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New England District
Concord, Massachusetts

Technical Support Services General Electric (GE) Housatonic River Project Pittsfield, Massachusetts

Contract No. DACW33-94-D-0009

FINAL FIELD SAMPLING PLAN

Task Order No. 0032
DCN: GEP2-082898-AACK

October 1998

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20 October 1998

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Work Order No. 10971-032-001-0132

Re: Contract No. DACW33-94-D-0009
DCN: CEP2-082898-AACK
Final Field Sampling Plan

Dear Mr. Lacroix:

Please find enclosed 6 copies of the Final Field Sampling Plan for the General Electric (GE) Housatonic River Project in Pittsfield, MA. Roy F. Weston, Inc. (WESTON®) is also providing 4 copies to Mr. Michael Nalipinski at the EPA office in Boston, MA; 3 copies to J. Lyn Cutler at MADEP in Springfield, MA; 1 copy to the HTRW Center of Expertise Document Distribution Center, in Omaha, NE; 1 copy to Margaret Meehan, EPA; 1 copy to Andy Beliveau, EPA Lab; and 2 copies to Danny Averett, USACE.

This submittal has undergone WESTON's technical and quality control review and coordination procedures to ensure: (1) completeness for each discipline commensurate with the level of effort required for the submittal; (2) elimination of conflicts, errors, and omissions; (3) compliance with project criteria; and (4) overall professional and technical accuracy of the submittal.

We look forward to your comments on this document in the near future. Please feel free to contact Mr. Steve A. Johnson at 610-701-7504 or me at 610-701-7366 if you should have any questions.

Very truly yours,

ROY F. WESTON, INC.


Lee dePersia
Project Manager

cc: M. Nalipinski, EPA
J. Lyn Cutler, MADEP
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M. Meehan, EPA
A. Beliveau, EPA Lab
D. Averett, USACE
DCN File – B. Eisenhardt
DCN File – D. Veilleux

LdP/wp
Enclosure



**FINAL
FIELD SAMPLING PLAN**

**GENERAL ELECTRIC (GE) HOUSATONIC RIVER PROJECT
PITTSFIELD, MASSACHUSETTS**

Contract No. DACW33-94-D-0009
Task Order No. 032
DCN: GEP2-082898-AACK

Prepared for:

**U.S. ARMY CORPS OF ENGINEERS
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October 1998

W.O. No. 10971-032-001-0130

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LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
ATD	automated thermal desorption
BGS	below ground surface
CAW	case-and-wash drilling
CCQC	contractor chemical quality control
CENAE-MRD	U.S. Army Corps of Engineers-Missouri River Division
CGI	combustible gas indicator
CLP	Contract Laboratory Program
COC	chain-of-custody
CPS	counts per second
D.O.	dissolved oxygen
DCD	drill-through casing driver
DCQCR	daily chemical quality control reports
DHH	downhole hammer
DI	de-ionized
DOT	Department of Transportation
DQCRs	daily inspection/quality control reports
DQOs	data quality objectives
DRT-MUD	mud rotary drilling
EOL	electromagnetic offset logging
EPA	U.S. Environmental Protection Agency
FID	flame ionization detector
FLM	Field Logistics Manager
FSL	FS Technical Lead
FSP	Field Sampling Plan
FTL	Field Technical Leader
GE	General Electric Company
GEOLIS	Geologic Logging and Interpretation System
gpm	gallon per minute
GPR	ground penetrating radar
GPS	Global Positioning System
HASP	Health and Safety Plan
HSA	hollow-stem auger
HSC	On-Site Health and Safety Coordinator
ID	inside diameter

LIST OF ACRONYMS

(Continued)

IDWs	investigation-derived wastes
LM	Logistics Manager
MAG	magnetometry
ml	milliliter
mmhos/m	units of millimhos per meter
MS/MSD	matrix spike/matrix spike duplicate
NAPL	non-aqueous phase liquids
ns	nanoseconds
NSF	National Sanitation Foundation
nT	standard nanoTesla
OD	outer diameter
OM	Operations Manager
ORP	oxidation reduction potential
OSHA	Occupational Health and Safety Administration
OSM	On-Site Manager
OU	operable units
OUMs	Operable Unit Managers
PID	photo-ionization detector
PM	Project Manager
PPE	personal protective equipment
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RI/FS	remedial investigation/feasibility study
RIL	RI Technical Lead
RPM	revolutions per minute
RQD	rock quality determination
SAP	Sampling and Analysis Plan
SOPs	Standard Operating Procedures
sorbers	sorbent containers
SPCS	State Plane Coordinate System
t ¹	one-way travel time
t ²	two-way travel time
TCE	trichloroethene

LIST OF ACRONYMS

(Continued)

TOC	total organic carbon
TR	traffic report
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator
UV	ultraviolet
VOA	volatile organic analysis
VOC	volatile organic compounds

Section 1

1. PROJECT DESCRIPTION

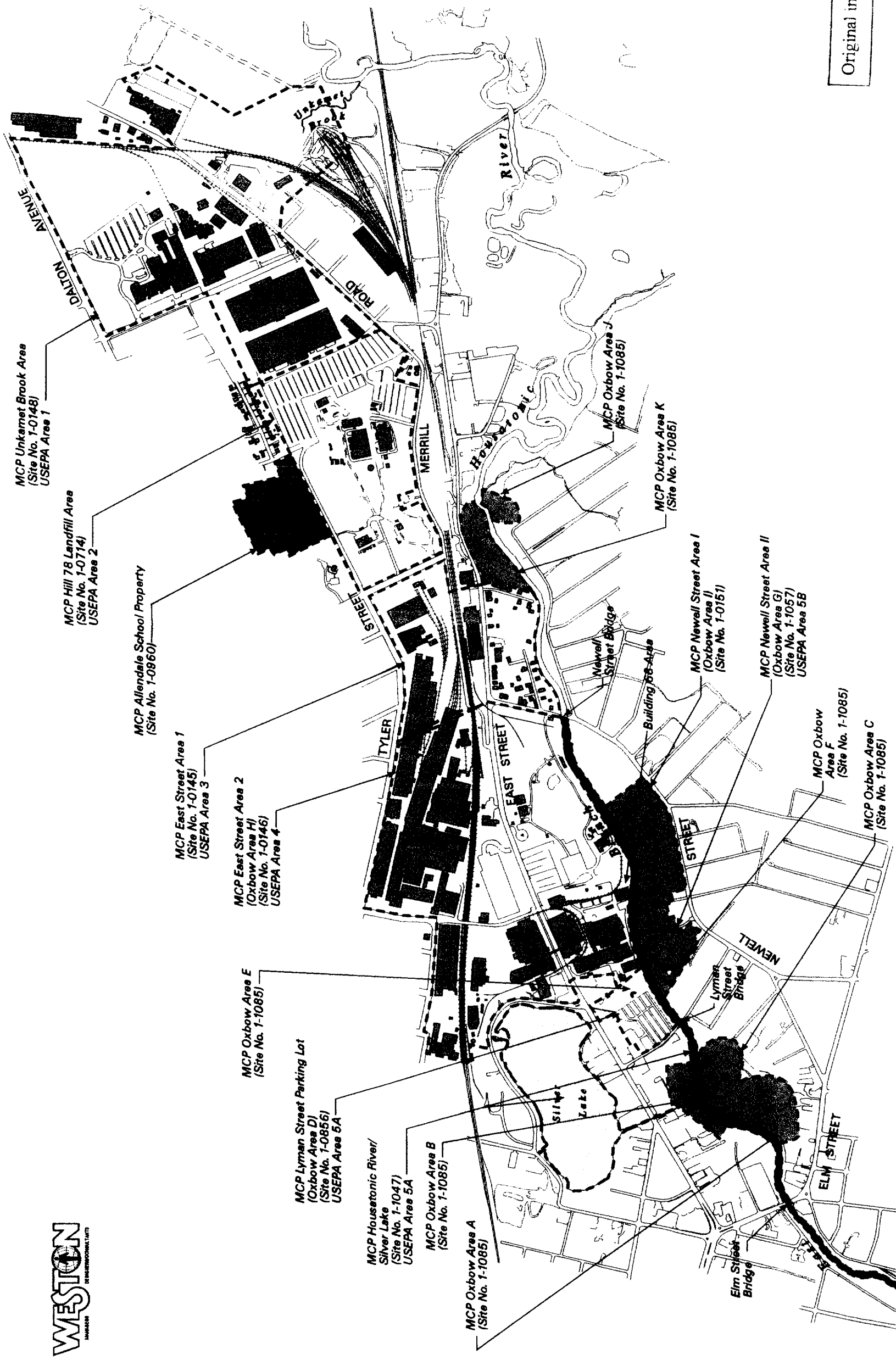
1.1 SITE DESCRIPTION AND BACKGROUND

This Field Sampling Plan (FSP) contains detailed procedures related to the collection and analysis of soil, sediment, water (ground and surface), and other field activities for the General Electric Company (GE) Site in Pittsfield, Massachusetts.

The facility is approximately 245 acres with approximately 5 million square feet of covered buildings. Industrial activities occur or have occurred throughout most of the GE facility. The facility consisted of three main production areas: the transformer division, ordinance division, and the plastics division.

GE began manufacturing electrical transformers and capacitors at the Pittsfield plant in 1903. Prior to 1977, the facility used insulating oil containing polychlorinated biphenyls (PCBs) as dielectric fluids in some capacitors and transformers [01-0082]. As a result of historic and associated product manufacturing operations, various oils, including PCB-containing oils, have been released to soil, surface water, and groundwater from leaking tanks, pipes, and spills. There are also areas within the site that contain subsurface concentrations of non-aqueous phase liquids (NAPL), including both light phase (LNAPL) and heavy phase (DNAPL) components.

To address the presence of soil and groundwater contamination, the facility has undertaken a number of remediation programs. These programs have been performed under existing agreements with the U.S. EPA and Massachusetts DEP. Investigations under the 1981 Consent Order indicated that groundwater contained contaminants including trichloroethene (TCE), chlorobenzene, and benzene, as well as metals. The sediments and water of the Housatonic River, Unkamet Brook, and Silver Lake are contaminated with PCBs.



LEGEND

- | | | | | | |
|--|----------------------------|--|----------------------------|--|------------------------------------|
| | O.U. #1 - GE Facility | | O.U. #3 - Allendale School | | O.U. #5 - Newell Street |
| | O.U. #2 - Housatonic River | | O.U. #4 - Silver Lake | | O.U. #6 - Oxbows A, B, C, J, and K |



Map produced by WESTON, adapted from Geographic Information System (GIS) database provided by TechLaw Inc.

Field Sampling Plan
GE Housatonic River Project
Pittsfield, Massachusetts

FIGURE 1-1
LOCATIONS OF OPERABLE UNITS (O.U.s)

This FSP is a compilation of field sampling methods, installation procedures, sample handling procedures, and quality assurance/quality control (QA/QC) procedures. As any new procedure is required, addendums to this document will be issued.

Section 2

2. PROJECT ORGANIZATION AND RESPONSIBILITIES

2.1 PROJECT PERSONNEL

To effectively execute the field program at the Pittsfield Site, the following management structure, with clearly defined positions, has been developed (Figure 2-1). General summaries of the responsibilities by position are presented in the following subsections.

Project Manager (PM)—The PM is responsible for the technical, financial, and overall management and quality assurance for this project.

Program Health and Safety Manager—The Health and Safety Manager ensures compliance with the Occupational Health and Safety Administration (OSHA) and the health and safety plan (HASP).

Project QA/QC Manager—The project QA/QC Manager is responsible for project quality assurance/quality control (QA/QC), ensuring consistency across OUs, and organizing the advisory group.

Operations Manager (OM)—The OM is responsible for the technical execution of the project work assignments. The OM is responsible for scheduling, subcontracting, technical supervision, and execution of the work assignments.

Operable Unit Managers (OUMs)—The OUMs are responsible for the overall completion of the remedial investigation/feasibility study (RI/FS) project for their respective OU. They are also responsible for the full scope of work pertaining to respective stages of the RI/FS, quality of deliverables, and for financial control, including subcontractor procurement and monitoring. They have overall responsibility for scheduling in coordination with the GE Pittsfield Project Scheduler, provide technical guidance and direction to RI and FS Managers and other team members, and are the direct point of contact with the EPA OU Leads.

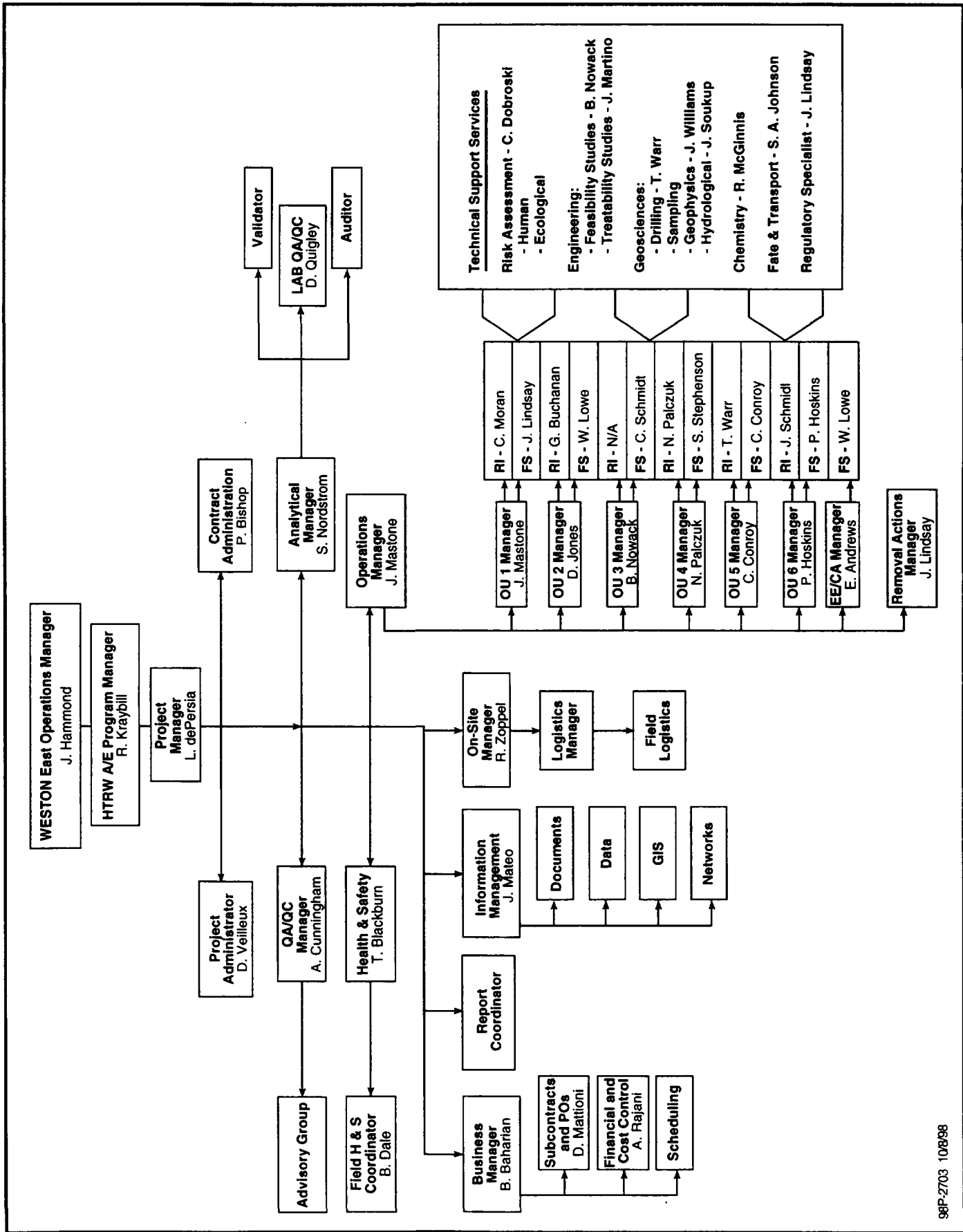


FIGURE 2-1 WESTON ORGANIZATION CHART - GE HOUSATONIC RIVER PROJECT

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RI Technical Lead (RIL)—The RIL is responsible for overall management of the RI and for tracking technical progress and reports within his/her OU. RILs coordinate with the Field Technical Leads to ensure that all tasks are performed correctly according to Work Plan and SAP requirements and to plan and accomplish RI objectives for the OU and coordinate with other OU Managers and RI Leads. They track and evaluate technical data as they are generated, and discuss with OU Managers the following items:

- Technical data gaps.
- Adjustments to schedule.
- Adjustments to scope concerning field activities.
- Coordinates with the Data Manager to obtain OU related data.

FS Technical Lead (FSL)—The FSL is responsible for the overall management of the FS and for tracking technical progress and reports within his/her OU. The FSL will coordinate with the FS team members to ensure that all tasks are performed correctly according to Work Plan requirements; coordinate with the Data Manager to obtain OU related data; coordinate with Technical Leads, as necessary, to plan and accomplish FS objectives for the OU; and coordinate with other OU Managers and FS Leads to execute the overall FS program. They track and evaluate technical data as they are generated, and discuss with OU Managers the following items:

- Technical data gaps.
- Adjustments to schedule.
- Adjustments to scope concerning field activities.

Removal Action Manager—The Removal Action Manager is the point of contract for EPA OSC and is the overall manager of removal action activities.

Technical Support Services Leads—The Technical Support Services Leads provide discipline specific guidance to technical staff and ensure compliance with project plan and protocols; ensure consistency across OUs for respective discipline; provide guidance and recommendations; and perform work for the OUM, RIL, and FSL in their individual areas of expertise. They also maintain familiarity with specific CENAE and EPA requirements as they pertain to their specific areas of expertise.

Field Technical Leader (FTL)—The FTL is responsible for the daily execution of field tasks, ensuring that field work is conducted in accordance with project procedures and requirements,

and act as central point of contact between field teams and OUMs regarding technical information and decisions. The FTL will report to the On-Site Manager and OUMs concerning daily and weekly field progress. They also ensure proper logbook assignments and check logbooks to ensure that data entry is accurate and complete, provide daily activity assignments to team members and subcontractors, and are responsible for monitoring field QA/QC and for ensuring that field notes are signed and copied at the end of the day.

GE Pittsfield On-Site Manager (OSM)—The OSM manages the GE Pittsfield WESTON project office and assigned personnel. The OSM ensures that access to OU areas is available for all on-site WESTON personnel and that access is available for all on-site intrusive work by obtaining digging permits and right-of way clearance. The OSM coordinates with OUMs, TILs, and FTLs daily to facilitate scheduling field activities and to track daily progress of all on-site activities; provides daily written reports, weekly summaries, and quarterly reports to the OPS MGR and appropriate client contracts; and serves as a point of contact with GE, CENAE, EPA and/or the regulatory agency personnel for WESTON activities. The OSM ensures that on-site WESTON employees are aware of on-site regulations established by WESTON and pertaining to access to areas and communication with CENAE, EPA, GE staff and others, and provides logistical support to all on-site WESTON personnel.

Logistics Manager (LM)—The LM coordinates with, supervises, and trains the WESTON On-Site Field Logistics Manager (FLM). The LM provides assistance and support to the OSM, and is responsible for WESTON's site facility (i.e., security, maintenance, construction, and operation) in coordination with OSM and FLM and for oversight of equipment purchase, maintenance, and inventory; record keeping; and security. The LM coordinates WESTON resources in use at the site, including equipment rental and shipping, and is responsible for all logistical coordination between West Chester, PA; Manchester, NH; and the GE Pittsfield Project Office.

Field Logistics Manager (FLM)—The FLM is responsible for daily inspections, maintenance and calibration of all field instruments, and maintenance of all WESTON field equipment on-site. The FLM performs ongoing inventory of all site equipment and supplies. The FLM is responsible for tracking equipment maintenance records; for maintenance of WESTON's site facilities, including offices, storage areas, indoor work areas, and assigned outdoor facilities,

excluding water treatment plants; for maintenance of WESTON site vehicles, as needed; and for WESTON site facility security. The FLM provides assistance and support to all on-site staff.

GE Pittsfield On-Site Health and Safety Coordinator (HSC)—The HSC coordinates and provides guidance on health and safety issues, and is responsible for giving daily safety briefings to field personnel.

Field Team Leader—The Field Team Leader is responsible for ensuring that sampling or other field activity that they are directing is performed by his or her team is in compliance with the FSP. The Field Team Leader communicates any problems or questions to the Field Technical Lead for resolution.

2.2 LABORATORY RESPONSIBILITIES

Analytical laboratories will be pre-qualified by providing WESTON with documented procedures, resumes of personnel and certifications, previous experience, and laboratory QA program information to verify that the laboratory has appropriate experience and expertise to perform the required analyses. From this list, a short list of laboratories to provide off-site analysis and a contractor to provide a field-based laboratory at the site will be selected via competitive procurement. Detailed project performance specifications, including sample handling, methodologies for sample preparation and analysis, required QC criteria, and deliverables, will be built into the subcontract agreements with both field and off-site laboratory vendors. Individual laboratory point-of-contacts will be identified prior to site mobilization.

All laboratory contractors providing off-site analyses will be approved by the U.S. Army Corps of Engineers-Missouri River Division (CENAE-MRD). It is anticipated that the field laboratory will be audited by the USACE-New England District upon mobilization to the site.

WESTON will be responsible for collection of all samples required for this project. WESTON will also be responsible for collection of any samples that may be sent to the laboratory for QA analysis.

The QA laboratory and the QA Project Manager for this project will be determined prior to the start of field work.

Section 3

3. SCOPE AND OBJECTIVES

3.1 PROJECT PURPOSE

The purpose of this project is to gather additional information required to develop a remedial design. The amount of information required is based on identified gaps in data (data gaps). The collection of data to fill these data gaps will be accomplished by a number of methods. This FSP is a compilation of field sampling methods, installation procedures, sample handling procedures, and analytical and quality assurance/quality control (QA/QC) procedures. As any new procedure is required, addendums to this document will be issued.

3.2 SCOPE OF WORK

Scopes of Work for the various OUs are being developed to address data gaps and to provide additional information required to design a remedial action for the site. The various scopes of work are being detailed in OU work plans, which are in preparation as of the submission of this document.

3.3 GENERAL QA/QC PROCEDURES

Quality assurance/quality control (QA/QC) samples will be collected and include QA duplicates, QC duplicates, trip blanks, and temperature blanks. These samples are collected to monitor field sampling, packaging/shipping activities, and the quality of analysis by the analytical laboratory. The procedures are listed in Subsection 4.10.

Samples will be sent to a CENAE QA laboratory by overnight delivery and analyzed to evaluate Contractor laboratory performance. WESTON will coordinate with the designated QA laboratory not less than 48 hours before sampling to ensure that the QA laboratory is alerted to receive the QA samples and process them within the time limits specified by applicable EPA method, regulation, and guidelines.⁷

Section 4

4. FIELD ACTIVITIES

As part of the various field investigations, several standard field procedures may be performed as required in the respective work plan documents for each OU. These include:

1. Geophysics
2. Soil Gas Survey
3. Groundwater Monitoring Well Installation, Development, and Abandonment
4. Groundwater Sampling
5. Surface Water Sampling
6. Soil Sampling
7. Sediment Sampling
8. Surficial Sampling
9. Biota Sampling
10. QA/QC Sampling
11. Decontamination

This section of the FSP describes these procedures and references the appropriate detailed procedures. Pertinent analytical procedures and protocols, as well as QA/QC requirements, are described in Section 5. Sample handling, packing, and shipping procedures are described in Section 6. All sampling and field procedures will be conducted in accordance with the requirements described in the Health and Safety Plan. All personnel should be familiar with ASTM Standard D5730-96, Standard Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Groundwater.

The majority of the practices and standard operating procedures (SOPs) presented in this section have been compiled and/or modified from the following sources:

- EM-200-1-3 – Requirements for SAPs
- EM 1110-1-4000 - Monitor Well Design
- WESTON SOPs
- American Society for Testing and Materials (ASTM) Standards

These procedures should be viewed as SOPs , which can be modified only through the issuance of a revised procedure.

All field work must be undertaken in compliance with the Health and Safety Plan (HASP), and no procedures outlined in this section have precedence over procedures outlined in the HASP.

The senior WESTON person at a work location, normally the Field Team Leader, will identify all visitors to that location; determine whether they have permission to be at the work location; and record their name, work affiliation, and reason for being at the work location.

4.1 GEOPHYSICS

4.1.1 Rationale

This subsection presents the various surface geophysical techniques that may be utilized at the site. It describes the methods, protocols, geophysical survey equipment, and procedures for:

- Ground Penetrating Radar (GPR)
- High-Frequency Seismic Reflection (Seismic)
- Terrain Conductivity or Electromagnetic Offset Logging (EOL)
- Electromagnetics (EM)
- Magnetometry (MAG)

Other geophysical methods required for future characterizations will be amended to this SAP as they are utilized.

Surface geophysical methods measure the response of the earth to induced electrical or acoustical energy or measure variations in natural potential fields. Changes in the parameters that are measured can be related to variations in the local geology, the extent of contaminant plumes, or the presence of buried materials. Geophysical investigations are most effective when used in conjunction with drilling or boring programs, and can be used, for example, to guide monitor well placement or help determine the depth to bedrock.

Each site must be evaluated separately in planning a survey, and all available information should be reviewed before committing to a particular method. Site conditions and possible sources of interference should be evaluated. In the field, the geophysical team leader should be prepared to modify traverse lines, sampling intervals, or techniques due to changing or unforeseen conditions.

4.1.2 Ground Penetrating Radar (GPR)

A comprehensive GPR survey will be conducted within the river and adjacent areas using a combination of high frequency (i.e., 500 MHz) and low frequency (i.e., 80 MHz) antennae. The

high frequency will provide information on the shallow river sediments (i.e., 0 to 6 feet), and the low frequency will provide information on the till unit and deeper sediments (i.e., > than 20 feet).

GPR uses high frequency radio waves to map features in the shallow subsurface. Pulses of energy at radar frequencies are directed into the subsurface, and the reflected energy is processed and either stored electronically or plotted as a subsurface, profile on a graphic recorder. Variations in the intensity and strength of the signal are caused by variations in the dielectric properties of the reflectors. The depth of penetration varies from site to site, but is significantly limited in clay-rich soils or soils with high conductivity. Identification of subsurface anomalies depends on both the physical sizes of the feature and its relative electrical contrast with its surroundings.

4.1.2.1 Survey Equipment

GPR surveying currently planned will be performed using a Geophysical Survey Systems, Inc., GPR System 10 A+, or equivalent instrument. The GPR System 10 unit consists of a control/display unit, mainframe/data storage unit, and microcomputer. Antennae ranging between 80 and 500-megahertz will be used for radar data collection. A 12-volt battery or 110 V generator will be used to power the GPR system. Selection of an appropriate GPR antenna will be based on soil conditions determined during the site calibration. Items required to perform the GPR survey include the following:

- Site References, including the HASP and pertinent technical documents.
- GPR System, complete with:
 - System and backup transducer cables, power source, and Operations Manual.
 - Software operating disks for system backup.
 - Appropriate antennae – i.e., 500, 300, 100 [bi-static-accessories], and 80 MHz.
 - Accessory kit – including tools, chart paper, 8 mm tapes and head cleaning tape, diskettes, alcohol swabs.
- Field Computer, complete with:
 - Appropriate software, power inverter, ZIP drive, ZIP disks, and diskettes.

- Survey equipment:
 - Transit, level, rod, prism, or Brunton Compass as required.
 - Global Positioning System [GPS] as required.
 - Four tape measures, 300 feet or greater.
 - Standard graph paper.
 - Field logbook.
 - Ancillary equipment – i.e., markers, flagging, spray paint, stakes, plastic pin flags, waders.
- Survey Vehicle:
 - Inflatable [Avon] Raft, canoe, or small John Boat for river surveys as needed.

4.1.2.2 Survey Preparation

Field Team Leaders and other key project members will meet with the Project Manager to discuss project requirements. Areas to be surveyed will be inspected for accessibility before scheduling the field survey. Nearby power lines or utilities are often sources of interference and will be taken into consideration. A certified operator will oversee the survey. Field personnel assisting the GPR survey will, at a minimum, need to be familiar with the GPR procedures.

A licensed surveyor will establish a reference grid of wooden stakes over the study area. GPR profiling in each area will consist of a series of parallel transects along with appropriate spacing based on objectives.

4.1.2.3 Field Procedures and Quality Control

Currently, a GPR survey is planned to be conducted in the Housatonic River from Lyman Street to Newell Street and adjacent riverbank areas. Data will be collected along specified transects. Grid spacings are based on the subsurface control needed and the objectives of the survey. Additional transects may be performed to confirm and/or enhance the resolution of potentially significant subsurface features.

4.1.2.4 Calibration

Prior to beginning the GPR survey, the system will be calibrated to soil and moisture conditions at the site. The purpose of the GPR calibration is to provide depth control. Calculating the pulse rate or velocity of the transmitted radar signal traveling in the soil at a specific area is a means of obtaining depth control. Subsurface lithology and moisture control the GPR pulse rate. The GPR unit will be calibrated as follows:

- Pull the GPR antenna over a subsurface feature that has a known depth. (Features that may be used for GPR calibration include buried utilities, underground storage tanks (USTs), or buried drainage culverts. The time required for the transmitted radar signal to travel from the GPR antenna on the surface to the buried object and back to the antenna is defined as the two-way travel time (t_2). Therefore, the one-way travel time (t_1) would be the time required for the radar pulse to go from the antenna to the buried feature or $t_2/2$. Travel time is expressed in units of nanoseconds (ns). If it takes 20 ns for a radar pulse to travel down to a feature buried at 5 ft BGS and back to the surface, the radar pulses is $1/2 \times 20 \text{ ns} / 5 \text{ ft}$, or 2 ns/ft).
- The calculated pulse rate is then used to adjust the time range on the GPR control unit to reach a specific depth of investigation. (For example, if the desired depth of investigation for the GPR survey is 10 feet and the radar pulse is 2 ns/ft, then the time range would be adjusted to at least 40 ns.)
- The GPR calibration will be performed prior to the start of the survey each day and when starting a new area. (Internal electronic calibration was performed by GSSI.)
- The operator will document in the field logbook the calibration settings (i.e., range, gains, H/L filters, and sensitivity) and calculations (soil dielectrics and velocities).

4.1.2.5 Surveying

For the overwater surveys, the antennae will be towed by boat or by wading. For the land surveys, the antennae will be towed manually by hand. Real time graphics or cross-sectional radar profiles will be produced in the field. The following elements should be included in the survey:

- The GPR operator must annotate the GPR paper record as follows:
 - Client.
 - Site name.
 - Date: DD/MM/YY.
 - Time: 24-hour clock.
 - Profile number.

- Direction of traverse.
 - Antenna frequency.
 - Time range (nanoseconds).
- After each transect is recorded, the GPR operator will annotate the profile positions above each marker line on the GPR record.
 - The operator must document in the field logbook the time, profile number, and the end points for each transect conducted. Cultural features (i.e., defraction from sheet piles) that may influence the radar profiles should also be noted.
 - At least one profile must be repeated each day to check for repeatability of GPR signatures.
 - When using the graphic recorder, clean the print bar and associated mechanisms, using alcohol swabs at least once a day.

4.1.2.6 Data Reduction and Processing

All field tapes/disks will be backed-up onto portable ZIP disks or equivalent storage media at the end of each day of the GPR survey. The original field tapes will not be used for data reduction or processing, but will be permanently archived. The copied files will be used for all data manipulation. The lead geophysicists will review the GPR records to determine whether reprocessing (using RADAN software) is required to enhance data interpretation. The senior geophysicists will review the results of the reprocessing, if it is performed.

Black and white copies of all GPR records will be produced for the survey, and selected records interpreted to have features significant to the survey objective(s) will be plotted in color.

4.1.3 Seismic (Sub-bottom Profiling)

Concurrent with the GPR activities, a High-Frequency Seismic Reflection survey is planned to be conducted within the river along the same transects as the GPR. The seismic reflection profiling system falls into the category of acoustic instruments known as sub-bottom profilers. The system provides continuous high resolution seismic reflection profiles in unconsolidated sediments of up to 100 feet. The emphasis of the seismic survey will be the upper till unit and upper bedrock surface. The Sub-bottom Profiler will be used to obtain rapid, continuous reflection soundings of the stratigraphic units below the bottom of the river (the sub-bottom).

4.1.3.1 Survey Equipment

Sub-bottom profiling will be performed using a Datasonics, Inc., High Resolution Model CAP 6600 CHIRP II Acoustic Profiling System, or equivalent instrument. The system consists of a seismic amplifier, source vehicle, power supply, and a hydrophone streamer cable. The system operates at acoustic frequencies between 0.5 and 23 kHz. Equipment required to perform the sub-bottom profiling survey include the following items:

- Sub-bottom profiler system, complete with:
 - System and backup transducer cables, power source, and Operations Manual.
 - Power source – 110/5kW generator. Note: Experience has shown high noise levels associated with the Honda units. Considerably lower noise levels were experienced using the Onan units.
 - Software operating disks for system backup.
 - Accessory kit – including tools, chart paper, diskettes, alcohol swabs.
- Field Computer, complete with:
 - Appropriate software, power inverter, ZIP drive, ZIP disks, and diskettes.
- Survey Equipment:
 - Transit, level, rod, prism, or Brunton Compass as required.
 - Global Positioning System [GPS] as required.
 - Four tape measures, 300 feet or greater.
 - Standard graph paper.
 - Field logbook.
 - Ancillary equipment – i.e., markers, flagging, spray paint, stakes, plastic pin flags, waders.
- Survey Vehicle:
 - Inflatable [Avon] Raft, canoe, or small John Boat for river surveys as needed.

The Sub-bottom Profiling System can be equipped with two sources: a 3.5- and 7.0-kHz chirp, and a 0.5- to 2.5-kHz bubble pulser. The chirp can attain sub-bottom layer resolutions to 6 to 8 cm, while the bubble pulser has a resolution on the order of 2 m.

The conflicting impact of energy sources is the energy available for penetration and deeper reflections and its ability to provide the necessary resolution. Some near-bottom sediment contains organic material that readily absorbs energy. Higher energy sources may allow penetration of these materials. The bubble pulser's greater energy content and broad spectrum allow significantly greater depth returns.

Graphic displays print real-time reflector returns to the transducer. Recording systems retrieve the data for later processing. The field recorders graph time of source firing versus time of arrival returns.

4.1.3.2 Survey Preparation

Field Team Leaders and other key project members will meet with the Project Manager to discuss project requirements. Areas to be surveyed will be inspected for accessibility before scheduling the field survey. A lead geophysicist will oversee the survey. Field personnel assisting the sub-bottom profiling survey will, at a minimum, need to be familiar with the procedures.

4.1.3.3 Field Procedures and Quality Control

The planned survey will be performed in the Housatonic River from Lyman Street to Newell Street and will be conducted by small boat/wading. The seismic system will be mounted in a boat and towed along predetermined transects to be specified in the work plan for OU 2.

Calibration

Stored calibrated data provides for real-time computation of the riverbed reflection coefficients, which can then be used with classification algorithms to predict the sub-bottom sediment types. Classification algorithms are included in the CHIRP II software.

Surveying

Sub-bottom profiling will consist of a series of parallel transects (consistent with the GPR lines) with appropriate spacing. Additional transects may be performed to confirm and/or enhance the resolution of a potentially significant subsurface feature. Real time graphics or cross-sectional profiles of the sub-bottom will be produced in the field. The following elements will be included in the survey:

- The operator must annotate the profile record as follows:
 - Client.
 - Site name.
 - Date: DD/MM/YY.
 - Time: 24-hour clock.
 - Profile number.
 - Direction of transect.
 - Source/frequency.
 - Time range.
- After each transect is recorded, the operator will annotate the profile positions above each marker line.
- The operator must document in the field logbook the time, profile number, end points for each transect conducted, range, gain, filter and sensitivity settings. Cultural features (i.e., defraction from sheet piles) that may influence the record should also be noted.
- At least one profile must be repeated each day to check for repeatability of sub-bottom structures.
- Clean the graphic recorder (print bar and associated mechanisms) using alcohol swabs at least once a day.

4.1.3.4 Data Reduction and Processing

The data will be processed using software such as *Chirpscan* or *Geodas*. Office processing of the field data determines the sub-bottoming properties empirically. The empiricisms are reduced when more sampling (boring) data are available to assess unit p and loss parameters for modeling. The processing incorporates the GPS locations with the time of firing records to approximate the individual “shot” along the towed boat path. The seismic evaluation resolves the layer and unit depths. From the firing surface locations and unit depths, the field graphs are

correlated to tow path distance versus reflector depths. Fence diagrams of depth and material types will result once all parallel and crossing surveys are resolved.

4.1.4 Resistivity—Electromagnetic Offset Logging (EOL) and 2D Reconnaissance

An initial Downhole Electromagnetic Offset Logging (EOL) is planned to be performed at Lyman Street Parking Lot in the area encompassing Oxbow Area D. The EOL produces a 3-dimensional resistivity image of the subsurface that reflects the changes in the physical or chemical properties of the subsurface materials. This area was one of three that were identified as having the highest potential for “free phase” NAPLs within OU 2.

The results of the survey will be evaluated in the field to determine whether the resistivity anomalies and boundaries (measured by the EOL) provide clearer definition of the stratigraphic layering and the gross plume characteristics. These criteria will be used to decide if the EOL will be expanded to the area west of Building 68 and the area encompassing Building 64.

Common surface resistivity surveys measure the electrical resistivity of the subsurface by introducing a direct or low frequency current into the ground. The resistivity values are a reflection of the underlying lithology and the interstitial fluids. EOL uses the same theory in a “down-hole” application.

