water through the tubing during deployment to jet out sediment that settled in the bottom of the screen. Resistance will sometimes be felt as the grout nozzle passes through the drive head. Rotate the tubing while moving it up and down to make sure the nozzle has reached the bottom of the screen and is not hung up on the drive head. Note: All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.

5. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing, placing it on the ground near the end of the tubing.

6. Repeat Step 5 until the sampler is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods; sharp bends create weak spots in the tubing that may burst when pumping grout. Operate the grout pump only when pulling the rod string so the probe hole is filled with grout from the bottom up as the rods are extracted.

7. Promptly clean and decontaminate all probe rods and sampler parts before the grout sets and clogs the equipment.

If grouting is not required, the SP-16 Groundwater Sampler can be retrieved by pulling the probe rods, as with most other Geoprobe® applications. The rod grip pull system should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall downhole when released during the pulling procedure. A standard pull cap may still be used if preferred. Refer to the owner’s manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

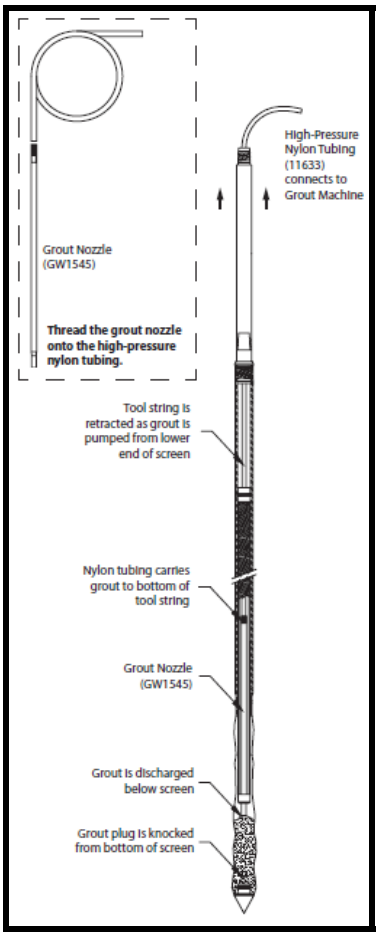

Figure 4. Grouting the SP-16 Sampler with a GW1520 or GW1530 Screen (Kejr, Inc., 2006)

5.3 Decontamination

To collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use according to *SOP-14, Equipment Decontamination Procedures*. Scrub all metal parts using a stiff brush and an Alconox soap solution. Steam cleaning may be substituted for manual washing if available. Rinse with distilled or clean, potable water and allow to air-dry before assembly.

6.0 Records

All materials and procedures used during installation of the DSP groundwater sampling should be documented in field notebooks according to *SOP-01, Note Taking and Field Log Books.*

7.0 References

Alaska Department of Environmental Conservation (ADEC). 2010. *Draft Field Sampling Guidance*. January.

Alaska Department of Environmental Conservation (ADEC). 2009. *Monitoring Well Guidance*. February.

Alaska Department of Environmental Conservation (ADEC). 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*. November 7.

Kejr, Inc. 2006. *Geoprobe® Screen Point 16 Groundwater Sampler Standard Operating Procedure*. Technical Bulletin No. MK3142. November.

New Jersey Department of Environmental Protection. 1994. *Alternative Ground Water Sampling Techniques Guide: Ground Water Sampling with the use of a Well Point*. http://www.state.nj.us/dep/srp/guidance/agws/. July.

U.S. Environmental Protection Agency (EPA). 2005. *Groundwater Sampling and Monitoring with Direct Push Technologies*. Office of Solid Waste and Emergency Response, Washington, DC. EPA 540/R-04/005. August.

8.0 Definitions

Point-in-time Groundwater Sampler: tools and devices that are used to rapidly collect samples to define groundwater conditions, typically during one sampling event.

Exposed-screen Installation: installation of a groundwater sampling tool in which the well screen is directly exposed to the subsurface formation during tool advancement.

Protected-screen Installation: installation of a groundwater sampling tool in which the well screen is covered or protected from direct exposure to the subsurface formation during tool advancement.

Well Point: a simple well, generally constructed of slotted steel pipe or continuous-wrap, wire-wound, steel screens, with a tapered tip on the bottom that can be driven into unconsolidated formations without drilling a borehole.

Geoprobe® Screen Point 16 (SP-16) Groundwater Sampler: a proprietary protected-screen installation groundwater sampling tool advanced by a Geoprobe® DPS drill rig.

9.0 Attachments

Attachment 1: *Geoprobe® Screen Point 16 Groundwater Sampler Standard Operating Procedure*

SOP-25

Direct Push Soil Gas Sampling

SOP-25: DIRECT PUSH SOIL GAS SAMPLING

1.0 Purpose

This standard operating procedure (SOP) describes the methodology for collecting discrete point-in-time soil gas samples from temporary points using direct push system (DPS) techniques.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in collecting DPS soil gas samples at Galena Forward Operating Location (FOL) projects and tasks and was developed according to Alaska Department of Environmental Conservation (ADEC) and other reference documents, including the following:

- *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009a)
- *Monitoring Well Guidance* (ADEC, 2009b)

This SOP focuses on the most commonly used DPS soil gas sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-15, Active Soil Gas Vapor Sampling*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*

3.0 General

DPS soil gas monitoring points have become increasingly common for contaminated site investigations and offer fast installation, replacement, and decommissioning. DPS soil gas monitoring points are often temporary (Geoprobe®, 2006). Significant advantages of DPS soil gas sampling include faster sampling and the ability to collect sequential samples at multiple depths from the same monitoring point to characterize the vertical profile of the unsaturated zone.

DPS soil gas equipment is generally categorized as either point-in-time soil gas samplers or DPS-installed vapor monitoring points. This SOP focuses on point-in-time soil gas samplers. Point-in-time soil gas samplers are tools and devices that are used to rapidly collect samples to define soil gas conditions, typically during one sampling event.

Initially, the collection of DPS soil gas samples involved collecting samples directly through DPS drill rods driven to depth. An expendable point was advanced to depth at the leading end of the drive rods, then the rods were retracted slightly to release the expendable point and create a void in the borehole where soil gas could enter the drill rods for sampling (Geoprobe®, 2006). However, this method could compromise sample quality because of possible leaks at each drill rod joint and cross-contamination from poorly decontaminated

drill rods. Therefore, Geoprobe® Systems developed the Post-run Tubing (PRT) System. This SOP focuses on use of the Geoprobe® PRT System for to collect DPS soil gas samples.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources, and for engaging field staff with adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if complications arise in following sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for coordinating and scheduling daily field activities. In addition, the FM is responsible for training field staff engaged in this activity in this SOP and for compliance with this SOP.

4.3 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for site-specific HS&E oversight and for overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the *Project-specific Health and Safety Plan* (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.4 Field Team Leader

The Field Team Leader (FTL) is responsible for maintaining compliance with sample handling and custody requirements, particularly the procedures to be used. The FTL, or their designee, should know the requirements for DPS soil gas sampling and maintain adequate documentation of soil gas sampling activities.

4.5 Safety Coordinator

The Safety Coordinator (SC) is either the FM or FTL. The SC assists the FM and HSM with the health and safety program, implements the personal protective equipment (PPE) requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

5.0 Procedures

5.1 Tools and Equipment

5.1.1 PRT System

The PRT System was developed to help eliminate some of the early problems encountered by sampling directly through the steel drive rods. The PRT method uses an adapter and tubing to isolate the soil gas sample from the steel drive rods, which eliminates possible leaks of ambient air from the rod joints into the soil gas being sampled (Geoprobe®, 2006). Figure 1 illustrates the Geoprobe® PRT System.

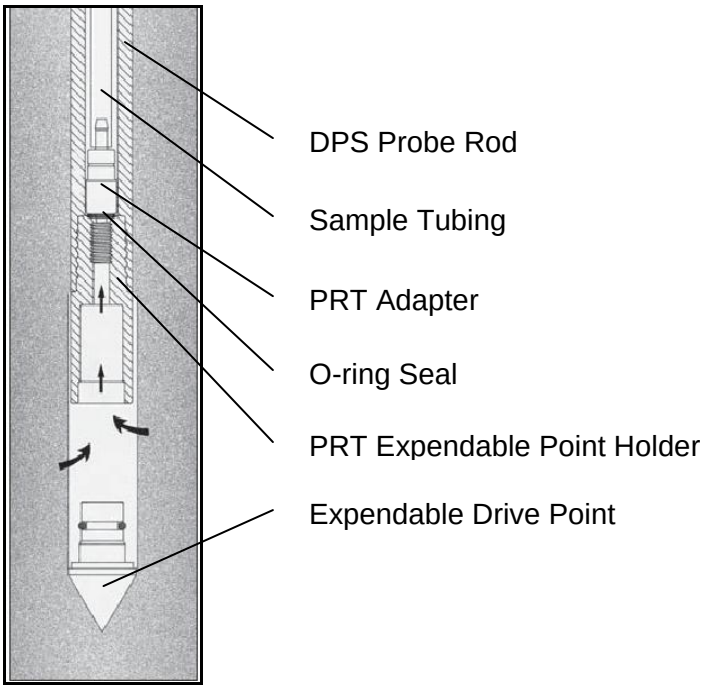

Figure 1. Cross Section of Geoprobe® PRT System with Rods Retracted and Ready to Sample (Geoprobe®, n.d.)

Different tool configurations are available for the PRT System, depending on the size of the probe rods used (Geoprobe®, 2006). In addition, the PRT Adapter must be selected to fit the tubing that will be used for sample collection (see Table 1). More information about PRT System equipment, including matching the appropriate tubing to the PRT Adapter used is available *SOP-25, Attachment 1: Direct Push Installation of Devices for Active Soil Gas Sampling and Monitoring* (Geoprobe®, 2006).

Table 1. Recommended Sample Tubing for Various PRT Adapters (Geoprobe®, 2006)

PRT Adapter Selection Guide			
PRT ADAPTER and PART NUMBER	**RECOMMENDED TUBING SIZE (ID)**	**GEOPROBE® TUBING PART NO.**	**TUBING INTERNAL VOLUME**
PR12S	1/8 in. (3.2 mm)	TB12T Teflon®	2.4 mL/ft (7.9 mL/m)
PR17S	0.17 in. (4.3 mm)	TB17L LDPE	4.5 mL/ft (14.6 mL/m)
	3/16 in. (4.8 mm)	TB17T Teflon®	5.4 mL/ft (17.8 mL/m)
PR25S	1/4 in. (6.4 mm)	TB25L LDPE	9.7 mL/ft (31.7 mL/m)
PR30S	5/16 in. (7.9 mm)	TB30T Teflon®	15.1 mL/ft (49.5 mL/m)
O-Rings for all PRT Adapters PR25R (pack of 25)			

NOTE: The sorption characteristics of certain tubing may not permit their use in all soil gas sampling applications.

5.1.2 Other Soil Gas Sampling Equipment

In addition to the PRT System tools, the following list of supplies/equipment may be needed to collect DPS soil gas samples. All equipment used for soil gas sampling should be verified by the source supplier to be pre-cleaned before use to eliminate the potential for cross-contamination. The following is a list of the significant other equipment likely required. For additional detail on soil gas sampling, refer to *SOP-15, Active Soil Gas Vapor Sampling*.

- Summa™ canister(s) (typically obtained from the analytical laboratory).
- Teflon® tubing or stainless steel tubing to collect the samples from the desired sampling zone (Tygon tubing will NOT be used).
- SwageLok® nuts and ferrules (1/4 inch), and T-connections for connecting to Summa™ canisters and leak testing equipment during leak testing.
- Oil-less low-flow vacuum pump for leak testing and purging PRT System lines and annular space.
- Helium detector or meter for leak testing.
- MiniRae or Multirae Photoionization Detector (PID), if field measurements of total volatile organic compounds (VOCs) and ambient air monitoring are required.
- GEM 2000 Landfill Gas Meter, if field measurements of CO_2, O_2, CH_4 are required.

- Low-flow Air Flowmeter to measure flow rates during purging and leak testing before sampling
- Flow controller (required for an active soil vapor sample).
- Vacuum gauge (0- to 30-inch mercury) (to measure the initial and final vacuum of the canister and to monitor filling rate when collecting an active soil vapor sample).
- Generator or battery to run vacuum pump. If generator is used, use enough extension cord to place generator downwind and away from sampling location.
- Log book and field data collection forms.

5.2 Geoprobe® PRT System Soil Gas Sampling

5.2.1 Preparation

Conduct the following steps in preparation for soil gas sampling (Geoprobe®, n.d.):

1. Decontaminate and clean all PRT System parts before using. Install O-rings on the PRT Expendable Point Holder and the PRT Adapter (see Figure 2).
2. Inspect the drill probe rods and clear them of obstructions.
3. Test fit the PRT Adapter with the PRT fitting on the PRT Expendable Point Holder to make sure that the threads are compatible and fit together well.
4. Push the PRT Adapter into the end of the selected tubing. Use electrical tape on the outside the adapter and tubing, or use a very tight-fitting, thick-walled tubing, to prevent the tubing from spinning freely around the adapter (Geoprobe®, n.d).

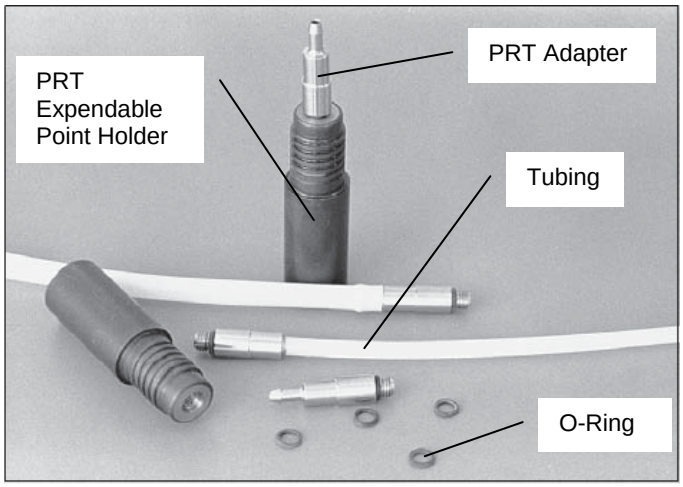

Figure 2. PRT System Parts (Geoprobe®, n.d.)

5.2.2 Probing

1. Drive the PRT tip tool configuration into the subsurface to the desired depth within the unsaturated zone. Connect DPS probe rods as necessary to reach the desired depth.
2. After the desired depth has been reached, disengage the PRT Expendable Point by pulling up on the probe rods.

3. Remove the pull cap from the top probe rod and position the DPS drill rig to allow room to work.

5.2.3 PRT Adapter Connection

1. Insert the PRT Adapter end of the tubing down the inside of the probe rods (see Figure 3).
2. Feed the tubing down the inside of the probe rods until it contacts the bottom of the PRT Expendable Point Holder (see Figure 4). Allow about 2 to 3 feet of tubing to extend from the probe rods before cutting off the remainder.
3. Grasp the excess tubing and apply some downward pressure on the tubing while turning it counterclockwise to engage the PRT Adapter threads with the PRT Expendable Point Holder (see Figure 5).
4. Pull up lightly on the tubing to test for adequate engagement of the threads. Failure of the adapter to thread properly into the PRT Expendable Point Holder means that soil intrusion may have occurred during driving of the probe rods or disengagement of the drive point.

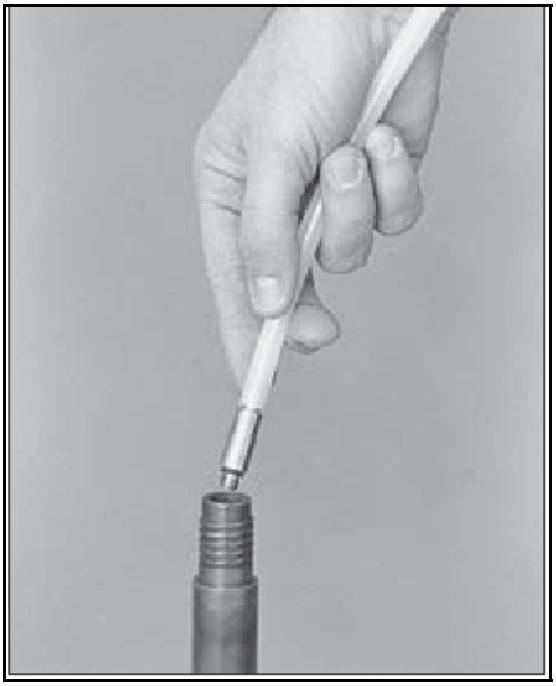

Figure 3. Inserting Tubing and PRT Adapter into Probe Rods (Geoprobe®, n.d.)

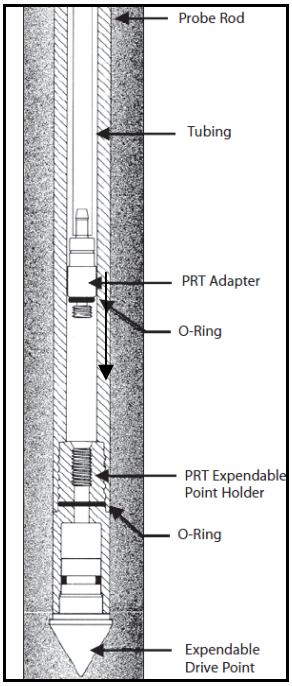

Figure 4. Lowering PRT Adapter and Tubing to PRT Expendable Point Holder (Geoprobe®, n.d.).

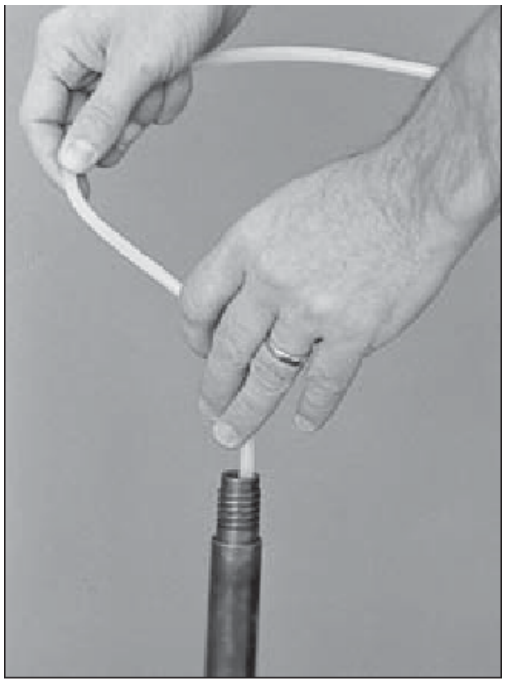

Figure 5. Engaging PRT Adapter Threads by Rotating Tubing (Geoprobe®, n.d.)

5.2.4 Soil Gas Sampling

1. Connect the aboveground end of the sample tubing to the soil gas sampling equipment.

   - If soil gas samples are to be collected in Summa™ canisters, connect the sample tubing to the soil gas sampling manifold and low-flow pump as described in *SOP-15, Active Soil Gas Sampling,* and begin purging and sampling at a flow rate of 200 milliliters per minute. Table 2 summarizes the recommended soil gas purging durations by PRT tool configuration.

   - If only field measurements with a PID or GEM 2000 Landfill Gas Meter are required, attach an approximately 6-inch piece of silicone tubing with zip-ties to the sample tubing and then connect the silicone tubing to the PID or landfill gas meter. Allow the PID or landfill gas meter to run and purge the PRT System for a minimum of 5 minutes. Once gas concentrations stabilize (± 10 percent), record the soil gas meter measurements in the Field Notebook and/or *SOP-25, Attachment 2: DPS Soil Gas Field Measurements Datasheet*.

   - If soil gas samples are to be collected for direct injection into a field gas chromatograph (GC), follow the procedures above for using a PID or landfill gas meter. Once the gas concentrations stabilize, insert the GC sample syringe through the silicone tubing and collect the sample while continuing to purge with the PID or landfill gas meter, as illustrated in Figure 6.

   - Additional details on soil gas sampling with Summa™ canisters, Tedlar® bags, and direct GC samples is available in *SOP-25, Attachment 1: Direct Push Installation of Devices for Active Soil Gas Sampling and Monitoring.*

Table 2. Purge Volume and Time with PRT System and Selected Probe Rods (Geoprobe®, 2006)

Rod Diameter, inches (cm)	1.0 (2.54)	1.25 (3.18)	1.5 (3.81)
Void Radius (r), inches (cm)	0.5 (1.27)	0.625 (1.59)	0.75 (1.91)
Void Lenght (L), inches (cm)	12 (30.5)	12 (30.5)	12 (30.5)
Single Void Volume (mL) (π x r^2 x L, where π ~ 3.141)	155	242	350
Tubing ID, inches (cm)	0.25 (0.64)	0.25 (0.64)	0.25 (0.64)
Tube Volume (mL/ft)	9.7	9.7	9.7
Tube Length (ft)	10	10	10
Total Tube Volume (mL)	97	97	97
Total System 1-volume (mL)	252	349	447
Approximate 3-System Volume (mL)	750	1050	1350
Required Purge Time at Flow Rate of 200 mL/min	3.75 min	5.25 min	6.75 min

Figure 6. Collecting a Soil Gas Sample for Direct Injection into a Field GC (Geoprobe®, n.d.)

5.2.5 Removal

1. After collecting a sample, disconnect the tubing from the attached soil gas sampling equipment (for example, PID or Summa™ canister)
2. Pull upward firmly on the tubing until it releases from the PRT Adapter at the bottom of the probe rods. If tape is used to connect the tubing to the PRT Adapter, a stronger pull may be necessary.
3. Remove the tubing from the probe rods and dispose of sample tubing according to Appendix B, Project-specific Waste Management Plan.
4. Retrieve the probe rods from the ground and recover the PRT Expendable Point Holder with the attached PRT Adapter.
5. Inspect the O-ring at the base of the PRT Adapter to verify that a proper seal was achieved during sampling. The O-ring should be compressed. Test this seal by capping the open end of the PRT Expendable Point Holder and applying vacuum to the PRT Adapter.
6. Decontaminate the PRT System parts, handle, and record, and package all laboratory soil gas samples according to *SOP-18* and *SOP-19*. Prepare for the next sample.

5.2.6 Abandonment

Abandon all DPS soil gas sampling probe boreholes by adding bentonite or grout into the borehole from the bottom to the ground surface (ADEC, 2009b). For very shallow probe boreholes (for example, less than 5 feet) in cohesive soils that remain open after the drive rods are removed, add bentonite powder or fine bentonite chips to the open hole incrementally and hydrate in approximately 1-foot lifts (Geoprobe®, 2006). Abandon deeper probe boreholes (for example, greater than 5 feet), by grouting with 20 to 25 percent solids bentonite grout slurry (American Society for Testing and Materials,1999). In general, a grout slurry should be pumped down the drive probe rods or a tremie tube as the drive probe rods are retracted from the bottom of the borehole (Geoprobe®, 2006).

6.0 Records

Record DPS soil gas sampling information in a Field Notebook, *SOP-25, Attachment 2: DPS Soil Gas Field Measurements Datasheet*, and/or *SOP-15, Attachment 3: Soil Gas Sampling Field Log Sheet* according to *SOP-01, Note Taking and Field Log Book*. Retain copies of all field documentation, including notes and photographs, in the project files.

7.0 References

Alaska Department of Environmental Conservation (ADEC). 2009a. *Draft Vapor Intrusion Guidance for Contaminated Sites*. July.

Alaska Department of Environmental Conservation (ADEC). 2009b. *Monitoring Well Guidance*. February.

American Society for Testing and Materials. 1999. *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other*

Devices for Environmental Activities. ASTM Standard D5299, ASTM International, West Conshohocken, Pennsylvania. December 10.

Downey, D.C., and J.F. Hall. 1994. *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing: Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential*. Prepared by Engineering-Science, Inc., for the U.S. Air Force Center for Environmental Excellence (AFCEE). February.

Geoprobe® Systems. N.d. *Soil Gas Sampling - PRT System Operation from Geoprobe Systems®*. (Available at: http://www.geoprobe.com/literature/instruction/soil%20gas%20PRT%20Oper.pdf).

Geoprobe® Systems. 2006. *Direct Push Installation of Devices for Active Soil Gas Sampling and Monitoring*. Technical Bulletin Number MK3098. Section 6.2. (Available at: http://www.geoprobe.com/literature/tech_papers/Soil%20Gas%20Sampling%20and%20Monitoring%20MK3098.pdf). May.

8.0 Definitions

Post-run Tubing (PRT) System – A proprietary DPS soil gas collection method and tool developed by Geoprobe® Systems in which sample tubing is lowered down the inside of the drive probe rods and a soil gas sample is collected from the end of the DPS tool.

Summa™ canister – An evacuated canister that is used to collect an air sample for VOCs or other soil gas analytes.

9.0 Attachments

Attachment 1: *Direct Push Installation of Devices for Active Soil Gas Sampling and Monitoring*

Attachment 2: *DPS Soil Gas Field Measurements Datasheet*

SOP-26

Geophysical Surveying Procedures

SOP-26: GEOPHYSICAL SURVEYING PROCEDURES

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used for conducting surface geophysical investigations including electromagnetic (EM) surveys using the Geonics EM-31 or EM-34; EM surveys using the Geonics EM-61; magnetic surveys; and ground penetrating radar (GPR) techniques during site characterization field investigations. This SOP is intended to be used in conjunction with the field sampling plan (FSP), quality assurance project plan (QAPP), and other SOPs developed for each specific project.

This SOP describes equipment, field procedures, and data reduction necessary to perform surface geophysical surveys. The locations and frequency of surface geophysical surveying will be specified in the FSP.

For purposes of this SOP, a station is the predefined interval along a traverse where individual electromagnetic field measurements collected.

For purposes of this SOP, a set of traverses are the lineal trends of station measurements conducted over a target investigation area. Traverses are set out by land survey methods to establish multiple parallel lines over the target investigation area. The distance between each parallel traverse is directly related to the station interval required for the investigation, the electromagnetic geophysical tools to be used, the size of the objects to be resolved and the depth of penetration of the electromagnetic methods employed.

2.0 Personnel Qualifications

A senior level geophysicist with knowledge and experience in the proposed geophysical surveying methods will oversee and/or perform the geophysical surveys.

3.0 Materials and Equipment

Various types of equipment and supporting materials will be needed for geophysical surveying. The geophysical survey instruments will be selected by the contractor depending on site conditions and project goals. Examples are:

- Geonics EM-31 or EM 34-3 terrain conductivity system or equivalent(depending on required depth of penetration and survey goals)
- Geonics EM-61
- Geometrics Model G858 Cesium Magnetometer (or equivalent)
- Geometrics Model G856 Magnetometer (or equivalent) for use as a magnetic base station
- Sensors and Software Pulse EKKO 100 or equivalent ground penetrating radar system

- Wood stakes or lath and pinflags (plastic pinflags if conducting magnetics or EM-61)
- Survey flagging
- Field logbook
- Waterproof and permanent marking pens
- Tape measure (200 feet minimum) (Note: for relatively smooth surfaces, a measuring wheel may be substituted)
- Extra paper and stylus for profile recorder when conducting GPR

4.0 Procedures

Surface geophysical techniques may be employed for several purposes. Subsurface features typically detected or revealed using an EM-31 or EM-34 include:

- Delineation of waste disposal areas
- Detection of buried metallic objects (including unspecified debris or buried drums)
- Delineation of variances in near surface soil densities due to previously excavated areas related to underground facilities removal (pipeline valve vaults, underground storage tanks, lift stations) or disposal activities, and or
- Resolution of the depth and orientation of some buried utilities.

Subsurface features typically detected or revealed using an EM-61 include:

- Detection of buried metallic objects (including buried drums)
- Detection of irregularly-shaped metallic landfill debris or refuse
- Estimation of the lateral extent of subsurface materials that have metallic constituents, and or
- Ordnance detection.

Subsurface features typically detected or revealed using a magnetometer surveys include:

- Detection of burial metallic (ferrous) objects and debris (including drums and scrap metal)
- Delineate lateral extent of trenches or lineaments of buried utilities that have ferrous metal constituents
- Location of underground utilities such as pipes or tanks; and or
- Ordnance detection.

Subsurface features typically detected or revealed using ground penetrating radar surveys include:

- Delineation of disposal activities
- Detection of buried metallic objects (borehole clearing, landfill or trench mapping)
- Mapping of near surface stratigraphy, and or
- Delineation of previously excavated areas related to waste disposal activities.

4.1 Geonics EM-31 or EM-34

EM methods involving the use of the Geonics EM-31 or EM-34 or equivalent provide a rapid means of measuring the electrical conductivity of subsurface soil, rock, and groundwater. These methods involve the induction of electrical current into the earth. A small alternating current is generated by a transmitter coil that transmits a primary, time-varying magnetic field into the ground. Through inductive coupling, the primary magnetic field produces small eddy currents in the subsurface, which in turn create their own secondary magnetic field. A receiver coil measures both the primary and secondary fields. The instrument measures variations in magnitude and phase of the individual currents voltage changes, which are related to the subsurface or terrain electrical conductivity. The conductivity values are recorded in a data logger, and subsequently downloaded to a computer and plotted on a map so that their variation over the site can be analyzed.

4.1.1 Preparation

A minimum amount of preparation will be made as a part of the geophysical surveys prior to any data collection. These may include a review and evaluation of all or part of the following:

- The purpose and expectations of the subsurface investigation will be defined.
- Existing relevant site, area, and regional soil characteristics, subsurface geologic and hydrogeologic information
- Site utility plans will be reviewed and utilities will be located in accordance and concurrent with SOP No. 17, Utility Clearance.
- Known hazards that pose a threat to the safety of field personnel will be defined.
- Appropriate field parameters will be defined, given the purpose of the survey (whether EM-31 or EM 34-3 is used, coil spacing, traverse spacing, station spacing, depth of penetration, etc.)
- The endpoints along each traverse will be surveyed and marked in the field with wooden lath or other wooden stakes.

Design of appropriate field or data acquisition parameters must consider the following:

- The coil spacing must be 1 to 1.25 times the required depth of penetration. If required depths are in excess of approximately 16 to 17 feet, an EM 34-3 must be used. If depths are less than approximately 16 to 17 feet, the EM-31 should be used. For some applications, such as bedrock investigations, the use of both instruments may be appropriate.

- Station spacing affects survey resolution. A station spacing of 5 to 25 feet is commonly used (spacing between parallel traverses). Actual spacing must consider instruments that will be used and take required resolution into account.
- Accurate definition of an EM profile anomaly requires several anomalous readings with adequate spacing along stations (data points along a traverse) that will overlap the feature by one-fourth to one-half its size in order to accurately resolve the anomaly.
- Background conductivity noise must be evaluated and/or determined to assess the potential usefulness of an EM survey. High noise levels can make interpretation difficult and can cause significant anomalies to be overlooked. Examples of EM noise include large ferromagnetic conductors such as railroad track or steel pipe, and above ground ferromagnetic conductors such as chain link fencing, steel monitoring well above ground completions, metal buildings, metal covered vaults, and reinforced concrete.
- Actual background electrical noise must be considered when collecting and interpreting the EM data. Background electrical noise can be from low voltage systems or from conventional AC electrical supply sources.

4.1.2 EM-31 or EM-34 Surveying Procedures

The field procedure for conducting an EM survey using the EM-31 or EM-34 is described below:

1. A visual survey along the proposed traverses will be conducted. The visual survey will include notation of overhead wires, manhole covers, and indications of buried cables or gas lines.
2. Excessive amounts or large pieces of metal on the ground surface will be noted in the field notebook.
3. Large nearby variations in topography (within 50 feet) will be noted in the field notebook.
4. The instrument battery will be checked for sufficient charge and the instrument tested using manufacturer's procedures for proper operation.
5. The site survey traverse will be initiated with the EM instrument. When using the EM 34-3, beginning with transmitter at the EM traverse endpoint, the receiver will be moved to the appropriate coil spacing, as indicated by the instrument meter. If the EM-31 is being used, coil spacing is fixed. (Note: The obtained reading is valid at the midpoint between the two coils).
6. The obtained conductivity value will be recorded in a data logger or field notebook.

The above procedure will be continued for each station along each traverse. For two or more coil spacings or orientations at each station, multiple passes along each traverse will be required, ensuring that occupied stations are repeated through the entire traverse with each coil orientation.

Data will be downloaded from the data logger or field notebook to the computer for further analysis.

4.1.3 Data Processing and Interpretation

The standard procedure for processing and interpreting the EM data obtained using the EM-31 or EM-34 is described below.

1. Conductivity values over the surveyed site for each coil spacing will be plotted.
2. By comparing the results of all plots, the data will be contoured to determine what variations of conductivity exist laterally.