All EM techniques have as their objective the measurement of resistivity variations (or its complement, conductivity variations) in the subsurface. Today’s environmental site-characterization resistivity surveys are generally designed and limited to mapping metal objects at shallow depth in the subsurface. The EOL surveys are designed to map and image subsurface resistivity variations associated with hydrocarbon plumes, dissolved-solid plumes, and geology and hydrogeology features to potential depths of several hundred feet.

4.1.4.1 Survey Equipment

The EOL method uses a surface source coil with a very low frequency signal to optimally induce a long wave-length, time-varying magnetic-field flux into the ground below the source coil location. The source coil is an optimally tuned coil with an area of about four square meters, a current of

about 10 amperes, and more than 30 turns of low resistance wire, all of which create an effective EM moment of more than 1,200 ampere-meters squared. Voltage data (which provide a measure of the magnetic-field flux) are remotely sensed by a finely-tuned amplifier coil EM receiver (in-hole probe or sonde).

4.1.4.2 Survey Design and Preparation

The first step of an EOL survey is to review all geologic and hydrogeologic data available, as well as to review site-specific sources of cultural and electrical noise interference. This will allow the laying out of the most advantageous geophysical survey patterns to be used to fulfill the survey objectives and to choose the most noise-free receiver well locations.

Site background information will be reviewed to assess the influence of geology, buried materials, disturbed soils, or waste plumes on the resistivity survey. Possible sources of electrical interference include buildings, power lines, pipelines, and railroads. Surveys should not be planned parallel to high voltage lines. The EOL must adhere to a strict set of requirements if they are to provide a complete and definitive image of the subsurface.

EOL Receiver Considerations

- The EOL surveys must have at least 2 sets of receiver wells on either side of the dam: two north of the river (on-site) and two south of the river (off-site). Receiver wells should be located on either side of the plumes (pools), and should be located outside any 150 foot square area at Lymon Street.
 1. It is required that the receiver wells, thus the logs, need to be 10 feet deeper than the depth of the model; there are no exceptions for DNAPL EOL models.
 2. A distance that is 5 times the depth of investigation must separate receiver wells.
 3. If the depth of investigation is > 50 feet bgs, 3 or more strategically placed receiver boreholes must be used.
 4. Boreholes must be located at least 50 feet or more from powerlines and at least 50 feet away from the edges of a NAPL plume.
 5. The average voltage of the receiver data should be equal to or greater than 3 times the average of the background noise (transmitter turned off). If the signal strength in an area is inadequate, then a different receiver borehole must be used.

- The EOL cannot propagate EM fields effectively through vertical conductive barriers - i.e., sheet pile.

EOL Transmitter Considerations

- Transmitter grid spacing - A fine spaced rectangular (Cartesian-coordinate) grid will be used for locating the transmitter. Grid nodes will be established using an appropriate spacing between 10 –40 feet as the survey requirements dictate.
- An equilateral triangle source on a floating platform/boat will be used if surveying is to be performed in the river. This triangle has the same effective EM moment as the 6-foot on a side square loop.
- A small power generator (1,600 watt, single phase, 60 Hz) and the power amplifier switch should be mounted on the platform.
- The EOL transmitter and the GPR can be operated together in real time without cross-talk affecting the GPR.

4.1.4.3 Field Procedures and Quality Control

Surveying

EOL equipment will be assembled and tested according to the manufacturer instructions before mobilization at the site. These procedures will vary slightly with the equipment used, but should include a battery check and an internal check of the electronics. All cables and connectors will be inspected for signs of breaks or frayed insulation.

EOL surveys, and subsurface geologic analyses, are based on sampled data. The signals received by the borehole receiver at different depths in a well are the result of the superposition of the flux from time-varying magnetic fields. These fields are generated by many “eddy currents” (image currents) created by the source coil (transmitter).

The magnetic field flux signals are measured by an in-hole receiver, which is finely tuned to the specific source-signal frequency being used. The frequency used in environmental EOL surveys is a low frequency chosen at one of the minimum-amplitude spectral points of the noise spectrum commonly found at culturally and industrially noisy sites. The signals from the receiver are passed through a high-Q inverted notch filter specified for the particular source-coil frequency. This step enhances signal over noise. The filtered signal is then passed to an integrator, which

performs additional signal-to-noise enhancement by summing and averaging the signal over many tens of cycles of the source signal.

Surveying consists of collecting a complete set of voltage measurements at 0.1-foot intervals along the receiver borehole with the source coil established at a fixed location. The source coil is moved to another surface location and new measurements are taken up the borehole. The process will be repeated until a three-dimensional matrix of the voltage data (to be converted to resistivities for the subsurface) has been adequately developed. The receiver will be moved to the next borehole and the procedure continued. For each run, the operator will annotate the log and document in the field logbook or EOL data sheet the following information:

Electromagnetic Offset Logging Data Sheet

Site _____	Log/Run Number _____
Date: DD/MM/YY _____	Time: 24-hour clock _____
Rx BH. ID. _____	BH Depth/Diameter _____
Survey Type _____	
Source Coil ID _____	Log/Run Number _____
Team Leader _____	Page _____ of _____

<i>Source Coil Coordinates (ft)</i>	<i>Source Signal Frequency (Hz.)</i>	<i>Sample Depth/Rate</i>	<i>Filter Settings</i>	<i>Noise</i>
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- At least one run must be repeated each day to check for repeatability of data
- Cultural features (i.e., sheet piles) that may influence the record should also be noted.

The geophysics team will evaluate the survey data in the field and assess whether the instrument configurations and station spacings selected will meet the objectives. The design may be modified if necessary in order to meet objectives.

4.1.4.4 Data Reduction and Processing

Data interpretation will consist of the following steps:

- The data will be processed using appropriate software. Office processing of the field data determines the resistivity contrast of subsurface features to its surrounding materials based on a set of strict empirical formulas. These formulas take into consideration several site variables:
 - Vertical thickness of target.
 - Minimum horizontal dimensions of the target.
 - Depth of target.
 - Distance to target.
- The data are processed to remove noise. Then apparent resistivity, first order and residual resistivity, and second order offset logs are developed.
- Several ASCII 1-D files are developed for each EOL to generate two-dimensional cross sections.

4.1.5 Terrain Conductivity Survey

Terrain conductivity surveys are conducted to identify variations in subsurface materials. The variations are attributable to changes in soil lithology, moisture content, groundwater depth, groundwater chemistry, bedrock depths, or buried metallic objects. EM-31, GEM-II, and EM-34 terrain conductivity surveys may be used by WESTON to identify waste disposal areas and other areas.

Terrain conductivity is measured by using a transmitter coil to induce a local electromagnetic field in the earth while simultaneously measuring the electrical response of the earth to the field through a receiving coil. The response is recorded directly as terrain conductivity, expressed in units of millimhos per meter (mmhos/m).

4.1.5.1 Survey Equipment

The depth of a terrain conductivity exploration depends on the instrument used, the spacing and configuration of the transmitting and receiving coils, and the transmitting frequency. The operator must determine the appropriate instrument configurations and station spacings necessary to meet the specified objectives. Depending upon the application, the instruments typically used by WESTON include the Geonics® Models EM-31, EM-34, and EM-61, and the GSSI Model GEM-300. The EM-31 can be operated by a single person using a fixed coil spacing

(i.e., distance between transmitter and receiver). It has a maximum depth of investigation of approximately 18 feet. The EM-34, which requires two people for operation, consists of separate transmitter and receiver coils connected by a cable. The maximum effective depth of investigation for the EM-34 unit is dependent on the selected coil spacings, coil orientations of the instrument, and the conductivity characteristics of the subsurface materials.

The Geonics EM-61 is a high-sensitivity, high-resolution, time-domain metal detector that uses a pulsed primary magnetic field to detect both ferrous and non-ferrous metallic objects. The EM-61 has the ability to detect a single (55 gallon) drum at a depth of over 10 feet beneath the instrument, yet it is less sensitive (than the EM-31) to nearby surficial cultural features.

The GSSI GEM-300 is a multi-frequency electromagnetic profiling system capable of measuring up to 16 discrete frequencies. The frequencies are defined by the operator to provide the maximum resolution for specific applications.

Data interpretation is performed by preparing a series of graphic plots of terrain conductivity values for the various survey instrument configurations along each line. Additionally, contour maps are prepared by combining the data from all survey lines for similar survey instrument configurations. Correlation of these data with other geological and geophysical data enables interpolation of subsurface conditions between or beyond boreholes.

4.1.5.2 Survey Design and Preparation

Method Limitations

The terrain conductivity method is limited in depth of penetration, as described above. Additionally, the instruments are susceptible to interference from manmade structures, such as buildings, fences, pipelines, and electric utilities. The vertical resolution of terrain conductivity is less than that of electrical resistivity; however, a combination of the terrain conductivity survey method with other geophysical techniques and existing lithologic data minimizes the inherent uncertainty.

4.1.5.3 Field Procedures

The field effort usually consists of an initial field test, conducting the terrain conductivity survey, and on-site data evaluation. The procedures follow.

- Equipment operator(s) check their pace distance while carrying the instrument by counting paces between established site grid stakes.
- Survey design is tested by conducting terrain conductivity measurements in areas of known geological and geophysical properties. If site geology permits, a test survey will be conducted in both an area of known geological/geoelectrical complexity and an area of relatively nonvariable geology. Terrain conductivity readings, station locations, and observations of surface features and terrain are recorded in the field logbook.
- Terrain conductivity readings are made with the instrument at all stations along survey lines using the appropriate dipole orientations and/or separations. All readings are made with the transmitter and receiver coils oriented in the direction of the survey line. Dipole orientations and separations are recorded in the field logbook. Line numbers, station locations, and readings are electronically recorded in the instrument's memory or at a logger.
- The lead geophysicist reviews the terrain conductivity data each time the full set of survey lines with a particular instrument configuration is completed.
- General trends of conductivity at the site and locations of any anomalous areas are noted. If appropriate, additional fill-in station locations at areas of high or unusual terrain conductivity measurements are collected.

4.1.5.4 Data Reduction and Processing

Office data reduction consists of final data reduction and interpretation procedures. The procedures are presented in this subsection. The key task in the office data reduction is the efficient QA/QC of all terrain conductivity files.

- The terrain conductivity data are reviewed by the lead geophysicist, who selects appropriate scales for terrain conductivity graphs and contour intervals for contour maps.
- Terrain conductivity plots are then prepared for the appropriate instrument configurations.
- Contour maps of terrain conductivity data for all instrument configurations are prepared.

The terrain conductivity data are reviewed and correlated to existing geologic and geophysical data.

4.1.6 Magnetometry Survey

Magnetometry surveys are usually conducted to locate areas containing concentrations of buried ferrous materials.

The magnetic method detects variations in magnetic susceptibility within the subsurface environment. Magnetic susceptibility is a physical property of matter that describes the ease of its magnetization. For example, while most sedimentary rocks have magnetic susceptibilities ranging between 10^{-6} and 10^{-5} electromagnetic units (cgs), iron alloys have susceptibilities ranging from 1 to 10^{-6} cgs. When the earth's magnetic field encounters a material with a high magnetic susceptibility, induced magnetization occurs. The material is magnetized, and the resulting induced magnetic field is the product of its volume magnetic susceptibility (cgs) and the earth's field intensity (nanoTesla). Consequently, variations in the earth's magnetic field may be measured at locations of buried ferrous materials.

4.1.6.1 Survey Equipment

Depending upon the application, the instrument typically used by WESTON is the Geometrics G-858 cesium vapor mobile Gradiometer/Magnetometer. The instrument operates on the principle of a self-oscillating split-beam cesium vapor (non radioactive Cesium 133) source. This magnetometer generates a small signal whose frequency is proportional to the intensity of the total magnetic field. Local perturbation (induced magnetization) generated by anthropogenic (i.e., buried ferrous drums) and natural (i.e., magnetic mineral deposits) features add to the intensity of the ambient magnetic field. The magnetometer measures the vector sum of the earth's magnetic field and the anomalous induced magnetic field in standard nanoTesla (nT) units.

The mobile Magnetometer/Gradiometer system is comprised of a console with an LCD screen connected to a cesium sensor mounted on a counterbalanced staff. The console displays the magnetic field and horizontal position data, stores high volumes of data in memory, and transmits the data at high speed to a processing computer for detailed analysis. The instrument allows for

discrete data acquisition at individual stations or automatic data acquisition at preset time intervals along a survey line.

Base station magnetometers include the GEM-19 and G-856.

Method Limitations

There are certain limitations to the magnetic method. Koerner et al. [00-2228] have experimentally determined that a single 55-gallon drum buried approximately 10 to 11 ft bgs probably will not be detected. In addition, they have shown that a single drum buried at a depth of 3 feet will sometimes escape detection at a lateral offset distance of 6 feet. Additional limitations include drum corrosion and magnetic noise from scattered surface debris.

4.1.6.2 Survey Design and Preparation

Prior to beginning a magnetometry survey, the magnetometers are prepared for data acquisition. The magnetometer's internal clock must be synchronized to local time, and the magnetometer tuned to the regional magnetic field to achieve the optimum signal strength.

4.1.6.3 Field Procedures

The magnetic surveys are conducted along pre-established grids, with the sensors set at a fixed height. The height of the sensors will be documented in the field logbook. Data will be recorded for the total magnetic field and magnetic gradient by entering the grid coordinate location and the associated magnetic field measurements in the magnetometer's digital memory. During the survey, locations of cultural features (e.g., metallic fences, powerlines, railroad tracks, and scrap metal) are recorded in the field logbook.

Base station readings are obtained (at an appropriate interval, i.e., 1-2 minutes) throughout the survey period to monitor (diurnal) variation of the earth's magnetic field by a fixed base station magnetometer. The base station should be located in an area known to be free of buried waste material and cultural interferences.

During the survey, the magnetic values obtained at the first and last stations along each traverse are manually recorded in the field logbook. Following each day's survey, the data from both the base station and survey magnetometer are uploaded to a field computer. These values must then be compared to the information recorded in the field logbook to ensure that the magnetometer is storing data correctly.

4.1.6.4 *Data Reduction Processing*

After the magnetics data are uploaded to the field computer, the data are formatted and edited using Excel software, or equivalent. Prior to any interpretation, corrections of diurnal variations are applied to the data. The edited data file is then loaded into a contouring program to produce vertical magnetic gradient and total field anomaly maps. The contour plots are interpreted for magnetic anomalies, taking into account cultural influences.

Anomalies are defined as deviations from local magnetic background readings. All sites have certain levels of magnetic noise associated with localized variations in magnetic susceptibility because of changes in subsurface lithology or cultural interferences.

All of the displays (i.e., total field, vertical gradient, cultural features maps, and the magnetic profiles) are then incorporated into an integrated interpretation, resulting in the identification of two types of magnetic anomalies. One type of anomaly results from surface cultural features. The second type of anomaly is likely the result of detection of buried ferrous materials.

More emphasis is placed on the vertical gradient data and maps during interpretation because gradient measurements decrease more rapidly than do total intensity measurements with distance from a buried magnetic source; therefore, the areal extent of the magnetic anomaly is reduced with gradient measurements. This results in a more accurate location of the source of the magnetic anomaly.

4.1.7 Data Management

Data management will consist of the following steps:

- Logbooks and data disks are coded, managed, and maintained.
- All graphs, maps, and original reports will be permanently stored.

4.2 SOIL GAS SURVEY

4.2.1 Rationale

The purpose of a soil gas survey is to collect samples of soil vapor from vadose zone soils and to analyze those samples for volatile chemical analytes in an on-site or remote laboratory. The most common objective of soil gas sampling is to provide an initial screening tool in site investigations. When used and interpreted properly, soil gas sampling can provide data that are relatively indicative of soil and/or groundwater quality conditions. Analysis can be qualitative (i.e., field instrument screening such as a photo-ionization detector (PID) or flame ionization detector (FID) screening) or quantitative (i.e., analysis with a gas chromatograph and/or mass spectrometer). There are two types of soil gas surveys: active and passive. The active survey removes soil vapor from the ground and measures it, and the passive survey uses a buried collection device, which is exposed for a measured time period and then analyzed. All soil gas surveying will be conducted in accordance with ASTM Standard D5314-92, Standard Guide for Soil Gas Monitoring in the Vadose Zone.

4.2.2 Background

Several factors influence the movement and distribution of volatile organic compounds through the soil pore spaces of the vadose zone. These factors include the permeability of the soil, degree of fracturing, degree of pore space blockage within the vadose zone (e.g., by perched water), chemical/physical properties of the volatile organic compounds, and chemical degradation. These factors are described in detail below:

- **Vapor permeability of the soil:** Along with chemical properties (described below), the soil permeability determines the diffusion of the volatile organic compounds within the soil gas. The volatile organics diffuse through the soil pore space from areas of high concentration to areas of low concentration. Volatile organics will generally diffuse faster in sandy soils than they will in less permeable silty or clayey sediments. Secondary porosity such as soil fracturing and root traces can provide preferred migration pathways for the flow of soil gas.
- **Blockage of the soil:** Heterogeneity can reduce the permeability of the soil by blocking or slowing down the diffusion of volatile organics within the soil gas in the vadose zone. Interstitial clay, soil moisture, perched water, and caliche deposits can

all block or partially block the pore spaces, and thus affect the diffusion of volatile organics.

- **Chemical/physical properties:** The chemical properties of the volatile compounds that affect diffusion through soil gas include: Henry's Law Constant (vapor solubility versus vapor pressure), vapor pressure, octanol-water partition coefficient, reactivity, and polarity. In other words, the more volatile compounds with higher partitioning to the vapor phase will diffuse farther and more rapidly than the less volatile compounds with lower partitioning.
- **Degradation:** Degradation can affect the diffusion of volatile organics: biodegradation and oxidation/reduction exert qualitative and quantitative effects on the migration profiles. The petroleum hydrocarbons, especially the aromatic fraction, are especially prone to these forms of degradation and will not diffuse as far as many halogenated species.

Because of the many factors that affect soil-gas diffusion, soil-gas surveys must be carefully designed and executed, and properly interpreted. In order to properly conduct a study, the factors in Table 4-1 and their proposed solutions should be considered ahead of time.

It is required that Field Team Leaders and other key project members meet with the Project Manager to discuss requirements for soil gas sampling. At a minimum, this discussion needs to address the following items:

- The contaminants of concern and their associated physical and chemical properties.
- The size of the area to be investigated.
- Subsurface soil conditions, if known, or county soil survey information.
- Historical site activities and available aerial photographs.
- Available facility personnel with knowledge of past facility activities.
- Soil gas analytical methods, and on-site versus off-site analysis.
- Site accessibility.

Table 4-1

Factors To Be Considered in Planning a Soil Gas Survey

FACTOR	SOLUTION
Homogeneously Low Permeability Soil (Sils and Clays)	Probes must be spaced more closely than in sandy soils. Special sampling techniques may be necessary.
Heterogeneous Blockage of Soils (Clay Layers, Perched Water, Caliche, etc.)	Probe spacings and depth will depend upon the distribution of "blockages" within the vadose zone. The results should be interpreted accordingly. If the program is conducted during the rainy season, then the probes must be advanced below the wetting front and above any perched water.
Site Access	If probe holes must be advanced through asphalt or concrete, coring may be necessary.
Chemical/Physical Properties	Probe spacing and depth should be modified depending upon the observations in the field and the properties of the target compounds (less volatile compounds will require closer spacing). Soil gas sampling may not be appropriate for substances of low volatility, and sampling other media (soils and/or water) and analyzing these media in the field with the mobile laboratory may be necessary.
Degradation	As stated above, degradation will affect the availability of various compounds, especially petroleum hydrocarbons, for diffusion. This limitation can be overcome by closer probe spacings. Soil and water sampling will not help with degradation problems, but rather with absorption and solubility problems (previous category).

4.2.3 Active Soil Surveying

4.2.3.1 Field Procedures

- Verify that permission to work on the site has been granted.
- Verify that utility clearance has been obtained and sample locations are clear.
- Verify that all equipment that will enter the well has been decontaminated, as appropriate.
- Set up the area to be sampled, in accordance with the Site Safety Plan and to facilitate data collection.
- Measure the organic vapor concentration in the breathing space above the soil gas probe hole using a PID or FID as specified in the Site Safety Plan.
- Measure the depth of the soil gas probe hole. Review the appropriate GEOLIS soil gas sampling form to verify soil gas sample data collection details.

Probe Installation

Appropriate depth holes of approximately one-inch or less in diameter will be initially placed approximately 25 to 50 feet apart, depending on considerations described in project planning. Locations should be established using an x, y coordinate grid system that is tied to an origin (0,0). The origin should be permanent and easily identified and re-located (i.e., telephone pole, manhole, existing well, etc.). Probes can be driven deeper with a truck-mounted percussion hammer or other drilling equipment. The holes may also be advanced using slam bars or hammer drills. The depth of penetration is dependent upon site conditions. If there is probe refusal at less than 3 feet, another location should be chosen in the same proximity, within five feet in any one direction. If the probe still can not be placed, another location should be selected. Care should be taken to advance the pilot hole beyond the root zone, where soils can have significant secondary porosity due to root mass, bioturbation, and cracks due to expansion and contraction. If soil cracks are prevalent, a hole should be advanced with a shovel or auger to a depth below the cracked zone, and the probe pilot hole advanced from there.

After the soil gas pilot hole has been advanced, a soil gas probe is inserted. The probe will consist of 1/4-inch outer diameter copper tubing with a 1/8-inch Teflon line inserted into the

tubing with tacks on the ends to prevent plugging of the tubing by soil. The probes have adjustable rubber stoppers to be packed into the surface soil, and bentonite paste added after placement to prevent ambient air from entering the sample probe hole. The inner Teflon line is then pulled upward to dislodge the tack from the tube bottom at the entrance to the probe, allowing free flow of soil gas.

Deeper sampling, at depths from 5 to 30 plus feet, is accomplished with a hydraulically operated percussion hammer. Lengths of threaded steel pipe equipped with a well-point fitting at the bottom end are pounded into the ground to the desired depth and then withdrawn several inches to release the well point, thus accessing the sampling train to the soil gas, which is purged through the Teflon tubing into a gas sampling bulb or Tedlar bag.

Sampling from in situ volatilization ports requires a slightly stronger pump than for soil-gas sampling, and rigorous care is needed to ensure that leaks in the sampling train are not present. A Teflon-shrouded fitting is attached to the sampling port with great care, and stainless steel tubing connects the port and the rest of the sampling train. A fairly large number of duplicates using different sampling trains should be used initially to verify the integrity of the system and to establish method confidence. The soil gas sampling configuration includes the pump, the copper and Teflon probe, flow meter, and gas bulb with stop-cocks or Tedlar bag.

Sampling

Personal sampling pumps will be used to evacuate the soil gas at each sample location at approximately 100 mL/min., if obtainable. Pumps will be calibrated daily by SKC Film Flowmeters that meet U.S. Bureau of Standards guidelines for laboratory equipment. Each sampling point will be purged until approximately three sampling train volumes have been evacuated. (Procedures for cases where vacuum conditions are produced (i.e., no flow) prior to three volumes are discussed later.) During the purge, soil-gas will be drawn through a soil gas sampling bulb. The bulb is typically 125 ml in volume. The pump assembly will be on the downstream side of the sampling bulb to prevent contamination of the sampling. Prior to the purging, a leak check will be performed. The downstream stop-cock (nearest the pump) will be turned off, and the flow meter should read zero. This stop-cock will be opened with the upstream stop-cock (furthest from the pump) closed, and the leak check process continued until the flow

returns to zero. (This procedure also serves to re-evacuate the sample bulb, which should be purged in the mobile laboratory prior to use at the sampling locations.) If leaks are detected, all hose clamps and swagelock fittings should be tightened until the flow is reduced to zero. When the leak check is completed, the sample bulb will be connected to the Teflon line of the probe and purging will be started.

When purging has been completed, the flow rate will be rechecked. Approximately five minutes of purging is recommended before the sample is collected. Next, the downstream stopcock will be closed, the upstream stopcock will be closed, and the pump turned off. The bulb will then be removed and transported to the mobile lab. In cases of low permeability soils, it may be preferable to leave the sampling probes in the ground for 24 hours prior to sampling so that a more representative sample can be collected due to the increased residence time. In this case, vapor should be purged from the probe with the sampling pump, through a sample bulb, creating a vacuum in the bulb/probe system. The following day, the stopcock nearest the probe is opened. This will draw soil vapor from the probe into the sample bulb without use of the pump. Alternative sampling may be performed by collecting a sample using a glass micro syringe from a septum located directly in the sampling train.

Decontamination Procedures

- **Bulb decontamination**

Bulbs will be decontaminated in one of two ways. In the case of minimum contamination, bulbs will be attached to a sampling pump and purged with room air for ten minutes. A 1,200-watt hair dryer will be used to heat the bulbs during purging. In cases where high levels of contamination are present, the bulbs can be decontaminated by heating in an oven set at $\sim 120^{\circ}\text{C}$. The heated bulbs will be purged under vacuum with the inlet air going through an activated charcoal filter. Bulbs can also be heated in the GC ovens during an analytical run and purged with nitrogen to remove contamination.

- **Probe decontamination**

Copper tubing will be washed with water, steam cleaned, and wiped dry with paper towels. Teflon tubing will be removed, wiped clean, and heated overnight at 100°C .

Documentation

Record all field measurements on the Soil Gas Data Form. Use a pen with black ink that is not water soluble (not a felt-tip pen). Make an entry in each blank. Where there is no data entry, enter UNK for Unknown, NA for Not Applicable, or ND for Not Done. If any procedure was not performed as prescribed, give the reason for the change or omission on the form. To change an entry, draw a single line through it, add the correct information above it, and initial the change.

4.2.4 Passive Soil Surveying

The steps and information herein are the Standard Procedures for carrying out a GORE-SORBER™ Screening Survey. Screening modules and organic analyses will be supplied/ conducted by W.L. Gore & Associates, Inc.

4.2.4.1 Collector Description

The sorbent containers and insertion/retrieval cords are constructed solely of inert, hydrophobic, micro-porous GORE-TEX. expanded polytetrafluoroethylene (ePFTE, similar to Teflon) with no fillers or plasticizers introduced during manufacturing. The unique feature of this construction is that the entire sorbent container surface area, as well as the surrounding insertion/retrieval “cord,” facilitates vapor transfer. Sorbent containers (sorbents) are typically filled with TENAX.

4.2.4.2 Field Operations

Materials

- GORE-SORBER screening modules and vials
- Fiberglass staff flags or some other means of location marking
- Correctly scaled site map
- Pen, clipboard, field notebook, chain-of-custody (COC) form, and SOP
- Measuring tape, transit, or other distance measuring device
- Electric rotary, hammer-action, or combination hammer with 1”carbide-tipped bit (31-36” long)

- Extension cord
- Electric power source (AC power outlet or generator)
- Slide hammer/tile probe
- Corks with screw eyes
- Insertion rod
- Latex surgical gloves or equivalent
- Paper towels and ASTM Type II water or equivalent
- Trash bags
- Knife, scissors, and needle nose pliers
- Cooler(s) with chilled ice packs or ice
- Small shovel
- Patching compound for concrete and/or asphalt holes (if required)

Installation

Lay out sampling grid using point spacing specified in work plan.

- From a known survey point, locate and mark all screening module location sites to the nearest inch using fiberglass staff flags.
- Note on field maps and/or field log any deviations to the sample grid as presented in the work plan.

Once a sample location has been established and utilities cleared, drill hole.

- A 9/16-in. to 1-in. hole is cored to a depth of 2 to 3 feet below ground surface (bgs). Installation depth is held constant for a given survey. This depth has been selected to keep the modules below the daily effects of atmospheric temperature changes. Coring is accomplished using a variety of tools depending on the nature of the material being cored. The holes should be vertical and as free from debris as possible.

Prepare sorber unit and note the unique serial number.

- Immediately after the hole is cored, a GORE-SORBER screening module is removed from its sealed container. Note that each module has a unique serial number recorded on top of the module vial and a metal tag attached to the module. Each vial is also

individually numbered. Record this number on the site map and/or field notebook immediately.

Insert sorber unit.

- Insert the stainless steel insertion rod into the pocket in the bottom of the module, and lower it into the hole. Ensure that the module goes the entire way down the hole. If a large resistance is felt during insertion, remove the module and re-drill the hole. Re-insert the module. When the module is completely inserted in the hole, press the insertion rod against the side of the hole. Twist the rod and pull the rod out.

Seal hole.

- Attach the end of the module to the screw eye in the cord. Do not remove the metal ID tag. Coil the excess retrieval cord and push it with the metal tag into the hole. Cork the hole to prevent the intrusion of rain and atmospheric gases during exposure. If the cork does not fit snugly into the hole, wrap a short length of the module retrieval cord around the cork and re-insert the cork into the hole.

Decontaminate the auger and insertion rod.

- After each use, decontaminate all intrusive equipment using decontamination procedures specified in Subsection 4.11.

4.2.4.3 Exposure Time

Exposure times, typically 14 days, are defined in the site work plan. Exposure times should be sufficient to allow equilibration of the modules with subsurface conditions. Actual subsurface exposure time and conditions will be measured and recorded.

4.2.4.4 Field QC Blanks

Field Blanks

Field blanks of ASTM Type II water will be collected. One temperature control blank must be included with each cooler shipped to Gore for analysis.

Temperature Control Blank

Water temperature control blanks are normally supplied by Gore with one blank supplied with each cooler of shipped modules. Temperature control blanks consist of a small vial of ASTM

Type I water that is used to determine the temperature of the modules upon arrival at the laboratory. One temperature control blank must be included with each cooler shipped to Gore for analysis.

Trip Blanks

The trip blank is a set of sorbent modules used to detect volatile organic compounds (VOC) contamination during sample shipping and handling. Trip blanks travel to the site with the sampling modules and are returned to the laboratory with the sampling modules. The trip blank will not be exposed to field conditions. The trip blank will be used to assess whether or not any chemical detected by the sorbers are the result of sources other than the study sites. One trip blank is to accompany each cooler containing VOCs. Trip blanks will be kept in sample refrigerators during the course of field work.

Field Duplicates

The collection of field duplicate samples provides for evaluation of overall sampling and laboratory precision by comparing analytical results of two samples of the same matrix from the same location. Two sorber units will be installed into one hole for a duplicate sample. The additional modules will allow for duplicate analysis of several modules from the same hole. If there is a wide difference in analytical results between duplicate samples, it can indicate poor precision of analytical technique and suggest increased evaluation of the data may be warranted. Field duplicates will be collected at a frequency of 10% of the samples collected per event.

4.2.4.5 Sorber Retrieval

Evaluate the sample site.

- Note any site disturbance that may have occurred since the sorber module was installed. Note any stains on the ground, cork removal, or other such features that might indicate tampering.

Remove cork.

Remove sorber unit from hole.

- Wearing surgical gloves, wrap retrieval cord once or twice around your hand. Using slow, steady tension, pull the cord straight out of the ground. Double check the Module ID# on the sample module, sample vial, and chain of custody/logbook to ensure that the correct module is retrieved from the correct grid position. Cut off the cork and discard.

Place sorber unit in vial.

- Put the entire retrieval cord, including the metal tag, back into the correctly labeled vial. Tightly reseal the vial. Immediately place the vial in a cooler with blue ice. Sorbers will be stored on-site in a freezer until shipped to the laboratory.

4.2.4.6 Sorber Shipment

The sorbers should be packed in the blue ice certified by W.L.Gore to be volatile free. Do not use Styrofoam peanuts or any other packing material that may contain volatiles or out-gas and contaminate sorbers during shipment. Bubble packing is acceptable.

Using the vial racks, coolers, and ice substitutes supplied by Gore, return the exposed vials and COC document to Gore's analytical laboratory via overnight carrier service.

4.3 GROUNDWATER MONITORING WELLS

4.3.1 Rationale

Sound groundwater sample integrity is dependent primarily on strict adherence to properly conceived monitor well construction and development procedures. In addition, it is equally important that boreholes (i.e., soil borings, wells, and piezometers) be abandoned properly, when necessary, to preclude the possibility of cross-contamination of water-bearing zones. To ensure that these goals are met, the following monitor well drilling, completion, development, and abandonment guidelines will be utilized.

4.3.2 Monitoring Well Installation

4.3.2.1 Drilling Methods and Equipment

The object of the following subsections is to outline the basic field procedures used to drill in both the overburden and the bedrock. All groundwater wells will be installed in accordance with ASTM Standard D-5092-90, Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers.

Never assume the rig will arrive on-site completely decontaminated from the previous job. Always inspect it. Road dust can have elevated levels of organics and inorganics attached to it. It is always a good idea to have the drillers lay out all the tools from their side tool panels and wash both the tools and the storage compartments. Between holes and on-site locations, ensure that dirty tools are decontaminated before being returned to these compartments.

The following standard field procedures should be followed at each borehole location:

- Check the location and number of the drilling location against a map and against the flag or stake. A good rule of thumb is to measure twice, and drill once.
- Back the rig into position so you do not have to drive over the finished hole.
- Set up the work area (and sample holding area) to be upwind of the rig exhaust. This may require the work area to be moved several times during the day.

- Count the total number (and note the types) of the various augers brought out to each site (including any on the truck). These numbers can be used as a check on drilling depth.
- Check the condition of the driller's downhole measuring device. Often these devices are missing several inches, tenths of inches, or feet, and, if used, will result in contradictory hole and well completion information. Remove any electrical tape or materials from any devices that if lost downhole could result in possible contamination of groundwater. Ensure that the measuring device is decontaminated each time it is used.
- Drilling is a team effort that includes WESTON personnel and the driller. Arrange with the driller before activities begin to keep you informed of what he/she sees or believes is happening downhole. For example, the driller can often tell you when the soil is getting harder or softer or when he/she is losing or gaining fluids (the hole is making water). These comments often may be related later to lithologic and hydrostratigraphic changes and, therefore, may verify WESTON logs.

Hollow-Stem Auger

Hollow-stem auger (HSA) drilling techniques will be employed to advance many of the borings scheduled to be drilled. HSA drilling uses a series of interlocking auger flights that consist of a continuous spiral or thread that is wrapped around and welded to a central hollow (tubular) stem or axle. The finished tool resembles a wood or machine screw, but without the taper. The lead auger has a set of teeth that cut into the penetrated earth materials. The auger threads then convey the cuttings to the surface. Hollow-stem augers are specified by their inside diameter (ID) and not the outer diameter (OD) of the hole they drill. All HSA drilling will be conducted in accordance with ASTM Standard D5784-95, Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices.

Advantages:

- Usually smaller sized rig than other drilling methods, resulting in more mobility. Shorter boom also allows this type rig to drill in areas of low clearance.
- Generally less messy than mud rotary techniques that require a water supply and may result in the need to containerize drilling fluids (e.g., muds) as well as cuttings.
- Because no drilling muds are used (introduced to the hole), soil and groundwater samples are considered more accurate or representative. Well development time should also be less than for the methods that use mud.

- Sample moisture content is more likely to be representative of the formation.
- Small-diameter monitor wells can be installed quickly and efficiently. The augers provide a temporary casing that prevents hole collapse, and there are no extra drilling fluids with which to contend.

Limitations:

- Limited in depth of penetration to approximately 75 feet (even less as auger size increases), depending on the materials encountered and the size of the drill rig.
- Difficult to drill through running or heaving sands.
- Can smear a layer of fine-grained soil on the side of borehole that may prevent groundwater from entering. In tight formations or in areas of difficult drilling, the friction of the augers may bake this skin, resulting in the finished well having limited or no recharge. The finer the matrix, the greater the chance for smearing the side of the hole.
- The augers can carry contamination down the hole during the drilling process.
- In many formations, the auguring process can be slower than other methods.
- Not effective in gravelly or in bouldery soils.
- The method limits the size of hole that can be drilled.
- Generally limited to overburden, weathered, or extremely soft bedrock.

Procedures:

- Once the rig is in place, ensure that it is level by insisting that the driller have a carpenter's level on each rig. Use the level on the rig and the auger. Some rigs have built-in bubble levels. Hanging the first auger and visually assessing its plumbness is not as acceptable, particularly on holes expected to be 15 feet or greater in depth.
- The first split-spoon is generally taken outside the augers. Standard blow count procedures, including the American Society of Testing Methods (ASTM) prescribed hammer weight and fall distances, must be followed and documented. Samples within the first 1 to 2 feet of the surface are often compressed by the split-spoon advancement process, resulting in what appears to be reduced recoveries.
- Be sure to measure and record the outer diameter of the augers (these may be worn and quite a bit less than the manufacturer's claim). These data are required for GEOLIS input (hole width).

- Do not allow the driller to *double spoon* during sampling. This is done by sampling an interval (e.g., 5 to 7 ft below ground surface (bgs)) and, without auguring over that interval, immediately sampling the next interval (e.g., 7 to 9 ft bgs) using the previous split-spoon's hole for guidance. This usually results in soil from the upper hole collecting in the second spoon, thereby compromising the sample.
- After the first sample is collected, a 5-foot length of auger is advanced and a split-spoon sample is collected from 5 to 7 feet. This is referred to as a 5-foot sampling interval. Continuous sampling is done by split-spooning an interval (e.g., 10 to 12 feet), then advancing the augers over that same interval. So the next sample would be taken ahead of the augers, from 12 to 14 feet and so on.
- A center plug, which prevents earthen materials from moving up into the augers, should be used in all but the hardest of sediments. The center plug is connected to the drive head of the rig by rods to ensure that the plug and rods rotate with the auger flights.
- The rods used to lower the split-spoon into the augers are also used, along with the auger count, to measure the relative position of the spoon from the surface. Inspect the rods prior to use to ensure that they are the lengths the drillers perceive them to be.
- Carefully watch the progression of the spoon while recording blow counts and note irregularities in the penetration rate.
- Record observations of:
 - Auger penetration rates.
 - Characteristics of auger cuttings (i.e., moisture content, color, and texture), including changes in the nature (behavior) of the cuttings. For example, if the soil begins to form balls or *rope*, moisture in the soil has probably increased at that depth.
 - Gravel, boulders, and competent bedrock will make the rig bounce, vibrate, or *dance* as well as chatter.
 - Steam coming off the augers. Slow the rig down if possible to prevent baking.
 - Remember that the cuttings appear at the surface after a time lag and that this lag increases with the depth of the hole; therefore, it is not possible to correlate cuttings with the exact depth being drilled.
- Running, heaving, or flowing sands occur when augers intercept a saturated soil unit whose fluid or formational pressure pushes its materials out into the boring and up the augers. The use of a center plug can help prevent this from happening, but not after the fact. If running sands are encountered, try one of the following techniques:

- Drill down below the running sand unit and muck out the augers using a sand pump, dart bailer, and/or roller bit wash.
 - Fill the augers with potable water to apply a reverse/positive pressure against that of the sands.
 - Drive casing inside the augers and continue the hole using rotary-flush (drive-and-wash) techniques.
- Drilling into or through sand (flowing and non-flowing), gravel, or expanding clay (i.e., clay units that, because of overburden pressures, expand into the hole) can lock up and bind the augers. Avoid leaving the augers in the hole for any prolonged period (e.g., overnight) if any of these conditions are encountered. This may be difficult when rock coring is required.
 - Record on a routine basis the levels of any fluids (depth to water and/or product) in the auger string.
 - Depth to bedrock is based on a combination of both split-spoon and auger refusal. If spoon refusal is met and the recovered sample does not verify bedrock, attempt to auger farther. The spoon may have been stopped by a boulder. Continuing the hole using the augers may push the obstruction aside. If the augers advance, continue to the next scheduled sampling interval and attempt to collect another spoon sample. Continue this process until both the spoon and augers have met refusal. Document all refusals (being careful to label them as being either spoon or auger refusal), rig gyrations, and physical conditions of spoons. The only sure way to determine bedrock refusal is to take a core.
 - If a boulder is struck with the augers and the target depth has not been achieved, move approximately 5 feet away from the hole if you are installing a well (10 feet away if you are not) and begin drilling a new borehole. Ensure that the original borehole is properly abandoned (see Subsection 4.3.2.7 for abandonment procedures).
 - Periodically measure hole depth (possibly in conjunction with photo-ionization detector (PID) or flame ionization detector (FID) readings) to verify that you are at the depth the driller says you are.
 - The 8-inch ID augers used for 4-inch monitor well placement can generally be used to a depth of 50 feet. At locations where the overburden is greater than 50 or where heaving sands are expected, HSA methods may be replaced with one of the other drilling methods described in the following subsections.

Direct Circulation Rotary

A number of the drilling techniques used come under the heading of direct circulation rotary procedures, including:

- Air/water rotary.
- Drill-through casing driver.
- Downhole hammer.
- Case-and-wash.
- Mud rotary.

These techniques all use circulation (commonly called drilling) fluids to cool and lubricate the cutting bit, stabilize the borehole, and remove cuttings from the hole. These fluids include water, mud (used for its higher viscosity), or air. These fluids are forced down the rotating drill pipe, out through the bit, and back up the annulus between the borehole wall (or casing) and the drill pipe. The fluids are generally collected in a pan or sump where the entrained cuttings separate from the fluid medium by gravity settlement. The fluids are recirculated back down the borehole and the process is repeated. Settled cuttings in the pan are generally shoveled out at intervals as they fill up the pan.

Air/Water Rotary

Bedrock wells will be drilled by air rotary methods using a truck-mounted rig. The major advantage of the use of air rotary drilling is that it minimizes the introduction of drilling fluids. All air rotary drilling will be conducted in accordance with ASTM Method D-5782-95, Standard Guide for Use of Direct Air Rotary for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices.

Air is the preferred circulation fluid. Air rotary drilling involves pumping air down a drill string to the bottom of the borehole and out through a rotating bit (roller bit). The air rotary method may be used in overburden when sampling was not required. Otherwise, air is used in conjunction with the downhole hammer.

Advantages:

- Capable of larger borehole diameters and depths than HSA drilling techniques; therefore, larger and deeper wells can be constructed using this method.
- Does not require a major supply of water as does mud rotary techniques. Less waste is generated and, therefore, there is less of a need for containerization.
- In short, it is a *cleaner* process than mud rotary.

- Since mud is not introduced into the hole, sample integrity from these holes is less questionable to most regulatory agencies. In addition, these holes require less development time than mud rotary boreholes.
- Allows inspector to map water entry zones, fractures, and voids by logging air losses with penetration.
- Relatively clean, quick, efficient way to cut through stiff or dense overburden without the use of casing.

Limitations:

- Less effective than mud in cleaning out cuttings from the borehole, particularly in larger diameter and deeper holes, thereby restricting well diameter and depth.
- Effectiveness decreased in coarse or loose sediments without the use of casing (which generally slows the process).
- Difficult to control air losses (lost circulation) downhole in fractured rock zones or highly permeable sediments without using casing.

Procedure:

- The air compressor on the rig is equipped with filters to eliminate the introduction of oil from the compressor. Be sure the filter has been recently replaced to avoid contamination of the air supply and the downhole environment with hydrocarbon lubricants.
- Check all casing to be advanced into the hole for cleanliness. Cutting fluid residues (high in solvents), road dust, and manufacturing oils are all common on these casings and need to be removed per the decontaminated methods outlined in Subsection 4.11. Any surface coatings (paint or lacquers) must be removed by the subcontractor.
- Potable water may be required during bedrock drilling to cool the bit and swivel and to control dust.
- Take samples of cuttings continuously with a strainer or sieve over 5-foot intervals, or more frequently if a change in lithology is suspected.
- Note changes in drilling speed that may be indicative of lithologic breaks. Similarly, quick downward movements of the drill string with corresponding loss of fluid usually indicates the presence of a fracture or void. An increase of water at this point suggests that the fracture is water-bearing.
- Listen for water cascading down the side of the hole or use a mirror to reflect a light source (e.g., the sun) down the hole to check for water entry zones. A weighted,

decontaminated tape can be moved down the borehole to determine these entry zone depths.

- When possible, estimate water entry flow rates. Check water levels when there is a lull or break in drilling. Recovery rates can be established over prolonged periods.
- Look for and document physical evidence of fractures. These include iron stained surfaces, slickensides, and calcium fill on cuttings.
- Always have a bucket of bentonite pellets ready to plug a borehole in the event that confining or retarding unit is penetrated.

Drill-Through Casing Driver

For drilling and construction of wells in which the unconsolidated sediments extend deeper than 50 feet, problems with running sands are expected, and/or dense sediment is suspected, the drilling method of choice will invariably require casing to be advanced in the overburden.

The drill-through casing driver (DCD) procedure involves a rig that is capable of advancing casing (pushing and/or rotating) as it drills. A dual rotary Barber rig has been used with great success. Other drill-through casing driver systems (e.g., ODEX) are also available. Both systems are capable of efficiently advancing a temporary casing to bedrock (up to approximately 150 feet deep) and pulling back the temporary casing during well installation.

Standard air rotary methods can be employed utilizing roller, drag, or button bit or an air hammer. The drill string is assembled inside the casing that is fitted with a drive shoe at the bottom. The casing is driven by air pressure through a piston. The process allows three procedures: (1) the drill bit and casing can advance as a single unit; (2) the casing can be driven first (in unconsolidated materials only) and the plug in the casing drilled out; or (3) the bit can be advanced a few feet ahead of the casing, the bit is withdrawn back into the casing, and the casing and bit are driven into the freshly cut borehole. The drill-through casing driver drilling method is particularly effective in poorly sorted materials. All DCD drilling will be conducted in accordance with ASTM Standard D-5872-95, Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices.

Advantages:

- More effective against running/heavy sands than HSA drilling techniques.
- Relatively rapid in terms of downhole drilling speed compared to HSA drilling techniques.
- No water or mud needed; therefore, no water (fluid) to containerize.
- No residual mud problems with well development or questions about sample integrity.
- Lost circulation problems are virtually eliminated because the casing is advanced with the bit.
- Able to drill through overburden or rock, and, therefore, no rig changing is necessary.
- Can drill in sand and gravel, glacial till, and running sand.

Limitations:

- Complicated drilling and setup procedure increases overall drilling time and may lead to more frequent downtime for repairs.
- Air pressure in hole can prevent water from entering the hole, thereby making delineation of water-bearing zones difficult.
- Because the system is somewhat closed, it is more difficult to get downhole readings, such as for water levels.

Downhole Hammer

The downhole hammer (DHH) is an air-operated percussion tool that pulverizes the rock in the borehole. A hammer repeatedly strikes a bit at the bottom of the borehole. The tool is connected to the rig by a drill stem that slowly rotates the bit and provides a feed or retract force for the operation of the hammer. The hammer tool is used as a replacement for the traditional roller bit. It is extremely effective in drilling hard rock. The advantages and limitations of this tool are generally the same as those described for the air circulation methods that employ it.

ODEX

ODEX, also known as TUBEX, is an adaptation of the air-operated downhole hammer. It uses a swing-out eccentric bit as a casing under-reamer. This arm swings out by the forward or reverse

rotation of the drill stem, and the tool is literally pulled down by the drive stem as the hole is advanced. A percussion bit, behind the swing arm, provides the cutting action. Cuttings are directed up the stem/casing.

Case-and-Wash

Case-and-wash drilling (CAW) procedures are used after setting casing into a confining unit. Once the casing depth is reached (not more than 5 feet into the confining unit), the augers are filled with mud to keep the hole open after the augers are removed. A permanent 10-inch-diameter nominal casing is next set 5 feet into the confining unit. The casing should not be pushed or driven into the confining unit. The casing is cemented in place using a cement/bentonite grout. Once the cement has set (a minimum of 8 hours), the mud inside the 10-inch casing is thinned to a water consistency and removed, and a temporary 6- to 8-inch casing is inserted into the 10-inch casing. The hole is then finished to bedrock using a roller bit (which cuts ahead of the temporary casing) and potable water as the circulating fluid.

Advantages:

- More effective against running/heavy sands than HSA drilling techniques.
- Relatively rapid in terms of downhole drilling speed compared with HSA.
- Water is used to advance the hole (rather than mud), and development time is shortened with a resulting decrease in the volume of wastewater for disposal. Sample integrity is less likely to be uncertain.

Limitations:

- Limited by the initial size of the auger hole.
- Slower than methods that do not require casing to be advanced with the bit.
- Requires a large source of potable water.
- Wastes and fluids require disposal.

Procedures:

- It is important to measure and document water levels during each of the drilling procedures. Measure water or fluid levels in the permanent casing and, as drilling proceeds, in the temporary casing as an indication of vertical head differences between the two intercepted units.

- Displace mud between the borehole wall and the permanent casing by tremie grouting with a cement/bentonite mixture, but only after thinning the mud already there to a density of 10 lb/gal or less. Containerize all fluids displaced.
- Wait a minimum of 8 hours for the cement grout to harden before re-entering the hole to drill.
- Before the temporary casing has been put in-place and after the cement is cured, remove by suction, bailer, or pump the mud inside the permanent casing. This mixture is potentially contaminated with chemicals from the upper water-bearing zone, and needs to be containerized and disposed of properly. The casing needs to be rinsed out as thoroughly as possible to remove any residue of contaminated mud. Similarly, the mud pan also needs to be cleaned. Once these activities have been done, fresh, potable water can be added to the hole, and the temporary casing can be advanced through the low-permeability unit that the permanent casing is keyed into.
- Count the number of drill rods on-site to help keep a record of downhole depths. When practical, measure or verify rod lengths.
- Document drilling rates as an indication of lithologic change. Ask the driller to inform you of the changes he/she feels with the rig, or when there are changes in fluid pressures. Fluid losses in unconsolidated materials may be indicative of porosity and permeability.
- Keep a log of fluid used and lost during the drilling process. The quantity of fluids lost should be added to the net number of volumes of water evacuated from a well during development.

Mud Rotary

Mud rotary drilling (DRT-MUD) methods have been used to construct bedrock monitor wells. The drilling mud holds the borehole open as drilling proceeds through unconsolidated material into competent bedrock.

Advantages:

- Low volatile emissions from the hole.
- Effective in keeping borehole open without casing or while casing is being inserted.
- Capable of drilling large diameter holes to greater depths than most other methods.
- Keeps contaminants out of hole once mud cake is formed on sides of borehole.
- Relatively quick and simple.

Limitations:

- Difficult to determine water-bearing zones.

- The use of mud and the need to change fluids between steps in drilling result in the generation of large quantities of potentially contaminated fluids that must be handled subsequently.
- The process is messy.
- Mud introduced into the surrounding formation before the cake forms must be removed during development. Hence, development time is slower. Failure to remove this mud from the formation can result in decreased well performance.
- Mud should be used only when absolutely necessary and only if integrity of the screened interval or other wells will not be compromised. The integrity of samples from wells screened adjacent to where mud has been used has been questioned.

Procedures:

- Ensure that the rig is level when starting using a carpenter's level.
- Inspect all downhole equipment, including casing, rods, and the roller bit before allowing their use in the borehole. Check the condition of the bit to make sure the buttons or teeth are secure. You should have the same number of teeth after drilling that you did before you started.
- Count the number of rods available at the site. This provides a fast and easy way to double check hole depths.
- Record the commercial name of the drilling mud being used and make sure the label specifies that it is pure bentonite mud with no additives. Accept no substitutes.
- Be sure the mud pan is intact, has no leaks, and has been cleaned properly.
- Log cuttings from the casing head or offset rather than the pan. Have the driller set up so this is convenient for you to do (so you do not have to interrupt his/her progress).
- Segregate fluids and solids when possible. Disposal costs are much higher for liquids. Label drums immediately so you do not have to re-open them later to inspect waste types or quantity.
- Change fluids between casings both in the hole and in the pan. Drillers will often try to avoid this step by thinning the mud with potable water. This just creates a bigger contaminant waste problem and increases the possibility of cross-contaminating between hydrogeologic units.
- Ensure that the driller washes out any pumps (including the ones on his/her rigs) between holes and casings, and overnight. Needing a pump and finding it full of bentonite stops a job immediately.

- Keep a liquids (fluids) log. Have the driller tell you when you lose fluids. Fluid losses and depths should be documented for a number of reasons. First, they can be used as an indication of increases in the porosity or permeability of the penetrated formation. Second, the volume of loss should be totaled for the hole and added to the volume of water to be removed during initial well development.
- Do *not* use mud rotary drilling within 2 feet vertically or 10 feet horizontally of a zone that will be screened or is currently screened in an adjacent monitor well. This includes bedrock holes that are to be completed as open-hole bedrock monitor wells.
- A sample of virgin drilling mud and a sample of drilling mud that has been circulated through the recirculation system should be obtained at the start of each drilling program and submitted for chemical analysis.
- Do not use mud in drilling bedrock where a well is to be completed as an open borehole.
- Note on the GEOLIS log the intervals where mud was used.

Bedrock Coring

Bedrock coring is performed in borings to verify bedrock depth and to confirm lithology. Collecting a rock core sample is the best approach to avoid mistaking boulders for the bedrock surface.

In general, the two primary rock coring methods are conventional rotary coring and wireline coring. The preferred method is conventional rotary coring, which uses a downhole assembly consisting of a diamond-impregnated NX core bit and a 10- or 15-foot long core barrel. The core bit and barrel are connected to drill rods that transmit drilling water and mechanical power to the bit. The core bit is designed to cut an approximate 3-inch-diameter borehole and a 2-inch-diameter rock core. The core barrel collects and holds the rock core as it is cut while it transmits drilling water to the core bit and protects the core from breakage. Drilling water is pumped down the drill rods to cool and clean the bit as it drills. The core is drilled/cut using rotary drilling techniques where the combination of rotation and weight (hydraulic pressure) applied to the bit advances the borehole and cuts the core.

Advantages:

- A relatively undisturbed rock sample is retrieved over the cored interval, allowing detailed analysis of the lithology, structure, and fracturing characteristics.

- The core confirms the presence or absence of bedrock.

Limitations:

- Coring is a time-consuming process because of setup time and slow drilling progress.
- The core may or may not be recovered fully, leaving important questions unanswered.
- The drilling and retrieval of the core normally induce fracturing in the rock core that must be distinguished from natural fractures.

Procedures:

- Determine the length of core required. Normally only a 4- to 5-foot core is needed to confirm bedrock.
- Consult with the driller concerning the need to install a small-diameter (4-inch ID) temporary casing in the borehole to keep the coring drill rods straight and to improve drilling water returns in large-diameter holes.
- Generally, to minimize induced fractures and to maximize core recovery, the driller will run the core bit at high revolutions per minute (rpm) and low pressure (weight). Prior to coring, discuss the procedures with the driller, inform him/her of the expected lithology and fracturing, ask him/her to note and pass along changes in the drilling rate/feel/vibrations to help confirm fracture zones, and emphasize the importance of drilling and handling the core carefully to minimize induced fracturing.

4.3.2.2 Materials

Casing/Screen

Typically, only polyvinyl chloride (PVC), Teflon (polytetrafluoroethylene or PTFE), and/or stainless steel will be used. All PVC screens, casings, and fittings will conform to the National Sanitation Foundation (NSF) Standard 14 for potable water usage or Annual Book of ASTM Standards: Volume 08.04; F-480-88A and bear the appropriate rating logo. If screen and/or casing manufacturers or suppliers remove or do not apply this logo, WESTON will verify that NSF or ASTM has appropriately rated the screens and/or casing. All materials will be as chemically inert as technically practical with respect to the site environment. All well screens will be commercially fabricated, slotted or continuously wound, and have an inside diameter (ID) equal to or greater than the ID of the well casing. An exception may be needed in the case of continuously wound screens because their supporting rods may reduce the full ID. Stainless

steel screens may be used with PVC or PTFE well casing. No fitting will restrict the ID of the joined casing and/or screen. All screens, casings, and fittings will be new. Screens will have the largest open area per unit length that is practical for the adjacent aquifer and available filter. Couplings within the casing and between the casing and screen will be compatibly threaded. Thermal or solvent welded couplings on plastic pipe will not be used. This also applies to threaded or slip-joint couplings thermally welded to the casing by the manufacturer or in the field.

Each cap will be constructed to preclude binding to the well casing due to tightness of fit, unclean surface, or frost, and secure enough to preclude debris and insects from entering the well. Caps and risers may be threaded; however, sufficient annular space will be allowed between the well and protective casing to enable one to thaw any frosted shut caps. Preferably, vents will *not* be placed in these caps or in the well riser/stickup. Vents may compromise water sample integrity by allowing foreign materials to enter the well between sampling events. Caps will be loose enough to allow equilibration between hydrostatic and atmospheric pressures. Special cap (and riser) designs will be provided for wells in floodplains and those instances where the top of the well may be below grade, e.g., in roadways and parking lots.

The use of well centralizers will be considered for wells deeper than 20 ft. When used, they will be of PVC, PTFE, or stainless steel and attached to the casing at regular intervals by means of stainless steel fasteners or strapping. Centralizers will not be attached to the well screen or to that part of the well casing exposed to the granular filter or bentonite seal. Centralizers will be oriented to allow for the unrestricted passage of the tremie pipe(s) used for filter pack and grout placement.

Filter Pack, Bentonite, and Grout

Filter Pack

All granular filters will be approved prior to drilling and will be discussed in the work plans. Discussions will include composition, source, placement, and gradation. If the actual gradation is to be determined during drilling, then more than one filter pack gradation will be on hand so that well installation will not be unnecessarily delayed.

Granular filter packs will be visually free of material that would pass through a No. 200 (75-micrometer (um)) sieve, inert, siliceous, composed of rounded grains, and of appropriate size for the well screen and host environment. The filter material will be packaged in bags by the supplier and therein delivered to the site.

Bentonite

Bentonite is the only drilling fluid additive that is typically allowed under normal circumstances. This includes any form of bentonite (powders, granules, or pellets) intended for drilling mud, grout, seals, etc. Organic additives will not be used. An exception might be made for some high yield bentonites, to which the manufacturer has added a small quantity of polymer. The use of any bentonite will be discussed in the work plans. Bentonite will only be used if absolutely necessary to ensure that the borehole will not collapse or to improve cuttings removal.

Grout

Grout, when used in monitor well construction or borehole/well abandonment, will be composed of Type I Portland cement, bentonite (0-10% dry bentonite per 94-lb sack of dry cement), and a maximum 6 to 7 gallons of approved water per sack of cement. The amount of water per sack of cement required for a pumpable mix will vary with the amount of bentonite used. The amount of water used will be kept to a minimum. Neither additives nor borehole cuttings will be mixed with the grout.

All grout materials will be combined in an aboveground rigid container or mixer, and mechanically (not manually) blended on-site to produce a thick, lump-free mixture throughout the mixing vessel. The mixed grout will be recirculated through the grout pump prior to placement. Grout will be placed using a grout pump and pipe/tremie. The grout pipe will be of rigid construction for vertical control of pipe placement. Drill rods, rigid PVC, or metal pipes are suggested stock for tremie pipes. If hoses or flexible plastics must be used, they may have to be fitted with a length of steel pipe at the downhole end to keep the flexible material from curling and embedding itself into the borehole wall. This is especially true in cold weather when the coiled material resists straightening. Grout pipes will have side discharge. The side discharge will help to maintain the integrity of the underlying material (especially the bentonite seal).

Surface Completion

Elements of well protection are intended to protect the monitor well from physical damage, to prevent erosion and/or ponding in the immediate vicinity of the monitoring well, and to enhance the validity of the water samples.

The potential for physical damage is lessened by the installation of padlocked, protective iron/steel casing over the monitor well and iron/steel posts around the well. The casing and posts will be new. The protective casing diameter or minimum dimension will be 4 in. greater than the nominal diameter of the monitor well, and the nominal length will be 5 ft. The posts will be at least 3 in. in diameter and the top modified to preclude the entry of water. Nominal length of the posts will be 6 ft. Special circumstances necessitating different materials will be addressed in the work plan.

Erosion and/or ponding in the immediate vicinity of the monitoring well may be prevented by assuring that the ground surface slopes away from the monitor well protective casing by the installation of a 2-ft by 2-ft coarse gravel blanket around the well.

Wells will contain a locking cover on the protective casing. The cover will be hinged or telescoped, but not threaded. All locks on these covers should be opened by a single key, if possible.

Water Source

To the extent practical, the use of drilling water will be held to a minimum. When water usage is deemed necessary, the source of any water used in drilling, grouting, sealing, filter placement, well installation, well decommissioning/abandonment, equipment washing, etc. will be approved prior to arrival of the drilling equipment on-site and specified in the work plans. Desirable characteristics for the source include:

- An uncontaminated aquifer origin.
- Wellhead upgradient of potential contaminant sources.
- Be free of survey-related contaminants by virtue of pretesting (sampling and analysis using a laboratory validated for those contaminants using methods within that validation).

- The water is untreated and unfiltered.
- The tap has accessibility and capacity compatible with project schedules and equipment.
- Only one designated tap for access.
- Surface water bodies will not be used, if at all practical.
- If a suitable source exists on-site, that source will be used.

The drilling subcontractor will have the responsibility to procure, transport, and store the water required for project needs in a manner to avoid the chemical contamination or degradation of the water once obtained. The drilling subcontractor will also be responsible for any heating, thermal insulation, or agitation of the water to maintain the water as a fluid for its intended uses.

Delivery, Storage, and Handling of Materials

Materials will be delivered to the site and stored in a secure area. Subcontractors are generally responsible for scheduling delivery and ordering those supplies pertaining to the installation of wells. An inventory will be kept to track the materials. Perishable materials will be covered with tarps and secured to prevent water damage. All materials will be handled in a safe manner and in accordance with health and safety protocols.

4.3.2.3 Well Installation

Preparation

Every morning before entering the field, the field team and drilling subcontractor will meet to discuss the location, construction, development, and/or abandonment criteria for the day's activities. The field geologist will also ensure that the drilling subcontractor obtains all necessary supplies for the day's work (e.g., bentonite, Portland cement, and screen and riser) and has decontaminated all equipment and manmade construction materials to be used downhole (e.g., augers and PVC or stainless steel screen and riser). All available areal data (e.g., borehole logs) should be reviewed to determine expected formation depths prior to the day's drilling.

Documentation

During any activities pertaining to well construction, abandonment, or development, the field geologist will note in the GEOLIS logbook the following information:

- Length of time required to perform all drill rig activities (e.g., overdrilling, well construction, abandonment/grouting, development times, and pumping rates).
- All well construction/abandonment supplies used (e.g., bentonite, Portland cement, Morie sand, and screen/riser footage).
- Any difficulties in well construction, development, or abandonment. This information may be used to substantiate a change of scope or explain anomalous sampling data.
- Exact measurements (using a tape measure) of screen, end cap trap, and riser lengths.
- A completed well construction diagram.
- At the end of the day or the following morning, before commencing with daily activities, the field geologist should go over the day's billing (time and materials). The driller's signature should be obtained acknowledging the accuracy of the figures reported. This is the only information available to verify subcontractor invoices.
- Get a copy of Driller's Log of Activities for the same period.
- Submit Well Completion Form.

Borehole Completion

The following procedure will be used to drill wells and piezometers:

- Mobilize to decontamination area.
- Decontaminate all equipment according to Subsection 4.11.
- Inspect the rig for any leaks (e.g., oil or hydraulic fluid) and the equipment for cleanliness (i.e., lack of dirt and grease). The only lubricant that may be used on equipment that enters a borehole is Teflon tape (with the exception of Numa Lube, which may be used in a downhole hammer).
- Mobilize to the site.
- Set up exclusion zone and work areas.
- Set up sampling and monitoring equipment, including a sample description table covered with Visqueen, if appropriate.

- Lithologic samples will be collected and described for every 5-foot interval (minimum), or more often if a change in lithology is observed or is required. Augered intervals between split-spoon samples will be described from cuttings when practical.
- Record all observations in the GEOLIS® logbook. It is critical to note any change in texture, color, moisture content, and bedding.
- Complete borehole and record completion information in the GEOLIS® logbook.
- Mark boring by appropriate method.
- Clean up area (i.e., leave the site as close to its original condition as possible):
 - Drum or spread any cuttings.
 - Line up, properly seal, and label all drums, noting the type of material in the drum and field instrument readings.
 - Remove all trash.

Borehole completion may take one of three forms:

- Piezometer construction.
- Monitor well construction.
- Borehole abandonment.

Completion procedures for each borehole type are described in the following subsections.

Piezometer Construction

Piezometers are installed where additional information is needed to more accurately evaluate the groundwater flow direction in a given aquifer. Piezometers can also be used to collect groundwater samples for analytical screening purposes. The following piezometer construction procedures will be followed:

- Piezometers will generally be constructed in boreholes advanced with 4.25-inch inner diameter (ID), hollow-stem augers.
- Piezometers will be constructed within the augers as the augers are pulled back and will typically be constructed using either 1- or 2-inch-diameter PVC with a 5-foot screen length and a threaded bottom cap with a drain hole drilled in the bottom cap to allow drainage if the water table drops below the total depth of the piezometer. The well screen will be machine-slotted with No. 10 slots (0.010 inch). The screened section will be threaded to attach to the PVC riser pipe. PVC cement will never be used to joint sections.

- Place decontaminated PVC screen and riser into the auger.
- Use Morie No. 1 or finer sand to create a filter pack that will extend from total depth to approximately 1 to 2 feet above the top of the screen as the augers are withdrawn from the borehole.
- Place a 2- to 3-foot-thick bentonite pellet seal above the filter pack. Add pellets slowly to minimize the risk of *bridging* that could result in inadequate sealing properties. Allow pellets to hydrate for 10 to 15 minutes. If the seal is located above the water table (dry), use a pure bentonite slurry or pour potable water on the pellets to cause them to hydrate. Depending on the hydrogeologic conditions encountered in the borehole and/or intended use, actual screen and filter pack lengths may vary (e.g., 1- or 2-foot screens may be used). The PM is responsible for approving any nonstandard construction details based on intended use and lithologic constraints.
- Tremie grout a cement/bentonite grout slurry from the top of the seal to 4 feet below ground surface (ft bgs). The grout slurry will consist of the following ratio of components:
 - 94 pounds of Type I Portland cement.
 - 4 pounds of pure sodium bentonite powder.
 - No more than 6.5 gallons of potable water.
- Proper grouting techniques are required to prevent cross-contamination. Thus, it is imperative that the field team closely supervise all grouting operations.
- Two piezometers may be installed in the same borehole if logistics warrant this type of procedure (i.e., difficult access or thick concrete at the ground surface). Nested piezometer installation will be conducted as described previously, except that a bentonite seal will be installed as an impermeable layer between the screened intervals. Specifically, the lower screen's bentonite seal will extend to 1 foot below the proposed depth of the upper screen. A 1-foot-thick filter pack base will be added to avoid possible contact of the upper screen with the bentonite seal.
- Complete the piezometer as directed in Subsection 4.3.2.4.

Overburden Monitoring Well Construction

Overburden monitor wells generally will be constructed in a borehole advanced by 8.25-inch ID, hollow-stem augers and without the use of drilling fluids where possible. However, in areas of high water table, running sands, or difficult drilling, either case-and-wash techniques, using 8-inch ID, hardened-steel casing with a drive shoe and a tricone roller bit, or drill-through casing driver techniques will be used. For descriptive purposes, split-spoon samples will be collected at 5-foot

intervals, or more frequently at the discretion of the supervising geoscientist. Lithology will be described following GEOLIS procedures. All water used for drilling operations and well development will be obtained from documented supply wells.

The overburden wells will generally monitor 10-foot intervals, or as specified in the work plan; however, screen length may be modified by the field geologist to accommodate specific data needs. Proposed screened intervals may be changed based on the results of soil screening with a PID or FID, or when highly permeable zones are encountered. Wells installed to monitor the water table will be screened from approximately 3 feet above the existing water level in the borehole to approximately 7 feet below this level to allow for seasonal groundwater table fluctuations. Where floating product is suspected to exist, screens will be installed to extend 5 feet above the water table.

After completion of the borehole, the monitor well will be constructed using either 4-inch-diameter, Schedule 40 PVC or Schedule 5 Type 304 stainless steel riser and well screen. PVC well screen will be machine-slotted and stainless steel well screen will be steel-wound. Stainless steel materials may be used for recovery well construction or where concentrations of organic contaminants are suspected. Well screen slot sizes for both PVC and stainless steel wells will be No. 10 or 20 (0.010 or 0.020 inch), depending on the grain size of the formation outside the screen. Filter pack size will be selected based on the mean grain size of the most finely grained geologic deposits in the screened interval, and should be designed to retain most of the formation.

Morie sand, used for the sand pack, should not extend less than 2 feet above the top of the screen. The mean grain size of the filter pack should be twice the mean grain size of the formation material based on lithologic information. A seal consisting of pure sodium bentonite pellets approximately 3 feet thick will be placed above the filter pack. If the seal is above the water table, a pure bentonite slurry will be used, or the pellets hydrated with potable water. Cement/bentonite grout will be tremied into place from the top of the bentonite seal to within 4 feet of the ground surface. The protective casing will then be installed, and grout will be added to the annulus between the borehole and the exterior wall of the protective casing. To prevent frost heaving, a pure bentonite slurry will be added to the annulus between the well casing and the

interior of the protective casing. Each batch of grout will be mixed to consist of 94 pounds of Type I Portland cement or equivalent, 4 pounds of pure sodium bentonite powder, and not more than 6.5 gallons of potable water. The bentonite pellets and grout seal should be a minimum of 5 feet thick (2 feet of pellets and at least 3 feet of cement/bentonite grout).

All well casing will be decontaminated as described in Subsection 4.11. PVC and stainless steel casing and screen will be joined with flush-threaded joints. Glue is not permitted to join casing or screen. If a slip cap is used for a bottom cap, it should be affixed to the well screen using stainless steel screws. All PVC will conform to the ASTM Standard F-480-88A or NSF Standard 14 (plastic pipe system). All stainless steel casing will be seamless and free of any lacquers or coatings.

Single-Cased Overburden Wells

A diagram depicting single-cased monitor well construction details is shown in Figure 4-1. The following construction details will be followed when installing single-cased overburden wells:

- Determine whether PVC or stainless steel materials are required at the location and discuss construction details (screen and filter pack size).
- Drill hole in bottom cap.
- Lower screen and riser into the augers to the bottom of the well. If the well exceeds 50 feet in depth, two centralizers will be used.
- Add the appropriate grade of Morie sand to the annulus around the screen to 2 feet above the screen as the augers are pulled back.
- Add a 3-foot-thick seal consisting of pure sodium bentonite pellets. The pellets must be frozen to retard hydration until the seal is emplaced if the pellets will be falling through a water column of greater than 20 feet. If the seal will be above the water table, a bentonite slurry will be used or potable water will be poured on the pellets to cause them to hydrate.
- Pellets will be tamped down to the top of the sand pack and allowed to hydrate for 10 to 15 minutes before the rest of the annulus is grouted.
- Tremie grout (above the bentonite seal).
- Complete well as directed in Subsection 4.3.2.4.

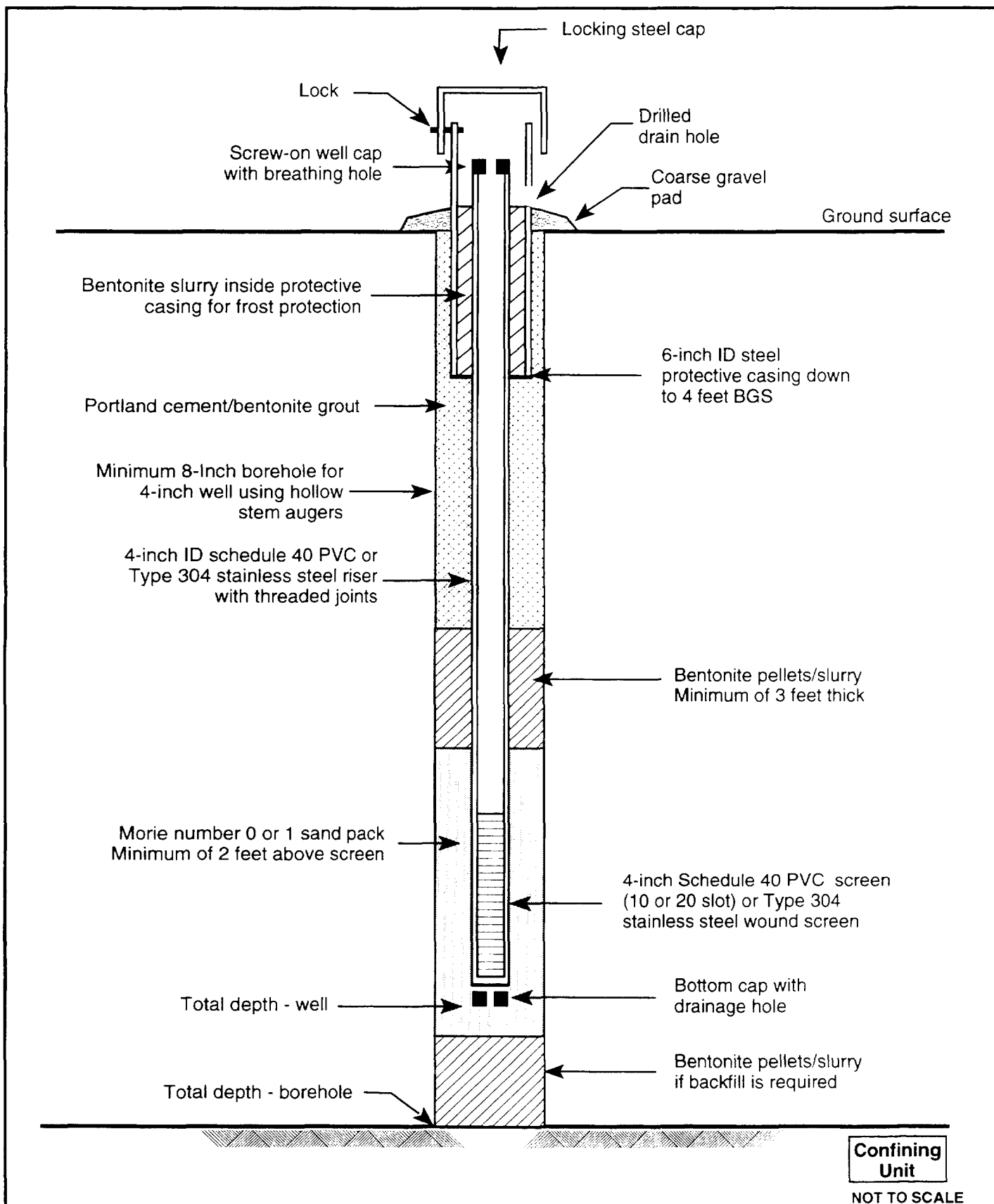


FIGURE 4-1
TYPICAL OVERBURDEN WELL INSTALLATION

Note: The bentonite and grout seal should be a minimum of 6 feet thick (3 feet of pellets or bentonite slurry and at least 3 feet of cement/bentonite grout). Deviations from these procedures are sometimes necessary because of field conditions, but must be approved.

Double-Cased Overburden Wells

A diagram depicting double-cased monitor well construction details is shown in Figure 4-2. Because of the possible need to investigate water quality beneath a confining unit, some wells may be double-cased. This is to prevent any cross-contamination between the units. Wells will be double-cased if the confining unit is greater than 5 feet thick and contamination is present above it.