4.2 Geonics EM-61

The EM-61 is a time domain electromagnetic instrument that is specifically designed to discriminate between earth materials and highly conductive metallic targets that are buried within the earth. It is capable of detecting both ferrous and non-ferrous metallic objects. The instrument generates rapid electromagnetic pulses through a transmitter coil. These pulses induce secondary electromagnetic fields in the near subsurface materials. The secondary electromagnetic fields induced from moderately conductive subsurface materials (soil and rock) are of relatively short duration. However, the secondary electromagnetic fields induced from metallic objects such as a drum are of relatively long duration. The EM-61 measures this prolonged response from metallic objects after the electromagnetic response from conductive earth materials dissipates, allowing the resolution of buried metallic targets. Depth of investigation of the instrument is relatively unaffected by site specific subsurface conditions, and is reportedly capable of detecting a single 55 gallon drum to a depth of 10 feet. Using a data logger, the instrument records the electromagnetic responses in units of millivolts. The electromagnetic response values are then plotted on a map so that their variation over the site can be analyzed.

4.2.1 Preparation

Steps 1 through 6 in Section 4.1.2 for the EM-31 or EM-34 will be performed prior to initiation of any data collection. Design of appropriate field or data acquisition parameters must consider the following:

- Station spacing affects survey resolution. A station spacing of 0.5 to 5 feet is commonly used. Actual spacing must take required resolution into account.
- Accurate definition of an electromagnetic profile anomaly requires three or more anomalous readings.
- Background electromagnetic response noise must be evaluated and/or determined to assess the potential usefulness of an electromagnetic survey. High electrical noise levels can make interpretation difficult and can cause significant anomalies to be overlooked. Actual background electrical noise must be considered when collecting and interpreting the electromagnetic data.

4.2.2 EM-61 Surveying Procedures

The standard field procedure for conducting an electromagnetic survey using the Geonics EM-61 is described below:

1. Steps 1 through 4 of Section 4.1.2 will be performed.
2. If the survey is to be conducted using the measuring integrated trailer or wheel trigger mode, the instrument will be calibrated by conducting a test line of set length. Several passes will be conducted along the test line to calibrate the wheel trigger distance to the site specific ground conditions. No other calibration of the EM-61 is required.
3. The instrument battery will be checked for sufficient change and instrument tested using manufacturer's procedures for proper operation.
4. The site survey traverse will be initiated with the EM-61 instrument.
5. The obtained electromagnetic response values will be recorded in a data logger.
6. The above procedure will be continued for each station along the traverse line.
7. Data will be downloaded from the data logger to the computer for further analysis.

4.2.3 Data Processing and Interpretation

The standard procedure for processing and interpreting the electromagnetic data obtained using the EM-61 is described below.

1. If data were collected using the wheel mode trigger, the data stationing will be corrected using the actual start and end station values.
2. Electromagnetic response values over the surveyed site will be plotted.

By comparing the results of all plots, the data will be contoured to determine the lateral and vertical variations of the electromagnetic response over the site. Subsurface anomalies, such as lineaments, variations in soil densities, or buried objects, can be revealed during the data analyses and comparison.

4.3 Magnetic Survey

A magnetic survey involves the measurement of the earth's magnetic field at various points on the ground surface and delineation of the local variation of the magnetic field. Variations in magnetic susceptibility of subsurface materials will produce anomalies within the magnetic field that can be measured using a magnetometer. Both the total magnetic field data and the magnetic vertical gradient data can be measured with the magnetometer. The total field intensity is simply the magnitude of the earth's magnetic field vector and the magnetic vertical gradient is the difference in the total field measured at different heights above the ground surface. The magnetic total field and vertical gradient values can be plotted on a map so that their variation over the site can be analyzed. Note that non-ferrous metals, such as aluminum or brass will not create a response that the magnetometer can measure and must therefore be detected by other methods.

4.3.1 Preparation

Steps 1 through 6 in Section 4.1.1 will be performed prior to initiation of any data collection. Design of appropriate field or data acquisition parameters must consider the following:

- Station spacing affects survey resolution. A station spacing of 5 to 25 feet is commonly used. Actual spacing must take required resolution into account.
- A magnetic anomaly is defined by three or more contiguous anomalous readings.
- Background magnetic noise must be evaluated and/or determined to assess the potential usefulness of a magnetic survey. High noise levels can make interpretation difficult and can cause significant anomalies of interest to be overlooked. Actual background noise must be considered when collecting and interpreting the magnetic survey data.
- High resolution magnetic surveys require the use of an extra magnetometer as a magnetic base station to allow removal of drift and diurnal variations. On occasion, this requirement may be reassessed depending on survey objectives. If an additional magnetic survey base station instrument is not used, repeated ties to a field base station must occur approximately every one-half hour to allow for drift corrections.
- Survey and traverse endpoints used in the field should be with a wooden stake or plastic pinflag. Stations should be identified with a designation based on a coordinate system that is consistent with the location where the work is conducted and the requirements of the interpretive software to be used in data processing.

4.3.2 Magnetometer Surveying Procedures

A standard field procedure for conducting a magnetometer survey is described below:

1. A visual survey along the proposed traverses will be conducted. The visual survey will include a review of site utility plans; notation of overhead wires, notation of manhole covers, buried cables, or indications of other buried lines. Utility locator services will identify telephone and utility features, if present.
2. Excessive amounts or large pieces of metal on the ground surface will be noted in the field notebook.
3. Large nearby variations in topography (within 50 feet) will be noted in the notebook.
4. The instrument battery will be checked for sufficient charge and the instrument tested using manufacturer’s procedures for proper operation.
5. Prior to commencing of data collection activities, the operator will remove ferromagnetic objects from his/her body and clothing including but not limited to jewelry, steel toe boots, belt buckles, keys, coins and watches. These objects can cause interference resulting in erroneous data. The base station magentometer will be placed in an area away from interference from ferromagnetic objects, including but not limited to buried waste, fences, automobiles and buildings. Base station readings can be obtained using a continuously recording base station magnetometer or by reoccupying a field base station using the mobile magnetometer. Regardless of the method used, base station data will be collected a minimum of once every 30 minutes.

6. The base station magnetometer and the mobile magnetometer will be time synchronized and will be tuned to the value appropriate for the latitude and longitude of the area. Tuning of the instruments will be done in accordance with the manufacturer's procedures as described in the operation manual.
7. The site survey traverse will be initiated using the mobile magnetometer. Depending on the exact make and model of the magnetometer, the sensor may have to be aligned with magnetic north.
8. The obtained magnetic response values will be recorded in the magnetometer memory, in a data logger, or field notebook. If the instrument indicates a high noise level, a visual scan of the area will be made to try to identify the source of the noise. Then the reading should be repeated and an appropriate note made in the field book.
9. The above procedures will be continued for each station along each traverse.

Upon completion of each day of data collection, the data will be downloaded from the magnetometer(s) or from the field notebook to a computer for further analysis.

4.3.3 Data Processing and Interpretation

The standard procedure for processing and interpreting magnetometer survey data is described below:

- Magnetometer survey response values must be corrected for magnetic drift according to standard geophysical practices. If a mobile magnetometer was used in conjunction with a base station magnetometer, correction of diurnal effects can be accomplished using the data reduction software provided with the instruments. If a single magnetometer was used, the total field data will be corrected using the reoccupied base station data.
- Plot the corrected values at each station location, producing a series of profiles or a grid, and contour the data to determine variations of the magnetic field.
- Using available information (borehole, geophysical, site conditions), interpret the magnetic anomalies with respect to possible sources.

4.4 round Penetrating Radar

Ground penetrating radar (GPR) involves a system that transmits electromagnetic pulses into the ground from an antenna near the surface. These pulses are reflected from a variety of subsurface interfaces back to the receiver. As the antenna is towed along a survey line, the GPR signals are processed and displayed on a graphic recorder. Data are displayed as two-dimensional continuous profiles along the surveyed line, depicting time versus distance. The display is similar to a geologic section, except that the record is a time section rather than a depth section. GPR can achieve excellent resolution of subsurface features when favorable conditions exist.

However, actual depth penetration is highly site-specific and depends on the near-surface soil conductivity. Highly conductive soils, such as clays, can reduce penetration to less than three feet. Less conductive soils, such as clean, well-sorted sandstone, will allow depth penetration of 30 feet.

4.4.1 Preparation

Two preliminary procedures must be conducted prior to GPR data collection. These procedures are:

1. Design the appropriate field parameters, given the purpose of the survey (e.g., orientation of traverses or a grid, grid spacing, spot surveys, frequency of antenna, necessity of antenna shielding, etc.)

2. Survey the traverse end points and mark these locations in the field with lath or wooden stakes. Transfer the traverse locations to the correct position on the base map.

Design of appropriate field or data acquisition parameters must consider the following:

- The antenna and associated transmitter frequency used must optimize the penetration depth and required resolution given the survey purpose. Typical antenna frequencies range from 50 Mhz up to 1000 Mhz. Higher frequency antennas allow greater subsurface resolution, but penetration is reduced compared to that allowed by lower frequency antennas. A minimum of two antennas should be mobilized and available for testing for a given GPR application.

- For surveys utilizing grids, the spacing of the traverse affects the survey resolution. A traverse spacing of 3 to 50 feet is commonly used. Actual spacing must take required resolution into account.

- The method of antenna towing must be evaluated given the site conditions. For smooth surfaces or terrain, the antenna can be towed directly on the surface. For areas with a significant cover of vegetation or with stones and rocks at the surface, the antenna may need to be suspended 6 to 18 inches above the ground or carried in a plastic, non-conductive wagon to prevent antenna damage and reduce or eliminate potentially dubious GPR data collection.

- Antenna shielding should be considered and designed to handle the field conditions. Surface features such as fences, powerlines, and trees can appear as prominent reflections on the GPR record.

4.4.2 Ground Penetrating Radar Surveying Procedures

A standard procedure for conducting a GPR survey is described below:

1. A visual survey along the proposed traverses will be conducted. The visual survey will include notation of overhead wires, manhole covers, monitoring wells, and indications of buried cables or gas lines.

2. Excessive amounts or large pieces of metal on the ground surface will be noted in the field notebook. Nearby buildings (within 50 feet) or significant variations in topography will be noted in the field notebook.

3. The moisture content of the soil, alluvium, or investigated media, as well as relative clay content, may significantly affect the penetration depths, and should be noted.

4. Conduct a test line using the instrument manufacturer's procedures. Instrument settings must be optimized to obtain appropriate data give project goals. Specific recording parameters that must be optimized include, but are not limited to, the following:

    - Radar scan speed
    - Signal range gain
    - High low pass filter settings
    - Transmitter pulse rate
    - Time range for recording
    - Recording printer speed
    - Antenna towing speed

Instrument settings should be varied during the surveying of the test area to determine the optimum recording settings. When evaluating GPR responses in a test area, the test should be conducted over a known buried feature in the survey area to help instrument setting optimization and to calibrate penetration depths. The GPR should be tested daily over the same features in the test area to use as a daily calibration and performance evaluation test.

1. Initiate a site survey traverse. Beginning at the GPR line endpoint, tow the antenna along the appropriate line at a rate, and using the optimum instrument settings, determined from the test line.

2. If hard copies of data from each traverse are printed or available, label all notations on the record to correspond to the notes made in the field book, including recording parameters.

Permanent copies of GPR data must be retained digitally on tape or disk, or on hard copy plots.

4.4.3 Data Processing and Interpretation

Data reduction of GPR data is limited. Most GPR data processing occurs in real-time (during data collection) through manipulation of the instrument settings. Interpretation requires the interpreter to consider all potential sources of a GPR anomaly, including interfering reflections from both surface and subsurface cultural features. For most GPR systems, additional processing techniques can be implemented if desired to reduce or eliminate noise effects from the data and enhance the results. Using site data, available borehole information (should it exist), or any other existing geophysical data, develop a subsurface model that is consistent with the available data.

5.0 Records

Oversight personnel will be responsible for documenting geophysical surveying. The documentation will be recorded at a minimum in the Field Notebook as discussed in *SOP-01 Note taking and Field Log* and on relevant data recording sheets accompanying the geophysical monitoring equipment. The information entered in the *Field Log* concerning geophysical surveying should include the following:

- Project/site location identification for geophysical survey
- Date and time (start and end, military time)
- Contract Task Order number
- Geophysical survey personnel (oversights name, operators name, company names)

- Geophysical survey equipment used (make and model)
- Equipment identification numbers
- Instrument specific data (instrument gain and time settings, instrument reading scale)
- General geophysical surveying methods and observations
- Weather and temperature
- Any deviations from the geophysical surveying methods outlined in SOP-26
- Any specific recording requirements outlined in section 6.

Dataloggers, hand-held GPS, or integrated personal digital assistants (PDAs) may also be utilized for additional field recording.

SOP-27

Passive Soil Vapor Surveys

SOP-27: PASSIVE SOIL VAPOR SURVEYS

1.0 Purpose

This standard operating procedure (SOP) describes the general methodology for installation and retrieval of passive soil vapor samplers for laboratory analysis.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in passive soil vapor sampler installation and retrieval activities at Galena Forward Operating Location (FOL), and was developed and should be performed per the following guidance documents:

- *Draft Field Sampling Guidance* (Alaska Department of Environmental Conservation [ADEC], 2010)
- *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009)
- *Appendix A, Project-specific Health and Safety Plan* (HSP)

This SOP focuses on the most commonly used soil sampling tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*

3.0 General

There are two basic types of soil vapor surveys typically performed during site assessments. The first type is an active soil vapor survey, where soil vapor is typically pumped into a sample container or directly into an analyzer, or if sample results of higher data quality than field screening are desired, the sample containers are shipped to the laboratory for analysis. The second type is the passive soil vapor survey where absorbent material is buried in the vadose zone so that the contaminant vapors can be selectively absorbed over time (typically over a one to two week period). The passive soil vapor samplers are retrieved and shipped to the laboratory for analysis. Passive soil vapor surveys are often used during site characterization to identify source areas and localized hotspots. This SOP only covers procedures for installing and retrieving passive soil gas samplers. SOP-15 covers procedures for obtaining active soil vapor samples with Summa™ canisters (or similar devices).

The Gore™ Sorber Module is an example of a passive soil vapor sampler for the screening of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs). The module is constructed of a chemically inert, vapor-permeable, and waterproof membrane. Housed within the membrane are adsorbents with an affinity for a broad range of organic compounds. VOCs and SVOCs compounds diffuse through the membrane and accumulate on the adsorbent material, as shown in Figure 1.

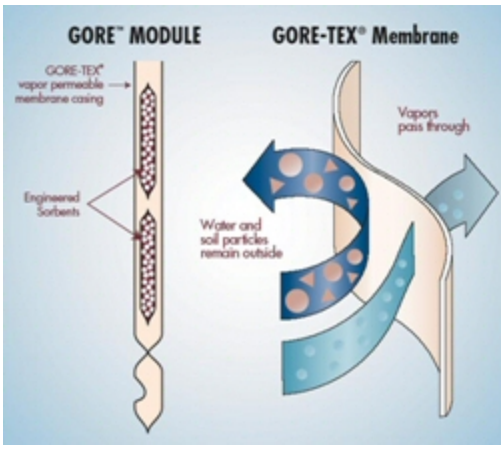

Figure 1. GORE™ Module Process (W. L. Gore & Associates, Inc., 2010).

Passive soil vapor modules are emplaced at the desired depth and location, exposed to the soil for an appropriate period of time, and then removed and submitted for laboratory analysis. Results are presented as total mass accumulated for the specific contaminants of interest and can be used as a qualitative screening value for directing future investigative work. The qualitative date from passive soil vapor sampling can be useful for identifying potential source areas, assessing soil vapor contaminates and concentrations, and evaluating the extent of soil vapor migration.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) supervises the development of the necessary project planning documents; assigns trained, qualified personnel to supervise the installation and retrieval of passive soil gas samplers as described in this SOP; and verifies that the necessary equipment and supplies are utilized to obtain representative soil vapor samples.

4.2 Field Team Leader

The Field Team Leader (FTL) supervises the installation and retrieval of passive soil gas samplers. The FTL is responsible for documenting all field related activities, and verifying that all onsite equipment is calibrated and correctly operated and maintained at all times.

4.3 Project Chemist

The Project Chemist is responsible for verifying that the laboratory selected to analyze vapor samples is qualified to do the work and meet the project data quality objectives (DQOs).

4.4 Field Sample Collector

The Field Sample Collector collects samples following procedures outlined in this SOP, and follows directions given by the FTL.

5.0 Procedure

The following sections provide a typical list of materials/equipment needed for installation and retrieval of passive soil gas samplers:

5.1 Equipment, Supplies, and Suppliers

The following list of supplies/equipment may be needed during the course of conducting a passive sampler soil vapor investigation. Check that all equipment used for passive soil vapor sampling has been verified by the source supplier to be pre-cleaned before use to eliminate the potential for cross contamination.