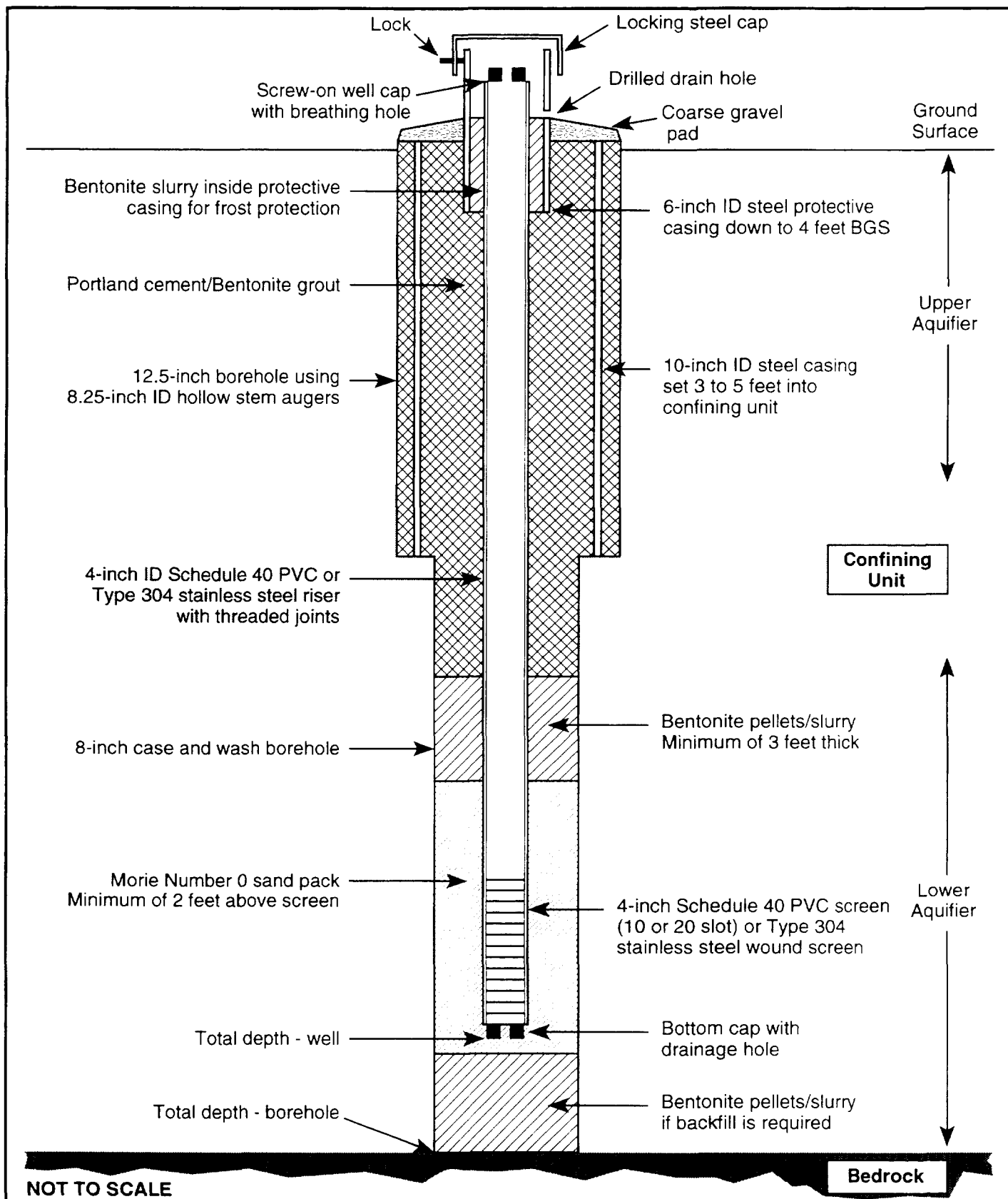
Boreholes for these wells will be advanced using either mud rotary drilling methods or 14-inch outer diameter (OD), hollow-stem augers. If hollow-stem augers are used, drilling mud may be used, if necessary, to keep the borehole open as the augers are removed. A 10- or 12-inch-diameter steel or PVC casing with a 1-inch-diameter PVC tremie line attached to the outside (with either a stainless steel wire or Teflon ties) will be placed into the borehole. In general, there should be a 2-inch clearance between the borehole and the casing to allow for adequate grouting (i.e., use a 10-inch casing in a 14-inch borehole). Drilling mud, if used, must be thinned to 10 lb/gal prior to grouting.

Grout will be pumped through the tremie line, filling the annular space from bottom to top. Alternatively, grout may be placed inside the casing as it is suspended in the hole, followed by a water chase to displace the grout so that it fills the annular space from the bottom of the hole to 4 ft bgs. The casing is then lowered into place and seated.

After the grout has set (a minimum of 8 hours), the borehole will be further advanced using air rotary, case-and-wash, or drill-through casing driver techniques to drive an 8-inch temporary casing to the desired screen interval. The well will then be constructed within the 8-inch casing while the temporary casing is pulled back, following the single-cased well installation procedure.

Bedrock Monitoring Well Construction

Bedrock wells will be drilled by rotary methods using a truck-mounted rig. The use of air rotary drilling minimizes the introduction of drilling fluids, but drilling mud may be used through the overburden. The purpose of mud rotary drilling methods is to hold the borehole open as drilling



**FIGURE 4-2
TYPICAL DOUBLE-CASED
OVERBURDEN WELL INSTALLATION**

proceeds through unconsolidated material into competent bedrock. Bentonite drilling mud may be used during drilling within certain limitations. Requirements and conditions under which the use of mud rotary drilling would not be acceptable are as follows:

- Mud rotary drilling should not be used within 2 feet vertically or 5 feet horizontally (i.e., adjacent wells) of a zone that will be screened or is currently screened in an adjacent monitoring well.
- Mud should not be used in drilling holes in bedrock that are to be completed as open-hole bedrock monitoring wells.

The only acceptable mud is natural sodium bentonite (Aquagel Gold Seal, manufactured by NL Baroid Inc.). A sample of virgin drilling mud mixed with de-ionized water in a decontaminated stainless steel bowl and a sample of drilling mud that has been circulated through the drilling rig recirculation system should be obtained and submitted for full TAL/TCL analysis (organics and metals) once during each drilling round (mobilization). Samples of cuttings will be taken continuously with a strainer. Lithology should be described at least every 5 feet and more frequently if a change in lithology (from drilling break or rate of penetration change) is encountered. Drilling mud must be removed or thinned to a density less than 10 lb/gal before the annular space is filled with grout.

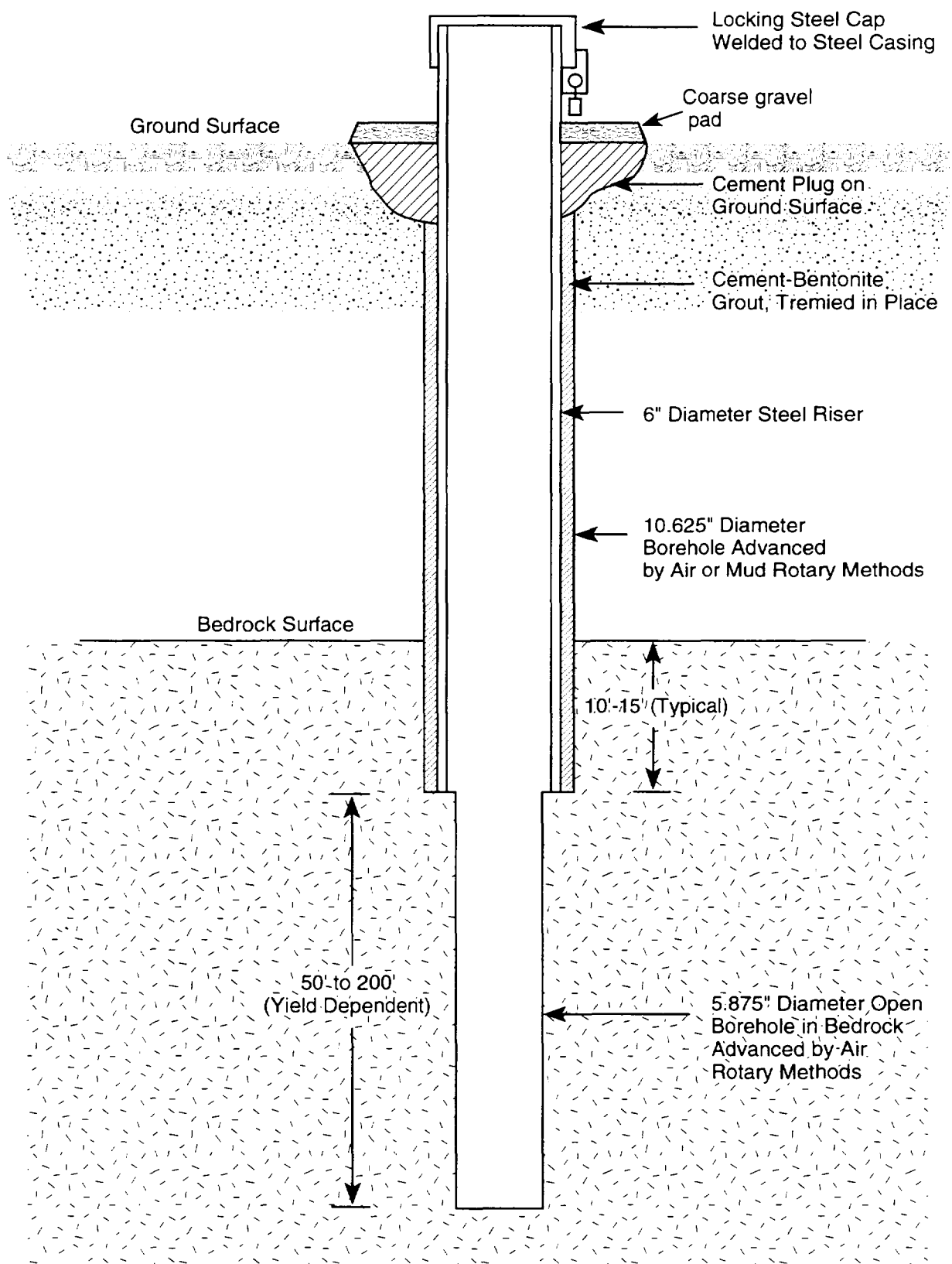
The use of air rotary drilling minimizes the introduction of drilling fluids. Potable water may be required during air rotary drilling to cool the bit and swivel. The air compressor on the rig will be equipped with filters to eliminate the introduction of oil from the compressor. The effectiveness of these filters should be checked daily by monitoring air passing through the downstream end of the air line with a PID or FID and/or a white cloth (to check for oil or other possible contaminants).

Samples of cuttings will be taken continuously with a strainer or shovel. Lithology should be described at least every 5 feet and more frequently if a change in lithology is encountered. If water is being injected during drilling, well yields should also be checked at least at the end of each drilling rod (normally 20 feet) by blowing the hole out with air only for approximately 5 minutes. Record open hole interval and yield in GEOLIS logbook.

For wells in which the unconsolidated sediments extend deeper than 50 feet, problems with running sands and/or dense glacial till may require that the drilling method advance casing (through the overburden). The preferred drilling method is a dual rotary system (e.g., Barber DR) that can rotate and advance casing while drilling. The dual rotary system rotates and advances a temporary casing that follows immediately behind the drilling bit. Other drill-through casing driver systems (e.g., ODEX) may be available. Regardless of the system proposed, it must be capable of efficiently advancing a temporary casing to bedrock (up to approximately 150 feet deep) and pulling back the temporary casing during well installation.

Competent bedrock monitor wells will be completed as open borehole wells as shown in Figure 4-3. The open borehole will be advanced approximately 50 feet below the bottom of casing or until a sustainable yield of at least 1 gallon per minute (gpm) is attained, but in no case will the borehole be advanced less than 15 feet or more than 200 feet beyond the bottom of the casing. The typical installation procedure follows:

- A 10.625-inch-diameter borehole will be advanced to bedrock using air or mud rotary techniques. To prevent collapse of the borehole when drilling through unconsolidated materials, the drill-through casing driver method (Barber DR or equivalent) may be used. This method is preferable to using drilling mud because it does not require drilling fluids.
- A 10.625-inch-diameter socket will then be drilled 10 to 15 feet into competent bedrock. Circulation should continue to clean out the hole prior to casing installation to ensure that no more than 1 inch of fill is present on the bottom.
- A 6-inch-diameter steel casing with threaded or welded joints finished with a steel drive shoe with a 1-inch PVC tremie line attached by stainless steel wire or Teflon ties to the outside will be lowered to the bottom of the socket and driven in as far as practicable. Any coatings on the steel casing, including lacquer, will be removed (by sand blasting, if necessary) prior to placement in the bedrock.
- The grout will be pumped through the tremie line and allowed to fill the annular space from the bottom of the hole upward as the oversized casing (if necessary) is pulled back until grout is observed at the ground surface.
- The grout will be allowed to set for a minimum of 8 hours.
- The borehole will then be advanced through the well casing, normally using the downhole hammer, to approximately 50 feet below the bottom of the casing, or until a sustainable yield of at least 1 gpm is attained. In no case will the borehole be advanced less than 15 feet or more than 200 feet beyond the bottom of the casing.



Note: Well may have flush-mount completions

NOT TO SCALE

**FIGURE 4-3
TYPICAL OPEN BOREHOLE - COMPETENT
BEDROCK WELL CONSTRUCTION**

4.3.2.4 Well Completion

Monitor wells will be completed aboveground at most locations. Where well stickup is of concern, the well will be completed as a flush mount, level with the ground surface.

Flush-Mounted Well

Flush-mounted wells will be completed as follows:

- Cut the casing 2 to 3 in. bgs, and install a protective locking lid consisting of a cast-iron valve box assembly or manhole cover.
- Center the lid assembly in a 3-foot-diameter concrete pad sloped away from the valve box.
- Provide a watertight expanding-rubber, locking casing cap to prevent infiltration of surface water.
- Maintain a minimum of 1 foot of clearance between the casing top and the bottom of the valve box.
- Clearly mark the well number on the valve box lid and well casing using an impact-labeling method and mark a surveying point on the inner casing.

Aboveground

Aboveground wells will be completed as follows:

- Extend the well casing 2 to 3 feet above ground surface.
- Provide an end plug or casing cap for each well. Drill a small (0.125-inch) hole into the PVC riser just below the PVC cap or into the PVC cap to allow air circulation in the well.
- Shield the extended well casing with a 6-inch carbon steel protective casing that is set over the well casing and cap and extends to a depth of 4 ft bgs.
- Grout the annular space between the borehole and the 6-inch casing with cement/bentonite grout to a depth of 4 ft bgs.
- Fill the annular space between the well casing and the protective casing with pure sodium bentonite slurry to protect the well casing from frost heave.
- Construct a 2- by 2-foot by 4-inch cement pad at the surface, sloped away from the protective casing. Do not construct cement pads until the casing grout has cured.

- Drill a small diameter hole (0.25- to 0.375-inch) in the protective casing near the top of the cement pad to allow for drainage and mark a survey location on the inner casing (mark with an indelible marker and cut a small notch in the PVC on the side toward the hinge).
- Install a lockable cap or lid on the protective casing.
- Mark the well number clearly on the protective casing cap using impact lettering.
- Install three 3-inch-diameter, concrete-filled steel guard posts, if directed to do so by the on-site geologist.
- The guard posts will be 5 feet in total length and installed radially from each well head.
- Recess the guard posts approximately 2 feet into the ground and set in concrete.
- The guard posts will not be installed in the concrete pad placed at the well base.
- Fill each guard post with concrete.

All wells will be secured as soon as possible after drilling. Corrosion-resistant locks will be used for both flush and aboveground well assemblies. The locks must have extended shanks.

Except where required to be finished flush with the ground surface, all bedrock wells will be finished with 2 to 3 feet of steel casing stickup and have locking caps.

4.3.2.5 Well Development

Well development is the process by which foreign materials and solids are removed from in and around the screen or open hole, allowing water to flow freely into the well. This process is accomplished by moving water or air through the well screen or borehole into and out of the surrounding material. Well development serves four principal purposes:

- Removes materials that have built up in the openings of the screen or borehole during the well drilling and installation process.
- Removes fine materials from the side of the borehole that result from the drilling procedures (e.g., drilling mud).
- Increases hydraulic conductivity of the filter pack and adjacent geologic materials by removing fine materials.

- Stabilizes the fine materials that remain in the vicinity of the well, thereby retarding their entry into the well.

The benefits are increased yield and reduced suspended solids. There are a variety of development methods that can be used including:

- **Mechanical surging**—In this method (surge blocking), a surge block is pushed in and pulled out of the well in a plunger-like fashion. As fines are flushed into the well, they must be bailed or pumped out. This method is the most effective method of development, but is only used to develop screened wells since it may cause collapse in an open borehole.
- **Bailing**—This method involves removing turbid water and silt from a well using a bailer. The process of lowering and raising the bailer helps move water in and out of the well, but is a relatively ineffective method of well development; however, it is a useful starting method in wells with very turbid water and high silt content.
- **Overpumping**—This method involves pumping at high rates, then allowing the well to recover before pumping again. This method is only effective in wells with moderately high yields and is only moderately effective in screened wells.
- **Backwashing**—This method involves pumping intermittently to lift water out of the well and then adding water back into the well causing a surging action. This method may have to be used in low-yielding wells, but only at the direction of the person in charge.

All materials placed in the wells must be decontaminated prior to their use. All pumps must be equipped with clean wiring (no electrical or duct tape) and have either PVC or polyethylene tubing.

Piezometer Development

Piezometers are generally only used to record changes in static water level. They are not developed after installation except as part of a sampling process.

Overburden Well Development

Overburden wells are developed as follows:

- Development should not be performed sooner than 24 hours after installation to ensure that the grout has had ample time to cure.

- Overburden well development will be performed using surge block techniques. Depending on well construction design, the surging will either be performed manually using a surge block connected to a tremie pipe (or equivalent) or operated mechanically from the drilling rig. The entire length of the saturated well screen will be surged. Surging will alternate with bailing for a minimum of 1 hour until sediment production nearly ceases.
- The wells will then be pumped (if yields are high enough: >0.5 gpm) using a decontaminated submersible pump supplied, installed, and removed by the drilling subcontractor (low-yielding wells should be pumped with the 2-inch OD adjustable rate pump). All pumps will have a minimum rating of 20 gpm and will be equipped with clean wiring and PVC or polyethylene tubing. The submersible pumps need to supply a range of pumping rates from 2 to 15 gpm, either by use of different pumps or throttling back on pump flow to meet well yield conditions.
- At regular intervals, such as every 15 minutes during development, purge rate; depth to water; and groundwater pH, temperature, electrical conductivity, PID/FID readings, and turbidity will be recorded. If PID or FID readings of the groundwater exceed background, the purge water will be containerized. Otherwise, the water may be discharged to the groundwater. Well development will continue until turbidity measurements are 5 NTUs or less and readings stabilize over 3 successive 5-minute intervals, or for a minimum of 1 hour or a maximum of 4 hours. After 4 hours, if a turbidity of 5 NTU cannot be achieved, the FTL must be notified.
- Because one of the objectives during well development is the determination of well yield in gpm, the depth to water will be measured at the same time as the other parameters, and the flow of the submersible pump (if used) will be adjusted so that the water level stabilizes. At that point, flow rate should be approximately equal to well yield. If the well goes dry during development, a 10-minute recovery test will be run to determine the rate that groundwater is entering the well. Water levels are taken at intervals of 0 seconds, 15 seconds, 30 seconds, 1 minute, 2 minutes, 5 minutes, and 10 minutes. An 8-inch well with a 4-inch-diameter screen contains approximately 1.2 gal/ft of groundwater in the sand pack area and 0.65 gal/ft of groundwater in the 4-inch casing above the sand pack. Therefore, if the recovery rate of an initially dry well is 2 ft/min, then the well yield would be approximately 2.4 gal/min. At the end of development, an estimation of yield will be recorded on the GEOLIS Well Development Form.

Bedrock Well Development

Bedrock monitor wells will be developed as follows:

- Initial development will consist of air surging the entire length of the open borehole at the completion of drilling using the drilling rig air compressor. Air surging will continue for a minimum of 15 minutes, or until water is free of settleable solids, for a

maximum of 1 hour. Field personnel will estimate well yield based on the rate of groundwater discharge during the initial development process.

- Final development will consist of overpumping the open borehole with a submersible pump at a rate of 10 to 20 gpm. At regular intervals, such as every 15 minutes during development, purge rate; depth to water; and groundwater pH, temperature, electrical conductivity, PID/FID readings, and turbidity will be recorded. Purge water will be containerized if PID or FID readings from the groundwater exceed background. Otherwise, the purge water may be discharged to the ground. Yield is determined by varying the pumping rate until water levels stabilize and noting whether the yield is different from the initial estimates. Pumping will continue until water turbidity, as monitored by field personnel, is < 5 NTU and readings stabilize over 3 successive 5-minute intervals, or for a minimum of 1 hour or a maximum of 4 hours. After 4 hours, if a turbidity measurement of 5 NTU cannot be achieved, the FTL must be notified.

4.3.2.6 Geophysical Logging

Purpose

Borehole geophysical logs measure the electrical and physical properties of the rocks, interstitial fluids, and, in some cases, the characteristics of well construction. Each log measures a unique parameter, and logs are best interpreted as an assemblage of data. The most common use of borehole logs in the groundwater and environmental fields is for correlation of geologic units from hole to hole.

The procedures outlined below are applicable to logging performed by WESTON or its subcontractors using analog equipment. Most of these procedures are not applicable to digital logging equipment used by major well-logging contractors unless the contractor is unable to provide evidence of recent shop calibration. All geophysical logging will be performed in accordance with ASTM Standard D5753-93, Standard Guide for Planning and Conducting Borehole Geophysical Logging.

The logs described in the section following are those most commonly used in shallow groundwater studies and could be run by WESTON or small logging contractors. Other types of both electric and nuclear logs are available from geophysical service companies. In particular, the gamma density and neutron logs often have application in groundwater and pollution studies. These logs, however, require a small nuclear source, and their use is governed by the Nuclear Regulatory Commission. It is more practical to contract these logs to licensed service companies.

Shop calibration should be available from logging contractors for their logs. Field quality checks then consist largely of documenting the calibration.

Procedures

Most field efforts, work projects, and sampling events will require participants to have a thorough understanding of multiple operating practices. Field personnel performing or monitoring logging will, at a minimum, need to be familiar with associated procedures and documents.

Field Team Leaders and other key project members will meet with the Project Manager to discuss logging requirements. Hole conditions (cased or uncased), hole sizes, locations, and water quality in the holes to be logged should be addressed. Decontamination procedures (if necessary) will be determined, and logging should proceed from the least to the most contaminated wells.

Logging locations should be inspected for accessibility before committing to a logging date. Service equipment or vehicles may be necessary if site conditions are poor. Nearby power lines or utilities are often sources of log interference and can be possible safety hazards.

Temperature Log

The temperature log should be run first in order to eliminate disturbance of the thermal profile caused by other logging runs. Thermal equilibrium, however, may not yet be attained at time of logging in recently completed boreholes. Usually, the differences in temperature with depth are of more interest than absolute temperature.

- Calibration of the temperature probes will be performed by the geophysics team members under the supervision of the Team Leader. Temperature probes should be placed in water baths and calibrated against mercury thermometers for response.
- The horizontal scale on the chart recorder must be expanded to provide maximum sensitivity (e.g., 1 inch 0.5 °F) and minimal off-chart deflection. The range of temperature values should be based on the average seasonal groundwater temperatures of the study area. These data will be obtained during the site pre-characterization phase.

- The temperature log will be run measuring from a fixed reference such as ground surface or top of casing. The logging speed should be carefully maintained at 8 to 10 feet/minute. A logging speed faster than 8 to 10 feet/minute seldom produces an accurate temperature log (Keys, [00-2227]).

Flow Meter Logs

The calibration of flow-measuring probes for quantitative analyses is done best in laboratory facilities designed for this purpose. Manufacturer specifications for impeller rotation (pulses per unit time) for various column diameters, fluid temperatures, and flow velocities are normally provided. On-site standardization or calibration can be performed by moving the flowmeter up and down the cased part of a well at controlled logging speeds while pumping. Calibration by this method, however, will only be valid at the casing diameter logged.

Qualitative measurements of inter-borehole flow direction and identification of zones that are accepting or producing flow may still be made by selecting a slow, constant logging speed that will maintain impeller rotation and prevent stalling. The optimal logging speed can be determined by moving the probe up and down the cased portion of the well at controlled speeds while the well is static (e.g., non-flowing).

The field procedures and quality control steps for flowmeter logging are as follows:

- Calibration of the logging probes will be performed by the geology team members under the supervision of the Team Leader. Under static conditions, ascending and descending runs will be made in the fluid-filled, cased portion of the well at controlled logging speeds and flowmeter response recorded (e.g., logging speed in feet per minute (ft/min) and impeller rotation in revolutions per minute (rpm)).
- The horizontal scale on the chart recorder must be expanded to provide maximum sensitivity (e.g., 1 inch = 5 rpm) and minimal off-scale deflection. The range of rpms should be based on the optimal logging speed obtained during calibration and borehole flow data obtained during drilling and coring activities.
- Flow meter logs will be run in the fluid-filled portion of the borehole in both ascending and descending directions. Constant logging speed must be carefully maintained in order to obtain representative logs of natural borehole conditions. Deviations in logging speed will otherwise be interpreted erroneously as zones of increasing or decreasing flow.

Caliper Logs

The caliper log will be run prior to running any of the lithology logs (gamma, SP, resistance) in each borehole so that the effects of hole diameter changes can be anticipated. Most logs that respond to lithology are also affected by changes in hole diameter.

The field procedures and quality control steps for caliper logging are as follows:

- Calibration of the caliper probe will be performed by the team under the supervision of the Team Leader. A machined calibration plate, drilled and marked every several inches, is fitted over the probe. One arm of the probe is placed into the appropriate holes for the range of diameters to be logged. Cylinders of calibrated diameter can also be used for caliper probe calibration. Values will be checked and labeled on the analog chart, and basing and sensitivity adjustments recorded on the quality control checklist. A final calibration is made inside the well casing, and log response is checked for drift.
- The horizontal scale on the chart recorder will be set at a corresponding appropriate scale.
- The caliper log is run from the bottom of the borehole logging up. The tool is lowered to the bottom and the arms are opened. Logging speed will not exceed 15 feet/minute and carefully maintained. Once the probe reaches the casing, a minimum of 10 feet will be logged inside the casing and checked against pre-run calibration values for tool drift.

Natural Gamma Logs

Gamma-ray logs can be run in either cased or uncased holes containing either fluid or air. In most site investigations, calibration of the equipment in calibration pits maintained by the U.S. Atomic Energy Commission and the American Petroleum Institute is neither practical or necessary. It is more important that relative calibration be maintained between holes at the same site or in the same general area. The probe output is usually measured in pulses or counts per second, and can be calibrated using pulse generators to establish the log scale.

For site-wide comparison of logs, it will therefore be important to maintain consistency with respect to the type and size of gamma ray probes that are used. Gamma probes with different size crystals or with different electronics probably will produce markedly different count rates in the same well at the same depth (Keys, [00-2227]).

The field procedures and quality control steps for natural gamma ray logging are as follows:

- The gamma ray probes will be calibrated using pulse generators or rate-meters to set the display scale. The time constants (pulse averaging time), recorder sensitivity (span), and zero positioning are recorded on a quality control checklist.
- The horizontal scale on the chart recorder should initially be expanded to provide maximum sensitivity or resolution of the sedimentary sequence. A scale of 1 inch per 10 counts per second (cps) usually provides proper resolution. The high and low end range can be selected by observing the probe response while lowering the tool to the bottom of the borehole. Other horizontal scales may be used on subsequent runs if less detail is desired. The actual recording of the gamma ray log will be performed on the ascending run.
- A logging speed not to exceed 20 feet per min will be used while logging the borehole. A constant logging speed must be maintained at all times except for later repeats across beds of interest. For short holes, a vertical depth scale of 1 inch to 10 feet of hole can be used. For holes exceeding 100 feet in depth, a depth scale of 1 inch to 20 feet of hole is appropriate.

Spontaneous Potential/Single Point Resistance Logs

The SP/Resistance combination tool is a type of electrical log and must be run in the uncased fluid-filled portion of the borehole. The resistance log is generally used for correlation and occasionally for semi-quantitative work. If correlation is the only purpose, then precise calibration is generally not critical. It is more important to maintain similar scales and relative calibrations, where possible, at any given site.

The field procedures and quality control steps for SP/Resistance logging are as follows:

- Calibration of the electric logging tools will be performed by the operator under the supervision of the Team Leader. The SP portion of the tool can be calibrated by connecting an accurate millivolt source (voltmeter) across the spontaneous potential electrodes and noting the chart response for the various fixed scales. The single point resistance portion of the tool can be calibrated by measuring a known resistance between the A and B electrodes. Various fixed resistances will allow the circuit to be calibrated at several scales.
- The horizontal scale on the chart recorder must be expanded to provide maximum sensitivity and minimal off-scale deflection. Typical horizontal scales for spontaneous potential logs in fresh water formulations would be 10 to 25 millivolts per inch. Common scales for single-point-resistance logs are from 20 to 500 ohms per inch. The range of scales for each of the electric logs may be selected after running the tool to the bottom of the borehole while measuring response, but not recording.

- The electric logs (SP/Resistance) will be run from the bottom of the borehole moving up the hole. A constant logging speed not to exceed 30 feet per minute will be maintained.

Post Field Operation

- Ensure that all equipment is accounted for, decontaminated, and, if applicable, ready for shipment.
- Make sure all logging locations are properly staked and the location ID is readily visible on the location stake.
- Fill out the appropriate GEOLIS forms and borehole Geophysical tables. Detailed procedures for completing GEOLIS forms can be found in the GEOLIS Logging Reference Manual. Be sure to use the most current version of this manual since it is periodically updated as the GEOLIS system is expanded and improved. The manual includes reference materials (i.e., tables, charts, diagrams, figures) pertinent to evaluation and definition of the various fields present on the forms as well as examples of completed forms.

4.3.2.7 Borehole/Well Abandonment

Borehole Abandonment

Borehole abandonment is conducted for one or more of the following reasons:

- Completion of an analytical or stratigraphic soil boring.
- Insufficient yield that precludes piezometer and/or well installation.
- Excessive difficulties incurred during drilling.

The following abandonment procedure will be practiced:

- Calculate the volume of grout needed to completely fill the borehole. Prepare an additional 10% of expected volume to compensate for settlement during grouting.
- Tremie pump a cement/bentonite grout slurry into the borehole, starting from the bottom to the natural ground surface.
- The grout slurry will consist of the following ratio of components:
 - 94 pounds of Type I Portland cement.
 - 4 pounds of pure sodium bentonite powder.
 - No more than 6.5 gallons of potable water.

Proper grouting techniques are critical for the prevention of cross-contamination. Thus, it is imperative that the field team closely observe all grouting operations.

Monitoring Well Abandonment

Monitoring wells may be abandoned based on the following criteria:

- Results of a survey of the condition of the monitoring wells (e.g., well construction and damage).
- Difficulties encountered during drilling (e.g., prolonged loss of circulation and borehole collapse).

The field team will document these or other difficulties in the GEOLIS logbook and relay this information to the supervisor. One or more of these individuals will determine whether abandonment is necessary. The following overburden/bedrock well abandonment procedures will be followed.

Overburden Monitor Well Abandonment

- Break up cement pad, remove demolition debris, pull outer steel protective casing with drilling rig (if possible), and remove PVC inner casing (if possible) or cut to a workable level.
- Overdrill to the total depth of the well using hollow-stem augers large enough to encompass the diameter of the original borehole.
- Remove remaining PVC casing and screen.
- Tremie pump a grout slurry into the borehole starting from the bottom to ground surface.
- An alternative option is to abandon the well in place by tremie pumping grout as directed previously. This procedure, however, must be pre-approved.

Bedrock Well Abandonment

- Calculate the estimated volume of cement/bentonite grout slurry needed plus 10%.
- If the bedrock well has a screened interval (fractured bedrock/hybrid well), overdrill the bedrock to the total depth of the well screen and remove the screen and riser, if possible.

- Tremie pump a cement/bentonite grout slurry from total depth to the natural ground surface. Cut the outer casing off at ground level, if directed to do so.
- Pressure grouting may be used, but this should be confirmed by the supervisor. If the pressure-grouting technique is used, the field team should document the pumping pressure in the GEOLIS logbook.

4.3.2.8 Water Level Measurement

These measurements will be taken at least 24 hours after development or immediately before sampling. Measurement will be made using an electronic water level meter. The depth to groundwater will be measured and reported to the nearest 0.01 ft. Measurement will be made from the highest point on the rim of the well casing or riser (not protective casing). This same point on the well casing will be surveyed for vertical control. Surface water levels will be measured at least to the nearest 0.1 ft using an adjacent temporary or permanent survey marker as a datum for current and future reference.

4.3.3 Determination of Free Product Presence

This section describes the field procedures to be used for the determination of free product in soil where free product is suspected. Areas that are suspected to contain free product or NAPL include:

- Areas adjacent to those where NAPL has been observed.
- Areas where groundwater contains contaminants exceeding 1% of their solubility.
- Areas where very high field screening readings were obtained and/or contain strong product odors.
- Areas where samples are collected at the top of a confining unit.

4.3.3.1 LNAPL Screening

Soil samples from areas of suspected LNAPL will be visually examined for the presence of LNAPL. If the sample is from the saturated zone, groundwater associated with the sample will be examined for the presence of a sheen. Unsaturated samples can be placed in a sample jar with water and shaken to see if a sheen is observed on the surface of the water.

4.3.3.2 DNAPL Screening

Each soil sample that is collected in the areas where DNAPL is suspected will be subjected to headspace screening. Headspace screening will be performed by placing a portion of a soil sample into an eight-ounce sample jar, covering the jar with aluminum foil, and replacing the lid. The jar will then be allowed to warm to about 60° F either by leaving it outside in warm weather or placing it in a warm vehicle during colder weather. Once warmed, the sample will be screened by removing the screw cap and inserting a field instrument probe through the aluminum foil and recording the result. Experience at other DNAPL sites in New England suggest that an instrument response greater than 10 units may be indicative of DNAPL.

Further DNAPL screen may include one of the following:

- Visual examination.
- Fluorescence test.
- Dye test.

Visual Examination

Each sample will be visually examined for the presence of DNAPL. Samples subject to the DNAPL screening procedure will be prepared in an open area. Under no circumstances should the jar be opened in an enclosed area. The sample will be examined for areas of strong black coloration.

UV Screening

Once the results of the visual examination have been recorded in the field notebook, the sample will be exposed to a portable ultraviolet (UV) light in a darkened location. A wooded box with the interior painted flat black and equipped with a viewing port may be used. Any milky white fluorescent areas on a sample will be noted in the logbook.

Dye Test

A dye test can be performed using SUDAN IV dye. SUDAN IV dye is added to the sample jar and the jar is shaken. SUDAN IV is known to turn DNAPL red. The sample will then be examined for signs of red and then noted in the logbook.

4.3.4 Aquifer Testing

This procedure defines the methods for collecting data to calculate in situ hydraulic conductivity by the use of slug test and pumping test methods.

4.3.4.1 Slug Tests

Slug tests are used to estimate the hydraulic conductivity (K), the transmissivity (T), and the storage coefficient(s) of a water-bearing zone. These parameters (K, T, s) are used to determine the rates of groundwater flow and contaminant transport.

Three types of tests are used commonly to characterize aquifer properties:

- **Laboratory Tests**—Provide point estimates of the one-dimensional vertical hydraulic conductivity while ignoring all but small-scale heterogeneities.
- **Slug Tests**—Provide in situ estimates of the two-dimensional horizontal hydraulic conductivity (and sometimes T and s) for a localized zone around a borehole.
- **Pumping Tests**—Provide in situ estimates of three-dimensional flow parameters for a relatively large area around a pumping well.

Typically, all three types of tests will be used together to characterize a site. The usefulness of laboratory tests, however, is limited because: (1) they do not effectively test macro-scale hydrologic features, such as fractures, and (2) they can only test flow in one dimension (usually vertical flow) and are not useful for evaluating two-dimensional horizontal flow. The use of pumping tests is limited by the expense of the tests and the need to dispose of large volumes of contaminated groundwater.

Slug tests involve displacing a known volume of water in a well instantaneously and measuring changes in the water level over time as the water level in the well returns to equilibrium. Displacing the water in the well is accomplished by lowering or raising the slug. A slug is a solid cylinder (or hollow, weighted, and capped cylinder) of PVC (or Teflon or stainless steel) with an attachment point for a hauling line. Other variations of the test include the instantaneous addition or removal of a known volume of water to or from the well. Tests performed by lowering the slug into the well and raising the water level are called falling-head slug tests. Tests performed by raising the slug out of the well and lowering the water level are called rising-head slug tests. Data

from both types of tests are comparable so long as the screened and filter pack section of the well is fully saturated (falling-head slug tests will produce erroneous results if the well screen or filter pack is partially saturated). Typically, falling-head tests and rising-head tests are conducted in pairs (when appropriate) as a quality control check to measure consistency of test results.

Slug tests have several advantages over other types of aquifer tests in that they:

- Can evaluate the hydraulic conductivity of small portions of a water bearing zone to assess aquifer heterogeneity.
- Are technically simple to conduct in the field.
- Are relatively inexpensive to complete, even in large numbers.
- Can be completed in a relatively short time.
- Pose fewer risks to the health and safety of field personnel.
- Pose little or no problems with the disposal of contaminated water.

However, slug tests are frequently presumed to have a low reliability. This is a significant criticism, because as Chu et al. [00-2224] noted, the accurate estimation of aquifer properties (i.e., K , T , s) is the most sensitive parameter in groundwater flow and contaminant transport modeling next to boundary conditions.

Slug test data are usually analyzed using the methods proposed by Hvorslev [00-2226], Cooper et al. [00-2225], and Bower and Rice [00-2223]. Hvorslev's method can be applied to a variety of different well and aquifer geometries, but has been used most commonly for unconfined systems. Bower and Rice's method is also designed for unconfined systems, and has been used more commonly than Hvorslev's method because it is somewhat easier to calculate. The CBP method is the most commonly used method for analyzing slug tests in confined aquifers. The CBP method is the only one of the four that uses type-curve matching instead of straight-line fitting to analyze the water level change data.

Procedures

Most field efforts, work projects, sampling events will require participants to have a thorough understanding of multiple operating practice. Field personnel performing aquifer slug tests, at a minimum, will need to be familiar with the following associated procedures:

- ASTM D4043 Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques
- ASTM D4044 Test Method (Field Procedure) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers
- ASTM D4104 Test Method (Analytical Procedure) for Determining Transmissivity of Non-Leaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Test)

Preparation

It is required that Field Team Leaders and other key project members meet with the Project Manager to discuss contractual requirements for surface aquifer slug tests. At a minimum, this discussion needs to address the following items:

- The extent and methods of the slug tests to be performed. Review available background information (i.e., topographic maps, aquifer data, geologic survey maps, well records, other site reports, etc.). If appropriate, prepare a work plan.
- Review associated operating practices for information on the performance of all relevant field activities that will be required to complete slug tests.
- Obtain appropriate permission for property access and off-site testing.
- Determine necessary testing and monitoring equipment. Decontaminate or pre-clean equipment. Inspect and test, if possible, all equipment to determine the operating condition of equipment to be utilized prior to performance of field activities.
- Obtain the appropriate GEOLIS Forms. The GEOLIS forms will include, the Location Identification Form, and optional Notes and Sketch Forms.
- Obtain a logbook for documentation of equipment checks and all other miscellaneous activities not documented in GEOLIS Forms.
- Contact delivery service to confirm ability to ship all equipment and samples to and from the site. Determine if shipping restrictions exist, and confirm regulations and specifications.

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

Field Preparation

- Confirm that all equipment has been decontaminated or pre-cleaned before testing.
- Conduct a site survey prior to site entry in accordance with the Health and Safety Plan.
- Locate the monitor wells to be tested, and check for proper labeling and signs of vandalism.
- Open the well lock and protective casing, remove the well cap, and monitor the well head with an organic vapor detector (PID or FID) or as specified in the Site Safety Plan. The resultant readings will determine the protective level required when working over the well head.
- Record in the logbook the appearance and physical condition of the monitor well, the depth to water, the stickup, and the depth of the well. Calculate the volume of standing water in the well.
- Calibrate the transducer.

Aquifer Slug Test Operation

The following are general procedures for performing slug tests. The procedures required for a particular slug test may vary slightly from those described, depending on site-specific conditions.

Take precautions to minimize the potential for cross-contamination between wells. Slugs and measuring devices that contact aquifer water must be properly decontaminated prior to initiating each test. If tests are performed on more than one monitor well, begin testing at the least contaminated well (usually the upgradient well(s)) and work downgradient in order of least to most contaminated wells thereafter.

Conduct the slug tests on undisturbed wells. If a test is conducted on a well that has recently been pumped for water-sampling purposes, the measured water level must be within 0.1 ft of the static water level before sampling or the slug test must not be conducted within 24 hours of sampling, whichever occurs first.

At least one week should elapse between the completion and development of a well and the performance of the aquifer slug test.

When the slug test is performed with an electronic data logger and pressure transducer, store all data internally on the logger. Download the data as soon as possible after the test to ensure that the data were collected properly. Maintain a hard copy printout of the data in the files as back up to electronic data loss or failure.

The time required for a slug test is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions, yet not so large that water flow is impeded or a suction is caused on slug withdrawal. The length of the test may range from seconds to several hours, but is typically in the range of minutes.

Before beginning the slug test, enter the required information into the electronic data logger. The type of information may vary, depending on the model used. When using different models, consult the operator's manual for the proper data-entry sequence to be used.

Aquifer Slug Test Procedure

To complete a slug test in the field, the following steps will be performed:

- Determine if the screened section of the well and the filter pack is fully saturated. Note in the logbook or on the Slug Test Information Sheet if the screen or the filter pack is not saturated.
- Unpack the data logging equipment. Examine it for visible damage. Check the operation of the data logging equipment. Record the results of the equipment check in the logbook.
- Pad the edges of both the inner and outer well casings with several layers of duct tape to protect transducer cables from sharp edges. Connect the transducer to the data logger.
- Measure out a length of transducer cable sufficient to lower a transducer to a point approximately 10 feet below the water level measured in the well. The transducer should not be lowered to a depth greater than 1 foot above the measured bottom of the well to avoid being clogged with sediment.

- Securely tape the transducer cable with duct tape to the outside of the well's protective casing.
- Complete the Slug Test Information Form and enter the required information into the electronic data logger. The type of information required by the logger may vary depending on the model used. Consult the data logger manual for the proper data entry sequence to be used. Typically, the following items must be entered:
 - Station ID or well numbers.
 - Test and step numbers.
 - Date and time.
 - Scale factor and off set for each transducer.
 - Initial water level.
 - Sampling rate.
- Attach a disposable rope to a slug of known volume. Measure and mark a length of rope sufficient to lower the top of the slug below the initially measured depth to water. Mark a point on the rope corresponding to where the bottom of the slug will be suspended just above the initial (top of) water level. Tie an attachment loop in the end of the rope.
- Lower the slug into the well to the marked point where the bottom of the slug is suspended just above the initial water level.
- Begin taking data on the electronic logger and lower the slug quickly and smoothly to displace and raise the water level to conduct a falling-head slug test. It is important to remove or add the volumes as quickly and smoothly as possible because the accurate analysis depends on an instantaneous change in water volume in the well.
- Continue measuring and recording depth-time measurements until the water level returns to a minimum 90 percent of pretest equilibrium conditions, or if a sufficient number of water level measurements have been made to clearly show a trend on a plot of the data showing recovery versus the logarithm of time. Generally, 10 to 30 minutes is adequate.
- Reset (step) the data logger data collection schedule, and quickly and smoothly remove the slug from the water until it is at a point where the slug bottom is just above the initially measured water level (i.e., lower marked point on the rope) to conduct a rising-head slug test. Secure the rope to the outer casing and repeat preceding step.
- Stop the data logger operation and remove all equipment from the well.
- Re-lock the well.
- Connect a field printer up to the data logger and generate a hard copy of the results of the slug test just conducted (if possible). Download data from the slug test onto a

floppy disk if a portable computer is available at the well site. If no computer is available at the well site, download the data at the earliest opportunity, but before the capacity of the logger is exceeded.

- Review the recorded data (if possible) to determine whether additional testing is required. If adequate information has been recorded, remove the transducer and slug from the well.
- Decontaminate the slug, the transducer cable, and any other equipment used in the well for the test. Do not reuse rope between wells.

Documentation

- Ensure that all equipment is accounted for, decontaminated (see Subsection 4.11), and ready for shipment.
- Make sure all slug test well locations are properly identified and readily visible.
- Deliver the original GEOLIS forms and field notebook to the Project Manager (or his designee). The original field documents should be copied and filed.
- Follow the QA/QC regimen established for the data. This should include documentation of all corrections or changes to the field forms. The field personnel should review these changes for accuracy at appropriate times during the QA/QC process.
- Analyze the slug test data using appropriate software packages or graphical solution methods. If the well screen was not fully saturated, do not analyze the falling head test.

Appropriate GEOLIS forms will need to be completed. Detailed procedures for completing GEOLIS forms can be found in the GEOLIS Logging Reference Manual. Be sure to use the most current version of this manual since it is periodically updated as the GEOLIS system is expanded and improved. The manual includes reference materials (i.e., tables, charts, diagrams, figures) pertinent to evaluation and definition of the various fields present on the forms as well as examples of completed forms.

4.3.4.2 Pumping Tests

This procedure identifies the requirements for performing tests that are used to determine the hydrologic characteristics of a water-bearing zone. The requirements of this procedure are applicable to monitoring well hydraulic testing. The scope of this procedure is limited to testing

used to characterize the hydrologic parameters of an aquifer and to determine the presence of a hydraulic connector between wells of a given water-bearing zone.

Discussion

An aquifer test is a controlled field procedure to determine the hydraulic properties of water-bearing soils and rocks. Groundwater flow varies in space and time, and depends on the hydraulic properties of the saturated porous or fractured media, and the boundary conditions imposed on the groundwater system. Pumping tests provide results that are more representative of aquifer characteristics than those predicted by slug tests, and can be used to determine the hydraulics of groundwater flow. These tests require a greater degree of activity and expense than slug tests, and are not always justified for all levels of investigation. As an example, slug tests may be acceptable at the reconnaissance level, but pumping tests are usually performed as part of a feasibility study in support of designs for aquifer restoration.

Aquifer characteristics that may be obtained from pumping tests typically include hydraulic conductivity (K), transmissivity (T), specific yield (Sy), storage coefficient (S), anisotropy, boundary effects, heterogeneity, and leakage factors. These parameters can be determined by graphical solutions and computerized programs.

A pumping test may also provide information about the effectiveness or productive capacity of the well. This type of information is often required for the design and installation of aquifer recovery systems.

There are a variety of aquifer pumping test types. This procedure focuses on the general procedures used for step drawdown tests, constant discharge tests, and packer pumping tests.

Procedures

Field personnel performing aquifer pumping tests, at a minimum, will need to be familiar with the following:

- ASTM D4043 Selection of Aquifer Test Method in Determination of Hydraulic Properties by Well Techniques

Preparation

It is required that Field Team Leaders and other key project members meet with the Project Manager to discuss contractual requirements for aquifer pumping tests. At a minimum, this discussion needs to address the following items:

- The extent and methods of the aquifer tests to be performed. Review available background information (i.e., topographic maps, aquifer data, geologic survey maps, well records, other site reports, etc.). If appropriate, prepare a work plan.
- Review associated operating practices for information on the performance of all relevant field activities that will be required to complete aquifer tests.
- Obtain appropriate permission for property access and off-site testing.
- Determine necessary testing and monitoring equipment. Decontaminate or pre-clean equipment. Inspect and test, if possible, all equipment to determine the operating condition of equipment to be utilized prior to performance of field activities.
- Obtain the appropriate GEOLIS® forms. The GEOLIS® forms will include the Log Book Identification form and optional Notes and Sketch forms. Obtain a logbook for documentation of equipment checks and all other miscellaneous activities not documented in GEOLIS® forms.
- Contact delivery service to confirm ability to ship all equipment and samples to and from the site. Determine if shipping restrictions exist, and confirm regulations and specifications.
- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

Step Drawdown and Constant Discharge Tests

Field Preparation

- A. Obtain assurances from the drilling contractor concerning the completion of the well installation, and development and the availability of the necessary equipment to conduct the pumping test. The drilling contractor is responsible for completing the following tasks and supplying the equipment listed below before the arrival of field personnel:
1. Drill, install, complete, and develop all pump wells and at least one observation well to the proper specifications identified.
 2. Install a submersible or turbine pump into the pumping well.

3. Install a totalizer meter and a flow meter in the discharge line of the pump well to accurately measure and monitor the volume and rate of discharge.
 4. Install sufficient pipe to transport the discharge from the pumping well away from the area to prevent infiltration in the pumped zone.
 5. Install a gate valve on the discharge pipe to control the rate.
 6. Place an outlet near the well head, but past the totalizer and flow meters, for water quality determination and sampling.
- B. WESTON personnel are responsible to calibrate all gauges, transducers, flow meters, and other equipment used in conducting pumping tests before use. Where possible, check all flow-measurement devices on-site using a container of measured volume and a stopwatch. Verify the accuracy of the meters before testing proceeds.
- C. Collect water levels at the test site for about one week before performing the test. This can be accomplished by using a continuous recording device like a Stevens Recorder. When utilized in conjunction with a barometer, these records establish the barometric efficiency of the aquifer. The records also help determine if the aquifer is experiencing an increase or decrease in head with time caused by recharge or pumping in the nearby area or diurnal variations. Record changes in barometric pressure during the test (preferably with an on-site barograph) in order to correct water levels for any possible fluctuations that may occur from changing atmospheric conditions. Project the pretest water level trends for the duration of the test. These trends or barometric changes may be used to correct water levels during the test so that they are representative of the hydraulic response of the aquifer from pumping the test well.
- D. The duration of the test is determined by the needs of the project and the aquifer properties. In general, longer tests produce more-definitive results. A duration of one to several days is desirable, followed by a similar period of monitoring the recovery of the water level. A knowledge of the local hydrogeology and a clear understanding of the overall objectives are necessary in determining the duration of the test. The effect of any hydrogeologic boundaries should be considered. There is no need to continue the test if the water level becomes constant with time.
- E. When using automatic data logging equipment, use the following steps:
- Determine if the screened section of the well and the filter pack is fully saturated. Note in the logbook or on the Pump Test Information Sheet if the screen or the filter pack is not saturated.
 - Unpack the data logging equipment. Examine it for visible damage. Check the operation of the data logging equipment. Record the results of the equipment check in the logbook.
 - Pad the edges of both the inner and outer well casings with several layers of duct tape to protect transducer cable from sharp edges.

- Connect the transducer to the data logger.
- Measure out a length of transducer cable sufficient to lower a transducer to a point approximately 10 feet below the water level measured in the well. The transducer should not be lowered to a depth greater than 1 foot above the measured bottom of the well so that it will not become clogged with sediment.
- Securely tape the transducer cable with duct tape to the outside of the well protective casing.
- Complete the Pump Test Information Form and then enter the required information into the electronic data logger. The type of information required by the logger may vary depending on the model used. Consult the operator's manual for the proper data entry sequence to be used. Typically, the following items must be entered:
 - Station ID or well numbers.
 - Test and step numbers.
 - Date and time.
 - Scale factors and serial numbers for each transducer.
 - Initial water level.
 - Sampling rate.

Operation

- A. The procedure to conduct step drawdown and constant head pumping tests includes monitoring the water level over time in the pumping well and each observation well while the pumping well is discharged at a known rate. Periodic checks of pumping rate will be recorded on the Pumping Rate Data form.
- B. When the pumping test is performed using an electronic data logger, and pressure transducer, store all data internally or on computer diskettes or tape. Directly transfer the information to the computer and analyze it. Maintain a computer printout of the data in the files for documentation. Take manually determined measurements periodically to verify data recorded by the data logger, and record both on the Transducer QA form.
- C. If an electronic data logger and pressure transducer are not used, record all data on the appropriate forms. Data collected manually during a logger-transducer pumping test will be recorded on the forms as completely as possible.
- D. During a pumping test, manual water level measurements should be taken as often as necessary to produce a meaningful indication of hydraulic properties of the aquifer. Measure water levels.

During the early part of the test, station at least one person at each observation well and at the pumping well. After the first two hours, two people are usually needed to continue monitoring the test. It is not necessary for readings at the wells to be taken simultaneously. It

is very important that depth-to-water readings are measured accurately and recorded at the exact time they are measured.

- E. After pumping is concluded, measure recovering water levels to verify the results obtained from the pumping portion of the test. Measure the recovering water levels in the pumping well and the observation wells for a period immediately following the cessation of pumping. Monitoring during recovery should occur for at least half the length of the pumping portion of the aquifer test. The decision to cease monitoring water levels will be based on the percent of aquifer recovery.

Post Operation

- A. If using an electronic data logger, follow the steps listed below:
 - 1. Stop the logging sequence.
 - 2. Print the data or send it to the computer by telephone.
 - 3. Save memory and disconnect the battery at the end of the day's activities.
- B. Decontaminate all equipment in accordance with decontamination procedures.
- C. Put the testing equipment in storage containers.
- D. Ensure that all equipment is accounted for, decontaminated, and ready for shipment.
- E. Restore the site to pretesting conditions as specified in the work plan.
- F. Make sure all wells are properly labeled and the location ID is readily visible on the guard pipe.

Documentation

- A. Record cleanup procedures and any uncompleted work in the logbook.
- B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.
- C. Review data collection forms for completeness.

Office

- A. Deliver original GEOLIS forms and logbooks to the Project Manager for technical review. Have forms reviewed, signed, and transmitted to the appropriate personnel (copies to the files) for placement in the project document control system, if required.

- B. Inventory equipment and supplies. Repair or replace all broken or damaged equipment. Replace expendable items. Return equipment to the Equipment Manager and report incidents of malfunction or damage.
- C. Interpret the pumping test results with the project hydrogeologist or Site Manager. Analyze data using appropriate analytical techniques.

Packer Tests

Packer testing is utilized to test the permeability of discrete hydrostratigraphic zones within the screened interval of a well. In general, a portion of the well screen is sealed off by pneumatically inflating rubber packers above and below the desired test zone. General guidelines for packer testing programs are as follows.

Prior to implementing a packer testing program for a well or group of wells, it is necessary to review existing well logs (cuttings) and/or geophysical logs. Additionally, it is recommended that downhole TV be run prior to packer testing, especially if the wells are old or the existing geophysical logs are incomplete. The more downhole information available (i.e., major water bearing zones, smooth and irregular borehole profiles, stratigraphic changes, casing depths, etc.), the easier it will be to design and carry out an effective testing program.

The following is a sequence of procedures and parameters that should be carried out and recorded during a packer test:

- Prior to testing each zone, obtain static water levels from each zone and calibrate the pressure transducers to these static levels.
- Inflate the packer(s) and allow each isolated portion of the borehole to stabilize. Double check each pressure transducer manually and record the head differentials above, between, and below the packer(s).
- Begin pumping of the test zone selecting a flow rate that will adequately stress the test zone. It is preferable to select a high pump rate and adjust back only if the zone appears to be dewatering. Otherwise, maintain a constant pump rate and record the drawdown in the test zone and in the isolated borehole portions above and below the straddled zone. The objective is to obtain a stable drawdown that can be maintained to within ± 0.5 ft over a 30-minute period with constant rate pumping. Specific capacities can be accurately estimated by dividing the pumping rate by the feet of drawdown (gpm/ft).

- Analytical samples, if required, should be collected once a stable drawdown has been obtained (as above), general water quality parameters have stabilized, and a minimum of three (3) test interval volumes have been purged.
- Shut down the pumping phase of the test and shut in the flow control valve to prevent water in the purge line from reversing back downhole. Monitor the recovery of the test zone until a minimum of 90% recovery is obtained.
- End test and deflate packer(s), moving up the borehole to the next zone of interest.

Documentation

Record pertinent information into the field logbook. Provide a complete description of the slug test procedure, including any variations of this procedure. The Field Team Leader will review the completed field logbook entries for correctness and completeness. Appropriate GEOLIS forms will need to be completed. Detailed procedures for completing GEOLIS forms can be found in the GEOLIS Logging Reference Manual. Be sure to use the most current version of this manual since it is periodically updated as the GEOLIS system is expanded and improved. The manual includes reference materials (i.e., tables, charts, diagrams, figures) pertinent to evaluation and definition of the various fields present on the forms as well as examples of completed forms.

4.3.5 Surveying

All topographic survey efforts conducted under contract will be certified by a surveyor with a current surveyor's license in Massachusetts.

Each boring and/or well installation will be topographically surveyed to determine its map coordinates referenced to either a Universal Transverse Mercator (UTM) grid or the State Plane Coordinate System (SPCS). These surveys will be connected to the UTM or SPCS by third order, Class II control surveys in accordance with the Standards and Specifications for Geodetic Control Networks (Federal Geodetic Control Committee, 1984). All borings, wells, temporary and/or permanent markers will have an accuracy of 1 ft within the chosen system.

Elevations for the natural ground surface (not the top of the coarse gravel blanket) and a designated point on the rim of the uncapped well casing (not protective casing) for each bore/well site will be surveyed to within 0.01 ft and referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929). These surveys will be connected by third order leveling to the

NGVD of 1929 in accordance with the Standards and Specifications for Geodetic Control Networks.

The topographic survey will be completed as near to the time of last well completion as possible. Survey field data (as corrected), to include loop closures and other statistical data in accordance with the Standards and Specifications referenced above, will be provided. Closure will be within the horizontal and vertical limits given above. These data will clearly be listed in tabular form: the coordinates (and system) and elevation (ground surface and top of well), as appropriate, for all borings, wells, and reference marks. All permanent and semi-permanent reference marks used for horizontal and vertical control (benchmarks, caps, plates, chiseled cuts, rail spikes, etc.) will be described in terms of their name, character, physical location, and reference value. These field data will become part of the project records.

4.4 GROUNDWATER SAMPLING

Instructions presented in this subsection are for collecting representative groundwater samples from temporary and permanent groundwater monitoring wells and, where applicable, other push-in well screen samplers. Typical overburden groundwater monitoring wells are 2 or 4 in. in diameter and are constructed of PVC or stainless steel.

4.4.1 Rationale

Sampling strategies are developed by the project team to satisfy project-specific data needs. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to ambient conditions, vertical extent, horizontal extent, and mobility in various media.

Sampling at sites is usually conducted in an attempt to identify contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. Groundwater monitoring wells are positioned at locations and depths to satisfy groundwater monitoring objectives. Groundwater samples collected from monitoring wells are evaluated as discrete samples collected from the same location. Groundwater samples collected from the same well are distinguished from each other because they are distributed through time. Unless each groundwater monitoring well has a sampler dedicated to the well, the order of sampling monitoring wells should be from the least contaminated wells to the most contaminated wells.

4.4.2 Procedures

4.4.2.1 Purge Volume

Sampling instructions for the most common techniques for collecting groundwater samples from groundwater monitoring wells are presented in this section. Additional information is presented in EPA/625/R-93/003. After completion of the well installation, the well should be developed to remove any fine material adjacent to the well casing. The well should be developed more than 48 hr prior to purging and sampling the well. Once a well has been located and properly identified,

field measurements should be noted in the bound GEOLIS® field logbook. A cross reference should be made between the previously recorded physical location/identification, locating the well to be sampled, to ensure the proper well has been selected. Misidentification of a sampling point in the field will result in erroneous data that may affect management decisions. Also included in field measurements are the physical measurements of the well and its physiochemical parameters. Physical measurements that may also be recorded in the field logbook include the presence and diameter of protective casing, diameter and construction material of the well casing, total depth of well from the top of casing, surveyor's mark, depth from top of casing to water, and the volume of water in the well and filter pack. The volume of water can be calculated by calculating the submerged length of the well and calculating the volume of water in the submerged casing and filter pack. Volumes of water in various well casing diameters are as follows:

Water Volume in Casing	
Nominal Casing Diameter inches (centimeters)	Gallons/Linear Foot (Liters/Linear Meter)
2 (5.1)	0.16 (2.03)
4 (10.2)	0.65 (8.11)
6 (15.2)	1.47 (18.24)
8 (20.3)	2.61 (32.43)
10 (25.4)	4.08 (50.67)
12 (30.5)	5.88 (72.96)

The volume of water in the filter pack should be calculated assuming a porosity of 30 percent within the filter pack. The volume of water present in the well casing and filter pack may be calculated as shown in the example below.

Example:

Assumptions: 2-in. well casing; well depth is 100 ft below ground surface, groundwater depth is 20 ft below the ground surface, and the boring diameter is 8 in.

$$\begin{aligned}
 \text{Volume of water in well} &= (\text{well depth} - \text{depth to water}) \times (\text{water volume in casing}) \\
 &= (100 - 20) \text{ ft } (0.1632 \text{ gal/ft}) \\
 &= 13.0 \text{ gal}
 \end{aligned}$$

$$\begin{aligned}
 \text{Volume of water in filter pack} &= (\text{volume of filter pack} \times 30\% / 23.1 \text{ in}^3/\text{gal}) \\
 &= ([\pi (8 \text{ in.})^2 / 2] \times 80 \text{ ft} (12 \text{ in./ft}) \times 0.3 / 23.1 \text{ in}^3/\text{gal}) \\
 &= 58.7 \text{ gal}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total volume in well casing and filter pack} &= 13 \text{ gal} + 58.7 \text{ gal} \\
 &= 71.7 \text{ gal}
 \end{aligned}$$

The volume of water in any size casing can be determined using the following formula.

$$\text{No. of gallons} = 5.8752 \times C^2 \times H$$

where C = Casing diameter, feet

H = Height of water column, feet

In addition to the physical measurements taken above and other information that may identify the well, physiochemical information such as specific conductance, pH, temperature, turbidity, and dissolved oxygen should be recorded initially (and in that order), during purging and prior to sampling (see following section).

4.4.2.2 Well Purging

To obtain a representative sample of groundwater from a groundwater monitoring well, the water that has stagnated and/or thermally stratified in the well casing must be purged or evacuated. The purging procedure allows fresh or representative groundwater to enter the well. The optimum or preferred method to ensure that fresh water representative of the aquifer in contact with the well screen is being sampled is to perform controlled sampling. When indicator parameters such as specific conductance, pH, temperature, turbidity, and dissolved oxygen are stabilized, the well is presumed to be adequately flushed for the representative sample. In many instances (low-flow purge method), purging rates must be kept below 1.5 L/min to avoid overpumping or pumping the well to dryness and to minimize turbidity. Ideally, wells should never be pumped to dryness. To accomplish this, pump rates may sometimes have to be adjusted.

Purging or evacuation of the well can be accomplished in several ways. In any instance, it is paramount to ensure that the purging procedure does not cause cross-contamination from one well to the next; therefore, the preferred method employs dedicated equipment and pumps. Because in many cases it may not be practicable to dedicate a pump to a specific well, it is

permissible to decontaminate this equipment, using approved methods. Tubing should always be dedicated and never used for more than one well.

The selection of an evacuation method often relies on the depth to water (DTW) in the well. For example, if the static DTW is less than 25 ft, a peristaltic pump may be the best method for evacuation. If the static DTW is greater than 25 ft, a low-flow capable submersible pump may be best. As mentioned earlier, care must be used to ensure that this does not act as a route of cross-contamination.

It is not recommended to use hand bailing for reasons such as the potential to aerate the well water, inadequate removal of fines, a concentration of floating product on the bailer that may introduce contamination, potential to introduce contaminants from inside of the well casing, and non-steady removal of water, which may result in dilution instead of evacuation of the well. In general, the mechanics of the hand-bailing method for well purging may introduce contamination potential and variability.

There are many pumps that may be used for well purging. Not all pumps are acceptable under all conditions. The preferred and most commonly used low-flow submersible pump is the Redi-Flow 2. Information on various pumps and methods of purging is provided later in this instruction.

A non-aqueous phase layer (NAPL) (free phase) may be present in a monitoring well designated for sampling. If it is suspected that the well contains an NAPL, an interface probe should be used to verify its presence. If an NAPL is present, the thickness should be measured and an appropriate bailer should be used to collect a sample of the product. Collection of a groundwater sample may not be appropriate if a NAPL is known to be in the well.

4.4.2.3 Sampling Devices

Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, well diameter, depth to groundwater, limitations of lift capacity of the sampling device, specified analytical parameters, and ease of decontamination

vary from technique to technique. Discussions of the advantages and disadvantages of each sampling technique are presented below.

Bailers

Bailers are one of the simplest and most commonly used sampling methods for sampling groundwater monitoring wells.

Applicability

Bailers are constructed of a wide variety of materials compatible with the parameter of interest. They are economical and convenient enough that a separate bailer may be dedicated to each well to minimize cross-contamination. An external power source is not required. Bailers provide a low surface-to-volume ratio, which reduces degassing of volatile organic compounds (VOCs). Cross-contamination can be a problem if the bailer is not adequately decontaminated. Bailers offer a relatively limited sample volume and may not be desirable for purging a well if large amounts of water need to be removed from the well for purging purposes. Bailers may also cause a surging action on the well, which may increase the turbidity of the well sample.

Method Summary and Equipment

Bailers are one of the simplest and most commonly used sampling methods for groundwater wells. Bailers are manufactured in numerous types, sizes, and construction materials. Bailers are typically weighted lengths of pipe attached to a cord with a check valve at the lower end. They are typically constructed of PVC, PTFE, or stainless steel. The PTFE bailer is recommended for collecting groundwater samples for VOC analysis. Bailers can be dedicated to a specific well, i.e., used only for purging and sampling that well. Dedicated bailers are typically stored to prevent cross-contamination or, less preferably, left hanging in the well itself. The bailer should be decontaminated after each use, regardless of whether the bailer is dedicated to one well or used to sample other wells. Disposable bailers are also available and are cost-effective for certain investigations. Haul-lines for bailers may consist of PTFE-coated stainless steel cable, polyethylene rope, or nylon rope. Of these three, nylon rope is the least desirable because it may introduce contaminants. The use of braided rope is discouraged, because it cannot be decontaminated. For each sampling event, the rope for dedicated bailers should be changed

following purging and prior to sampling. For non-dedicated bailers, rope should be changed between wells. After removal, the rope should be properly discarded.

Sampling Procedure

- Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging purposes.
- Attach decontaminated bailer to cable or line for lowering or use dedicated bailer already in well.
- Lower bailer slowly until it contacts water surface.
- Allow bailer to sink and fill with a minimum of surface disturbance.
- Slowly raise bailer to surface. Do not allow bailer line or bailer to contact ground.
- Purge well until the pH, temperature, and specific conductance are each at equilibrium, and begin sampling. Equilibrium is established as follows: pH variation less than 0.2 pH units, temperature variation less than 0.5 degree Celsius, and less than 10 percent variation in specific conductance.
- Equilibrium will be established by three consecutive readings, where one casing volume is pumped between each reading.
- Tip bailer to allow slow discharge from top to flow gently down the side of the sample bottle with minimum entry turbulence. If a bottom drain is present on the bailer, it is recommended that a slow steady flow be achieved through the bottom drain.
- Repeat as needed to acquire sufficient volume to fill all sample containers.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Verify that a PTFE liner is present in cap. Secure the cap tightly.
- Label the sample bottle with an appropriate label.
- Be sure to include all necessary information.
- Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.

- Record the information in the field logbook, or field sheet, and complete all chain-of-custody documents.
- Thoroughly decontaminate the bailer after each use, regardless of whether the bailer is dedicated to one well or used to sample other wells.
- Close well.

Portable submersible pump

Portable submersible pumps are an effective technique for pumping water at a steady rate, but require an external electrical power source.

Applicability

Advantages of submersible pumps include their ability to pump variable amounts from various depths. This advantage makes these pumps applicable not only for purging and sampling, but also for aquifer characterization tests. Pumping rates for various units range from as little as 100 ml per minute to 1,000 gpm. The pumping rate for most units can also be individually adjusted. Disadvantages of submersible pumps are that they require an external electrical power source and may be difficult to decontaminate between wells. The propeller construction of the pump assembly may cause degassing of volatile organic compounds.

Method Summary and Equipment

For submersible pumps, the pump assembly, the electric drive motor, and associated hoses and electrical cables are suspended from a steel cable or discharge pipe and submerged in the well. Intake is typically located between the motor and the pump assembly. Horsepower, head, and lift capacity range widely. Submersible pumps are available for 2-in. and larger wells. Some pumps are constructed of stainless steel and PTFE to maintain sample integrity. Submersible pumps far exceed the pumping limitations of other sampling equipment.

Sampling Procedures

Recommended sampling procedures are discussed below.

- Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.

- Determine the saturated water column in the well using an electronic water level indicator. Calculate fluid volume in the casing, and determine the amount of water to be removed for purging purposes.
- Lower the decontaminated pump to below the water level and begin pumping. Collect or dispose of purged water in an acceptable manner. Lower the pump as required to maintain submergence.
- Measure rate of discharge frequently. A bucket and stopwatch are commonly used.
- Purge well until the pH, temperature, and specific conductance are each at equilibrium, and begin sampling. Equilibrium is established as follows:
 - pH variation less than 0.2 pH units, temperature variation less than 0.5 degree Celsius, and less than 10 percent variation in specific conductance. Equilibrium will be established by three consecutive readings, where one casing volume is pumped between readings.
- Reduce the pump discharge rate to less than 500 mL/min. Fill sample bottles by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. Cap each bottle as filled.
- Preserve the sample as necessary; the pH is sufficient for the criteria.
- Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate label.
- Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Complete chain-of-custody documents, field logbook, and field sheets.
- Pull pump and decontaminate.
- Close well.

Bladder Pump

Bladder pumps employ a closed collection system that eliminates agitation and air or gas contact with the sample.

Applicability

Advantages of the bladder pump include its ideal design for sampling wells for VOC analysis from wells as small as 2 in. in diameter. The pump can pump water from various depths and at adjustable rates. It can operate in low-yielding wells without the possibility of burning out the pump if the well is pumped dry. The inlet for the pump body is typically at the lower end, thus requiring minimum submergence. Top-ended inlet pumps are also available for floating product recovery. Disadvantages of the bladder pump include its relatively low pumping rate. It also requires an outside power source of compressed air or gas and may be difficult to decontaminate between wells.

Method Summary and Equipment

The closed system provides the best method available for sampling wells for VOCs. The pump fills through a lower check valve under hydrostatic pressure, collapsing the bladder in the pump body. The bladder is then pressurized with gas or air causing it to expand, thus applying pressure in the pump body. The bladder is pressurized using a control box and air compressor assembly. This in turn closes the lower check valve and forces the contents of the pump body up through the sample line check valve. Venting the bladder will allow the pump to refill and begin another cycle. An inflatable packer is often used in conjunction with bladder pumps to reduce the amount of water to be purged for sampling. The packer is often positioned immediately above the well screen so that only water in the screened area of the well will require purging once the bladder is properly inflated.

Sampling Procedure

Recommended sampling procedures are discussed below.

- Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- Determine the amount of water to be removed for purging purposes. Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing if an inflatable packer is not present in the well. If an inflatable packer is present in the well, refer to construction diagrams of the well to determine the saturated water column below the packer. Make sure that the packer is not within the screened interval.

- Attach a pressurized air hose to the packer connection (if present) and inflate packer to proper pressurization level, typically 60 to 80 psi. After the packer is inflated, re-attach pressurized air hose to the bladder pump connection and purge the well as discussed above.
- Measure the rate of discharge frequently. A bucket of known volume and a stopwatch are commonly used.
- Purge the well until the pH, temperature, and specific conductance are at equilibrium and begin sampling. Equilibrium is established as follows: pH variation less than 0.2 pH units, temperature variation less than 0.5 degree Celsius, and less than 10 percent variation in specific conductance.
- Equilibrium will be established by three consecutive readings, where one casing volume is pumped between each reading.
- Fill the necessary sample bottles by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. The pump discharge rate should be less than 500 mL/min. Cap each bottle as filled.
- Preserve the sample as necessary, and verify that the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap and secure cap tightly. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- Complete chain-of-custody documents, field log-book, and appropriate field sheets.
- De-pressurize packer (if present), remove the pump, and close well.

Peristaltic Pump

Peristaltic pumps operate in a manner similar to centrifugal pumps, but displace the fluid by mechanical peristalsis.

Applicability

An advantage of the peristaltic pump is its design, which isolates the sample from the moving part of the pump and allows for easy decontamination by removal or replacement of the flexible tubing. Tubing can be dedicated to wells to reduce decontamination time. Disadvantages of these pumps include their low pumping rates and their limited height of intake lift (less than 20 ft).

These pumps also require an outside power source and, like other suction pumps, are not suitable for collecting samples for VOC analysis because of potential degassing effects.

Method Summary and Equipment

A flexible sampling tube is mounted around the pump chamber, and rotating rollers compress the tubing, forcing fluid movement ahead (the peristaltic effect) and inducing suction behind each roller. Peristaltic pumps generally have very low pumping rates suitable only for sampling shallow water tables in small-diameter wells.

Sampling Procedures

Recommended sampling procedures are discussed below.

- Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging purposes.
- Install clean medical grade silicon tubing in the peristaltic pump and attach the silicon tubing to the glass tubing outlet from the sample bottle.
- Attach the inlet glass tubing from the sample bottle to the required length of new PTFE suction line and lower to the midpoint of the well screen, if known, or slightly below the existing water level.
- Purge the well until the pH, temperature, and specific conductance are each at equilibrium and begin sampling. Equilibrium is established as follows: pH variation less than 0.2 pH units, temperature variation less than 0.5 degree Celsius, and less than 10 percent variation in specific conductance. Equilibrium will be established by three consecutive readings, where one casing volume is pumped between each reading.
- Collect volatile organic analysis samples, if required, with a bailer.
- Fill sample bottles by allowing the discharge to flow gently into the bottle with minimal entry turbulence. Pump discharge should be less than 500 mL/min. Cap each bottle as filled.
- Preserve the samples as necessary and verify that the pH is sufficient for the criteria.
- Verify that a PTFE liner is present in the cap. Secure the cap tightly.

- Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- Complete chain-of-custody documents, field sheet, and field logbook.
- Allow system to drain, then disassemble. Decontaminate or replace tubing for next sampling.
- Close the well.

4.4.2.4 Low-Flow Sampling Methods

Applicability

This standard operating procedure (SOP) is in accordance with the EPA Region I Low Stress (Low Flow) SOP: SOP No. GW 0001, Revision Number 2, dated July 30, 1996. This SOP provides a general framework for collecting groundwater samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). This SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation); however, this procedure is flexible and can be used in a variety of well construction and groundwater yield situations. Samples thus obtained are suitable for analyses of groundwater contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals, and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs).