- Passive sample modules obtained from vendor/manufacturer
- Insertion rod or other installation tools provided by vendor/manufacturer
- String/wire from vendor/manufacturer
- Plug from vendor/manufacturer
- Plastic zip-ties
- Aluminum foil and quick drying grout if installation under pavement
- Nitrile gloves
- Camera
- Flags and location map
- *Field Log Book* and *Field Data Collection Forms*
- Instructions from supplier (examples included as SOP-27, Attachments 1 and 2)
- Permanent markers (care should be taken any time markers are used around vapor sampling equipment because of the presence of VOCs in most markers)
- Shipping containers and custody seals

Obtain equipment necessary for passive sampler investigations by contacting appropriate vendors/manufacturers, as follows:

- Gore™ Sorber modules and supplies: Contact the W.L. Gore & Associates, Inc. sales office in San Francisco, phone (415) 648-0438. For questions regarding installation or retrieval, phone Jim Whetzel or Diane Cooper at (410) 392-7600.
- Vaportec™ modules and supplies: Contact Vista GeoScience in Golden, Colorado, by phone at (930) 277-1694.

5.2 Passive Soil Vapor Module Installation

Deploy passive soil vapor modules following the procedures below. However, the manufacturer's recommended procedures should be followed and take precedent over these general instructions. Examples of vendor instructions are included in SOP-27, Attachments 1 and 2. Alterations to these procedures may be necessary depending on project objectives.

- Prepare passive soil vapor samplers with the needed length of wire or cord in accordance with manufacturer's directions.
- Using a Direct Push Drill Rig (See SOP-05), hand auger, slide hammer, or handheld rotohammer, drill a down to the desired sampling depth. Installation at shallow depths in

soft soil can often be obtained with handauger or rotohammer. Refer to manufacturer's directions for diameter of the hole (typically 1/2 to 2 inches).

- Install passive soil vapor sampler into borehole as described in manufacturer's directions.
- Seal the hole at the surface with a plug supplied by the manufacturer, inserted so that it is flush with the top of the natural soil. If installation is under asphalt or concrete the hole may have to be sealed with aluminum foil to protect the sampler and surface sealed with temporary quick drying cement.
- Clean all downhole tools and change gloves before moving to the next location.

5.3 Passive Soil Vapor Sample Module Retrieval

- Open the top of the hole by removing the plug. If the hole has been sealed with concrete, a hammer and chisel or rotohammer can be used, taking care not to cut the wire that holds the sampler in place.
- Lift the sampler out and verify that the sample identification label is correct
- Place the sampler in a vial supplied by the manufacturer and seal the lid. Make sure the lip of the vial and the thread of the cap is clean, to ensure an adequate seal.
- Backfill holes by filling with bentonite chips or other suitable material.
- Samplers should be managed in accordance with *SOP-19, Sample Handling and Custody*.

6.0 Records

All field measurements and observations will be recorded in the Field Notebook (see SOP-01). Field measurements should include sample location, sample depth, sample collection start and end time, weather observations, serial numbers of passive sampler and information on any other equipment used.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). July 2009. *Draft Vapor Intrusion Guidance for Contaminated Sites*.

W.L. Gore & Associates, Inc. 2010. *GORE™ Modules for Passive Soil Gas Collection.* http://www.gore.com/en_xx/products/geochemical/petroleum/surveys_petroleum_modules.html. Accessed February 17, 2010.

8.0 Definitions

None.

9.0 Attachments

Attachment 1: *Gore™ Module Information and Installation*

Attachment 2: *VaporTec Information and Installation*

SOP-28

Multi–Increment® Sampling for Surface Soil

SOP-28: MULTI–INCREMENT® SAMPLING FOR SURFACE SOIL

1.0 Purpose

This standard operating procedure (SOP) summarize requirements for the effective design and field implementation of multi-increment® sampling (MIS) of soil for site characterization at contaminated sites. The MIS process provides a view of mean contaminant concentrations over the area of a decision unit (DU).

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in MIS sampling at Galena Forward Operating Location (FOL) projects and tasks and was developed according to Alaska Department of Environmental Conservation (ADEC) and other reference documents, including the following:

- *Draft Guidance on Multi Increment Soil Sampling* (ADEC, 2009)

This SOP focuses on the most commonly used MIS tasks and applications anticipated at Galena FOL and should be used in conjunction with other applicable project SOPs in Appendix H, Field Standard Operating Procedures, including the following:

- *SOP-01, Note Taking and Field Log Books*
- *SOP-05, Hollow Stem Auger and Direct Push Drilling Methods*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*

3.0 General

The objective of environmental sampling is often to determine the nature and quantity of contaminants present in a specific medium at a given site. MIS is statistical sampling methodology used to represent a specific population (DU) and provide a foundation for defensible decision making (Envirostat, 2010). The foundation of MIS is based on the theory of particulate sampling developed by a geologist, Pierre Gy, to improve the quality of data gathered in support of mining and mineral exploration (Pitard, 1993). MIS improves the reliability of sample data by reducing the variability of the data as compared to conventional discrete sampling strategies (Ramsey and Hewitt, 2005; Jenkins et al., 2005). In addition, MIS sample data have higher reproducibility. MIS does this by obtaining multiple sample increments throughout a DU (defined as the area or volume in question). These increments are combined into one bulk MIS sample that is submitted to the laboratory, resulting in a better representation of mean concentrations in a DU. MIS approaches can be used for collection of non-volatile and volatile contaminants in surface and subsurface soils (Hawaii Department of Health [HDOH], 2008; ADEC, 2009).

Heterogeneity is common when sampling contaminated environmental media, and a large portion of sampling error is a result of compositional and distributional heterogeneity. Both compositional and distributional heterogeneity contribute to fundamental error (FE) and grouping and segregation error (GSE). To minimize FE and GSE, enough mass must be

collected and analyzed to represent all particles in the exact proportion found in the population and to collect sample increments randomly and in enough locations to capture the spatial variability. MIS controls these two major types of sampling error in most soil sampling situations (ADEC, 2009). In general, a minimum 30 to 50 random increments are required; however, if greater distributional heterogeneity is expected, more increments are required. Under most circumstances, MIS samples are prepared by collecting a minimum of 30 increments of soil from a specified DU and combining these increments into a single bulk MIS sample.

A DU is the defined area or volume for which a decision must be made (for example, deciding whether risks are acceptable or not). For valid MIS data, sampling must be used in conjunction with an appropriate DU (ADEC, 2009). Therefore, the identification of DUs is one of the most important factors when using MIS. DUs should be restricted to actual source zones and must not incorporate large, uncontaminated areas. The boundaries of the DU should be well defined and supported by background or investigation information, such as historical photos, historical documentation, site interviews, and field screening techniques. DUs should be identified and delineated during project planning and approved by the client and ADEC before obtaining MIS samples. Because MIS provides an “average” concentration for a DU, agreement on the DU boundaries is crucial.

In addition to sampling an appropriately defined DU, MIS sample increments must be collected from multiple random locations within the DU. This SOP details a stratified random approach to establish a consistent protocol.

Once the random MIS sample increments are collected in the field, the increments are placed in a single sample container to produce the single MIS sample. The MIS sample is sieved to a particle size less than 2 millimeters (mm) to remove large particles and reduce sample mass. Soil particles less than 2 mm are generally considered soil and are of most interest for contaminant analysis, while larger particles are considered gravel, rocks, or other material (for example, sticks and roots) (HDOH, 2008). Sieving the soil sample to less than 2 mm also establishes the maximum particle size of the sample, which is necessary to determine the minimum sample mass necessary for extraction/analysis in the laboratory. Sieving can be conducted either in the field or the laboratory; however, sieving samples in the field could be difficult because of high moisture content in soils or lack of adequate field facilities, appropriate equipment, or planning. Therefore, laboratory processing of the field samples is preferred because of the more "controlled" working environment, where sieving is facilitated by initial air-drying of the samples (HDOH, 2008).

After sieving, the MIS sample must be either sub-sampled in the field for mass reduction, or the entire sieved MIS may be sent to the laboratory for processing and sub-sampling before analysis (HDOH, 2008). During sub-sampling, the entire sieved sample is spread out into a thin layer (approximately 0.25 inch thick) and approximately 30 increments are collected in stratified random locations across the (spread-out) sample.

The MIS procedures in this SOP are most applicable to gasoline-range organics (GRO); diesel-range organics (DRO); residual-range organics (RRO); volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylenes (BTEX); semivolatile organic compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. MIS techniques may also be used for metals analyses, but sample grinding would be required to decrease particle size or increase digestion mass (ADEC, 2009). If grinding is proposed for metals MIS samples, the samples must be prepared by using a puck mill grinder (ADEC, 2009).

Considerations should also include the possibility of metals being introduced into the sample from the grinder (for example, chromium) and arsenic being released from the soil matrix via the grinding process.

Standard MIS procedures may not be applicable to peat, tundra, and other matrices not amenable to sieving. For sampling in these matrices, alternate sample collection, processing, and sub-sampling methods will be required and alternate sample methods should be pre-planned and approved by ADEC before sample collection. In general, MIS sample collection, including increment sampling, sieving, sample preparation, and sub-sampling should be well documented in the field notebook and photographed when valuable.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and engaging field staff with adequate experience and training to successfully comply with and execute project-specific SOPs and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to adequately identify the best methods and technology for the job given the current understanding of the site and project goals. In addition, the PM should be consulted if complications arise in following sample handling and custody procedures.

4.2 Field Manager

The Field Manager (FM) is responsible for the coordinating and scheduling daily field activities. In addition, the FM is responsible for training field staff engaged in this activity and for compliance with this SOP.

4.3 Field Data Manager

The Field Data Manager (FDM) is responsible for the maintaining and managing the sample tracking and scheduling program used to track field MIS samples. If field sieving or sub-sampling of MIS samples are required, the FDM may be required to conduct these activities. The FDM should consult the FM, Field Team Leader (FTL), and Project Chemist regarding MIS field sample processing.

4.4 Health and Safety Manager

The Health and Safety Manager (HSM) is responsible for site-specific HS&E oversight and overall compliance with project HS&E requirements. The HSM conducts HS&E evaluations, selects the appropriate safety procedures for the project, lists the requirements in the *Project-specific Health and Safety Plan* (HSP) (Appendix A), and coordinates with the FM to complete and certify the HS&E program.

4.5 Field Team Leader

The FTL is responsible for maintaining compliance with MIS sample techniques and methods, particularly the procedures to be used. The FTL, or their designee, should know the requirements of MIS and maintain adequate documentation of sample collection activities. The FTL should take responsibility for collecting MIS samples accurately and

correctly and for coordinating with the FM and FDM to successfully conduct any MIS field sample processing before laboratory analysis.

4.6 Field Sampler

The Field Sampler, under the supervision of the FTL (who may be the same person), should confirm that samples are correctly collected, labeled, tracked by chain of custody, and stored until they are delivered to the FTL or FDM. The Field Sampler should maintain custody of the samples until they are relinquished to the FTL or FDM. The Field Sampler is responsible for informing the FTL and/or FDM of sampling conditions and potential deviations in sample collection.

5.0 Procedures

5.1 Tools and Equipment

Proper equipment should be used that results in quality DU sampling design and collection of samples that do not contain more soil particles from one part of the sample than from other parts. The heterogeneous distribution of contaminated particles in the soil could lead to biased sample results. Therefore, care should be taken when designing and constructing DU grids, and sample increments should be collected in a manner that produces a cylindrical or core-shaped sample. Cylindrical or core-shaped samples can be accomplished using a soil core sampler (preferred) or a trowel or large spoon (if used to collect a core-shaped sample). The most appropriate type of sampling device depends in part on the hardness of the soil or how rocky it is. Whatever tools are used, the objective should be collecting core-shaped sample increments. It is important to understand field conditions and to test proposed sampling tools and methods at the site before selecting a particular type or combination of tools.

The following tools and equipment are recommended for MIS:

- Compass
- Calculator
- Tape measure
- Survey stakes
- Pin-flags
- Survey twine
- Stake hammer (2 pounds)
- GPS handheld unit (for example, Trimble GeoXT or GeoXH)
- Disposable soil core sampler (for example, TerraCore® sampler, En Core® sampler)
- Pre-tared, pre-preserved volatile sample containers
- Large, unpreserved non-volatile sample containers (for example, zipper-seal bags or 2-gallon buckets)
- Large stainless steel spoons or scoops
- Small stainless steel spatula or spoon

- Stainless steel trowels
- Stainless steel trays (e.g. cookie sheets)
- #10 grain size (2-mm) sieves
- Digital camera
- Field notebooks

5.2 Reconnaissance, Planning, and Field Staging

During the DU planning process, conduct a historical records search and site walk to determine if there may be areas with elevated levels of contamination because it may be desirable to break these “hot spots” into separate DUs. This is also useful for planning sample collection locations if access to some areas will be difficult. Consider the logistics of sampling around buildings or in areas of heavy vegetation when planning the DU grid.

5.3 Decision Unit and Grid Construction

To collect an MIS sample, a systematic random sample collection scheme is used that spreads out the sample collection points roughly equally across the DU (HDOH, 2008). For example, a square-shaped DU could be divided into a 30-cell grid pattern containing five rows and six columns, with one increment collected from each grid cell in a systematic random fashion. For more rectangular-shaped DUs, fewer rows and more columns might be used. The number of rows and columns of grid cells may be modified as needed for odd-shaped DUs as long as a minimum of 30 grid cells of approximately equally size are constructed. Figure 1 shows a few example grid designs for rectangular and non-rectangular DUs.

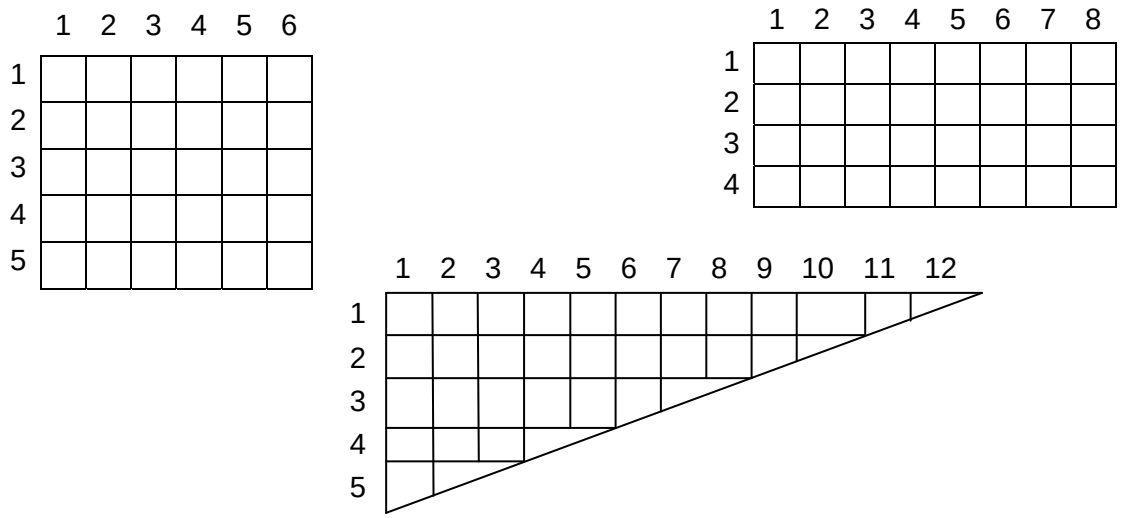

Figure 1. Example MIS Sample Grid Designs

The following procedures should be used for MIS sample grid construction:

1. Lay out the DU corners according to the sample design indicated in the site-specific sampling plan in Appendix D. If the orientation of the DU isn’t predefined in the site-specific sampling plan, all MIS sample grids should be constructed with top of the grid to

the north or as most practical based on site obstacles. Locate the corners of the sample grid by using one of the following methods:

- Use survey or GPS coordinate locations.
- Consider proximity to landmarks or features (for example, 10 feet west of the southwest corner of Building XYZ).
- Use indicators of historical activities (for example, less mature vegetative growth that might indicate the edge of a historical use area).
- Center around a specific location. The following steps are suggested for constructing a “square” grid boundary effectively around a specific location (see Figure 2):

  A. Mark the center of the DU with a wooden stake.

  B. Determine the overall width and length of the DU from the site-specific sampling plan (Appendix D). Using a compass and tape measure, measure half the overall DU length to the top of the grid (for example, north direction). Stake the center of the top border. Note the compass bearing from the center stake to the top border stake.

  C. Using the compass and tape measure, measure half the overall DU width from the top border stake at a perpendicular compass bearing to either the left or right of the top border stake. Stake this location, which should be either the top right or top left corner of the DU (for example, northeast or northwest corner of the DU).

  D. Using the compass and tape measure, measure the entire DU width from the corner stake, past the top center stake and to the adjacent top corner stake, making sure the two corner stakes and the top center stake are in line.