Method Summary

The mid-point of the saturated screen length is used by convention as the location of the pump intake; however, significant chemical or permeability contrast(s) within the screen may require

additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permeability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help ensure that the low stress procedure will not underestimate contaminant concentrations.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved; b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization); and c) discontinue purging, collect samples, and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives). Option 3 is the preferred option.

All changes and modifications must be approved before implementation in the field, and must include adequate technical justification for the proposed changes.

Equipment

Extraction Device

- Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or Teflon).
- Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).
- The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than the

pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

Tubing

- Teflon or Teflon lined polyethylene tubing is preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs, and inorganics.
- PVC, polypropylene, or polyethylene tubing may be used when collecting samples for inorganics analyses; however, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.
- Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs; however, it should be used with caution when sampling for metals.
- The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.
- Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump to minimize gaseous diffusion.

Water Level Measuring Device(s)

- Water level measuring device(s) capable of measuring to 0.01 foot accuracy (electronic tape or pressure transducer). Use of pressure transducers must include check measurements with a water level “tape” at the start and end of each record.

Power Source

- If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

Field Parameter Monitoring Instruments

- Measurements include pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature.
- Flow measurement supplies include a graduated cylinder or other measuring vessel and a stop watch.
- Interface probe, if needed.
- Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods

are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

- PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

Other Supplies

- Decontamination supplies (for example, non-phosphate detergent, distilled/de-ionized water, isopropyl alcohol, etc.).
- Logbook(s) and other forms (for example, well purging forms).
- Sample bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, and field data from last sampling event.
- Well keys.
- Site-specific Sample and Analysis Plan/Quality Assurance Project Plan.

Preliminary Site Activities

- Check well for security damage or evidence of tampering; record pertinent observations.
- Lay out sheet of clean polyethylene for monitoring and sampling equipment.
- Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument, and record the reading in the field logbook.
- If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.
- A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft) and total well depth (to 0.1 ft) be measured the day before in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

- Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation.

Purging and Sampling Procedure

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

1. Install Pump

- Lower pump, safety cable, tubing, and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. If possible, keep the pump intake at least two feet above the bottom of the well to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

2. Measure Water Level

- Before starting pump, measure water level. If recording pressure transducer is used, initialize starting condition.

3. Purge Well

- Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s).
- Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging until indicator field parameters stabilize.
- Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 L/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump startup, drawdown may exceed the 0.3 feet target and then “recover” as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the

screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

- Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally, the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

4. Monitor Indicator Field Parameters

- During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging, emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete, and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at 3- to 5-minute intervals, are within the following limits:
 - Turbidity (10% for values greater than 1 NTU).
 - DO (10%).
 - Specific conductance (3%).
 - Temperature (3%).
 - pH (± 0.1 unit).
 - ORP/Eh (± 10 millivolts).
- All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate buildup within the cell. This buildup may affect indicator field parameter values measured within the cell, and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.
- The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

5. Collect Water Samples

- Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).
- VOC samples should be collected first and placed directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.
- During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that $\frac{1}{4}$ inch or $\frac{3}{8}$ inch (inside diameter) tubing be used to help ensure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel), or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water-filled portion of pump tubing, allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate, and new indicator field parameter values.
- Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g., EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to ensure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.
- If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low-flow procedures. The use of an in-line filter is required, and the filter size (0.45 μ m is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of groundwater prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health risk calculations.
- Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

6. Post Sampling Activities

- If recording pressure transducer is used, remeasure water level with tape.
- After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.
- Before securing the well, measure and record the well depth (to 0.1 ft), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event; however, it is recommended if the well has a “silting” problem or if confirmation of well identity is needed.

7. Secure the well.

All monitoring instrumentation shall be operated in accordance with EPA analytical methods and manufacturer’s operating instructions. EPA analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846 with exception of Eh, for which the manufacturer’s instructions are to be followed. Instruments shall be calibrated at the beginning of each day. If a measurement falls outside the calibration range, the instrument should be re-calibrated so that all measurements fall within the calibration range. At the end of each day, check calibration to verify that instruments remained in calibration. Temperature measuring equipment, thermometers, and thermistors need not be calibrated to the above frequency. They should be checked for accuracy prior to field use according to EPA Methods and the manufacturer’s instructions.

4.4.2.5 Filtration Techniques

This section outlines two different techniques for the filtration of liquid media (i.e., groundwater, surface water, and potable water). The procedures will address in-line filtration, where the filter assembly is under positive pressure, and vacuum filtration, where the filter assembly is under negative pressure. In addition, the procedures describe and recommend specific filtration equipment. Filtration of aqueous samples is performed when the removal of silt, algae, particulate, and other debris is desired. Predominantly, filtration is employed when water samples are to be tested for dissolved metals. Filtered samples for metals (dissolved fraction) and other strongly sorbed contaminants such as PCBs should be analyzed in conjunction with non-filtered samples to determine the concentration in solution versus metals associated with solids.

The following instructions will focus on positive and negative pressure filtration of aqueous media. In the instructions, specific types of filtration devices will be referenced. Because most filtration will be for the purpose of determining “dissolved” versus total metals, these instructions assume a filter pore size of 0.45 μm . Analytical methods used to determine dissolved metal concentrations have historically used 0.45- μm filters to separate dissolved and particulate phases. Filters less than 0.45 μm may be necessary in certain circumstances.

Positive Pressure Filtration

Aqueous samples that may require positive pressure filtration include groundwater samples, surface water samples, and potable water supply samples. To filter an aqueous sample using the positive pressure technique, a pump, filter, and tubing are required. The following are examples of equipment that may be used for positive pressure in-line filtration.

Pump:

Pump System

High Flow Range: 3 - 2,300 mL/min

Low Flow Range: 06 - 460 mL/min

System Flow Control: $\pm 10\%$

Filter assembly:

Groundwater Sampling Capsule

0.45- μm pore size

1/4" - 1/2" tapered barb fitting

Continuous Use Pressure: 60 psi @ Ambient

Maximum Momentary Pressure: 100 psi @ Ambient

Filtration Procedure

- Use polytetrafluoroethylene (PTFE) tubing for pump and filter connections.
- Connect the 0.45- μm in-line filter to the discharge tubing from the pump. Make sure the flow arrow on the filter is pointing in the correct direction.
- Apply pressure to the liquid sample (via pump) to force it through the filter into a sample container.
- Replace the in-line filter when the flow becomes too restricted because of buildup on the filter. To replace the filter:

- Discontinue pumping (turn off pump).
- Relieve the pressure in the system (line between the pump and the filter).
- Disconnect the filter and replace with a new one.

Negative pressure filtration

Aqueous samples that may require negative pressure filtration include groundwater samples, surface water samples, and potable water supply samples. To filter an aqueous sample using the negative pressure technique, a pump, filter, sample collection container, and tubing are required. The following equipment may be used for negative pressure (vacuum) filtration:

Pump:

Hand-Operated Vacuum/Pressure Pump

Maximum Vacuum: 25-in. Hg

Maximum Pressure: 15 psi

Composition: Metal or PVC

Filter Assembly:

Nalgene Filter Funnel/Collection Flask

Filter Composition: Cellulose nitrate

Pore Size: 0.45 or 0.8 μm

Collection Flask Capacity: 500 mL

Composition of Assembly: Polystyrene (sterilized)

Filtration Procedure

- Select a pre-sterilized filter assembly with a 0.45- μm pore size.
- Connect vacuum tubing to the pump and the filter assembly. Use PTFE tubing for pump and filter connections.
- Pour the aqueous sample into the filter funnel portion of the filtration assembly. Avoid transferring solids that may have settled to the bottom of the collection flask.
- Using the hand pump, create a vacuum in the collection flask portion of the filtration assembly to start filtration.
- Replace the filter funnel portion of the assembly when the filter becomes too restricted because of solids buildup on the filter. To replace the filter:

- Depress the pressure/vacuum release button.
- Disconnect the filter funnel and replace it with a new one.
- Create a vacuum with the hand pump and continue filtering the remaining sample.

Potential Problems

One inherent problem associated with the filtration of aqueous environmental samples is the filter becoming clogged. The following are some considerations regarding liquid filtration:

- Always have extra filters available at the sampling site.
- Pre-filter dirty samples with a larger pore size filter.
- For highly turbid samples, a negative filtration system may be more efficient.
- Avoid pouring sediments from the bottom of the collection flask into the filter funnel.
- When the filtrate flow becomes too slow because of filter loading, change the filter. Avoid increasing the pressure and rupturing the filter membrane.

4.4.2.6 Field Measurement Procedures and Criteria

This section presents a description of the field procedures that must be followed before collecting any type of water sample. The procedures in this section are usually performed by the sampling team.

Procurement of equipment and/or supplies for field efforts will be coordinated with the Equipment Manager. Equipment used for measuring the basic physical and chemical properties of water include:

- Water level probe (including oil/water interface probe and modified tape measure for total depth measurement).
- Turbidity meter.
- Conductivity/temperature meter.
- Dissolved oxygen meter.
- Alkalinity kit.
- pH meter.

- Photo-ionization detector (PID) such as a HNu

Physical Parameters

Water Level Measurement

Groundwater level measurements will be taken prior to purging or sampling using an electric water level probe. The following procedure will be used for obtaining water level measurements from monitoring wells and piezometers:

- Approach the well with a working HNu or equivalent, a well key, and a water level indicator (switched on). Where practical, the surface of the water column should be visually examined for the presence of hydrocarbons; if present, the thickness of the hydrocarbon layer will be measured using an oil/water probe.
- Open the well cap just enough to insert the probe of the PID or FID and take a reading. A decision to upgrade personnel protective equipment (PPE) may be necessary based on the PID or FID readings in the breathing zone.
- Remove well cap(s) and insert the water level probe or oil/water interface probe into well.
- Note the water level measurement to the nearest 0.01 foot with respect to the established survey point on top of the well casing.
- Take water level measurements three times per well or until measurements are within 0.01 foot.
- Record measurements on the GEOLIS Water Level Form.
- Decontaminate the water level probe (including the oil/water probe, if necessary) with ASTM Type II reagent-grade water (do not rinse with any solvents unless product was encountered).
- Measure the total depth of well using the modified tape measure. Measuring tapes must be fully decontaminated between each well.
- Note total depth and any other observations concerning well condition in the GEOLIS field logbooks.

Chemical Parameters

Water purged before sampling must be measured for temperature, pH, electrical conductivity, turbidity, dissolved oxygen, field alkalinity, and total VOCs.

Total VOC Measurement

Total VOCs can be screened from either water or soil samples using an HNu photo-ionization or equivalent equipment. The following procedure should be followed:

- Fill a sample jar half full with the water sample.
- Cap the sample jar and agitate.
- Open the cap while placing PID or appropriate probe under the cap.
- Record the highest measured reading (PID or FID) in the GEOLIS logbook.
- Discard the water sample and jar according to proper site procedures.

The in-field measurement of a sample's VOC content is only a qualitative and not a quantitative measurement. Measurement of sample vapor does not preclude the need to collect air vapor measurements in the breathing zone for safety purposes.

The standard operating procedures for monitoring the other chemical parameters are presented in Appendix C, Field Screening Instrument Calibration Procedures.

4.4.2.7 *NAPL Sampling*

LNAPL Sampling

LNAPL are generally low-density immiscible organics that have densities less than water. These chemicals tend to float on the water surface and commonly occupy the capillary fringe zone above the water table. For this reason, if LNAPL is suspected, the groundwater monitoring wells must be screened across the water table.

Measurement of the thickness of the floating layer may be determined by using an oil/water interface probe or clear bailer. Prior to the purging of groundwater from the well, a sample of the floating layer may be obtained using a bailer that fills from the bottom. Care should be taken to lower the bailer just through the floating layer, but not significantly into the underlying groundwater. A sample jar can be lowered down to the floating product, but it must be well secured to avoid being dropped down the well.

If more than one distinct LNAPL layer is present in a well, each layer should be sampled. Samples should be analyzed for chemical composition and physical parameters (e.g., specific gravity, water solubility, etc.).

DNAPL Sampling

DNAPLs include chlorinated solvents and other chemicals that have densities greater than water. DNAPL chemicals tend to migrate downward through the saturated zone until they encounter lower permeability beds within the aquifer. Measurement of the thickness of the DNAPL must be performed prior to sampling. Measurement may be accomplished using an interface probe.

A DNAPL sample may be obtained using a dual check valve bailer or a Bacon Bomb Sampler (see Subsection 4.5.2.1). Samples should be analyzed for chemical composition and physical parameters (e.g., specific gravity, water solubility, etc.).

4.4.2.8 Potable Water Sampling

Scope of Application

Instructions presented in this section are for collecting representative potable water (tap water) samples. Discussions are based on the assumption that a supply tap is available for sampling the selected location, for example, a residence. Under this assumption, the only applicable sampling method would be the hand-held bottle.

Potable water samples may also be collected for evaluating contamination in a particular well or identifying the need for alternate water supply systems. When sampling residential wells, the sample tap should not be located after a household purification system (i.e., water softening or filtration). In these cases, an outdoor tap may have to be sampled.

When sampling potable water, utmost care must be taken to ensure that samples are representative of the water being sampled. This is important not only from a technical and public health perspective, but also from a public relations standpoint. Poor sampling techniques may result in incorrect results (either not detecting a compound that is present or by contaminating the

sample and falsely indicating a compound that is not present). If incorrect results are disclosed to the public, it may be impossible to change public opinion when correct results are reported.

Potable water wells must be purged before the sample is collected. This procedure ensures that water representative of the formation is sampled. The tap should be opened and allowed to flow until the pH, conductivity, and temperature have reached equilibrium. This procedure ensures that any contaminants that might have entered the area of the tap from external sources have been avoided. If the project requirements make it necessary to distinguish the concentration of metals in solution from the concentration of metals associated with solids, filtration of the potable water sample will be required. Potable water samples should be representative of the water quality within the household or office under investigation. The sampling tap must be protected from exterior contamination associated with being too close to the sink bottom or to the ground. Contaminated water or soil from the faucet exterior may enter the bottle during the collecting procedure, since it is difficult to place a bottle under a low tap without grazing the neck interior against the outside faucet surface. Leaking taps that allow water to flow from around the stem of the valve handle and down the outside of the faucet or taps in which water tends to run up on the outside of the lip are to be avoided as sampling locations. Aerator, strainer, and hose attachments on the tap must be removed before sampling. These devices can harbor a bacterial population if they are not cleaned routinely or replaced when worn or cracked. The tips of the faucets should be rinsed with alcohol or bleach before samples are collected. Residual chlorine should also be tested prior to sampling using a Hach Kit. Whenever a steady stream of water cannot be obtained from taps, after such devices are removed, a more suitable tap should be sought. Taps where the water flow is not steady should be avoided because temporary fluctuation in line pressure may cause sheets of microbial growth that are lodged in some pipe section or faucet connection to break loose. A smooth-flowing water stream at moderate pressure without splashing should be obtained. Then, without changing the water flow, which could dislodge some particles in the faucet, the samples can be collected.

Occasionally, samples are collected to determine the contribution of transmission pipes, water coolers, water heaters, etc., to the quality of water in private residences, offices, etc. The purpose of these investigations may be to determine if metals, e.g., lead, are being dissolved into the

water supply. In these cases, it may be necessary to ensure that the water source has not been used for a specific time interval, e.g., over a weekend or a three- or four-day holiday period.

Sample collection may consist of collecting a sample of the initial flush and collecting a sample after the indicator parameters have reached equilibrium. Regardless of the type of sample bottle being used, the bottle cap should not be placed on the ground or in a pocket. Instead, the bottle should be held in one hand and the cap in the other, using care not to touch the inside of the cap. Exercise care not to lose the PTFE liner in certain bottle caps. Contaminating the sample bottle with fingers or permitting the faucet to touch the inside of the bottle should be avoided. Sample bottles should not be rinsed before use. When filling any container, care should be taken not to splash drops of water from the ground or sink into either the bottle or cap. To avoid dislodging particles in the pipe or valve, the stream flow should not be adjusted while sampling. Name(s) of the resident or water supply owner/operator and the resident's exact mailing address, as well as his/her home and work telephone numbers, should always be obtained. This information is required in order that the residents or water supply owner/operators can be informed of the results of the sampling program.

4.4.2.9 *Sample Containers and Preservation*

Sample Containers

Samples should be collected and containerized in the order of volatilization sensitivity of the parameters. A preferred collection order for some common groundwater parameters is:

1. Volatile organics (VOA).
2. Total organic carbon (TOC).
3. Extractable organics (BNAs or SVOCs).
4. Total metals.
5. Dissolved metals.
6. Phenols.
7. Cyanide.
8. Sulfate and chloride.
9. Turbidity.
10. Nitrate and ammonia.

Sample Preservation

Many of the chemical constituents and physiochemical parameters that are to be measured or evaluated in monitoring programs are not chemically stable; therefore, sample preservation is required. Appropriate preservation techniques for various parameters and sample containers that the sampler should use for each constituent or common set of parameters are specified in Subsection 4.12.

Water samples to be analyzed for purgeable organic compounds should be stored in 40-ml septum vials with screw caps and like all other samples, a PTFE-silicone disk should be placed in the cap to prevent contamination of the sample by the cap. Disks should be placed in the caps (PTFE side to be in contact with the sample) in the laboratory prior to the beginning of the sampling program. The 40-mL vials should be completely filled to prevent volatilization, and extreme caution should be exercised when filling a vial to avoid any turbulence that could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost but air space in the bottle is eliminated. After the bottle is capped, it should be turned over and tapped to check for bubbles. If any bubbles are present, the procedure must be repeated. Care should be taken to ensure that no loss of preservative occurs, if applicable.

The following general precautions should be taken when sampling:

- a. A clean pair of new, disposable gloves should be worn each time a different location is sampled and gloves should be donned immediately prior to sampling.
- b. All work should be conducted on a clean surface, such as a stainless steel table.
- c. Sample containers for source samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting, preserving, tagging, etc.
- d. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples.
- e. If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples.

- f. Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- g. Field personnel should use equipment constructed of PTFE, stainless steel, or glass that has been properly pre-cleaned. PTFE or glass is preferred for collecting samples where trace metals are of concern.
- h. Collection of adequate field control samples.

4.4.2.10 Field Quality Control Sampling Procedures

Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background (upgradient) sample replicates that are sent to USACE's QA laboratory and analyzed to evaluate the contractor's laboratory replicates collected by primary laboratory. QC samples are replicates collected by the sampling team for use by the primary laboratory. A detailed discussion of field control samples is contained in Subsection 4.10.

4.4.2.11 Decontamination Procedures

All equipment that will enter the well must be decontaminated prior to its entry. The inside surface of pumps and tubing apparatus must be decontaminated by drawing the decontamination solution through the equipment. Field measurement equipment such as water level indicators should be cleaned as described in Subsection 4.11. If the sampling equipment is being prepared for later use, it should be wrapped in cleaned foil. The sampling equipment should remain wrapped in this manner until immediately prior to use. Additional sampling devices may be needed on-site to ensure an adequate drying time. The requirement for dedicated equipment should apply to all bailers used for collecting samples. Bailers, other sampling equipment, and sample bottles must be physically separated from generators during transport and storage. Decontamination procedures for field equipment are discussed in Subsection 4.11.

4.4.2.12 Documentation

Bound field logbooks should be used for the maintenance of field records. All aspects of sample collection and handling as well as visual observations shall be documented in the field logbooks as outlined in Section 5.

All entries in field logbooks should be legibly recorded, and contain accurate and inclusive documentation of an individual's project activities.

4.5 SURFACE WATER SAMPLING

4.5.1 Rationale

Instructions presented in this section are for collecting representative surface water samples from surface water bodies. Surface water bodies can be classified into two primary types: flowing and standing. Flowing bodies include industrial effluent, municipal wastewater, rivers, sewers, leachate seeps, streams, or any other lotic water body. Standing bodies include lagoons, ponds, nonaqueous (e.g., surface impoundments), lakes, or any other lentic water body. Surface water samples can be collected from various depths of the water bodies using some of the techniques described in this chapter.

4.5.1.1 *Surface Water Sample Locations*

Due to the nature of the media, locations for surface water samples are restricted to locations within the water body under evaluation. However, variations of location within the water body may include depth, horizontal location, and time.

4.5.1.2 *Sample Collection*

The type of sample should be designated when selecting a sampling method. Surface water samples may be discrete or composite samples. A discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease. Composites are samples composed of two or more specific aliquots (discrete samples) collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can, in certain instances, be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask the presence of contaminants by diluting isolated concentrations of analytes that may be present in the environmental matrix.

4.5.1.3 *Quality Control Sampling*

4.5.2 *Procedures*

Sampling instructions for the most common techniques for collecting surface water samples are presented in this section. Prior to sample collection, water body characteristics (size, depth, flow) should be recorded in the field logbook. Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect sampling quality. When wading in a stream always collect the samples on the upstream side. In addition, if sediment samples are to be collected at the same locations as water samples, the water samples must be collected first. If the project requirements make it necessary to distinguish the concentration of metals in solution from the concentration of metals associated with solids, filtration of the surface water will be required. Filtration techniques are discussed in Subsection 4.5.2.2.

The factors that will contribute to the selection of a sampler include the width, depth, and flow of the location being sampled, and whether the sample will be collected from the shore or a vessel. Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast-flowing rivers and streams, it may be nearly impossible to collect a mid-channel sample at a specific point. Low-flowing streams and leachate seeps present the opposite problem. In these cases, the sampler should attempt to find a location where flow is obstructed and a pool is created. If this is not possible, the only way to obtain a sample may be to dig into the sediment with a decontaminated trowel to create a pooled area where the liquid will accumulate. However, this method is not recommended since the sample will probably be highly turbid. If the banks are not sloped, sampling personnel may be able to collect the liquid directly into the sample bottle from the edge of the water body. In some instances where the liquid to be sampled cannot be reached, a pond sampler, by virtue of its extension capabilities, may be necessary. In these cases, the pond sampler should be assembled to ensure that sampling personnel are not in danger of falling into the water body being sampled. For a stream, channel, or river, the sample should be collected at mid-depth. For standing liquid, the sample should be collected just below the surface or at mid-depth. Specific sampling strategies may be altered depending on the contaminants of

concern. For instance, when sampling for hydrocarbons or other light nonaqueous phase liquids it may be better to sample at the surface.

Once the sample is obtained it should be transferred directly into the sample bottle. The sampling device should be decontaminated before the next sample is taken. If sampling below the water surface is required, some of the samplers discussed below will allow collection of discrete representative liquid samples at various depths. Proper use of the sampling device chosen includes slow lowering and retrieval of the sample, immediate transfer of the liquid into the sampling container, and notation in the logbook of the depth at which the sample was collected.

4.5.2.1 Samplers

Each sampling technique presents various disadvantages and advantages for its application. For example, desired depth, tidal influences, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. Samplers include:

- Hand held bottle
- Dippers and pond samplers
- Peristaltic pump
- Kemmerer sampler
- Weighted bottle
- Bacon bomb sampler

Discussions of the advantages and disadvantages of each sampling technique are presented below.

Hand-held bottle

Applicability

Filling the sample containers directly is advantageous when the sample might be significantly altered during transfer from a collection vessel into another container. This would affect samples being collected for VOC analysis. The hand-held bottle is not applicable for samples required at depth.

Method Summary and Equipment

Samples from shallow depths can be readily collected by merely submerging the sample containers.

Sampling Procedure

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- Submerge the sample container with the cap in place with minimal surface disturbance so that the open end is pointing upstream.
- Allow the device to fill slowly and continuously using the cap to regulate the speed of water entering the bottle.
- Retrieve the sample container from the surface water with minimal disturbance.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete the chain-of-custody form and field sheets.

Dippers and pond samplers

Applicability

Dippers and pond samplers prevent unnecessary contamination of the outer surface of the sample bottle that would otherwise result from direct immersion in the source. Dippers and pond samplers can either be reused or discarded. Discarding the samplers would eliminate the need for decontamination. With the pond sampler, samples can be obtained at distances as far as 10 ft from the edge of the source, preventing the technician from having to physically contact the source. The tubular handle may bow when sampling very viscous liquids if sampling is not done

slowly. Dippers and pond samplers perform similar functions, except that the length of the dipper is smaller.

Method Summary and Equipment

The pond sampler consists of an adjustable clamp attached to the end of a two or three-piece telescoping aluminum or fiberglass pole that serves as the handle. The clamp is used to secure a sampling beaker.

Sampling Procedure

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- Assemble the dipper or pond sampler. If appropriate, make sure that the sample container and the bolts and nuts that secure the clamp to the pole are tightened properly.
- Collect samples by slowly submerging the pre-cleaned dipper or pond sampler with minimal surface disturbance. Make sure that the open end is pointed upstream.
- Retrieve the dipper or pond sampler from the surface water with minimal disturbance.
- Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the dipper/sampler's edge.
- Empty the sampler slowly, allowing the sample stream to flow gently down the side of the bottle with minimal entry turbulence.
- Continue delivery of the sample until the bottle is filled.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete the chain-of-custody documents and field sheets.
- Properly clean and decontaminate the equipment prior to reuse or storage.

Peristaltic Pump

Applicability

An advantage of the peristaltic pump is its design, which isolates the sample from the moving part of the pump and allows for easy decontamination by removal or replacement of the flexible tubing. This method can both extend the lateral reach of the sampler and allow sampling from depths below the water surface. Disadvantages of these pumps include their low pumping rates and their limited height of intake lift (less than 20 ft). These pumps also require an outside power source and, like other suction pumps, are not suitable for collecting samples for VOC analysis because of potential degassing effects.

Method Summary and Equipment

Peristaltic pumps displace fluid by mechanical peristalsis. A flexible sampling tube is mounted around the pump chamber, and rotating rollers compress the tubing, forcing fluid movement ahead (the peristaltic effect) and inducing suction behind each roller.

Sampling Procedure

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- Install clean, medical-grade silicone tubing in the pump head, as instructed by the manufacturer. Attach the silicon tubing to the glass tubing outlet from the sample bottle.
- Select the length of suction intake tubing necessary to reach the required sample depth and attach it to the intake side of the sample bottle. Heavy-wall PTFE, or a diameter equal to the required pump tubing, suits most applications. (A heavier wall will allow for a slightly greater lateral reach.)
- If possible, allow several liters of sample to pass through the system before actual sample collection. Collect this purge volume and return it to the source after the sample aliquot has been withdrawn.
- Fill the necessary sample bottles by allowing pump discharge to flow gently down the side of bottle with minimal entry turbulence. Cap each bottle as filled.
- Preserve the sample as necessary; the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.

- Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete the chain-of-custody documents and field sheets.
- Allow system to drain, then disassemble. Decontaminate tubing if necessary; otherwise, discard appropriately.

Kemmerer Sampler

Applicability

The Kemmerer sampler is a practical method for collecting discrete, at-depth samples where the collection depth exceeds the lift capacity of pumps. The use of the Kemmerer sampler is limited, however, because it is typically constructed of brass.

Method Summary and Equipment

The Kemmerer sampler is a messenger-activated water sampling device that is used to sample water from a specific depth. In the open position, water flows easily through the device. Once lowered to the desired depth, a messenger is dropped down the sample line tripping the release mechanism and closing the container. In the closed position, the bottle is sealed at the top and bottom, isolating the sample during retrieval.

Sampling Procedure

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- Inspect Kemmerer sampler to ensure that sample drain valve is closed (if equipped).
- Measure and mark sampler line at desired sampling depth.
- Open bottle by lifting top stopper-trip head assembly.
- Gradually lower bottle until desired sample depth is reached (predesignated mark from Step 3).

- Place messenger on sample line and release.
- Retrieve sampler; hold sampler by center stem to prevent accidental opening of bottom stopper.
- Rinse or wipe off exterior of sampler body.
- Recover sample by grasping lower stopper and sampler body with one hand (gloved), and transfer sample by either lifting top stopper with other hand and carefully pouring contents into sample bottles or holding drain valve (if present) over sample bottle and opening valve.
- Allow sample to flow slowly down the side of the sample bottle with minimal disturbance.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete all chain-of-custody records and field sheets.
- Decontaminate sampler.

Weighted Bottle

Applicability

The weighted bottle can be used to obtain samples from a specific depth. The glass construction of the sampler can make the use of this sampler more desirable than the Kemmerer in some sampling situations.

Method Summary and Equipment

The weighted bottle can be used for collecting representative samples from a specific depth. The sampler consists of a glass bottle, a weighted sinker, a bottle stopper, and a line that is used to open the bottle and to lower and raise the sampler during sampling. Once the sampler is lowered

to the desired sampling depth, the stopper is opened, and the bottle is filled and retrieved to the surface.

Sampling Procedure

- Spread new plastic sampling location sheeting on the ground at each to keep sampling equipment decontaminated and to prevent cross-contamination.
- Assemble the weighted bottle sampler.
- Measure and mark the sampler line at the desired sampling depth.
- Lower the sampling device to the predetermined depth.
- When the sampler is at the required depth, pull out the bottle stopper with a sharp jerk of the sampler line and allow the bottle to fill completely. (This is usually evidenced by the cessation of air bubbles.)
- Retrieve the sampler.
- Rinse or wipe off the exterior of the sampler body.
- Allow sample to flow slowly down side of sample bottle with minimal disturbance.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete all chain-of-custody records and field sheets.
- Decontaminate sampler.

Bacon Bomb Sampler

Applicability

The Bacon bomb sampler is a widely used, commercially available sampler, designed for sampling petroleum products and viscous liquids. It is very useful for sampling larger storage

tanks because the internal collection chamber is not exposed to a product until the sampler is triggered. It is useful in collecting samples at various vertical locations. Like the weighted bottle sampler, the Bacon sampler remains unopened until it reaches the desired sampling depth. The Bacon sampler is difficult to decontaminate and it is difficult to transfer the sample into the sample bottles. The possibility of aerating the sample exists if the sampler does not completely fill with water and air is entrapped in the sampler during retrieval.

Method Summary and Equipment

The Bacon bomb sampler is constructed of brass or stainless steel and is available in two sizes: 1.5 in. or 3.5 in. in diameter. Samplers range in volume from 4 oz to 32 oz. The Bacon bomb sampler is equipped with a trigger that is spring loaded. When opened, the trigger allows liquid to enter the collection chamber. When the trigger is released liquid is prevented from flowing into the collection chamber or out of the collection chamber.

Sampling Procedure

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- Measure and mark the sampler line at the desired sampling depth.
- Lower the Bacon bomb sampler carefully to the desired sampling depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut. · Release the trigger line and retrieve the sampler.
- Transfer the sample to the sample bottles by pulling on the trigger. Allow the sample to flow down the side of the sample bottle with minimal disturbance.
- Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- Record the information in the field logbook and complete all chain-of-custody records and field sheets.

- Decontaminate the sampler.

4.5.2.2 Filtered Sample Collection

The techniques for the filtration of liquid media (i.e., groundwater, surface water, and potable water) are presented in Subsection 4.4.2.4, Filtration Techniques.

4.5.2.3 Field Measurement Procedures and Criteria

Subsection 4.4.2.5 outlines the instruments used in obtaining field measurements for water. In addition to these measurements another instrument is used for surface water measurements and is described below.

Physical Measurements

Flow Velocity

The March McBirnie flow meter is a direct-reading instrument that is used to measure the flow rate of water in a stream channel in feet per second. The machine is factory-calibrated and can be checked daily by turning the scale control to the calibrate position. If the indicator does not line up with the calibration line, the meter needs to be returned to the manufacturer.

To measure flow velocity, the following steps should be completed:

- If the water is less than 0.76 meter (30 inches) deep, and the channel is less than 3 meters (10 feet) wide:
 - Insert probe to 60% of the depth in the center of stream.
 - Measure velocity.
- If the water is deeper than 0.76 meter deep, and the channel is less than 3 meters wide:
 - Insert probe to 20% of the depth.
 - Measure the velocity.
 - Insert the probe to 80% of the depth.
 - Measure the velocity.
 - Record the velocity.
 - Average these two readings.

- If the water is less than 0.76 meter deep, and the channel is greater than 3 meters wide:
 - Insert the probe to 60% of the depth at 25%, 50%, and 75% of the channel width.
 - Record each reading.
 - Measure velocity at each point.
- If the water is greater than 0.76 meter deep, and the channel is greater than 3 meters wide:
 - Insert the probe to 20% of the depth at 25%, 50%, and 75% of the channel width.
 - Measure the velocity at each point.
 - Insert the probe to 80% depth at 25%, 50%, and 75% of the channel width.
 - Measure velocity at each point.

4.5.2.4 Sample Containers and Preservation Techniques

Sample Containers

Refer to Subsection 4.12 to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Refer to Subsection 4.12 for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

1. Volatile organics (VOA).
2. Total organic carbon (TOC).
3. Extractable organics (BNAs or SVOCs).
4. Total metals.
5. Dissolved metals.
6. Cyanide.
7. Sulfate and chloride.
8. Turbidity.
9. Nitrate and ammonia.

Sample Preservation

Methods of sample preservation are relatively limited and are generally intended to retard biological action, and hydrolysis, and to reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and protection from light. The

sampler should refer to Subsection 4.12 or the specific preservation method in SW-846 for the appropriate preservation technique.

4.5.2.5 *Field Quality Control Sampling Procedures*

Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or -background (upgradient) samples. QA samples are replicates which are sent to USACE's QA laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are replicates collected by the sampling team for use by the primary laboratory. A detailed discussion of field control samples is contained in Subsection 4.10.

4.5.2.6 *Decontamination Procedures*

All equipment that will enter the water must be decontaminated prior to its entry. The inside surface of pumps and tubing apparatus must be decontaminated by drawing the decontamination solution through the equipment. Sampling equipment should be decontaminated, as described in Subsection 4.11. The sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed on-site to ensure an adequate drying time. During transport and storage, sampling equipment and sample bottles must be physically separated from engines/generators that are used to power some sampling equipment.

4.5.2.7 *Documentation*

Bound field logbooks should be used for the maintenance of field records. All aspects of sample collection and handling as well as visual observations shall be documented in the field logbooks as outlined in Section 5.

All entries in field logbooks should be legibly recorded, and contain accurate and inclusive documentation of an individual's project activities.

4.6 SOIL SAMPLING

4.6.1 Rationale

Instructions presented in this section are for collecting representative soil samples. Soil sampling can be classified into two primary types: surficial and subsurface. Bedrock has also been included under this category because most of the equipment used for subsurface soil sampling is also used for rock core sampling. Instructions for sampling surficial and subsurface soils by the following techniques are included in this section: spade and scoop, hand auger and tube sampler, split spoon sampler, ring-lined (California) barrel sampler, thin-walled (Shelby) tube, continuous barrel sampler, and core barrel sampler. This also addresses other types of geotechnical soil sampling which may be adapted for environmental purposes.

4.6.1.1 Sampling Locations

Sampling at sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. Because of the nature of the media, soil samples can vary considerably across a site. Physical properties of the soil, including grain size and cohesiveness, may limit the depth from which samples can be collected and the method required to collect them. In most soils, hand-powered equipment can only be used to a depth of approximately 4 to 5 ft. At greater depths, soil sampling is normally performed with a drill rig or other mechanically driven device.

4.6.1.2 Sample Types

The type of sample should be designated when selecting a sampling method. Application techniques for sample methods include discrete (grab) or composite samples. A discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected immediately and at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease. Composites are samples composed of two or more specific aliquots (discrete samples)

collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can, in certain instances, be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask the presence of contaminants by diluting isolated concentrations of analytes that may be present in the environmental matrix.

4.6.1.3 Sample Collection and Field and Laboratory Analysis

Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. Subsurface soil conditions themselves will restrict the application of certain samples. For example, the thin-walled tube sampler is not applicable for sampling sands. Discussions of the advantages and disadvantages of each sampling technique are presented below.

4.6.2 Procedures

4.6.2.1 Sampling Methods

Presented below are sampling instructions for the most common techniques of collecting soil samples. Prior to sample collection, the soil sampling location and characteristics (soil type, depth) should be recorded in the field logbook. Selection of soil sampling equipment is usually based on the depth of the samples. Manual techniques are usually selected for surface or shallow, subsurface soil sampling. At greater depths, mechanically driven equipment is usually required to overcome torque induced by soil resistance and depth. Additional information on collecting soil samples is presented in EPA/625/R-93/003.

Spade and Scoop

Applicability

The spade and scoop method is a very accurate, representative method for collecting surface and shallow subsurface soil samples. This method is usually limited to soil depths less than 1 ft.

Method Summary and Equipment

The simplest, most direct method of collecting surface soil samples is to use a spade and stainless steel scoop. A typical garden spade can be used to remove the top cover of soil to the required depth, and the smaller stainless steel scoop can be used to collect the sample.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Carefully remove the top layer of soil to the desired sample depth with a pre-cleaned or decontaminated spade.
- Using a pre-cleaned or decontaminated stainless steel scoop or trowel, collect the sample aliquot for VOC analysis first, then homogenize enough soil in a stainless steel bowl for the remaining sample containers.
- Transfer sample into the appropriate sample bottle with a stainless steel lab spoon or equivalent.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and maximum sampling depth for the hand auger is typically between sample locations.

Hand Auger and Tube Sampler

Applicability

Equipment for the hand auger is replaced with the tube corer, lowered into the borehole, portable and easy to use. Discrete subsurface soil sampling and forced into the soil at the completion depth. The pies can be collected efficiently without the use of a drill corer is rig. Disadvantages of the hand auger include its limited sampling depth. The tube sampler may not penetrate gravelly or rocky

soils.