  E. Calculate the diagonal (hypotenuse) distance from one of the top corners to the opposite bottom corner. $\text{Length}^2 + \text{Width}^2 = \text{Hypotenuse}^2$. Using the tape measure, measure the calculated distance from one of the top corners to the opposite bottom corner, making sure the two corner stakes and the DU center stake are in line. Stake the bottom DU corner.

  F. Conduct the previous step again for the opposite bottom corner.

  G. Measure and adjust the width and length between the top corners and the bottom corners. If the width, length, and diagonal measurements of the DU are approximately equal, respectively, the DU should be “square.”

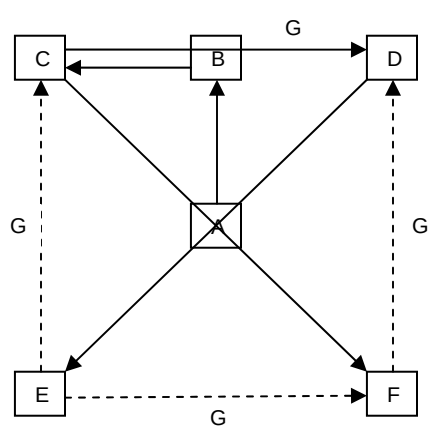

Figure 2. Suggested Method for Constructing a Square Decision Unit

2. Once the DU grid corners are determined and staked, start to subdivide the DU into a minimum of 30 equally sized increment grids cells. Begin by placing stakes at each row and column division along the boundaries of the DU.
3. Use flags or survey twine to define the edges of each grid cell and complete construction of the MIS sample grid. Figure 3 shows a completed MIS sample grid.

Figure 3. Example Completed MIS Sample Grid

4. Sketch the MIS sample grid design, orientation (compass bearing), overall dimensions, cell dimensions, nearby features, and any other valuable information in the field notebook. Photograph the completed MIS sample grid for future reference. Survey the center and corner stake locations of the DU or record them with a GPS unit.

5.4 Selection of Random Increment Locations

This SOP presents a stratified random approach to collect a sample increment from a random location in each DU grid cell. Use the following procedures to determine the random sample location within each grid cell:

1. Begin by theoretically subdividing each grid cell into four quadrants, as shown in Figure 4.

NW = 1	NE = 2
SW = 3	SE = 4

Figure 4. Theoretical Quadrants of Each Grid Cell

2. Randomly determine which quadrant will be sampled within each grid cell using the list of randomly generated numbers in Table 1. To select a random quadrant to sample, ask an individual (can be anybody) to select a number between 1 and 30.

3. Find the number that the individual selected in the first column of Table 1 and determine the corresponding number between 1 and 4 next to the selected number. The corresponding number between 1 and 4 denotes which quadrant should be sampled in each grid cell. Sample from the same selected quadrant in all grid cells. The random numbers in the second column of Table 1 were generated using the Microsoft Excel® RANDBETWEEN random number function. Additional random numbers can be generated using the same Excel function or another random integer generator (http://www.random.org/integers/) (Haahr, 2010).

Table 1. List of Randomly Generated Values and Corresponding Theoretical Grid Cell Quadrants

Individual's Selected Number	Randomly Generated Number	Theoretical Quadrant to Sample	Individual's Selected Number	Randomly Generated Number	Theoretical Quadrant to Sample
1	4	SE	16	3	SW
2	1	NW	17	4	SE
3	2	NE	18	1	NW
4	2	NE	19	3	SW
5	2	NE	20	4	SE
6	3	SW	21	1	NW
7	1	NW	22	3	SW
8	4	SE	23	2	NE
9	3	SW	24	1	NW
10	3	SW	25	4	SE
11	4	SE	26	3	SW
12	2	NE	27	4	SE
13	3	SW	28	4	SE
14	2	NE	29	1	NW
15	2	NE	30	4	SE

4. Once a number is selected and used, cross out that selected number in Table 1 and do not reuse that number for another MIS DU. If an individual selects a previously selected number, ask the person to select another number instead. Continue to use numbers from Table 1 until all 30 selection values are used.

5.5 Sample Collection

5.5.1 Volatile Analyses Sampling (VOCs, GRO, BTEX)

The concern with MIS for volatile analyses is that collecting and sieving the sample material leads to volatilization of the contaminants. Therefore, MIS samples for volatile analyses must be collected before those for non-volatile analyses, and each sample increment must be deposited directly into a methanol-preserved sample container to reduce contaminant losses due to volatilization. To minimize the potential loss of volatiles, sample increments should be collected with minimal disruption and as quickly as possible to minimize exposure to ambient air.

In addition, sieving must not be performed for volatile analyses (that is, for GRO, BTEX, or VOCs). Because samples for analyses of volatiles cannot be sieved, total sampling error should be minimized by submitting additional sample mass to the laboratory for analyses, such as 60 to 150 grams of soil. Additionally, the individual increments should consist of smaller particles (less than 2 mm) to the extent possible so that the volatile sample matrix is similar to the non-volatile sieved sample matrix and to minimize FE. Large rocks or clumps of soil should not be collected as part of sampling for volatile analyses because they increase sampling error.

Before sampling, the proper pre-tared containers and methanol volume must be provided by the approved project laboratory. The laboratory should provide the correct pre-tared, narrow-mouthed, amber bottle containing methanol preservative to facilitate MIS (ADEC, 2009). Anticipate the amount of sample to be collected, the required volume of preservative, and the necessary sample container size before mobilizing to the field. The sample container should be large enough to prevent preservative loss due to splashing or leaking during sampling and shipping.

The following procedures should be used for MIS for volatile analyses:

1. Begin by placing the appropriate amount of methanol into the narrow-mouthed, amber sample container, if not pre-preserved by the laboratory. Volatile organic analyses require that samples be field preserved with a minimum 1:1 ratio of methanol preservative to sample material (for example, 1 gram of soil to 1 milliliter of methanol). Additional soil mass is preferred as long as the soil remains completely submerged in the methanol at all times (ADEC, 2009).

2. Using decontaminated hand tools (for example, shovel, hand auger), excavate a small surface soil sample test pit or boring to a depth of 6 inches below ground surface (bgs) anywhere in the selected quadrant of the first DU grid cell (for example, NW, NE, SW, or SE). If the selected quadrant is obstructed (for example, by a boulder or site feature) or observably stained, the selected quadrant should be avoided and a substitute quadrant should be randomly selected and sampled instead. Note and sketch observable stains and sampling obstructions in the field notebook. If stains are observed, notify the FM of the stain so that discrete soil sampling of the stain can be considered.

3. Prepare to collect MIS sample increments by putting on a new pair of disposable nitrile gloves immediately before collecting soil samples. The same pair of gloves can be worn to collect each sample increment in the DU as long is care is taken to avoid cross-contamination. If personnel are transitioning between using hand tools to excavate and to collect samples, a new pair of disposable nitrile gloves should be put on before collecting samples.

4. Collect a 2- to 5-gram MIS sample increment for either VOC, GRO, or BTEX analysis at approximately 6 inches bgs using a soil core sampler (for example, TerraCore® or En Core® sampler) with a new, disposable sample syringe or tip, as described in Section 5.7 of *SOP-07, Surface and Subsurface Soil Sampling*. Immediately place the soil increment directly into the sample container containing the methanol preservative. Immediately replace the lid on the container.

5. Repeat Step 3 at the same location and sample depth for any additional volatile contaminant analyses, such as VOCs, GRO, and BTEX.

6. Collect a second 2- to 5-gram MIS sample increment for percent moisture analysis using the same core sampler from the same previous location and sample depth. Place the soil increment in a similar unpreserved 4- or 8-ounce sample container. Use the smallest sample container possible; if thirty, 5-gram MIS increments of a low-density mineral or highly organic soil are collected, an 8-ounce sample container may be necessary. This unpreserved sample must be submitted to the laboratory for a percent moisture determination for the volatile analyses.

7. Proceed to the next grid cell and repeat Steps 2 through 5, collecting sample increments from the same grid cell quadrant and same sample depth. Extrude each soil increment into the same methanol preserved and unpreserved sample containers, as appropriate, until all grid cells in the DU are sampled. It is acceptable to use the same hand tools, soil core sampler, and disposable sample syringe or tip without decontamination because the MIS sample increments are combined.

8. Collect non-volatile and MIS duplicate and triplicate samples at the designated grid cells and DUs as discussed in Sections 5.4.2 and 5.4.3.

9. Once MIS increments are collected from all the grid cells in the DU seal the sample containers.

10. Label each sample container appropriately and complete the chain-of-custody form. Place the samples in a cooler at approximately 4 degrees Celsius (°C) (±2°C) and package the samples for delivery to the laboratory according to *SOP-18, Packaging and Shipping of Environmental Samples* and *SOP-19, Sample Handling and Custody.*

11. Record MIS activities in the field notebook as follows:

    - Sketch the MIS DU and grid pattern.
    - Indicate which random number from Table 1 was used and which grid cell quadrant was sampled in the notes.
    - Show the collection locations of all the MIS sample increments on the field notebook sketch.
    - Take photographs of the sampling activities and DU grid, including post-sampling photographs of the area to document the sampling locations.
    - Describe and classify the surface soils collected according to Universal Soil Classification System (USCS) nomenclature as described in *SOP-06*. At a minimum, do this for the bulk MIS sample after all the increments have been collected.

Additionally, during increment collection, the soil should be described at each significant change in lithology type encountered across the DU.

- Note any observed stains and sampling obstructions. Describe any color or odor for observed stains.
- Document any deviation from the MIS procedure, including sampling of a different grid cell quadrant.

5.5.2 Non-volatile Analyses Sampling (DRO, RRO, SVOCs, PAHs, PCBs, Pesticides, and Metals)

During the planning stages of an MIS effort, contact the project laboratory to determine the sample mass normally extracted for the required non-volatile analyses and the expected laboratory processes and requirements, including any laboratory grinding, sieving, or sub-sampling. Clear communication between the environmental professional, the laboratory, and ADEC is very important before field mobilization. Alaska DRO (AK 102) and RRO (AK 103) methods call for the extraction of 10 to 30 grams of sample soil. However, for MIS, a minimum of 30 grams of soil must be extracted per analysis to adequately minimize FE. The project laboratory must agree to this minimum extraction mass before sampling and comply with it during analysis. The analyzed mass should be stated in the laboratory data report for verification.

The following procedures should be used for MIS for non-volatile analyses:

1. Using decontaminated hand tools (for example, shovel, hand auger), excavate a small surface soil sample test pit or boring to a depth of 6 inches bgs anywhere in the selected quadrant of the first DU grid cell (for example, NW, NE, SW, or SE). If the selected quadrant is obstructed (for example, by a boulder or site feature) or is observably stained, the selected quadrant should be avoided and a substitute quadrant should be randomly selected and sampled instead. Note and sketch observable stains and sampling obstructions in the field notebook. If stains are observed, notify the FM of the stain so that discrete soil sampling of the stain can be considered.
2. Prepare to collect MIS sample increments by putting on a new pair of disposable nitrile gloves immediately before collecting soil samples. The same pair of gloves can be worn to collect each of the sample increments within the DU as long is care is taken to avoid cross-contamination. If personnel are transitioning between using hand tools to excavate and to collect samples, a new pair of disposable nitrile gloves should be put on before soil sampling.
3. Collect all volatile analyte samples before collecting non-volatile analyte samples, according to Section 5.4.1.
4. Begin by collecting a 35- to 60-gram MIS sample increment from approximately 6 inches bgs with a decontaminated large spoon or scoop, as described in Section 5.7 of *SOP-07, Surface and Subsurface Soil Sampling*. Avoid collecting material larger than 2 mm, such as stones and roots. All material greater than 2 mm will be sieved out, so more mass may be needed to achieve the required minimum 30 laboratory sub-samples after sieving.
5. Immediately place the soil increment directly into the large, clean, unpreserved sample container, such as a 1-gallon Ziploc® bag or plastic pail. If Ziploc® bags are used, double-bagging the sample is recommended in case the bag tears.

6. Proceed to the next grid cell and repeat Steps 1 through 3, collecting sample increments from the same grid cell quadrant and same sample depth. A bulk sample volume of approximately 2.5 to 5 kilograms, or 1-gallon of material, should be collected from the DU. It is acceptable to use the same hand tools and sample spoon or scoop between sample increments without decontamination because the MIS sample increments are combined.
7. Once MIS sample increments are collected from all the grid cells in the DU, seal the sample containers and verify that sufficient bulk sample volume has been collected.
8. Label each sample container appropriately and complete the chain-of-custody form. Place the samples in a cooler at approximately 4°C (±2°C). If the samples will be sent directly to the project laboratory, package the samples for delivery to the laboratory according to *SOP-18, Packaging and Shipping of Environmental Samples* and *SOP-19, Sample Handling and Custody.* Otherwise, continue to cool the samples until field sieving and sub-sampling can be conducted.
9. Record the MIS activities in the field notebook as follows:
   - Sketch the MIS DU and grid pattern.
   - Indicate which random number from Table 1 was used and which grid cell quadrant was sampled in the notes.
   - Show the collection locations of all the MIS sample increments on the field notebook sketch.
   - Take photographs of the sampling activities and DU grid, including post-sampling photographs of the area to document the sampling locations.
   - Describe and classify the surface soils collected according to USCS nomenclature as described in *SOP-06*. At a minimum, do this for the bulk MIS sample after all the increments have been collected. Additionally, during increment collection, describe the soil at each significant change in lithology type encountered across the DU.
   - Note any observed stains and sampling obstructions. Describe any color or odor for observed stains.
   - Document any deviation from the MIS procedure, including sampling of a different grid cell quadrant.

5.5.3 MIS Triplicate Sampling

An MIS duplicate and triplicate sample, known as a triplicate sample set, must be collected to verify that an MIS sample truly represents the DU and allows for the calculation of the relative standard deviation and 95 percent upper confidence limit (ADEC, 2009). At least one MIS triplicate sample set is required for all MIS projects. The MIS triplicate sample set must be collected from a DU with known or suspected reportable levels of contamination. For sites with multiple, similar, DUs, triplicate sample sets must be collected at a rate of 10 percent (ADEC, 2009). Additional triplicate samples may be required because of site conditions or non-similarity of DUs.

The following procedures should be used to collect an MIS triplicate sample set:

1. Determine the theoretical quadrant in which to collect the MIS duplicate and MIS triplicate samples using the process described in Section 5.3. The MIS duplicate and

triplicate should be collected from separate quadrants that are not the quadrant in which the primary sample was collected. Figure 5 shows example locations for a MIS triplicate sample set in a DU grid.

2. Collect MIS duplicate and triplicate samples for the same volatile and non-volatile analytes as the primary sample, following the procedures in Sections 5.4.1 and 5.4.2. Treat all MIS duplicate and triplicate samples the same as the primary MIS sample.

NW Primary Sample	NE Triplicate Sample
SW Duplicate Sample	

Figure 5. Example MIS Triplicate Sample Set Locations

5.5.4 Field Sieving and Sub-sampling

After field sampling and collection of a bulk MIS sample, non-volatile MIS samples must be sieved and sub-sampled either in the field or a laboratory. Sieving samples in the field can be difficult because of high moisture content in soils or lack of adequate field facilities, appropriate equipment, or planning; therefore, laboratory processing of the field samples is preferred under most circumstances. If field sieving and sub-sampling are required, use the following procedures:

1. Evaluate the soil and consider whether the moisture content is high enough that soil drying is necessary before the bulk MIS sample can be sieved with a #10 (2-mm) sieve. The sample should only be dried if necessary; drying may not be appropriate for some contaminants (for example, pesticides or PAHs), as there are currently insufficient data to document whether or not drying results in the loss of analytes (ADEC, 2009). If necessary, drying is only acceptable for less temperature-sensitive or photosensitive contaminants, such as DRO, RRO, and PCBs. Losses of these types of contaminants due to temperature, light, biodegradation, and other natural process are assumed to be minimal for normal drying times (1 to 3 days). Excessive drying times of 3 to 7 days are not recommended, and may affect analytical holding times and data quality. If excessive drying times are required, consider the data estimated and flag appropriately.

   If drying is required, follow these steps:

   a. Evenly spread the entire bulk sample onto a clean, decontaminated tray, such as a stainless steel cookie sheet, approximately ½ to 1 inch in thickness.

   b. Dry at ambient room temperature only until the soil matrix is amenable to sieving. Drying at elevated temperature (that is, baking) is unacceptable.

   c. Turn the soil on a minimum regular basis, if necessary to facilitate drying.

2. Begin sieving the entire bulk sample through a clean, decontaminated #10 sieve (2 mm) onto a clean, decontaminated container or tray (for example, stainless steel cookie sheet”). Do not sieve only enough bulk sample to collect sufficient analytical amounts; this invalidates the MIS process and is not permissible (ADEC, 2009). Approximately 0.5

to 1.0 kilogram of soil smaller than 2 mm should be available for sub-sampling after sieving.

3. Spread the remaining soil evenly on a clean, decontaminated tray (for example, stainless steel cookie sheet) approximately ½ inch deep.
4. Roughly divide the tray into 30 to 50 equal subsections.
5. Using a small, decontaminated laboratory spatula, collect an approximately 1-gram (approximately ½ tablespoon) subsample from each of the subsections using a laboratory balance to verify that proper sub-sample mass is collected. Because fines tend to settle, scrape the spatula along the bottom of the tray to make sure that every particle size is equally represented in the sample.
6. Place all 1-gram subsamples into a single, appropriate sample container (2- or 4-ounce) for submittal to the project laboratory. The final sample mass per sample container must meet the 30- to 50-gram minimum amount of material to be analyzed by the laboratory (30 grams of soil is approximately equal to 1 ounce of soil volume).
7. Repeat Steps 5 and 6 to collect additional samples for percent moisture analysis and for any additional analytes and place the sub-samples into separate sample containers as appropriate. A minimum 30-gram final sample size is required for analyte extraction and analysis; if additional material is available in the primary sample, this material may be used for the percent moisture analysis instead.
8. Label each sample container appropriately and complete the chain-of-custody form. Place the samples in a cooler at approximately 4°C (±2°C). Package the samples for delivery to the laboratory according to *SOP-18, Packaging and Shipping of Environmental Samples* and *SOP-19, Sample Handling and Custody.* Notify the FDM when final MIS sample preparation is complete so the samples may be logged into the sample tracking and scheduling program.
9. Record the MIS sub-sampling activities in a field notebook, including the methods and steps used for drying, sieving, and sub-sampling. Record the drying duration and soil turning frequency if the samples are dried. Take photographs of the sieving and sub-sampling activities. Briefly describe the bulk soil sample characteristics, including moisture content, color, observed range of grain sizes, percent fraction greater and less than 2 mm, any observed staining or odors, and any other observations. Document any deviation from the MIS procedure.

6.0 Records

Record all MIS activities, including field bulk sample collection, sieving, and sub-sampling, in a field notebook, according to *SOP-01, Note Taking and Field Log Books*. Chain-of-custody forms, photographs, and any other sampling documentation should comply with *SOP-01* and a copy should be retained in the project files.

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). March 2009. *Draft Guidance on Multi Increment Soil Sampling*.

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Jenkins, T. et al. 2005. *Representative Sampling for Energetic Compounds at Military Training Range*. Environmental Forensics, Volume 6, pp. 45-55.

Pitard, F.F. 1993. *Pierre Gy's Sampling Theory and Sampling Practice*. 2nd edition, CRC Press.

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8.0 Definitions

Bulk MIS Sample – The compilation of all MIS increments collected from a decision unit (DU).

Compositional Heterogeneity – The variability of contaminant concentrations between the particles that make up the population. This type of heterogeneity results in fundamental error (FE).

Decision Unit (DU) – The area or volume in which a decision must be made (for example, deciding whether risks are acceptable or not). The decision unit may be as small as a 55-gallon drum or as large as acres in size.

Distributional Heterogeneity – The non-random distribution across a population due to slight spatial variations. This type of heterogeneity results in grouping and segregation error (GSE).

Fundamental Error (FE) – A result of not representing proportional concentrations of all of the particles in a population.

Increment – A group of particles collected from a population with a single operation of the sampling device.

Sieving – Pouring material (for example, the bulk MIS sample) through a sieve.

Stratified Random Sampling – A statistical sampling method that divides the sample population (decision unit) into representative strata (grid cells), then randomly sampling within each stratum with the number of samples proportional to relationship of each stratum to the entire population.

Sub-sampling – Dividing the sieved bulk MIS sample to create a final laboratory sample.

9.0 Attachments

None.

SOP-29

Test Pit Excavation and Sampling

SOP-29: TEST PIT EXCAVATION AND SAMPLING

1.0 Purpose

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to excavate, sample, and backfill test pits. This SOP serves as a supplement to the site-wide and investigation area specific work plans and field sampling plans (FSPs), and is intended to be used in conjunction with the other SOPs in this volume.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors engaged in test pit excavation and sampling activities for Galena Forward Operating Location (FOL) projects and was developed per the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses only on the most commonly used test pit excavation and sampling tasks, and applications anticipated at Galena FOL. This SOP should be used in conjunction with other project SOPs in Appendix H, Field Standard Operating Procedures, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-02, Site Reconnaissance, Preparation, and Restoration*
- *SOP-03, Utility Clearance for Intrusive Operations*
- *SOP-04, Organic Vapor Monitoring and Air Monitoring*
- *SOP-06, Boring Log Completion, Soil Classification, and Logging*
- *SOP-07, Discrete Surface and Subsurface Soil Sampling*
- *SOP-13, Groundwater Sample Procedures*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-19, Sample Handling and Custody*

Should field tasks and procedures be added to a project that are not included in this SOP, they must be defined in Appendix H, Field Standard Operation Procedures and/or Appendix A, Project-specific Health and Safety Plan (HSP), before implementation*.* Changes to field procedures and/or equipment should be implemented and documented according to *SOP-20, Field Procedure Change Management.*

3.0 General

Selecting the proper equipment for test pit excavation and soil sampling is a critical part of the field investigation. This SOP describes excavation and sampling methods generally used for test pit excavation, sampling, and backfilling, as well as the commonly used tools for these techniques.

In addition to selecting the proper type of excavation and sampling technology, test pit excavation activities should conform to state regulations and be supervised by a qualified geologist or engineer. Either the excavation contractor or CH2M HILL will obtain all permits, applications, and other documents required by state and local authorities and the client. In addition, the following general guidelines should be thoroughly considered during planning and commencement of all test pit investigations:

- Review site background information for the investigation area. This includes identifying and understanding the type(s) of contaminant(s) released, the manner of release, and the affected media.
- Select the proper test pit technology and excavating equipment. All excavation activities should conform to state regulations.
- Coordinate locations of test pits conducted at Air Force installations with the appropriate Restoration Program Manager (RPM) before excavation commences.
- Determine the proper test pit dimensions based on the investigation objectives.
- Before mobilization to each test pit location, determine that the location is free of subsurface or overhead utilities according to the procedures described in *SOP-03, Utility Clearance for Intrusive Operations*.
- Take appropriate precautions during test pitting to avoid introducing contaminants into the excavation.
- Excavate test pits in areas of no or low anticipated contamination first progressing toward areas of increasing contamination. Under ideal conditions, upgradient areas without contamination should be excavated first.
- Before mobilization to each test pit location, decontaminate the excavation equipment by steam cleaning, high-pressure hot water, or similar methods according to the procedures described in *SOP-14, Equipment Decontamination Procedures*. The equipment must not leak any fluids that may enter the excavation or contaminate equipment placed in the excavation.
- To the extent practical, restore the site to its pre-investigation conditions.

Record all information pertinent to documenting the above requirements in the field log book and the Test Pit Log, according to *SOP-01, Note Taking and Field Log Books*.

Qualified geologists will oversee soil excavation, confirmation sampling, and backfilling; perform logging and sampling activities; and have applicable field experience in overseeing excavation work. Other qualified personnel may include geotechnical and civil engineers or field technicians with an appropriate amount of applicable field experience and training under the direct supervision of another qualified person. Personnel overseeing excavation activities must be familiar with health and safety requirements in the project-specific health and safety plan (HSP) and local, state, and federal regulations governing excavations.

The following materials and equipment may be needed for the excavation and sampling of test pits:

- Field logbook
- Indelible black-ink pens

- Camera with film
- Tape measure
- Backhoe
- Shovels, picks, or scoops
- Teflon bailer and nylon cord
- Protective clothing and equipment, as required
- Appropriate field monitoring instruments
- Decontamination supplies and equipment (for example, high pressure sprayer/washer, wash/rinse tubs, brushes, liquinox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags, potable water, distilled or deionized water)
- Sample containers, coolers, ice (or ice substitute), chain-of-custody (COC) forms, as specified in the FSP
- Stainless-steel trowels, scoops, bowls, and knives
- Stainless steel slide hammer drive sampler with extension rods, stainless steel tubes, Teflon® sheeting, and plastic caps
- Drums and/or roll-off bins for containment of excavated material
- Drums or other approved water-tight containers for containment of water if pit/trench dewatering is required
- Plastic sheeting for covering excavated materials, if required
- Run-off/run-on control equipment and materials, if necessary (for example, hay bales, silt fence, plastic sheeting)

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff has adequate experience and training for project-specific implementation of the health, safety, and environment (HS&E) management process and project SOPs. The PM and Health and Safety Manager (HSM) cooperatively have overall HS&E program responsibility; however, specific tasks may be delegated to other project staff. The PM retains ultimate HS&E responsibility for the project. The PM will solicit the appropriate technical expertise to verify that the project has identified the best test pit excavation and sampling technology for the job given the current understanding of the site lithology.

4.2 Health and Safety Manager

The HSM is assigned to oversee site-specific HS&E and verify overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP (Appendix A), coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and certify the PPE program, and conduct project health and safety audits on the effectiveness of HS&E program.

4.3 Safety Coordinator (SC)

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTLs) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and on-going HS&E procedures are effective.

4.4 Field Team Leader

Each FTL, in conjunction with the SC, is responsible for overall compliance with this technical procedure. The FTL is responsible for following these procedures or delegating tasks to team members to perform test pit excavation tasks. The FTL should verify that subcontractors are adequately complying with this technical procedure and that air monitoring is adequately conducted by or provided to subcontractors per the HSP.

4.5 Field Geologist

The Field Geologist supervises the test pit excavation and collection of soil samples, recording all field data as described in this SOP, the HSP, and *SOP-01, Note Taking and Field Log Books*.

5.0 Procedures

Unless otherwise specified in the work plan or FSP, a test pit will consist of an open excavation through soil and/or buried material. Depending on the work plan/FSP requirements, test pits will typically extend to the base of the buried or disturbed material being investigated, or to the water table or to competent bedrock. The target depth of the test pit will be specified in the work plan/FSP.

Important: Unless specified in the site-specific FSP and HSP and approved by the HSM, personnel will not enter a test pit/trench at any time. Substantial local, state, and federal regulations and site-specific health and safety requirements apply for entry into excavations over a few feet deep. The PM and HSM must be notified before any activity involving entry of personnel into excavations.

Test pits may be square or rectangular in shape and any size. Test trenches are normally 3 to 6 feet wide and extend to any length needed to explore site conditions. Larger and deeper excavations may be required for project specific objectives, or where field conditions warrant. The field geologist will determine the exact depth and construction of the pit(s) or trench(es) during excavation.

5.1 Preparation

The following activities will be performed in preparation for test pit excavation and sampling:

- Before any intrusive digging, clear the excavation area for buried utilities in accordance with *SOP-03, Utility Clearance for Intrusive Operations*.
- Construct erosion and run-off/run-on control facilities, as required by the site-specific FSP (Appendix D).
- As specified in the HSP, verify that emergency procedures and evacuation routes are understood by all personnel.

- Review heavy equipment communication procedures and test communication tools including hand signals and hand radios.
- Don required PPE. Verify that required health and safety monitoring equipment is readily available and properly calibrated, as specified in the HSP.
- Photograph and sketch the site before excavation. Sketch the site in the Field Notebook.
- Move all equipment, machinery, and supplies to the test site. Verify that excavating equipment has free access and movement about the test site.

5.2 Test Pit Excavation

Test pits will be excavated using a backhoe unless otherwise specified by the site-specific FSP (Appendix D). Procedures for excavating the test pit are:

- Carefully excavate thin layers of soil (no more than two feet thick with each scoop of the backhoe) and stockpile a safe distance away from the test pit or deposit in the appropriate investigation-derived waste (IDW) container as specified by the PM or HSM and/or site-specific FSP (Appendix D).
- Watch carefully for the presence of buried materials, especially materials that may pose a safety hazard. If buried containers potentially containing liquids are encountered, cease excavation and notify the PM and HSM.
- Obtain field instrument measurements during excavation as required by the Appendix D site-specific FSP or by the HSP. Record all information in the Field Notebook.
- Segregate contaminated soils into different stockpiles based on field screening results.
- If pit walls cave in, lay back walls sufficiently to prevent caving.
- During excavation, log the lithology of the test pit walls and collect soil samples as specified in the site-specific FSP (Appendix D).
- Photograph all significant features exposed by the test pit. Record all pertinent photograph information on the test pit log and in the Field Notebook.
- Excavated material will be placed in designated IDW containers (for example, drums or roll-off bins) or on plastic sheeting per the site-specific FSP (Appendix D).

5.3 Collection of Soil Samples

5.3.1 Subsurface Soil Samples

The site-specific FSP may require sampling of subsurface soil for chemical analysis. Unless otherwise specified in the FSP, collect subsurface soil samples from the excavated material removed from the test pit (for example, from the backhoe bucket). Obtain soil samples from freshly uncovered soil from the bucket corresponding to the depth of interest.

Procedures for collecting soil samples at discrete depths for chemical analysis will involve the following steps (per SOP-07, *Discrete Surface and Subsurface Soil Sampling*):

1. Remove a backhoe bucket of material from the desired depth. Screen the bucket with a photoionization detector/flame-ionization detector (PID/FID). Conduct volatile organic

compound (VOC) headspace screening if specified in the site-specific FSP. (see SOP-04, *Organic Vapor Monitoring and Air Monitoring*).

2. If VOC, gasoline-range organics (GRO), diesel-range/residual-range organics (DRO/RRO), or semi-volatile organic compounds (SVOC) samples are to be analyzed, use a decontaminated stainless steel scoop, trowel, or other appropriate device to collect the samples from the backhoe bucket. Collect VOC, GRO, DRO/RRO, and SVOC samples from the portion of the bucket exhibiting the highest PID/FID reading. For VOC and GRO samples, ensure the soil in each sample container is immediately preserved with methanol. For DRO/RRO and SVOC samples, immediately fill the sample containers fully to eliminate head space. Tightly seal the sample containers with the appropriate lids. Label and handle the sample containers in accordance with *SOP-19, Sample Handling and Custody*.
3. For the non-VOC/SVOC analyses, use a decontaminated stainless-steel scoop or trowel to collect 5 increment samples of equal volume of excavated material from the backhoe bucket. Make sure that sufficient volume of sample is collected to meet analysis sample volume requirements.
4. Combine the increment samples in a decontaminated stainless-steel bowl and mix thoroughly.
5. Immediately fill the appropriate sample containers, as specified in the site-specific, from the mixture. Label and handle the containers as specified in *SOP-19, Sample Handling and Custody*.
6. Decontaminate the sampling equipment according to *SOP-14, Equipment Decontamination Procedures.*

5.3.2 Water Samples

The site-specific FSP (Appendix D) may require sampling of groundwater that enters a test pit for chemical analysis. Collect water samples as grab samples by lowering a Teflon bailer on a nylon cord into the pooled water in the pit. Fill the appropriate sample containers using the bailer (see *SOP-13, Groundwater Sampling Procedures*). The sample containers will be handled according to *SOP-19, Sample Handling and Custody*.

5.4 Backfilling of Test Pits

Backfill test pits using clean fill material; unless stockpiled soil from the specific test pit is otherwise approved by the client, PM, and ADEC. The source of the fill may be imported clean material or excavated material determined to be clean based on field screening or analytical results. As possible, backfill test pits the same day as excavation, immediately after completion of sampling and/or logging. If pits are left open overnight, restrict access to the pit using barricades or fencing.

The following steps must be followed when backfilling test pits:

- Backfill test pits on the same day as the excavation, or as soon thereafter as practical. The source of the fill will be determined before excavating the test pits.
- Place fill in the trench or pit bottom in approximately 1-foot lifts.
- Compact each lift using the backhoe bucket.

- Decontaminate all equipment according to *SOP-14, Equipment Decontamination Procedures.*

6.0 Documentation

The field geologist is responsible for documenting test pit observations and activities. A detailed, complete, and accurate record will be documented on the Test Pit Log form (Attachment 1) to be completed during or immediately following test pit excavation, sampling, and backfilling. If an item on the form is not applicable, indicate NA on the form. Perform lithologic logging of test pit samples according to the applicable sections of *SOP-06, Boring Log Completion, Soil Classification, and Logging.*

At a minimum, the following information will be obtained and recorded on the log:

- Test pit location identification
- Excavation date(s)
- Test pit length, width, and depth
- Sample numbers and locations
- Lithologic material descriptions
- Photographs (numbers, locations, descriptions, and direction)
- Sketch of test pit location and cross section on grid on back of log

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

Denver Federal Center Site-wide RCRA Facility Investigation. May 2000. *Standard Operating Procedure for Test pit/Trench Excavation and Sampling*.