Method Summary and Equipment

Hand augers are the simplest and most direct method for sampling subsurface soil samples. Although the maximum sampling depth for the hand auger is typically 5 ft, greater depths can be sampled depending on the soil type. Hand augers come in various diameters and various types. The auger bit is used to bore a hole to the desired sampling depth and then withdrawn. The auger bit is then replaced with the tube corer, lowered into the borehole, and forced into the soil at the completed depth. The corer is then withdrawn and the sample is collected.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Attach the auger bit to a drill rod extension and further attach the “T” handle to the drill rod.
- Clear the area to be sampled of any surface debris (twigs, rocks, litter). It may be advisable to remove the first 8 to 15 cm of surface soil for an area approximately 15 cm in radius around the drilling location.
- Begin drilling, periodically removing accumulated soils. This prevents accidentally brushing loose material into the borehole when removing the auger or adding drill rods.
- After reaching desired depth, slowly and carefully remove auger from boring.
- Remove auger tip from drill rods and replace with a pre-cleaned or decontaminated thin-wall tube sampler. Install proper cutting tip. If non-cohesive materials, (i.e., sands) are being sampled, then it may be necessary to use a bucket hand auger.
- Carefully lower corer down borehole. Gradually force corer into soil. Take care to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring because the vibrations may cause the boring wall to collapse.
- Remove corer by twisting to prevent losing core. and unscrew drill rods.
- Remove cutting tip and remove core from device.
- Discard top of core (approximately 2.5 cm), which represents any material collected by the corer before penetration of the layer in question. Place remaining core into VOA sample container or stainless steel bowl for homogenizing.

- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and between sampling locations.

Split-Spoon Sampler

Applicability

The split spoon sampler is used for sampling subsurface soil in cohesive and non-cohesive type soils. It is used extensively for collecting subsurface soil samples for chemical analysis. The split spoon sampler will require a drill rig and crew for collecting samples greater than 5 ft.

Method Summary and Equipment

The split spoon sampler is typically a 2- or 3-in. -diameter, thick-walled, steel tube that is split lengthwise. If a 2-in. diameter split spoon sampler is used, then standard penetration tests can be taken to determine the density of the soil (ASTM 1967). A cutting shoe is attached to the lower end; the upper end contains a check valve and is connected to the drill rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed and the sampler is lowered into the hole on the bottom of the drill rods. The sampler is driven into the ground in accordance with the standard penetration test.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Assemble the sampler by aligning both sides of the barrel and then screwing the drive shoe on the bottom and the heavier headpiece on top.
- Place the sampler in a perpendicular position on the material to be sampled.

- Drive the tube utilizing a sledge hammer or drill rig if available. Do not drive past the bottom of the headpiece because this will result in compression of the sample.
- Record the length of the tube that penetrated the material being sampled and the number of blows required to obtain this depth. Typically, the number of blows per 6 in. of depth is recorded.
- Withdraw the sampler and open it by unscrewing the drive shoe and head and splitting the barrel. If split samples are desired, a decontaminated stain-less steel knife should be utilized to split the tube contents in half longitudinally.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Transfer sample into an appropriate sample bottle with a stainless steel lab spoon or equivalent.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to label the bottle carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and between sampling locations.

Ring-lined (California) Barrel Sampler

Applicability

The ring-lined barrel sampler provides the ability to collect samples without losing volatiles or moisture. Soil is contained in the rings and it can be easily and quickly capped after it is removed. The relatively small size of the rings allows easy sample shipping and handling. However, the opportunity for describing the soil is diminished because most of the soil is conceded in the ring apparatus. Because rings are not always accepted by the laboratory, prior arrangements should be made with the laboratory.

Method Summary and Equipment

Ring-lined barrel samplers are typically 3 in. in diameter and are used to obtain representative subsurface soil samples with a split sampling barrel that has removable rings. The rings are typically constructed of plastic, stainless steel, or brass and fit inside the barrel assembly. Rings are commonly used within the California Modified sampler and are typically 3 in. long.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Assemble the sampler by placing eight 3-in.-long rings in the 2-ft-long sampler. Align both sides of the barrel and screw the drive shoe on the bottom and the heavier headpiece on top.
- Place the sampler in a perpendicular position on the material to be sampled.
- Drive the tube utilizing a sledge hammer or drill rig if available. Do not drive past the bottom of the headpiece because this will result in compression of the sample.
- Record the length of the tube that penetrated the material being sampled and the number of blows during each 6-in. increment.
- Withdraw the sampler and open it by unscrewing the drive shoe and head and the splitting barrel. Remove the sampling rings. Trim the soil at the end of the rings so that it is flush with the endings. For chemical samples, cap the end of the rings with a teflon-lined plastic cap or appropriate weight teflon sheet and plastic cap. For geotechnical samples, a plastic cap is suitable. Seal each end cap with plastic electrical tape.
- Label the sample ring with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place sealed sample rings on ice immediately.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and between sampling locations.

Thin-walled (Shelby) Tube Sampler

Applicability

Thin-walled tube samplers allow collection of undisturbed samples in cohesive type soils (i.e., clays). They are primarily used for collecting soil samples for certain geotechnical tests. Thin-walled tube samplers are not the ideal container for transporting samples to the laboratory for chemical analysis. The opportunity for describing the soil is diminished because most of the soil is concealed in the tube.

Method Summary and Equipment

The thin-walled tube sampler is designed to take undisturbed samples in cohesive type soils. The thin-walled tube sampler is available in either brass, galvanized steel, plain steel, or stainless steel and is manufactured in either 30- or 36-in. lengths. It is available in 2-, 3-, and 5-in. diameters; however, the 3-in. diameter is the most commonly used. Thin-walled tube samplers are usually used for sampling cohesive soils for geotechnical evaluation, rather than chemical analysis.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Place the sampler in a perpendicular position on the material to be sampled.
- Push the tube into the soil by a continuous and rapid motion, without impact or twisting. In no instance should the tube be pushed further than the length provided for the soil sample.
- When the soil is so hard that a pushing motion will not penetrate the sample sufficiently for recovery, it may be necessary to collect a disturbed sample with the split-spoon sampler. Extremely dense and hard soils may result in damage to the thin-walled tube sampler.
- Before pulling out the tube, rotate the tube at least two revolutions to shear off the sample at the bottom. For geotechnical analysis, seal the ends of the tube with wax or rubber packers to preserve the moisture content. In such instances, the procedures and preparation for shipment should be in accordance with ASTM Method D1587-83. For chemical samples, seal the ends of the tube with PTFE-lined plastic caps. Seal each end cap with plastic electrical tape.

- Label the sample tube with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and between sampling locations.

CME (Central Mine Equipment) Sampler

Applicability

The CME sampler provides good samples for describing soil profiles because of the long length of the samples. Discrete samples for chemical analysis can only be collected within a 5-ft increment. This sampler may not be effective in non-cohesive soil types and requires the use of a drilling rig.

Method Summary and Equipment

The CME sampler is a split barrel sampler that is used in conjunction with the hollow stem auger drilling technique. The sampler is typically 5 ft long and is 4 in. in diameter. The sampler fits inside the lead hollow stem auger and collects soil as the auger is advanced into the soil.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Assemble the sampler by aligning both sides of the barrel and then screwing the drive shoe on the bottom and the heavier headpiece on top.
- Attach the sampler to the drill rod extension and place the sampler inside the lead auger bit.
- Drive the sampler and the lead auger bit utilizing a well rig.
- Withdraw the sampler and open it by unscrewing the drive shoe and head and the splitting barrel. If chemical samples are desired, a decontaminated stainless steel knife should be utilized to divide the tube contents in half longitudinally.
- Transfer the sample into an appropriate sample bottle with a stainless steel lab spoon or equivalent.

- Secure the cap tightly.
- Place filled sample containers on ice immediately.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate sampling equipment after use and between sampling locations.

Core Barrel

Applicability

Core barrel sampling is used primarily for collecting samples for rock profiling purposes. Rock samples are not typically submitted for chemical analysis.

Method Summary and Equipment

Core barrel drilling is used to obtain samples of rock or soils that are too hard to sample by soil sampling methods. Double tube core barrels work the best. Core bits used for this type of sampling are impregnated with diamonds that cut through the formation allowing a continuous rock sample to be collected.

Sampling Procedure

- Place the core barrel into position with the bit touching the ground or the surface to be cored.
- Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled.
- Remove the core barrel from the hole and disassemble it as necessary to remove the core.
- Place the recovered core in a core box in accordance with ER 1110-1-1802, and ER 1110-1-1803. The core is placed in the core box with the upper end of the core at the upper left corner of the core box. Cores should be placed in the core box as a book would read, from left to right and top to bottom, within the longitudinal separators. Space blocks or plugs should be placed at the beginning of each core run. Core boxes

should be marked on the outside to indicate the top and bottom, and the inside upper left corner of the box should be permanently marked with the letters UL to indicate the upper left corner. Soft or friable cores should be wrapped in plastic film or sealed in wax.

Cone Penetrometer Rigs

Applicability

Cone penetrometer rigs have traditionally been used to collect geotechnical data for design of foundations and earth structures. Recent developments have expanded the use of this equipment to the area of soil and groundwater sampling. Cone penetrometer rigs may also be used to delineate contaminant plumes. EPA/625/R-93/003 discusses the use of a cone penetrometer.

Method Summary and Equipment

The cone penetrometer rig typically consists of a truck with a fully enclosed work area on the back. Within the work area is a hydraulic ram and computers to record data. The penetrometer collects data by pushing 1.5-in.-diam instrumented probes into the ground. As the probes are pushed they collect data and transmit the data to the onboard computer. This data can be viewed on the computer screen as the probe is advanced, allowing evaluation of the data immediately. The soil sampler used with the cone penetrometer consists of a lined steel cylinder with a retractable tip. The liner (typically a plastic type material) is placed in the sampler and the retractable tip is set at the bottom end of the sampler. The sampler is then advanced to the top of the interval where the soil sample is to be collected. The tip is remotely released and the sampler is pushed ahead into the interval to be sampled. Using this procedure, the soil sampler is pushed to the desired depth and the sample is collected without producing soil cuttings typically generated during soil boring activities. This type of soil sampler can be used with equipment other than cone penetrometers.

Sampling Procedure

- Assemble decontaminated cone penetrometer device that will be pushed into the ground to collect data or samples.

- Push the data collection tip to the desired depth and record the data on the onboard computer. For the soil sampler, advance the sampler to the top of the interval to be sampled, release the tip, and advance the sampler to collect the soil sample.
- While removing the data collection tip, backfill the hole with grout by pumping grout through the tip as it is retracted. Following removal of the soil sample, backfill the hole with grout using the tremie method or by pouring the grout into the hole from the ground surface.
- Remove the liner from the soil sampler and begin sampling with the acquisition of any VOC samples, conducting the sampling with as little disturbance as possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of a different location is desired, the sample is transferred to the stainless steel bowl for mixing.
- Transfer sample into an appropriate sample bottle using a stainless steel spoon or equivalent.
- Check that a PTFE liner is present in the cap. Secure the cap tightly.
- Label the sample bottle. Complete the label completely and clearly, addressing all the categories and parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Decontaminate the equipment following each probe or sample.

Piston Sampler

Applicability

Piston samplers are used to collect soft subsurface soils that cannot be collected using other techniques.

Method Summary and Equipment

The piston sampler consists of a sampling barrel with a piston that is retracted during sampling. Retraction of the piston creates a vacuum within the sample barrel that aids in retaining the sample in the barrel. Various piston type samplers are available, and each should be operated per

the manufacturer's recommendations. EPA/625/R-93/003 and EPA/540/8-91/012 discuss the use of a piston sampler.

Sampling Procedure

- Assemble decontaminated piston sampler and attach to rods that will lower the sampler down the borehole.
- Lower sampler to the desired depth. Advance the sampler into the soil while actuating the piston to create a vacuum within the sample barrel.
- Carefully remove the piston sampler from the borehole.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to a stainless steel bowl for mixing.
- Label the sample bottle with the appropriate sample label. Complete the label carefully and clearly, addressing all the categories or parameters.
- Place the sample in an appropriate container and put the container on ice.
- Complete all chain-of-custody documents and record in the field.
- Prepare samples for shipping.
- Thoroughly decontaminate the sampler after use.

4.6.2.2 Field Measurement Procedures

The purpose of this section is to identify field methods for field screening soil. Visual assessment and instrument readings will be used to screen field samples and residual samples. Residual materials may include excess samples, cuttings, and other materials.

Preparation

- Review screening procedures, equipment operation manuals.
- Calibrate field screening instruments in accordance with the manufacturer's instructions and operating procedures.

- Document calibrations in the field logbook.
- Determine the ambient air temperature. If the ambient air temperature is below 15° C, select an area where soil samples can be kept warm for head space readings.

Field Screening

Prior to and during collection of a soil or sediment sample, visually observe the sampling area and sample for signs of releases that include the following:

- Surface discoloration or staining.
- Stressed or discolored vegetation.
- Physical evidence of hydrocarbons or other contamination.

Record visual observations of the sampling area in the field logbook. Include a sketch and dimensions of any area where visual signs of a release are observed.

Instrument Readings

Take instrument readings prior to sampling to monitor ambient air for health and safety purposes. Record this information in the field logbook.

Soil and or sediment headspace readings are taken in the following manner:

- Place soil/sediment sample in a clean, dry, glass jar so that the jar is not more than half full. Cover the jar with aluminum foil and replace the lid.
- If the ambient temperature is low, bring the jarred samples to an area where they can be warmed.
- Gently shake the jar to aid sample volatilization.
- Remove the lid and insert the probe through the aluminum foil, but not into the sample, as this will clog the instrument. Record the instrument reading the area of the log reserved for headspace readings.
- Do not submit the jarred sample for laboratory analysis.
- Dispose of the jarred sample in accordance with residual management protocols.

4.6.2.3 Sampling for Chemical Analysis

VOC Soil Sample Collection

The EPA has established a new extraction method for volatile organic compounds. This new method resulted from EPA research indicating that analytical results for volatile compounds are inaccurate and biased low using Method 5030 extraction. Loss of volatile compounds such as BTEX results from volatilization and decomposition or biodegradation caused by light, moisture, age, biological organisms, and air; therefore, Method 5035 was promulgated.

A routine analytical sample will include the following five subsamples:

- One VOA vial for low concentration analysis
- One duplicate for low concentration analysis
- One VOA vial for high concentration analysis
- One duplicate for high concentration analysis
- One VOA vial for moisture determination

En-Core™ Sampler

The En-Core Sampler has been approved for collection of samples and this method is the preferred sampling method for use at the site. The En-Core Sampler (or equivalent) selects a small volume (about five grams) of soil that is stored in a chamber that is submitted to the analytical lab. *The sample must be received, prepped, and analyzed within two days of collection. Therefore, all samples must be shipped the day they are collected.*

Two or three En-Core samplers will be required per analytical sample:

- One En-Core sampler for low concentration analysis.
- One En-Core sampler for high concentration analysis or low concentration duplication.
- One En-Core sampler for reparation.
- One VOA jar with Teflon cap for moisture determination.

The En-Core Sampler is a single use device. It can not be cleaned and/or reused. The following is the procedure for using the En-Core Sampler.

- Hold the coring body and push the plunger rod down until the small o-ring rests against the tabs. This will assure that the plunger moves freely.
- Depress the locking lever on the En-Core T-Handle. Place the coring body, plunger end first, into the open end of the T-Handle, aligning the two slots on the coring body with the two locking pins in the T-Handle.
- Twist the coring body clockwise to lock the pins in the slots. Check to ensure the Sampler is locked in place. The sampler is now ready for use.
- Turn the T-Handle with the T up and the coring body down. This positions the plunger bottom flush with the bottom of the coring body (ensure that the plunger bottom is in position).
- Using the T-Handle, push the Sampler into the soil until the coring body is completely filled. When full, the small o-ring will be centered in the T-Handle viewing hole.
- Remove the sampler from the soil and wipe any excess soil from the exterior of the coring body.
- Place a cap on the coring body while it is still in the T-Handle. Push and twist the cap over the bottom until the grooves on the locking arms seat over the ridge on the coring body. The cap must be seated to seal the Sampler.
- Remove the capped Sampler by depressing the locking lever on the T-Handle while twisting and pulling the Sampler from the T-Handle.
- Lock the plunger by rotating the extended plunger rod fully counter-clockwise until the wings rest firmly against the tabs.
- Attach a completed circular label from the En-Core Sampler bag to the cap on the coring body.
- Label outside label on En-Core sampler bag and add a custody seal.
- Return the full En-Core Sampler to a zip-lock bag. Seal the bag and place on ice.

4.6.2.4 Test Pit Excavation

This procedure defines the safe methods to be followed during the excavation, logging and sampling of test pits. Included in this discussion are procedures for obtaining representative samples and proper documentation of sampling activities.

Discussion

The scope of this document is limited to project activities relating to test pit construction, soil and waste description, and sample collection. The objectives of test pit excavation are to:

- Describe the physical nature of consolidated or unconsolidated subsurface earthen materials.
- Characterize disposal areas.
- Describe waste materials.
- Determine subsurface soil characteristics.
- Collect representative samples of materials encountered.

Preparation

Field Team Leaders and other key project members must meet with the Project Manager to discuss requirements for test pit activities. At a minimum, this discussion needs to address the following items:

- The extent of the test pit field effort. Determine the number, location and type of samples to be collected including Q/A Q/C samples. Review available background information (i.e., topographic maps, soil survey maps, geologic survey maps, other site reports, etc.). If appropriate, prepare a work and sampling plan with appropriate site maps.
- Review associated operating practices for information on the performance of all relevant field activities that will be required to complete near surface or shallow soil sampling activities.
- Determine necessary sampling and monitoring equipment. Decontaminate or pre-clean equipment. Inspect and test, if possible, all equipment to determine the operating condition of equipment to be utilized prior to performance of field activities.
- Verify that the client representatives have been notified of test pit activities, including dates, times, equipment, subcontractors, number of personnel, duration, operations clearances, utility clearances, and other information affecting site operations and client personnel or safety. All test pit locations are required to be utility-cleared by the client or utility companies in writing prior to any intrusive activities. Verify utility clearances have been completed prior to sampling. In no instance shall WESTON personnel perform utility clearances or act on behalf of a client to obtain utility clearances.

- Obtain the appropriate GEOLIS Forms, which at a minimum will include, the Location Identification Form, the Test Pit Logging Form, and optional Notes and Sketch Forms. See Appendix B for samples of GEOLIS Forms. If project requirements specify another form for recording test pit information, obtain those form (s).
- Obtain a logbook for documentation of equipment checks and all other miscellaneous activities not documented in GEOLIS Forms.
- Contact delivery service to confirm ability to ship all equipment and samples to and from the site. Determine if shipping restrictions exist and confirm regulations and specifications.
- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
- Notify analytical laboratory of sample types, the number of samples, and approximate arrival date.
- Confirm that all equipment has arrived, has been decontaminated or pre-cleaned before sampling and is operational.
- Conduct a site survey prior to site entry in accordance with the Health and Safety Plan.
- Identify and locate all test pit areas. Stake anticipated limits of excavation as indicated on the site map, and mark stakes with the test pit number. Complete appropriate GEOLIS Location Identification Forms.
- Ensure that site access to excavation areas has been obtained and cleared with appropriate personnel. Confirm utility clearances from the client representative and other utility representatives. Obtain signatures of client representative and other utility representatives in the field logbook and on the site map documenting that utility clearances have been completed. If test pits are in a high-traffic area, set up an exclusion zone using yellow marking tape strung from stakes or other semi-permanent objects.

Test Pit Excavation

Excavate test pits with a backhoe that uses a 2- to 3- foot wide bucket capable of efficient excavation to the appropriate depth.

- At those sites requiring restoration or containing contaminated materials, remove and stockpile the topsoil or contaminated material before test pit excavation. Make shallow cuts of 1- to 2-foot depths and stockpile the material on the downwind or

downslope side of the trench. Maintain ample space (a minimum of 2 feet) between the stockpiled material and test pit to maneuver excavation equipment.

- Depending on the strength of the surficial deposits being trenched, mapping may occur concurrently with the advancement of the trench. The site geologist and an assistant should conduct the mapping of the trench wall at a safe distance behind the backhoe, lessening the risk of exposure to caving induced by backhoe vibrations.
- When appropriate, restrict access to the trench area(s). Use barricades with flashing lights to preclude vehicle and pedestrian traffic and delineate a perimeter that contains the trench, windbreak, and topsoil/contaminated material stockpiles. If the trench area is accessible to livestock, install a single-wire electric fence or other type of temporary fencing to prevent entry into the site area.
- Do not stand near the edge of the pit because of the danger of collapse.
- Sketch the development of the test pit in map view in the field logbook or in the GEOLIS Notes and Sketch Forms. Complete vertical profiles at several locations along the length of the test pit. Sketch a longitudinal section of the test pit. Indicate the lateral changes in soil or fill conditions.
- Record physical attributes of units that are distinct because of lithology, texture or color. Utilize the ground surface adjacent to the test pit as the reference elevation. In addition to bedding planes and lithologic interfaces, geologic features (like cobble strings) may aid in following stratum continuity, particularly if individual units are difficult to discern.
- Describe samples using the soil field classification system designated for the project. Photographs are useful. Reference photographs in the field logbook.
- Excavated material will be placed on plastic and isolated from contact with surface soils to the extent practical. Arrange the excavated material in such a way that it can be placed in the test pit in the approximate reverse order from which it was removed.
- Samples will be collected as described in Subsections 4.6.2.3 and 4.12 of this document.
- Backfill the test pit with the material excavated. Replace the material in the reverse order from which it was removed. Compact the material after replacement of each foot of backfilled material. Mound the surface slightly to allow for subsidence of the backfill.
- Stabilize the surface soils of the test pit by seeding and covering with hay or straw to minimize erosion, if required by project scope of work.
- The pits are not to remain as open excavations overnight. Plan test pits to be completed within one work day. Test pits are required to be backfilled the same day as excavated.

- Decontaminate backhoe equipment between test pits as specified in Subsection 4.11.

Test Pit Sampling

- When required, collect samples from material excavated by the equipment during excavation of the test pit. Do not enter the test pit. Collect samples at locations and frequencies specified in the Work Plan or as determined during office preparation activities.
- Select parts of excavated material not contacting the bucket of the excavation equipment by scraping the surface layer away with a clean sampling implement. Use a second clean implement to collect the sample.
- If sampling for volatile organic analytes (VOAs), collect this sample first from a fresh surface to minimize effects of aeration. Place the soil in the sample container, and seal without delay.
- When composite samples are specified, collect an equal volume of each discrete homogeneous sample. Place discrete samples in a stainless steel, or tempered container and mixed thoroughly to obtain a composite sample representative of the sampling interval. Using a decontaminated or disposable sampling tool, place the sample in appropriately marked laboratory-provided containers.
- When discrete sampling is specified, direct the backhoe operator to excavate a bucket from the specified depth or use a shovel if depth is easily accessible. Using the appropriate sampling tools, collect the soil from the backhoe bucket and place into the appropriate jars.
- Samples may also be sieved through a 0.25- or 0.375-inch sieve. Sieving serves to remove non-soil debris, reduce sample size and promote sample homogeneity.
- Record pertinent information about each sample in a field logbook or on a GEOLIS Test Pit Logging Form.

Post Operation

- Ensure that all equipment is accounted for and ready for shipment.
- Ensure that a Chain-Of-Custody is completed and included as part of shipping documents.
- Make sure all test pit locations are properly identified and location markers are readily visible.
- Deliver the original GEOLIS forms and field notebook to the Project Manager (or his designee). The original forms should be copied and filed.

- Follow the QA/QC regimen established for the data. At a minimum, this should include documentation of all corrections or changes to the field forms whenever they are made. Field personnel should review these changes for accuracy at appropriate times during the QA/QC process.

4.6.2.5 Sample Containers and Preservation Techniques

Sample Containers

Refer to Subsection 4.12 or the specific analytical method for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

1. Volatile organics (VOA).
2. Total organic carbon (TOC).
3. Extractable organics (BNAs or SVOCs).
4. Total metals.
5. Phenols.
6. Cyanide.
7. Total solids.

Sample Preservation and Handling

Many of the chemical constituents and physiochemical parameters that are to be measured or evaluated in soil investigation programs are not chemically stable, and therefore sample preservation is required. Appropriate preservation techniques and sample containers that the sampler should use for each constituent or common set of parameters for various parameters are specified in Subsection 4.12.

When subsequent analysis allows, soil samples should be collected using a clean stainless steel scoop, spoon, or trowel and placed into clean stainless steel or other appropriate homogenization containers. The sample should be mixed thoroughly to obtain a homogeneous, representative sample prior to placement into the sample container. When compositing samples from different locations or at different times is desired, all components of the composite sample are mixed in the homogenization container before the composite is placed in the sample container. The samples collected for volatile analysis should *never* be homogenized. They should be transferred

carefully directly from the sample collection device to the sample container in order to minimize contaminant loss through agitation/volatilization or adherences to another container.

Samples to be analyzed for purgeable organic compounds should be stored in containers identified in Subsection 4.12. A PTFE-silicone disk should be in the cap to prevent contamination of the sample by the cap. Disks should be placed in the caps (PTFE side to be in contact with the sample) in the laboratory prior to the beginning of the sampling program. The sample container should be completely filled to prevent volatilization. There should be no headspace left in the sample jar after filling. The sample jar should be closed as soon as possible after filling.

The following general precautions should be taken when sampling:

- a. A clean pair of new, disposable gloves should be worn each time a different location is sampled and gloves should be donned immediately prior to sampling.
- b. Sample containers for source samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting, preserving, tagging, etc.
- c. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples.
- d. If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples.
- e. Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- f. Field personnel should use equipment constructed of PTFE, stainless steel, or glass that has been properly pre-cleaned. PTFE or glass is preferred for collecting samples where trace metals are of concern.
- g. Collection of adequate field control samples.

4.6.2.6 Field Quality Control Sample Procedures

Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background samples. QA samples are replicates which are sent to USACE's QA laboratory and analyzed to evaluate the contractor's

laboratory performance. QC samples are replicates collected by the sampling team for use by the primary laboratory. A detailed discussion of field control samples is contained Subsection 4.10.

4.6.2.7 *Decontamination Procedures*

All sampling equipment must be decontaminated prior to its use. Sampling equipment should be decontaminated as described in Subsection 4.11. The sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed on-site to ensure an adequate drying time.

4.6.2.8 *Documentation*

Bound field logbooks should be used for the maintenance of field records. All aspects of sample collection and handling as well as visual observations shall be documented in the field logbooks as outlined in Section 5.

All entries in field logbooks should be legibly recorded, and contain accurate and inclusive documentation of an individual's project activities.

4.7 SEDIMENT SAMPLING

4.7.1 Rationale

Instructions presented in this section are for collecting representative sediment and sludge samples from surface water bodies. Sediment can be considered as any material that is submerged/saturated (at least temporarily) or suspended in any surface water body. This includes sludges, lake bottom sediments, perennial and intermittent stream sediments, and marine sediments. For discussion purposes, sampling devices are classified into the following categories according to applicability: (1) surface sediments/shallow water (scoop), (2) subsurface sediments/shallow water (hand auger/tube sampler, and hand driven split spoon sampler), (3) surface sediments/deep water (Ponar, Ekman, and Smith-McIntyre samplers), and (4) subsurface sediments/deep water (gravity corer and soil coring device/silver bullet sampler).

4.7.1.1 *Sampling Locations*

Depositional patterns should be considered against the sample objectives when deciding the sediment sample locations. These patterns differ between standing or flowing bodies of water. Generally, for flowing water (e.g., stream or river beds), the depositional areas are normally found inside bends, and downstream of islands or obstructions. Areas directly downstream of the joining of two streams should be avoided because the flows may not immediately mix. For standing water bodies, the center of the mass or a discharge point should be sampled for sediments. Selection of sample locations should satisfy investigation objectives.

4.7.1.2 *Sample Types*

The type of sample should be designated when selecting a sampling method. Sediment samples can be discrete (grab) or composite.

4.7.1.3 *Suggested Samplers*

Samplers for this medium are dictated significantly by project objectives of surficial versus subsurface samples and site constraints of the water depth. Each sampling technique presents

various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. Discussions of the advantages and disadvantages of each sampling technique are presented below.

4.7.2 Procedures

4.7.2.1 Sampling Methods

Presented below are sampling instructions for the most common techniques for collecting sediment and sludge samples. For additional information see EM 1110-2-5027, Plumb (1981), and Spigolon (1993). Prior to sample collection, water body characteristics (size, depth, flow) should be recorded in the field logbook. Sampling should proceed from downstream locations to upstream locations so that disturbance from sampling does not affect sampling quality. Additionally, if the surface water samples will be collected at the same locations as sediment samples, the water samples must be collected first. The factors that contribute to the selection of a sampler include the width, depth, flow, and the bed characteristics of the surface water body to be sampled, the volume of sample required, and whether the sample will be collected from the shore or a vessel. In collecting sediment samples from any source, care must be taken to minimize disturbance and sample washing as it is retrieved through the liquid column. Sediment fines may be carried out of the sample during collection if the liquid above is flowing or deep. This may result in collection of a non-representative sample due to the loss of contaminants associated with these fines.

The sampler should place the sample in the bottle and decant the excess liquid. If liquid flow and depth are minimal and sediment is easy to reach, a trowel or scoop may be used to collect the sediment sample. However, when the liquid above the sediment collection point is either flowing or greater than 6 in. in depth, a corer or other device that eliminates sample washing must be used to collect the sample to minimize washing the sediment as it is retrieved. One of the coring devices listed will allow the collection of an undisturbed core of sediment. It may be necessary to decant standing water from the top of the core. This should be done carefully and prior to transfer to the sample bottle. A decontaminated trowel should be utilized to transfer the sample

from the corer directly into the bottle. After collection, the sampling device should be decontaminated before collecting the next sample.

In some instances, the dimensions of the surface water dictate that a barge or boat must be used. The device used for sample collection in this case will, again, depend upon the depth and flow of the liquid above the sample location and the bed characteristics of the surface water. Generally trowels or scoops cannot be used in an offshore situation. Instead, cores or dredges are a more efficient means for sample collection. The barge or boat should be positioned upstream (if there is flowing water) of the desired sample location. As the corer or dredge is lowered it may be carried slightly downstream, depending upon the force of the flow. Upon retrieval, the contents of the corer or dredge should be transferred directly into the sample bottle using a decontaminated trowel. Both the corer or dredge and the trowel should be decontaminated before collecting the next sample.

Scoop or Trowel

Applicability

Surface sediments/shallow water

The scoop or trowel method is a very accurate procedure for collecting representative samples. This method can be used in many sampling situations but is limited to sampling exposed sediments or sediments in surface waters less than 6 in. deep. The scoop or trowel sampler is not effective for sampling in waters more than 6 in. deep.

Method Summary and Equipment

The simplest, most direct method of collecting sediment samples is with the use of a stainless steel scoop or trowel. A stainless steel scoop or trowel can be used to collect the sample and a stainless steel bowl can be used to homogenize the sample when applicable to the subsequent analysis.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Sketch the sample area or note recognizable features for future reference.
- Insert scoop or trowel into material and remove sample. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 cm of material prior to collecting the sample.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Transfer sample into an appropriate sample bottle with a stainless steel spoon or equivalent.
- Check that a PTFE liner is present in cap. Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label care-fully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record in the field logbook.
- Decontaminate sampling equipment after use and between sample locations.

Tube sampler

Applicability

Surface sediments/shallow water

Equipment for the tube sampler is portable and easy to use. Discrete sediment samples can be collected efficiently. Disadvantages of the tube sampler include its limited sampling depth and inability to collect sediment samples in water bodies greater than a few feet in depth. The tube sampler may not penetrate gravelly or rocky sediments.

Method Summary and Equipment

Tube samplers are a simple and direct method for obtaining sediment samples. The corer is forced into the sediment. The corer is then withdrawn and the sample is collected. In non-cohesive soils, sample retention may be a problem. In this case a piston-type sampler is recommended.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Clear the area to be sampled of any surface debris (twigs, rocks, litter).
- Gradually force corer into sediment.
- Remove corer.
- Remove sediment core from corer and place core on a clean working surface.
- Discard top of core if any organic material is present.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media. If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Repeat as necessary to obtain sufficient sample volume.
- Transfer sample into an appropriate sample bottle with a stainless steel spoon or equivalent.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents, and field sheets and record in the field logbook.
- Decontaminate sampling equipment after use and between sample locations.

Hand Auger and Tube Sampler

Applicability

Subsurface sediments/shallow water

Equipment for the hand auger is portable and easy to use. Discrete sediment samples can be collected efficiently. Disadvantages of the hand auger include its limited sampling depth and inability to collect sediment samples in water bodies greater than a few feet in depth. The tube sampler may not penetrate gravelly or rocky sediments.

Method Summary and Equipment

Hand augers are a simple and direct method for obtaining sediment samples. Although the maximum sampling depth for the hand auger is typically 5 ft, greater depths can be sampled depending on the sediment type. Hand augers come in various dimensions and various types. The bucket auger bit is used to bore a hole to the desired sampling depth and then withdrawn. The auger tip is then replaced with the tube corer, lowered into the borehole, and forced into the sediment at the desired depth. The corer is then withdrawn and the sample is collected. Potential problem encountered with this method is sloughing of the borehole after auger.

Sampling Procedure

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Attach the auger bit to a drill rod extension and further attach the “T” handle to the drill rod.
- Clear the area to be sampled of any surface debris (twigs, rocks, litter).
- Begin drilling and periodically remove accumulated sediment. This prevents accidentally brushing loose material into the borehole when removing the auger or adding drill rods.
- After reaching the desired depth, slowly and carefully remove the auger from boring.
- Remove auger tips from drill rods and replace with a pre-cleaned or decontaminated thin-wall tube sampler. Install proper cutting tip.

- Carefully lower corer down borehole. Gradually force corer into sediment. Take care to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring because the vibrations may cause the boring wall to collapse.
- Remove corer and unscrew drill rods.
- Remove cutting tip and remove core from device.
- Discard top of core (approximately 2.5 cm), which represents any material collected by the corer before penetration of the layer in question.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Repeat as necessary to obtain sufficient sample volume.
- Transfer sample into an appropriate sample bottle with a stainless steel spoon or equivalent.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets, and record information in the field logbook.
- Decontaminate sampling equipment after use and between sample locations.

Hand-Driven Split-spoon Sampler

Applicability

Subsurface sediments/shallow water

The split spoon sampler is used for obtaining sediment samples in cohesive and non-cohesive type soils. Similarly to the hand auger, the split spoon sampler can only be used in shallow water. However, because it is hammered into place, it can sometimes penetrate sediments that are too hard to sample with a hand auger.

Method Summary and Equipment

See Subsection 4.6.2.1.

Sampling Procedure

See Subsection 4.6.2.1.

Ponar Sampler

Applicability

Surface sediments/deep water

Ponar samplers are capable of sampling most types of sludges and sediments from silts to granular materials. They are available in hand-operated sizes to winch-operated sizes. Ponars are relatively safe, easy to use, prevent escape of material with end plates, reduce shock waves, and have a combination of the advantages of other sampling devices. Ponar grab samplers are more applicable for a wide range of sediments and sludges because they penetrate deeper and seal better than spring-activated types (e.g., Ekman samplers). Penetration depths will usually not exceed several centimeters. Grab samplers are not capable of collecting undisturbed samples. As a result, material in the first centimeter of sediment cannot be separated from the rest of the sample. Ponars can become buried in soft sediment. The Ponar sampler is not recommended for the acquisition of VOA samples.

Method Summary and Equipment

The Ponar grab sampler is a clamshell-type scoop activated by a counter-lever system. The shell is opened, latched in place, and slowly lowered to the bottom. When tension is released on the lowering cable, the latch releases and the lifting action of the cable on the lever system closes the clamshell.

Sampling Procedure

- Place plastic sheeting around the sampling location to prevent cross-contamination.

- Attach a decontaminated Ponar to the necessary length of sample line. Solid braided 5-mm (3/16-in.) nylon line is usually of sufficient strength; however, 20-mm (3/4 - in.) or greater nylon line allows for easier hand hoisting.
- Measure the depth to the top of the sediment with a weighted object.
- Mark the distance to the top of the sediment on the sample line with a proximity mark 1 m above the sediment. Record depth to top of sediment and depth of sediment penetration.
- Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- Tie free end of sample line to fixed support to prevent accidental loss of sampler.
- Begin lowering the sampler until the proximity mark is reached.
- Lower the sampler rapidly through last meter until contact is felt.
- Allow sample line to slack several centimeters. In strong currents, more slack may be necessary to release mechanism.
- Slowly raise dredge to clear surface.
- Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- Place Ponar into a stainless steel or PTFE tray and open. Lift Ponar clear of the tray, and decontaminate.
- Repeat until sufficient sample volume has been collected.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Collect a suitable aliquot with a stainless steel laboratory spoon or equivalent, and place sample into appropriate sample bottle. Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.

- Decontaminate sampling equipment after use and between sample locations.

Ekman Sampler

Applicability

Surface sediments/deep water

The Ekman sampler collects a standard size sample. The Ekman sampler is not useful in rough waters or if vegetation is on the bottom.

Method Summary and Equipment

The Ekman sampler is another type of clamshell-type grab sampler and works similarly to the Ponar sampler described previously. However, because the Ekman sampler is much lighter than the Ponar sampler, it is easier to handle and can even be attached to a pole for shallow applications. The Ekman sampler is unsuitable for sampling, rocky, or hard bottom surfaces.

Sampling Procedure

- Place plastic sheeting around the sampling location to prevent cross-contamination.
- Attach a necessary waters to sampler (3/16-in.) decontaminated Ekman sampler to the length of sample line or in shallow the end of a pole. Because the Ekman is lightweight, solid braided 5-mm mylar line is sufficient.
- Measure the depth to the top of the sediment with a weighted object.
- Mark the distance to top of sediment on the sample line with a proximity mark 1 m above the sediment. Record depth to top of sediment and depth of sediment penetration.
- Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- If using a sample line, tie the free end of the sample line to fixed support to prevent accidental loss of sampler.
- Begin lowering the sampler until the proximity mark is reached.
- Lower the sampler at a slow rate of descent through the last meter until contact is felt.