8.0 Attachments

Attachment 1 *Test Pit Log*

SOP-30

Surface Water Sampling

SOP-30: SURFACE WATER SAMPLING

1.0 Purpose

This standard operating procedure (SOP) describes the methodology for collecting surface water samples for laboratory analyses and water quality determinations.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors with the responsibility for determining water quality, and for the collection, preparation, preservation, and submittal of surface water samples for laboratory analyses developed in accordance with the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used surface water sampling tasks and applications anticipated at Former Galena Forward Operating Location and should be used in conjunction with other applicable project SOPs in *Appendix H, Field Standard Operating Procedures*, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*
- *SOP-20, Field Procedure Change Management*

3.0 General

Surface water samples will only be collected as discrete samples. Actual sampling locations will be confirmed in the field prior to initiation of the sampling program. Samplers should anticipate accommodating in-field adjustments. When surface water and sediment samples are collected from the same location, water samples will be collected first. In practice, such factors as safe access and handling, and bad weather will influence sample acquisition.

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs, and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to ensure that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E issues and ensures overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE for the project, lists the requirements in the health and safety plan (HSP) (*Appendix A*), coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and certify the PPE program, and conducts project health and safety audits on the effectiveness of the HS&E program.

4.3 Safety Coordinator

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTL) by the FM, to assist in implementing the project HSP. The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and ongoing HS&E procedures are effective.

4.4 Field Team Leader

The FTL should ensure that surface water samples are collected in accordance with this SOP and other SOPs in *Appendix H*. The FTL should also be required to make rational and justifiable decisions when deviations from this SOP are necessary because of field conditions or unforeseen problems. The FTL should consult the FM if significant deviations from the sample and analysis plan are necessary because of field conditions. The FTL should also ensure that the applicable requirements of *Appendix A,* the HSP, and *Appendix B, Project-specific Waste Management Plan,* are followed.

5.0 Procedures

5.1 Surface Water Sampling Methods

The following is a general guideline for collecting surface water samples:

- Set up a staging area and organize sampling equipment near the first (farthest downstream) sampling location.
- Arrange sample containers, sampling equipment, and decontaminated equipment being careful not to step on or otherwise contaminate the working area.
- Wear PPE in accordance with the site HSP (*Appendix A*).
- Collect surface water samples as described below.
- For all samples, mark the sampling location on a site map. Photograph (optional but recommended) and describe each location, and place a numbered stake closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at a future date.

5.1.1 Direct Grab Method for Unpreserved and Unfiltered Samples

Samples from shallow depths can readily be collected by the direct grab method, that is, submerging the sample container. This method can be performed when preservatives have not been added to sample containers prior to sampling.

Use the following procedures for direct grab method sample collection:

- Label the sample bottle with an appropriate label and cover the label with clear waterproof sealing tape. Record all applicable information in the field log book (see *SOP-01, Note Taking and Field Log Books*).
- Collect samples for volatile analysis first.
- With minimum surface disturbance, submerge the unpreserved sample bottle with the mouth of the container facing upstream, and allow sample stream to flow gently into the bottle.
- For volatile analysis, completely fill the container so that no headspace is present. In the event headspace is present, the discard water in the vial downstream from the sampling site and attempt this procedure a maximum of three times before substituting with a new vial. For other samples, fill the container approximately two-thirds full, leaving adequate space to allow for expansion.
- After sample collection is completed, submerge a water quality monitoring probe at the sampling site to take water quality measurements in accordance with *SOP-12, Field Water Quality Measurements and Calibration*.

5.1.2 Sampling (or Transfer) Device Method for Preserved Samples

It is prudent to use the sample transfer device method when preservatives have been added to sample containers prior to sampling. This device may be disposable or constructed of a nonreactive material, such as glass, stainless steel, or Teflon; and it can be used in most sampling situations except where adhesion of a contaminant to the surface of the transfer container (oils and grease) may pose a problem. The sampling device will have a capacity of at least 500 milliliters to minimize the number of times the liquid must be sampled, thus reducing possible disturbance to any sediment layers.

A carboy, dipper, beaker with pour spout and handle, ladle, ice scooper, pond sampler, or other container constructed of inert material, such as glass, stainless steel, or Teflon, can be used to transfer water from the sample source to a sample bottle. This prevents unnecessary contamination of the outer surface of the sample bottle that might otherwise result from direct immersion of the sample bottle in the water, and it prevents loss of preservative. Use of a sampling device also prevents the technician from having to physically contact the sample media. Depending on the sampling application, the transfer vessel can be either disposed of or reused. If reused, the vessel and any other apparatus that could come into contact with the sample will be thoroughly decontaminated in accordance with *SOP-14, Equipment Decontamination Procedures*, prior to sampling a different source.

Use the following procedures for transfer device method sample collection:

- Label the sample bottle with an appropriate label and cover the label with clear waterproof sealing tape. Record all applicable information in the field log book (see *SOP-01, Note Taking and Field Log Books*).
- Collect samples for volatile analysis first.
- If a carboy is used to collect large quantities of surface water, fill the carboy to 1/10 capacity and rinse three times with the water to be sampled, prior to sample collection. Rinse water will be discarded downstream or away from the sampling location. The

mouth of the carboy will be facing upstream during sampling. Downstream samples will be collected prior to upstream samples. Care will be taken not to disturb bottom sediments. If a pond sampler will be used, ensure that the sampling beaker, and the bolts and nuts that secure the clamp to the pole are tightened properly.

- With minimal surface disturbance, submerge a pre-cleaned stainless-steel dipper or similar device. The mouth of the container will be facing upstream. The sampler, if wading, will remain downstream of the sample collection point. In addition, downstream samples will be collected prior to upstream samples. Care will be taken not to disturb bottom sediments. Allow the device to fill slowly and continuously. If disturbed, wait until the sediment settles.
- Collect samples for volatile analysis immediately after filling the sampling device to ensure the integrity of the sample where possible aeration could occur.
- Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the device. Empty the device slowly, allowing the sample stream to flow gently into the bottle with minimal disturbance.
- For samples to be analyzed for volatiles, completely fill the container so that no headspace is present. For other samples, fill the container approximately two-thirds full, leaving adequate space to allow for expansion.
- For samples to be analyzed for dissolved metals, use a parastaltic pump, silicone tubing, and an in-line (0.45 micrometer) filter to filter the water from the sample collection device. The filtered water will be placed directly into an appropriate sample container, leaving adequate space to allow for expansion.
- After sample collection is completed, submerge a water quality monitoring probe at the sampling site to take water quality measurements in accordance with *SOP-12, Field Water Quality Measurements and Calibration*.
- Properly discard or decontaminate all sampling devices.

5.2 Quality Assurance/Quality Control Procedures and Samples

Quality assurance (QA)/quality control (QC) samples should be collected during surface water sampling according to the *Field QC Sample Summary* and *Site-specific Sampling Plans* in *Worksheets 17* and *20* and in *Appendix D*. QA/QC samples should be assigned unique sample identification, and handled and submitted to the laboratory in the same manner as field samples.

5.2.1 Equipment Blanks

Equipment blanks should be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. An equipment blank sample is collected in the field by running American Society for Testing and Materials Type II Reagent-Grade water (or deionized water with less than 15 microSiemens conductivity) across the surface of reusable, decontaminated sampling equipment and into appropriate sample containers.

5.2.2 Field Duplicate Samples

Field duplicates will be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. Field duplicate samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.2.3 Matrix Spikes and Matrix Spike Duplicates

Matrix spikes and matrix spike duplicates (MS/MSD) samples will be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. MS/MSD samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.2.4 Sample Identification, Handling, and Documentation

Samples should be identified, handled, and recorded as described in this SOP and in accordance with *SOP-01, Note Taking and Field Log Books; SOP-18, Packing and Shipping of Environmental Samples;* and *SOP-19, Sample Handling and Custody*.

5.3 Equipment

The following equipment is required for surface water sampling:

- Surface water sampling device (for example, Niskin bottle or stainless-steel beaker)
- Instruments used to measure water quality parameters (for example, YSI)
- Field notebook
- Waterproof permanent marker
- Paper towels or Kim wipes
- Appropriate decontamination equipment
- Appropriate PPE as designated in the HSP
- Waders/rubber boots
- Cooler with ice
- Sample containers and preservatives specified in *Worksheets 17* and *20* and in *Appendix D*
- Sample containers (for example, 1-liter amber) for other constituent sampling
- Sample labels and waterproof sealing tape
- Hoses/tubes (for example, medical-grade silicon tubing)
- Mark sticks
- Garbage bags for PPE
- Measuring tape
- Appropriate sampling data forms, for example, field sampling reports, chain-of-custody forms
- Parastaltic pump
- In-line (0.45 micrometer) filters

5.4 Equipment Decontamination

All sampling devices will be decontaminated. Procedures presented in *SOP-14, Equipment Decontamination Procedures*, will be followed prior to sampling, between sampling locations, and at the end of the day for decontamination of reusable field equipment and for personnel decontamination. A deionized rinse of the sampling equipment is an appropriate decontamination procedure for use between samples collected from the same surface water ecosystem. It is not necessary to decontaminate the YSI meter when sampling downstream to upstream in the same surface water ecosystem.

6.0 Records

Field notes will be kept in a bound field log book following the format specified in *SOP-01, Note Taking and Field Log Books*. The following information is required depending on the sampling method performed:

- Verbal description of sample location if global positioning system coordinates are unavailable
- Distance of sample collection point from right or left edge of water
- Discharge or flow rate of water at sampling location
- Estimate of water depth
- Estimate of surface area of water body
- Sample collection method (grab or discrete)
- Surface water and site conditions (for example, floating oil or debris, gassing)
- Location of any discharge pipes, sewers, or tributaries
- Instrument calibration
- Required site maps (if a staff gauge is measured and not co-located with a surface water location, it must be included in the site map)
- Weather observations (for example, wind speed, sunny or cloudy sky, and approximate wave height)

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

de Vera, E.R., B.P. Simians, R.D. Stephens, and D.L. Storm. 1990. *Samplers and Sampling Procedures for Hazardous Waste Streams*. EPA-600/2-80-018.

U.S. Environmental Protection Agency. 1977. *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*. EPA-530/SW-611.

8.0 Definitions

Surface water: includes all water on the surface of the ground directly exposed to the atmosphere, including, but not limited to, lakes, ponds, reservoirs, artificial impoundments, streams, rivers, springs, seeps, and wetlands.

SOP-31

Sediment Sampling

SOP-31: SEDIMENT SAMPLING

1.0 Purpose

This standard operating procedure (SOP) outlines protocols for sampling sediments. This SOP applies to the collection of sediment samples in surface water bodies such as streams, rivers, ditches, lakes, ponds, lagoons, and wetlands.

2.0 Scope

This SOP applies to all CH2M HILL personnel and subcontractors with the responsibility for the collection, preparation, preservation, and submittal of sediment samples for laboratory analyses developed in accordance with the following Alaska Department of Environmental Conservation (ADEC) guidance documents:

- *Draft Field Sampling Guidance* (ADEC, 2010)
- *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures* (ADEC, 2002)

This SOP focuses on the most commonly used surface water sampling tasks and applications anticipated at Former Galena Forward Operating Location and should be used in conjunction with other applicable project SOPs in *Appendix H, Field Standard Operating Procedures*, including the following*:*

- *SOP-01, Note Taking and Field Log Books*
- *SOP-14, Equipment Decontamination Procedures*
- *SOP-18, Packing and Shipping of Environmental Samples*
- *SOP-19, Sample Handling and Custody*
- *SOP-20, Field Procedure Change Management*

3.0 General

Sediment is defined by ADEC as material of organic or mineral origin that is transported by, suspended in, or deposited from water. This procedure applies to the collection of sediment samples only in surface water bodies such as streams, rivers, ditches, lakes, ponds, lagoons, and wetlands. Sediment samples will only be collected as discrete samples. Actual sampling locations will be confirmed in the field prior to initiation of the sampling program. Samplers should anticipate accommodating in-field adjustment.

When surface water and sediment samples are collected from the same location, water samples will be collected first because disturbing the sediment may influence the analytical results of the surface water samples and cause cross contamination. If sampling both surface water and sediment, or just sediment, sample from the most downstream point first and proceed upstream.

When collecting sediment samples to be analyzed for volatile organic compounds, do not pool or homogenize the sample. Slowly decant off any liquid phase and then fill the specified container(s) with the solid, ensuring no headspace. Samples for nonvolatile organic and inorganic analyses can be placed in an appropriate collection pan or bowl and homogenized before they are placed in sample containers.

If the person collecting the sediment sample needs to enter the water to collect the sample, this should be done downstream of the actual sample location, and care must be taken not to disturb the sediment in the location to be sampled. In practice, such factors as safe access and handling, and bad weather will influence sample acquisition.

Wear appropriate personal protective equipment (PPE) as prescribed by the health and safety plan (HSP, *Appendix A*).

4.0 Responsibilities

4.1 Project Manager

The Project Manager (PM) is responsible for providing adequate resources and ensuring that field staff have adequate experience and training to successfully comply with and execute project-specific SOPs, and implement the project health, safety, and environment (HS&E) program. The PM will solicit the appropriate technical expertise to ensure that the project has identified the best sampling methods and technology for the job given the current understanding of the site and project goals.

4.2 Health and Safety Manager

The Health and Safety Manager (HSM) is assigned to oversee site-specific HS&E issues and ensure overall compliance with project HS&E requirements. The HSM conducts PPE evaluations, selects the appropriate PPE for the project, lists the requirements in the HSP (*Appendix A*), coordinates with the Field Manager (FM) and/or Safety Coordinators (SC) to complete and certify the PPE program, and conducts project health and safety audits on the effectiveness of the HS&E program.

4.3 Safety Coordinator

The role of SC is either taken by the FM or is designated to Field Team Leaders (FTL) by the FM, to assist in implementing the project HSP (*Appendix A*). The SC assists the FM and HSM with the HS&E program, implements the PPE requirements described in the project HSP, and receives input from project staff that the assigned PPE requirements and ongoing HS&E procedures are effective.

4.4 Field Team Leader

The FTL should ensure that sediment samples are collected in accordance with this SOP and other SOPs in *Appendix H*. The FTL should also be required to make rational and justifiable decisions when deviations from this SOP are necessary because of field conditions or unforeseen problems. The FTL should consult the FM if significant deviations from the sample and analysis plan are necessary because of field conditions. The FTL should also ensure that the applicable requirements of *Appendix A,* the HSP, and *Appendix B, Project-specific Waste Management Plan,* are followed.

5.0 Procedures

The water content of the sediment to be sampled may vary greatly. Likewise, the sediments themselves may range from very soft to dense. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site. If the preferred equipment identified in the following procedures is unable to collect a sediment sample (that is, too rocky), a shovel or hand auger may be used (see *SOP-20, Field Procedure Change Management*).

5.1 Sediment Sampling Methods

The following is a general guideline for collecting sediment samples:

- On arrival at the site, set up and organize sampling equipment near the first (farthest downstream) sample location.
- Arrange sample containers, sampling equipment, and decontaminated equipment.
- Wear PPE in accordance with the site HSP.
- Collect co-located surface water sample, if required.
- Collect sediment sample. The preferred methods of collecting sediment samples will be by hand corer or polyvinyl chloride (PVC) pipe method.
- For all samples, mark the sampling location on a site map. Photograph (optional but recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at a future date.

5.1.1 Hand Corer Method

The hand corer method is intended to collect firm sediment samples. Use the following procedures for hand corer method sample collection:

- Label each sample container properly, cover the label with clear tape, fill out appropriate chain-of-custody information, wipe outside of the container with paper towel or Kim wipe, and place in iced cooler.
- Ensure that the corers and (optional) liners are properly decontaminated prior to initiation of sampling and between each sample location.
- Gently push the corer into the sediment with a smooth continuous motion to a depth of approximately 9 inches (or other pre-specified depth).
- Twist the corer to detach the sample, then withdraw the corer in a single smooth motion.
- Remove the top of the corer and slowly decant excess water.
- Remove the nosepiece and deposit the sample onto a stainless-steel, polytetrafluoroethylene (PTFE), or PTFE-lined tray or bowl.
- Decant, if appropriate and necessary.
- Transfer the sample into sample containers (volatile analysis first) using a disposable sample scoop or stainless-steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid the risk of cross contamination. If specific data quality objectives mandate (except for volatile analysis samples), the sediment sample will be homogenized in a bowl using a sampling spoon prior to placement into sample containers.
- Decontaminate equipment for the next sample location or at the conclusion of all sampling.

5.1.2 Polyvinyl Chloride Pipe Method

The PVC pipe method is intended to collect sediment samples that are soft. Use the following procedures for PVC pipe method sample collection:

- Label each sample container properly, cover the label with clear tape, fill out appropriate chain-of-custody information, wipe outside of the container with paper towel or Kim wipe, and place in iced cooler.
- Gently push pipe into sediment with a smooth continuous motion to a depth of approximately 9 inches (or other pre-specified depth).
- Cap the pipe, forming an airtight seal, to create a vacuum as it is withdrawn from the sediment.
- Slowly decant excess water.
- Deposit the sample onto a stainless-steel or PTFE tray or bowl.
- Decant if appropriate and necessary.
- Transfer the sample into sample containers (volatile analysis first) using a stainless-steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs and the risk of cross contamination. If specific data quality objectives mandate (except for volatile analysis samples), the sample will be homogenized in a bowl using a sampling spoon prior to placement into sample containers.
- Decontaminate equipment.

5.1.3 Scoop, Trowel, Spoon, or Ladle Method

This method is intended to collect sediment samples that are very soft. Use the following procedures for very soft sediment sample collection:

- Label each sample container properly, cover the label with clear tape, fill out appropriate chain-of-custody information, wipe outside of the container with paper towel or Kim wipe, and place in iced cooler.
- Insert the sampling device into the sediment at the selected sampling point and slowly remove the sample.
- Slowly decant excess water.
- Deposit the sample into a stainless-steel or PTFE tray or bowl.
- Transfer the sample into sample containers (volatile analysis first) using a stainless-steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs and the risk of cross contamination. If specific data quality objectives mandate (except for volatile analysis samples), the sample will be homogenized in a bowl using a sampling spoon prior to placement into sample containers.
- Decontaminate equipment prior to collecting sample from next location.

5.2 Quality Assurance/Quality Control Procedures and Samples

Quality assurance (QA)/quality control (QC) samples should be collected during sediment water sampling in accordances with the *Field QC Sample Summary* and *Site-specific Sampling Plans* in *Worksheets 17* and *20* and in *Appendix D*. QA/QC samples should be assigned unique sample identification, and handled and submitted to the laboratory in the same manner as field samples.

5.2.1 Equipment Blanks

Equipment blanks should be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. An equipment blank sample is collected in the field by running American Society for Testing and Materials Type II Reagent-Grade water (or deionized water with less than 15 microSiemens conductivity) across the surface of reusable, decontaminated sampling equipment and into appropriate sample containers.

5.2.2 Field Duplicate Samples

Field duplicates will be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. Field duplicate samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.2.3 Matrix Spikes and Matrix Spike Duplicates

Matrix spikes and matrix spike duplicates (MS/MSD) samples will be collected at a frequency specified in *Worksheets 17* and *20* and in *Appendix D*. MS/MSD samples will be collected simultaneously or in immediate succession to the normal samples using identical sampling techniques.

5.2.4 Sample Identification, Handling, and Documentation

Samples should be identified, handled, and recorded as described in this SOP and in accordance with *SOP-01, Note Taking and Field Log Books; SOP-18, Packing and Shipping of Environmental Samples;* and *SOP-19, Sample Handling and Custody*.

5.3 Equipment

The following equipment is required for surface water sampling:

- Stainless-steel, PTFE, or PTFE-lined sampling tray or bowl
- Stainless-steel or PTFE dip sampler, scoops, trowels, spoons, and ladles
- PVC pipe, 2-inch diameter
- Sand core sediment sampler, liners (optional), and extensions
- Jaw-type sampler
- Sample bottles
- Sample cooler with ice
- Rubber boots/waders
- PPE (as required in the HSP)
- Field notebook with waterproof markers
- Decontamination equipment and materials, as appropriate
- Plastic bucket (for rinse water/solvents, decant, and/or spoils)
- Appropriate sample data forms (for example, chain of custody)
- Clear tape
- Pen, pencil, and Magic Marker
- Sample labels

- Paper towels
- Garbage bag for PPE

5.4 Equipment Decontamination

All sampling devices will be decontaminated. Procedures presented in *SOP-14, Equipment Decontamination Procedures*, will be followed prior to sampling, between sampling locations, and at the end of the day for decontamination of reusable field equipment and for personnel decontamination.

6.0 Records

Field notes will be kept in a bound field log book following the format specified in *SOP-01, Note Taking and Field Log Books*. The following information is required depending on the sampling method performed:

- Verbal description of sample location (if global positioning system coordinates are unavailable)
- Distance of sample collection point from right or left edge of water
- Estimate of sediment depth
- Sample collection method
- Sediment and site conditions (for example, debris, gassing)
- Weather observations (for example, wind speed, sunny or cloudy sky).

7.0 References

Alaska Department of Environmental Conservation (ADEC). January 2010. *Draft Field Sampling Guidance*.

Alaska Department of Environmental Conservation (ADEC). March 2004. *Sediment Quality Guidelines.*

Alaska Department of Environmental Conservation (ADEC). November 7, 2002. *Underground Storage Tanks Procedures Manual: Guidance for Treatment of Petroleum-Contaminated Soil and Groundwater and Standard Sampling Procedures*.

U.S. Environmental Protection Agency. 1987. *A Compendium of Superfund Field Operations Methods.* EPA/540/P-87/001.

SOP-32

Aquifer Pumping Test

SOP-32: **AQUIFER PUMPING TEST**

1.0 Purpose

The purpose of this technical procedure is to ensure that aquifer pumping tests are properly performed and documented to acquire representative aquifer data.

2.0 Scope

Standard Operating Procedure (SOP)-32 applies to all CH2M HILL personnel and subcontractors engaged in aquifer pumping tests at Galena Forward Operating Location (FOL). SOP-32 was developed in accordance with the following guidance documents:

- Kruseman, G.P. and N.A. de Ridder. 1991. *Analysis and Evaluation of Pumping Test Data.* Second Edition. International Institute for Land Reclamation and Improvement. Wageningen, The Netherlands: p. 377.
- American Society for Testing and Materials (ASTM). 2004. *Standard D5092: Standard Practice for Design and Installation of Ground Water Monitoring Wells.*

This SOP focuses aquifer pumping test at Galena FOL and should be used in conjunction with other applicable project SOPs, including the following:

- SOP-01, *Note Taking and Field Log Books*
- SOP-09, *Monitoring Well Development*
- SOP-11, *Continuous Water Level Monitoring*
- SOP-12, *Field Water Quality Measurements and Calibration*
- SOP-14, *Equipment Decontamination Procedures*
- *SOP-20,* Field Procedure Change Management

3.0 General

3.1 Basic Concepts

An aquifer pumping test is a partially controlled field experiment designed to estimate the hydraulic properties of water-bearing material. In general, the aquifer is hydraulically stressed by extracting water, and the response to the stress, measured as changes in water levels at observation wells, is analyzed to determine aquifer properties. The hydraulic properties are specific to the test method, with transmissivity, storage capacity, and their respective derived parameters (hydraulic conductivity and the storage coefficient) being the basic properties determined by most test methods. In addition, aquifer boundary conditions (e.g., leaky conditions, barrier boundaries, and recharge boundaries), and the spatial and temporal distribution of a cone of depression may also be estimated by using the aquifer test data.

Other stresses on the aquifer can lead to degradation of aquifer test data, depending on conditions. These stresses include precipitation, regional water level trends, barometric pressure variations, tidal and other surface water fluctuations, loading and unloading stresses (i.e., heavy equipment movement), and overlapping cones of depression caused by

other pumping wells. Good knowledge and measurements of these stresses are essential to properly analyze pumping test data.

3.2 Conceptual Site Model

The specifics of aquifer test programs depend on the conceptual site model of the groundwater system (including its potential relationship to surface water systems), the availability and spatial distribution of data monitoring points, and the purpose of the test program. A conceptual understanding of the hydrogeology of the site can be developed by reviewing driller's logs and borehole geophysical logs of the wells to be tested, and previous reports on the hydrogeology of the area.

A good conceptual site model is essential because different hydrogeologic settings require different testing approaches and analytical techniques. If the site conditions do not correspond with the assumptions used in the model, the analysis will be invalid. For example, water table aquifers may require longer discharge periods than confined aquifers to provide an adequate data set, or, in the case of a partially penetrating extraction well, the spatial distribution of monitoring wells must meet specific conditions. As another example, if the purpose of the test program is to evaluate surface water losses due to pumping, special data collection (e.g., shallow nests of piezometers in the bed of the water body) may be required.

4.0 Responsibilities

4.1 Project Manager

The project manager (PM) is responsible for making sure that aquifer pumping tests are performed in compliance with these procedures and the requirements of the enforcing agencies.

4.2 Field Manager

The field manager (FM) is responsible for making sure that (1) aquifer pumping tests are performed in compliance with event-specific plans and this procedure and (2) field team members are trained and certified competent in the prescribed procedures.

4.3 Field Team Leader

The field team leader (FTL) develops or directs the development of a detailed plan that includes the specifics regarding the aquifer test. The FTL, or their designee, should know the principles behind aquifer testing and data requirements.

4.4 Health and Safety Manager

The health and safety manager (HSM) oversees site-specific health, safety, and environment (HS&E) protocols and overall compliance with project HS&E requirements. The HSM conducts personal protective equipment (PPE) evaluations, selects the appropriate PPE, lists the requirements in the project-specific health and safety plan (HSP) (see Appendix A), coordinates with the FM and safety coordinators (SC) to certify the PPE, and conducts health and safety audits to evaluate the effectiveness of the HS&E program.

4.5 Safety Coordinator

The SC role is fulfilled either by the FM or the FTL(s). The SC assists in implementing the project-specific HSP. The SC assists the FM and HSM with the health and safety program, implements the PPE requirements, and receives feedback from project staff regarding the effectiveness of the PPE and HS&E procedures.

5.0 Procedure

The equipment needed for conducting an aquifer pumping test, procedures for the test, and data analysis are discussed in the following sections.

5.1 Equipment

The following equipment is required to perform an aquifer pumping test:

- Manual water level meters, transducers, and data loggers
- Portable computers and data disks
- In-line flowmeter and pressure gauge
- In-line discharge valve
- In-line sampling port
- Pump and back-up pump; pumps must have check valves to prevent backflow into the well when pumping stops
- Stopwatch
- Calculator
- Logbook
- Decontamination and spill equipment
- Generator(s) when onsite power is not available
- Recording barometer, rain gauge, and recording surface water stage gauge (if required by conditions)
- Pump/discharge line assembly, including secondary containment, if required
- Pump electrical control system
- Tanks for containerizing discharge or a system for treating discharge (if containerization or treatment are not required, a sufficiently distant surface water body or storm drain are usually adequate for disposal of water)
- Flashlights, fire extinguishers, and light stands to illuminate the exclusion zone and other work areas
- Hand-held radios or cellular telephones
- 5-gallon bucket

- Work table
- Equipment necessary for sampling of field parameters (see SOP-12)

The proper arrangement of in-line equipment is necessary for accurate data collection. The flowmeter or totalizer is the first in line, where the discharge pipe comes out of the well. Approximately 2 feet of straight pipe are required before the flowmeter connection to reduce turbulent flow at the flowmeter. Next (in any order) are the low-flow sampling spigot and the master flow valve. The discharge pipe or hose is attached after the spigot and valve; the discharge pipe must be long enough to reach the destination for the pumped water. If flexible discharge hose is used, care should be taken to reduce or eliminate kinks, which can increase in-line pressure and reduce pumping rates.

5.2 Aquifer Pumping Test Procedures

General procedures for pre-test, testing and post-test activities are specified in the following section.

5.2.1 General Procedures and Pre-test Activities

General procedures and pre-test activities are as follows:

- All downhole intrusive equipment (e.g., pump and water-level monitoring devices), discharge line components, and sampling equipment must be decontaminated before and after use in accordance with SOP-14.
- An exclusion zone must be set up to include the area surrounding the pumping well, the discharge line, and the treatment system/storage tanks.
- Water-level measuring devices, flowmeters, and data loggers must be calibrated and tested before aquifer testing begins.
- All time recording devices shall be calibrated to a master clock before a test.
- Generators and electrical power systems shall be tested.
- Before beginning any aquifer test, a short-term test of the system shall be undertaken to check for proper system operation and pressure, the presence of leaks, and the flowmeter response. The discharge value shall also be adjusted to the specified flow.
- All wells shall be monitored at least 24 hours prior to testing to determine ambient water level trends and patterns.
- Water levels in all wells shall be manually measured immediately before beginning tests.
- The recovery period between two tests shall be at least as long in duration as the pumping period of the first test, or until water levels have recovered to 99 percent of pre-test levels.
- Data from totalizing flowmeters shall be recorded before and after any event that alters the total flow reading.
- All data and events will be recorded in logbooks or on specified data sheets. Example data sheets are included in Attachment 1.

- A step test (ideally a minimum of three steps) may be undertaken before a constant discharge test to (1) determine optimum pumping rates and drawdown, (2) calibrate the discharge valve and pressure gauge, and (3) provide a data set to calculate well losses.

5.2.2 Test Activities

The duration of an aquifer test begins when the well is pumped and continues past the cessation of pumping until water levels have sufficiently recovered. The following procedures will be followed during aquifer testing:

- Automatic water level readings will be measured by using a linear or logarithmic time scale. A logarithmic time scale is preferred for locations where rapid initial changes in water levels are expected, such as pumping wells. A linear scale is generally sufficient for observation wells, unless pre-test activities indicate that rapid water level changes are expected at the observation wells.
- Manual water level readings shall be recorded every 10 minutes for the first hour of pumping and every one-half hour afterwards, and likewise for the recovery portion of the test. The FTL may adjust this schedule, if necessary.
- Pumping rates shall be recorded every 10 minutes for the first hour of pumping and every one-half hour afterwards. The FTL may adjust this schedule if necessary. Pumping rates shall be adjusted to maintain rates at ±10 percent of the target discharge rate. The discharge valve shall never fully opened at the beginning of a test. A generator failure or refueling may interrupt the discharge period and degrade the data; therefore, a second generator with automatic and manual power switchover should be included in the test program.
- During the first hour of any test, the discharge line, treatment system, storage tanks, flowmeters, pressure gauges, and data loggers shall be monitored frequently. After the first hour, monitoring shall continue hourly.
- At the end of discharge tests, water level recovery shall be monitored and recorded until 90 percent of the discharge drawdown is recovered, or as determined by the FTL. The pumping well transducer shall be reset to begin logging logarithmically after pumping.

5.2.3 Data Analysis

Depending on the type of aquifer and local setting, a variety of analysis techniques are available for data interpretation. Attachment 2 includes a decision tree that can be used to determine the appropriate test/analysis method(s) for a given site.

5.4 Report

The format for the aquifer pumping test report shall contain the following information, in accordance with ASTM D5092-90:

- Introduction
- Hydrogeologic setting
- Equipment
- Methods
- Testing procedures
- Presentation and interpretation of test results

5.5 Precision and Bias

It is generally not practical to specify the precision of test methods because the response of aquifer systems during aquifer testing depends on ambient system stresses and the unique character of each aquifer. No statement can be made about bias because no true reference values exist.

Failure to account for or quantify concurrent boundary conditions or aquifer stresses, such as those discussed in Section 3.1, can reduce precision and bias the data and data analysis.

6.0 Records

All materials and procedures used during installation of wells should be documented in a field notebook, on the well construction datasheets, or both, in accordance with SOP-01*, Field Note Taking and Field Logbooks*. Submit well completion reports to regulatory agencies as required and maintain all copies of field notes and well completion reports in the project files.

7.0 References

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8.0 Definitions

Air lift pumping: cycling air pressure on and off for short periods of time to dislodge fine-grain particles in the well bore; steady, low pressure removes the fines from the well.

Extraction well: a well designed for extracting groundwater.

Mechanical surging: forcing water to flow into and out of the well screen by operating a plunger (or surge block) or bailer up and down in the riser; a pump or bailer is used to remove the dislodged sediment.

Monitoring well: a well constructed by one of various techniques for the purpose of extracting groundwater for physical, chemical, or biological testing, or for measuring water levels. A monitoring well specifically designated to record water level changes during an aquifer test may be referred to as an *observation well*.

Reinjection well: a well designed to reinject extracted groundwater after it has been treated to remove contaminants.

Over pumping: a monitoring well pumped at a rate considerably higher than during normal operation to dislodge fine-grained materials from the filter pack and surrounding strata.

Well jetting: spraying the well screen area with water while simultaneously air-lifting material from the well.

9.0 Attachments

Attachment 1: Example Data Sheets

Attachment 2: Decision Tree for Selection of Aquifer Test Method