- If using a sample line, place a messenger on the sample line and release, allowing the messenger to slide down to the sample line and activate the spring.
- Slowly raise dredge to clear surface.
- Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- Place Ekman sampler into a stainless steel or PTFE tray and open. Lift Ekman sampler clear of the tray and decontaminate.
- Repeat until sufficient sample volume has been collected.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Collect a suitable aliquot with a stainless steel laboratory spoon or equivalent, and place sample into appropriate sample bottle.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.
- Decontaminate sampling equipment after use and between sample locations.

Smith-McIntyre Sampler

Applicability

Surface sediments/deep water

The Smith-McIntyre sampler can be used in rough water because of its large and heavy construction. It reduces premature tripping and can be used in depths up to 3,500 ft. The flange on the jaws reduces material loss. It is good for sampling all sediment types. However, because of its large and heavy construction, the Smith-McIntyre sampler is cumbersome to operate.

Method Summary and Equipment

The Smith-McIntyre sampler is also a type of clamshell-style grab sampler and works similarly to the Ponar sampler described previously.

Sampling Procedure

- Place plastic sheeting around the sampling location to prevent cross-contamination.
- Attach a decontaminated Smith-McIntyre sampler to the necessary length of sample line or in shallow waters to the end of a pole. Because the Smith-McIntyre sampler is large and heavy, a winch may be necessary for hoisting and lowering the sampler.
- Measure the depth to the top of the sediment with a weighted object.
- Mark the distance to top of sediment on the sample line with a proximity mark 1m above the sediment. Record depth to top of sediment and depth of sediment penetration.
- Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- If using a sample line, tie the free end of sample line to fixed support sampler.
- Begin lowering the mark is reached. to prevent accidental loss of sampler until the proximity mark is reached.
- Lower the sampler at a slow rate of descent through the last meter until contact is felt.
- If using a sample line, place messenger on sample line and release, allowing messenger to slide down the sample line and activate the spring.
- Slowly raise dredge clear to surface.
- Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- Place Smith-McIntyre sampler into a stainless steel or PTFE tray and open. Lift Smith-McIntyre sampler clear of the tray and decontaminate.
- Repeat until sufficient sample volume has been collected.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.

- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Collect a suitable aliquot with a stainless steel laboratory spoon or equivalent, and place sample into appropriate sample bottle. Secure cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.
- Decontaminate sampling equipment after use and between sample locations.

Gravity Corer

Applicability

Subsurface sediments/deep water

Gravity corers are capable of collecting samples of most sludges and sediments. They collect essentially undisturbed samples that represent the profile of strata which may develop in sediments and sludges during variations in the deposition process. Depending on the density of the substrate and the weight of the corer, penetration to depths of 30 in. can be attained.

Method Summary and Equipment

The gravity corer is a metal tube with a replacement tapered nosepiece on the bottom and a ball or other type of check valve on the top. The check valve allows water to pass through the corer on descent but prevents a washout during recovery. The tapered nosepiece facilitates cutting and reduces core disturbance during penetration. Most corers are constructed of brass or steel and many can accept plastic liners and additional weights.

Sampling Procedure

- Place plastic sheeting around the sampling location to prevent cross-contamination.

- Attach a decontaminated corer to the required length of sample line. Solid braided 3/16-in. nylon line is typically sufficient; 3/4-in. nylon, however, is easier to grab during hand hoisting.
- Secure the free end of the line to a fixed support to prevent accidental loss of the corer.
- Allow corer to free fall through liquid to bottom.
- Retrieve corer with a smooth, motion. Do not bump corer as some sample loss.
- Remove nosepiece from corer continuous lifting this may result in and slide sample out of corer into stainless steel or PTFE pan.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Transfer sample into appropriate sample bottle with a stainless steel lab spoon or equivalent.
- Check that a liner is present in cap. Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.
- Thoroughly decontaminate the gravity corer after each use.

Soil Coring Device/Silver Bullet Sampler

Applicability

Subsurface sediments/deep water

The soil coring device and the silver bullet sampler are used when a core sample is desired.

Method Summary and Equipment

The soil coring device consists of a brass cylinder with a handle for turning. The bit of the corer is sharp plastic. A plastic collection tube that will hold a sample is placed on the inside of the brass cylinder. This device may be substituted for the soil auger if core analysis of depth profiles needs to be done. A serious limitation of this instrument is that the depth of the core is only 1.6 ft long. Also, the cutting edge of the coring device is plastic and is unable to pass through very rocky or tightly packed soil. The silver 'bullet sampler consists of a cylinder into which the sampler is fitted with a T-handle, which is used to manipulate the sampler. The bit is changeable. The silver bullet sampler is designed to take core samples in peat substrates. Due to its design, the sampler lends itself well to uses in waste sampling. It is versatile and can be used as a soil coring device because the body is adjustable to reach greater depths. Also, the silver bullet sampler has a serrated bit, which allows the sampler to move through rocky or tightly packed substrate more easily.

Sampling Procedure

- Place plastic sheeting around the sampling location to prevent cross-contamination.
- Insert borosilicate collection tube into the sampler.
- Place the sampler in position with the bit touching the ground.
- Press down on the T-handle while rotating the sampler clockwise.
- After reaching the required depth, turn the sampler 360° counterclockwise and remove from the ground taking care not to lose any of the sample.
- Remove the borosilicate glass collection tube and collect sample, or cap at both ends for sample shipment.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Check that a PTFE liner is present in cap. Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.

- Place filled sample containers on ice immediately.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.

Vibratory Coring Device

Applicability

Subsurface sediments/deep water

Vibratory corers are capable of collecting samples of most soils, sediments, and sludges.

Method Summary and Equipment

The vibratory system consists of a tripod that supports a core tube. An external power source is necessary to drive a top head and cause vibrations. The vibratory motion causes the soil sediments to become fluidized and the core tube to slip through the soil or sediment.

Sampling Procedure

- Assemble decontaminated vibratory corer and connect external power source (i.e., air compressor).
- Attach decontaminated corer to the required length or top of the soil or sediment. Begin vibratory coring until the core tube has fully penetrated.
- Carefully remove the core tube and remove the core liner.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as is possible to the media.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to the stainless steel bowl for mixing.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place the sample in an appropriate container and put the container on ice.
- Complete all chain-of-custody documents and field sheets and record information in the field logbook.

- Thoroughly decontaminate the vibratory corer after each use.

4.7.2.2 Sample Containers and Preservation Techniques

Sample Containers

Refer to Subsection 4.12 or the specific analytical method to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Refer to Subsection 4.12 for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

1. Volatile organics (VOA).
2. Total organic carbon (TOC).
3. Extractable organics (BNAs or SVOCs).
4. Total metals.
5. Phenols.
6. Cyanide.
7. Total solids.

Sample Preservation and Handling

Many of the chemical constituents and physiochemical parameters that are to be measured or evaluated in investigation programs are not chemically stable; therefore, sample preservation is required. Appropriate preservation techniques and sample containers that the sampler should use for each constituent or common set of parameters are specified in Subsection 4.12. The samples collected for volatile analysis should *never* be homogenized or composite. They should be carefully transferred directly from the sample collection device to the sample container in order to minimize contaminant loss through agitation/volatilization or adherences to another container.

4.7.2.3 Field Quality Control Sampling Procedures

Field control samples are collected by the sampling team to determine whether data are of suitable quality. They include blanks, replicates, and/or background samples. QA samples are replicates which are sent to USACE's QA laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are replicates collected by the sampling team for use by the

primary laboratory. A detailed discussion of field control samples is contained in Subsection 4.10.

4.7.2.4 *Decontamination Procedures*

All equipment that will enter the sediment must be decontaminated. Sampling equipment should be decontaminated as described in Subsection 4.11. Sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed on-site to ensure an adequate drying time.

4.7.2.5 *Documentation*

Bound field logbooks should be used for the maintenance of field records. All aspects of sample collection and handling as well as visual observations shall be documented in the field logbooks as outlined in Section 5.

All entries in field logbooks should be legibly recorded, and contain accurate and inclusive documentation of an individual's project activities.

4.8 SURFICIAL SAMPLING

4.8.1 Rationale

Instructions presented in this section are for collecting representative samples from various surfaces. Surficial sampling is used to assess the existence and/or extent of contamination on various surfaces rather than in a soil, water, or air matrix. For example, the contamination of the interior of a building may be assessed by collecting wipe samples of the process vessels and ventilation ducts. Surface samples are not typically analyzed for VOCs. Typical sample parameters include PCBs, dioxins/furans, pesticides, semi-volatiles, metals, and explosives. Surface samples are typically divided into three media. The media include non-porous surfaces, porous surfaces, and dust/soot. Non-porous surfaces can be sampled by wipe sampling; porous surfaces can be sampled by chipping or coring the surface; and dust/soot can be sampled by sweep sampling. Instructions for these techniques are included in this section. If these methods are difficult to implement due to irregular surface shapes or other limitations, a rinsate sample can be collected.

The data from surficial sampling is typically required for risk assessments or compliance issues. Therefore, the sampling strategy is either based on a biased approach to locate and/or identify contamination or a systematic approach for decontamination verification.

4.8.1.1 *Sampling Locations*

Surficial sampling can be conducted by either biased or systematic sampling. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the contaminant's fate. Specific requirements for selecting sampling locations may be applicable for risk assessments or verification of cleanup levels. For example, sampling locations for verification of PCB cleanup levels are established in 40 CFR 761. Additional guidance for selecting sampling locations can be found in EPA/600/2-85/028, EPA/560/5-85/026, and EPA/560/586/017.

4.8.1.2 Types of Samples

Surficial samples are discrete samples. Discrete (grab) samples are defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected immediately and at one particular point in the sample matrix. Representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

4.8.1.3 Suggested Samplers

Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. Discussions of the advantages and disadvantages of each sampling technique are presented below.

4.8.2 Procedures

4.8.2.1 Sampling Methods

Presented below are sampling instructions for the most common techniques for collecting surface samples.

Surface Wipe Sample

Applicability

This method of monitoring surficial contamination is intended for non-volatile species (e.g., PCBs) on non-porous surfaces (e.g., metal, glass). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, and available surface area.

Method Summary and Equipment

Surface wipe sampling methods vary and are dependent on the data objectives. A generalized procedure is presented here for reference.

Sampling Procedure

- Place an appropriately sized square template cut-out over the area to be sampled (Toxic Substances and Control Act (TSCA) requires 100 cm²).
- Remove a gauze pad from the box of gauze using decontaminated tongs (filter paper may also be used). Be sure to use a new pair of surgical gloves.
- Soak the gauze or filter pad in appropriate solvent.
- Using a decontaminated pair of tongs, wipe the area framed by the template cutout with the moistened gauze in one direction.
- Without allowing the gauze to contact any other surface, fold the gauze with the exposed side in, and then fold it again to form a 90-degree angle in the center of the gauze.
- Place the gauze in an amber laboratory sample container angle first and replace the container cap.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label properly and clearly, addressing all categories or parameters.
- Place filled sample container on ice immediately, if desired.
- Complete all chain-of-custody documents and record information in the field.
- Prepare the samples for shipment.
- Mark the area of the cutout using a paint stick, if possible.
- Record the location data, station number, sample time, date, and names of the sampling crew in the field logbook or log sheet for each wipe sample. In addition, document the sampling locations by a dimensioned sketch in the field logbook or log sheet if the sampled area cannot be marked by a paint stick or if locating the area from the field notes would be difficult.
- Dispose of generated waste material properly.

Chip/Core Sample

Applicability

This method of monitoring surficial contamination is intended for non-volatile analytes (e.g., PCBs) on porous surfaces (e.g., cement, brick, wood). Suggested sampling points include floors near process vessels, storage tanks, loading docks, etc.

Method Summary and Equipment

Samples from porous surfaces can be obtained by breaking up a designated surface with a chisel, brushing up the chipped pieces, and transferring the sample into a bottle. A core sample can also be collected using appropriate power tools. However, most confirmatory sampling requires that only the upper quarter inch of the media be sampled. Core samples may dilute contaminants that may only be present in the upper quarter inch and are therefore discouraged.

Sampling Procedure

- Once the sample location has been determined, measured, and marked off, sample collection can begin as follows: (Place an appropriately sized square template cut-out over the area to be sampled.
- Use a decontaminated chisel and hammer to break up the surface to be sampled (TSCA requires 100 cm²). Avoid scattering pieces. Chip the area to less than 1/4 in. in depth.
- Record the depth at which the chips were taken.
- Collect the chipped pieces using new clean gloves and a pair of decontaminated tongs.
- Transfer the sample directly into the sample bottle.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample container on ice immediately.
- Complete all chain-of-custody documents and record information in the field.
- Prepare the samples for shipment.

- Decontaminate sampling equipment after use and between sampling locations.

Sweep Sample

Applicability

This method of monitoring surficial contamination is intended for non-volatile analytes (e.g., PCBs) in residue found in porous (e.g., asphalt) or non-porous (e.g., metal) surfaces. Sweep sampling allows collection of dust/residue that may help in the assessment of contaminant determination and delineations.

Method Summary and Equipment

Dust and residue samples can be collected with a bristle brush and dustpan in places where solvents cannot be used or when large amounts of dust/residue make wipe samples impractical.

Sampling Procedure

- Once the sample location has been determined, measured, and marked off, sample collection can begin as follows:
- Put on clean, chemical-resistant gloves (separate pair for each location).
- Place an appropriately sized square template cut-out over the area to be sampled (TSCA requires 100 cm²).
- Sweep all residue from the area to be sampled into the dustpan.
- Transfer the sample directly into the sample bottle.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place filled sample container on ice immediately.
- Complete all chain-of-custody documents and record information in the field.
- Prepare the samples for shipment.
- Decontaminate sampling equipment after use and between sampling locations.

4.8.2.2 Sample Containers and Preservation Techniques

Sample Containers

Wipe samples should be placed in amber jars. The cleanliness of a batch of pre-cleaned bottles should be verified by the container supplier or in the laboratory. The residue analysis should be available prior to sampling in the field.

Sample Preservation and Handling

Chip, core, and sweep samples should be handled in the same fashion as sediment/soil samples. Wipe samples do not designate a preservation technique, but may implement protection from light and/or cooling. Appropriate preservation techniques and sample containers that the sampler should use for each constituent or common set of parameters are specified in Subsection 4.12. Methods of sample preservation are relatively limited and are generally intended to retard biological action, and hydrolysis, and to reduce sorption effects. Preservation methods are generally limited to refrigeration and protection from light.

4.8.2.3 Field Quality Control Sampling Procedures

Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates and/or background samples. QA samples are replicates which are sent to USACE's QA laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are replicates collected by the sampling team for use by the primary laboratory. A detailed discussion of field control samples follows:

Duplicate/split samples

True duplicate/split samples cannot be collected in a wipe sampling program. The gauze used to collect the wipe sample cannot be divided to obtain a duplicate/split sample because the contaminants will not be spread evenly on the gauze. The same surface area cannot be wiped a second time to obtain a duplicate/split sample because the first wipe sample will remove the contaminants from the wiped area. Collecting a sample from an area adjacent to the first sampling area is a viable alternative for collecting a duplicate/split sample. However, the sample

is not a true duplicate/split sample and the contaminant concentrations in the samples from the adjacent area may not be the same, and, therefore, are referred to as collocated field duplicates.

Wipe Blank Samples

Wipe blanks are samples collected in the field to determine if any interference has been caused by the sample collection materials (i.e., gauze, solvent, or sampling equipment). Wipe blanks are obtained by preparing the gauze for sampling, placing the solvent on the gauze, and placing the gauze in the sample containers. The gauze does not contact any sampling surface.

Background Samples

Background samples are recommended to be taken in conjunction with chip/core samples. Background samples should be taken using the same procedures used to obtain the field samples. The samples should be obtained from an uncontaminated area of the same matrix used to collect the field samples. The rationale for collecting background samples is to determine if there are any interferences inherent to the porous matrix.

Rinsate Blank Samples

Rinsate samples consist of reagent water collected from a final rinse of surfaces after decontamination procedures have been performed. The purpose of the rinsate samples is to determine the thoroughness of the decontamination procedures performed.

4.8.2.4 Decontamination Procedures

All sampling equipment must be decontaminated prior to its use. Field equipment should be cleaned as described in Subsection 4.11. The sampling equipment should be placed in a plastic bag until immediately prior to use. Additional sampling devices may be needed on-site to ensure an adequate drying time.

4.8.2.5 Documentation

Bound field logbooks should be used for the maintenance of field records. All aspects of sample collection and handling as well as visual observations shall be documented in the field logbooks as outlined in Section 5.

All entries in field logbooks should be legibly recorded, and contain accurate and inclusive documentation of an individual's project activities.

4.9 BIOTA SAMPLING

4.9.1 Rationale

Comprehensive biological sampling will be performed as required during Operable Unit remedial investigations. The actual biological sampling requirements may include:

- Habitat and ecological condition assessments.
- Functional assessments of those habitats.
- Aquatic and terrestrial community/population studies.
- Biological tissue collection and analyses.
- Toxicological Sampling (toxicity tests or bioassays).

Additionally, surface water, sediment and floodplain sampling may be performed concurrent with the biological investigations. Information collected during the field investigations will be used to further characterize ecological conditions and, in conjunction with the chemical analyses, will be evaluated as a part of the ecological risk assessment. In an effort to maximize effectiveness, the ecological evaluations should be conducted, at a minimum during peak biological activity periods for those communities of interest.

4.9.2 Procedures

4.9.2.1 *Aquatic Biota Sampling*

The aquatic biota that may be sampled include periphyton, macroinvertebrate, fish, and select bivalve communities. Surface water and sediment sampling will also be performed at each biota sampling location. Procedures for sampling biota, sediment, and surface water are presented in detail in WESTON's Standard Operating Procedures for Biological and Associated Sampling (1994) and are summarized in the following subsections.

Macroinvertebrates Sampling

Benthic sampling can be qualitative (a general assessment of the taxa of aquatic insects present, possibly with some observations of their relative abundance) or quantitative (an estimate of the numbers (total or by taxa) present so that a statistical confidence of the estimate can be made).

Quantitative macroinvertebrate investigations may be performed to support site-specific ecological assessments. Reference areas will be selected that represent similar, but unaffected (with respect to site contamination) waterbodies, e.g. rivers, streams, ponds, and lakes. The specific locations of reference areas will be determined in the field and will be based on the morphometry and flow characteristics of the stream, e.g. riffle, run, glide as well as substrate and vegetation characteristics as compared with other sampling stations. To the extent possible, macroinvertebrate sampling stations will be selected based on similarity of flow, substrate, shading, and other stream characteristics to reduce variability between sampling stations. Preliminary qualitative macroinvertebrate sampling will be used to facilitate the selection of reference areas and the locations of quantitative sampling activities.

Three to five replicate samples will be collected at each station using either a grab sampler, e.g., Ekman dredge, Petite Ponar dredge for lentic environments, or a Surber (or some modification, e.g., PIBS) sampler for lotic environments depending on depth. The effective depth for the use of a Surber sampler is about 30 cm. For those sample results that will be compared, similar sampling devices will be used. To the extent possible, benthic stations will be located as near as possible to sediment and water quality stations. Each replicate sample will be processed separately by rinsing all collected material through a 500-micron mesh net or sieve (No. 30 screen) to remove fine silt, clay, and/or debris.

All material retained on the sieve will be placed in prelabeled plastic containers and preserved with a 5-10 % formalin solution, 70% ethyl alcohol, or 40% isopropyl alcohol. Note that alcohol should be used for short-term storage only, unless the animals are fixed in formalin first. In the laboratory, samples will be washed with fresh water, sorted, identified to the lowest practical taxon, and enumerated. Macrobenthos population analysis may include the following statistical methods and treatments:

- Number of individuals (ANOVA).
- Number of taxa (ANOVA).
- Shannon diversity.
- Evenness.
- Biotic index.
- Community similarity.

Interpretation of macrobenthos data will be based primarily on the results of these analyses.

When possible, the macrobenthos community of the study streams will be compared with the macrobenthos community of the reference stations. A list will be prepared of benthic species and a tabulation made of the numbers of each species collected at each sampling station included in the benthic evaluation.

To facilitate the evaluation of differences in the macrobenthic communities attributable to physical differences in substrate among stations, a sediment sample from each benthos station will be submitted to the laboratory for grain size analysis, percent moisture, and TOC content. In addition, the following physical and chemical parameters of the surface water at each of the stations will be measured or described:

- pH.
- Conductivity.
- Temperature.
- Dissolved oxygen.
- Water velocity.

Biological sampling will correspond to the proposed surface water/sediment analyses, both spatially and temporarily, to provide an integrated ecological approach. In addition to the benthos sampling, field personnel will describe the substrate in detail, make a qualitative assessment of the vegetative community, complete the field data sheet, and record any observable effect of contamination on the flora (e.g., signs of plant stress and lack of vegetation). In shallow water less than 0.76 meter deep, the 60% depth velocity will be used to estimate the mean velocity in the vertical. The 60% depth method involves making one velocity measurement at 60% of the total depth if the depth below the surface is less than 3 feet. In deeper water, the velocity should be measured at 20% and 80% of the total depth below the surface. The average of these two readings is an estimate of the mean velocity in the vertical (Nielsen and Johnson, [00-2229]). A single velocity estimate in the center of the channel is sufficient for narrow streams less than 3 meters wide. For wider streams, velocity will be estimated at points 25%, 50%, and 75% of the total width across the stream, and stream depths will be recorded along with velocity measurements in the field logbook.

Documentation

Sampling team members must complete an aquatic biology sampling form at each sampling point. This form includes information on weather, location, stream characteristics, vegetation, water parameters, and sediment characteristics.

Fish Sampling

Fish tissue sampling may be conducted as required to identify and quantify contaminants in fish tissue that pose human health or ecological risks. Generally, descaled, skin-on fillet composite samples are required for human health risk assessments and whole body composite samples are required for ecological risk assessments. Prior to initiation of fish sampling, background data on contaminants of concern must be known and decisions regarding fish species and amount(s) of tissue to be collected must be made. Contingencies should be considered, including alternative species, minimum sample size, and numbers of individuals to collect since fish sampling rarely proceeds as planned.

Fish sampling will be conducted in the season(s) appropriate to the data quality objectives for the human health and ecological risk assessments. For example, as much of the toxicological concern with chemical exposure to wildlife is associated with reproductive impairment, it is important that the breeding season of piscivorous birds or mammals be considered when developing the sampling schedule.

Sampling sites will be selected based on previous surface water, sediment, and other site-specific investigations regarding contaminant concentration and areal extent. Sampling locations may be refined at the time of sampling based on access and availability of specimens to meet minimum sample mass requirements.

At each location, two species, if present in sufficient numbers, will be retained for tissue analysis. The two species will represent two distinct trophic levels: a bottom feeder or forage fish, and a predator, preferably an edible game fish. Every effort will be made to capture the same two species at all locations. Preferred species to meet the data quality objectives for the Human Health Risk Assessment (HHRA) include those species which are actively caught and

consumed in a particular waterbody. Prior to the sample collection, this information will be obtained from local agencies, etc.

Before removing the fillet, larger fish will be stunned by a sharp blow to the base of the skull with a stick or metal rod. This rod will be cleaned to prevent contamination and will be used for the sole purpose of stunning fish. After scales are removed, fish will be filleted in the field on flat aluminum foil or a Teflon-coated surface. One skin-on fillet, scales removed, will be taken from the right side of the fish.

As with the HHRA, the data quality objectives will direct the collection effort for the Ecological Risk Assessment. Fish that will be collected for the ecological assessment will be those fish and the size class, typically foraged by piscivorous birds and mammals.

All samples will be analyzed for percent lipids and site-specific contaminants of concern. Prior to collection, a Scientific Collector's Permit will be procured, if required. Fish will be collected using the electroshock method. All field sampling personnel will be trained and experienced in the proper and safe use of all fish sampling equipment, especially, but not limited to, the safe use of electroshocking equipment. Wadeable waters will be sampled intensively, with effort exerted in all available habitats, including riffles, runs, and pools.

Other field observations, such as the sampling techniques employed; problems encountered; modifications to the sampling procedure; water quality parameters measured (e.g., water temperature, dissolved oxygen concentration, conductivity, and pH); habitat conditions (e.g., substrate, percent cover, shoreline vegetation, gradient, current velocity, and presence/absence of food organisms); and fish species observed or collected, including weights and lengths, will be noted in the field logbook. The total time (labor hours) spent observing habitats also will be recorded. Fish retained for laboratory analysis will be carefully handled to prevent contamination by the samplers' hands or by field equipment. All fish retained for tissue analysis will be weighed (to the nearest gram) and measured (to the nearest millimeter) and the data recorded on a specimen label and in the field logbooks prior to fillet removal or wrapping the fish when a whole-body analysis is required.

Specimen labels will be produced for each fish and will contain the following information:

- Sample identification code.
- Date.
- Time of collection.
- Preservatives (frozen only).
- Analysis required.
- Sampling personnel.
- Type of tissue (fillet or whole body).
- Species.
- Length (millimeters) and weight (grams).

Each individual fillet (or whole fish, when required) will be rinsed in distilled water to remove debris, wrapped separately in aluminum foil (shiny side toward the sample), placed in separate Ziplock plastic bags, labeled, and stored on dry ice (-10 ° C) for transport to the laboratory. No preservatives other than dry ice will be used for fish or fish tissue samples. Aluminum foil will be cleaned prior to use by rinsing it with acetone and again with pesticide-grade hexane and allowing it to dry in a contaminant-free area. Fish tissue samples will be packed with dry ice for shipment. Sections 19 and 20 describe COC procedures and sample handling, packing, and shipment requirements. If samples are not transported to the laboratory on the day of sampling, they will be stored on dry ice. Samples will be frozen on receipt by the laboratory and will remain frozen until the time of analysis.

Documentation

Sampling team members must complete an aquatic biology sampling form at each sampling point. This form includes information on weather, location, stream characteristics, vegetation, water parameters, and sediment characteristics.

Waterfowl Sampling

Waterfowl specimens (samples) will be collected using an airboat, traps, or firearms. Every effort will be made to provide live ducks to the sample processors as soon as possible after collection. Individuals that are alive when provided to the processors will be sacrificed by cervical separation. After sacrificing, samples should be kept on wet ice in the field. If samples cannot be processed immediately, samples will be held in wet ice until processing is initiated (not longer than 24 hours). The wet ice will be retained in double ziploc bags to avoid contact

with samples. While awaiting processing, samples should be placed in large ziploc bags or wrapped individually in aluminum foil, with time, date, and collection location information provided on a field tag.

Each individual will be assigned a specific identifier. In addition, sample numbers will be assigned to each tissue sample submitted for analysis or archival (see data sheet for waterfowl collection and tissue processing).

Processing of samples should be as follows:

- Individual specimens should first be dispatched and metrics should be recorded (see data sheet) by the processing team with appropriate information recorded on the tissue sample data sheet. Prior to dissection, all dissecting implements will be decontaminated with alconox, DI water rinse, and isopropanol rinse; tissue samples removed during dissection for analysis will be weighed (to the nearest 0.1 gram); any signs of internal pathology or gross external pathology will be recorded on the tissue sample data sheet (comments section). Any gross abnormalities will be preserved in formalin for later evaluation.
- After dissection, individual tissue samples will be wrapped in aluminum foil (shiny side out, dull side next to sample). Aluminum foil will be isopropanol-rinsed and washed with DI.
- A sample label will be placed on the exterior of each individually wrapped sample. The sample should be securely taped with clear tape. The sample label should contain the sample ID, sample type, and site name.
- Aluminum-wrapped, labeled samples will be placed in a ziploc bag and sealed. That bag should be placed in another ziploc bag along with a sample-specific ID tag.
- Samples should be kept on dry ice until they are shipped (with dry ice) to the analytical laboratory (or the USFWS field office for freezer storage). For large cooler/ numerous sample shipments, layering of samples with dry ice and newspapers allows for better sample preservation and longer dry ice persistence. Sample containers (coolers) will be sealed with a signed and dated custody seal.
- All pertinent information regarding each sample (sample number, sample type, date collected, etc.) should appear on a standard EPA chain-of-custody form and be included in a sealed ziploc bag, taped to the lid, inside each sample cooler.
- Samples should be sent Federal Express Overnight (next morning delivery) or hand-delivered. Samples sent to the USFWS should be shipped to:

Ken Carr/Ken Munney
USFWS
22 Bridge St., Unit 1
Concord, NH 03301

Phone: 603-225-1411

Fed. Ex Acct. #: 1510-1036-9

Shippers should call ahead to the receiving laboratory or the USFWS and notify that samples are being sent for next day delivery. Samples should not be sent to USFWS if Ken Munney, Ken Carr, or Drew Major are not available for receipt of the shipment. Samples need to be sent for arrival on a weekday only; therefore, Thursday is the last day of the week to ship samples. Shippers should also call the receiving laboratory of USFWS the day of delivery to verify receipt of samples.

4.10 QUALITY ASSURANCE/QUALITY CONTROL SAMPLING

4.10.1 Field Duplicates/Field Replicates

For each sampling round, one duplicate sample is collected for every 10 routine samples. These duplicate samples are collected immediately following the collection of the samples they are intended to duplicate for groundwater samples. Soil duplicates from split-spoons will be collected by splitting the soil in the spoon lengthwise and dividing the soil into the standard and duplicate containers. When collecting a duplicate from a California split-spoon, the duplicate is collected from a brass tube immediately adjacent to the standard tube. Note that a duplicate sample was collected in the appropriate GEOLIS logbook. Duplicates will be handled in the same manner as all other samples.

For QA/QC samples, the first character of the four-character sample identifier is a letter to identify the sample type, as discussed in Subsection 3.1.3. For duplicate (replicate) QA/QC samples, the second character in the sample identifier is always the number 1, which indicates that the sample is a duplicate of the sample denoted in the location identifier.

4.10.2 Equipment Blanks

Equipment blank samples are collected daily and analyzed to determine the effectiveness of decontamination practices. Equipment blanks (also called rinse blanks) are collected at a frequency of 5 to 10% of samples. If fewer than 10 samples are collected in a day, 1 equipment blank sample will be collected. Equipment blank samples are collected as follows:

- Sample bottles for equipment blanks are the same as routine sample bottles and will be prepared prior to sampling.
- Fill a decontaminated Teflon bailer with ASTM Type II reagent-grade water and pour water from the bailer into the equipment blank sample jars.
- After all bottles are filled, label the bailer with the associated routine sample ID number and use bailer to sample that same well.
- Note in the GEOLIS logbook that an equipment blank was collected for that particular well.

Once collected, handle equipment blank samples the same as routine samples.

4.10.3 Trip Blanks

The purpose of a trip blank sample is to determine whether factors during transport may have affected sample quality.

A trip blank consists of four VOC sample bottles filled with ASTM Type II reagent-grade water prepared in the laboratory. Trip blanks will be obtained the morning prior to sampling and will accompany the associated routine sample bottles in the same cooler. When the day of sampling is completed, the trip blanks will be handled the same as routine samples and returned to the laboratory. Trip blanks will be collected at a frequency of 1 per day of VOC sample shipment. A note should be made in the GEOLIS logbook that a trip blank accompanied the particular samples.

4.10.4 Ambient Blanks

The purpose of an ambient blank is to determine whether ambient environmental conditions in the sample collection area have affected the quality of the samples. Ambient blanks will be collected at sites where VOC sampling is being done as requested by the PM. Note in the GEOLIS logbook that an ambient blank was collected at the particular well.

Ambient blanks will be collected as follows:

- Once on-site remove the caps from four VOC sample bottles pre-filled with ASTM Type II reagent-grade water and place them in an area where they will not interfere with sampling operations.
- Expose ambient blanks to the atmosphere for the duration of purging and sampling at the well location.

4.10.5 Verification Samples

Verification (confirmatory) sampling involves the collection of soil samples from homogenized material at the same location as the sample collected for mobile laboratory analysis to verify the accuracy of mobile laboratory analytical methodology. Sample frequency and identification of

which borings will have confirmatory samples is determined in the workplan. The samples are collected from a brass tube immediately adjacent to the original sample. Verification samples are handled in the same manner as routine samples.

4.10.6 MS/MSD Samples

Matrix spike/matrix spike duplicate (MS/MSD) samples are collected for the laboratory to perform internal QC checks. MS/MSD sampling involves collection of triple the volume of a routine groundwater sample. No additional volume is required for soils. MS/MSD samples are collected at a rate of 1 for every 20 samples. They are collected as separate samples immediately after the collection of the routine samples for the same parameter. The sample collection procedure is as follows:

- Additional bottles will be prepared the first day so the sampling teams will be ready to sample. For example, a routine sample for BNAs requires two amber glass, 950-mL bottles. An MS/MSD sample for BNAs requires six amber glass, 950-mL bottles.
- Note in the GEOLIST logbook that an MS/MSD sample was collected at that particular well. Once collected, handle samples the same as routine samples.

The MS/MSD samples are identified using the standard nomenclature as outlined in Subsection 5.3, with the designation of MS/MSD on the COC form and on the sample containers. Chain-of-custody procedures are presented in Section 5.

4.10.7 Split Sampling

WESTON participates in several external audits sponsored by state regulatory agencies and EPA. These audits include performance and system audits. When representatives from these agencies are on-site with the sampling teams, they will be collecting samples to be analyzed in a laboratory of their choice. Keep in mind the following when oversight personnel are split sampling:

- Oversight personnel must have the proper PPE to come on-site with the sampling team. WESTON may not supply them with any equipment.

- Agencies are to provide their own sample bottles, although the WESTON sampling team will collect all samples.
- Note in the GEOLIS logbook the name and agency of the oversight representative, and its split sample ID number.
- Once collected, split samples are handed back to the oversight personnel.

For sample identifier designation, follow the procedures outlined in Subsection 5.3.

4.11 DECONTAMINATION

To minimize the possibility of cross-contamination of samples (contamination of a sample by chemicals picked up at another area and transferred to an analytical sample by sampling or drilling equipment), proper decontamination procedures must be followed consistently. Depending on the equipment being decontaminated and the chemicals requiring removal, one or more of the following procedures will be used:

- Detergent wash with non-phosphate detergent.
- Steam cleaning.
- Solvent rinse-methanol (or equivalent and acetone or methanol and hexane [all HPLC grade]).
- Reagent grade nitric acid rinse.
- De-ionized (DI) water rinse.
- Potable water rinse.

Generally, solvents are used to remove organic compounds, such as VOCs and BNAs; nitric acid is used to remove residual metals; and the detergent wash and steam cleaning are used to remove gross contamination and soil. All material and equipment should arrive intact and in clean condition. Recommended procedures for equipment decontamination during drilling, test pit operations, sampling and other field investigation procedures are described in the following subsections.

4.11.1 Drilling Equipment

Drilling rigs will arrive on-site in clean condition and will be inspected by a WESTON geologist. After arrival at the site, all equipment, tools, and tool storage areas that will be used in the drilling, sampling, and completion of the soil borings and monitor wells will be steam cleaned before initiating drilling at any site to remove road dirt. The frequency and procedures for decontamination of drilling equipment are as follows:

- The drill rig and all equipment will be steam cleaned when they are moved to new sites, or more often if required by WESTON.
- The drill rig (i.e., deck derrick and undercarriage) will not be steamed cleaned between soil borings and wells at the same site unless gross contamination is present on the rig that could fall off and enter subsequent boreholes. It is very important during this initial decontamination of the rig to check the threads of the drilling rods

and drilling bits for grease, and to remove it (with a wire brush and Liquinox detergent) if it is present. The only allowable “lubricant” on the threads is Teflon tape.

- The surfaces of the drilling equipment including drill rods, augers, bits, and associated tools (including any tape measures) will be decontaminated at a central site-specific decontamination area using the following procedures:
 - Remove all gross amounts of mud/soil using a shovel, wire brush, or other tools.
 - Transport drill rig and tools to site decontamination area.
 - If necessary, use a brush and a Liquinox detergent/potable water solution to scrub the drilling tools that may enter a subsequent borehole (if the soil/mud on the tools can be easily removed by steam cleaning this step can be skipped).
 - Steam clean drilling tools using a Liquinox/potable water solution.
 - Steam clean drilling tools using potable water to rinse the detergent solution off the tools and drilling rig.
 - Steam clean all manmade construction materials, including temporary and permanent casing, riser pipe, and well screen, with a Liquinox/potable water solution followed by a potable water rinse.
 - Drill rods and manmade well construction materials will be decontaminated on steel rack (1 set per rig on-site), provided by the driller, that keeps the piping 2 or 3 feet above the ground. Precautions should then be taken, by using plastic sheeting, to ensure that decontaminated casing, augers, and other equipment do not come into contact with the ground and that the storage areas on the drill rig or tender are clean.
- At the decontamination site, it may be necessary to fill out properly a Hot Work Permit, depending on the type of steam generator present.
- During split-spoon sampling, subcontractor personnel may be required to help decontaminate the used split-spoons by performing the initial gross cleaning of the split-spoon using a Liquinox (or equivalent) solution and scrub brushes. WESTON personnel will supervise the initial cleaning and then complete the balance of the decontamination procedures. If, because of sample preparation or description activities, the on-site WESTON personnel are unable to complete the decontamination in a timely manner and subcontractor personnel are waiting for split-spoons, standby charges will not be incurred. It will be the responsibility of the subcontractor personnel to complete the split-spoon decontamination, including solvent rinse, under WESTON supervision.

Note: Chargeable subcontractor decontamination time includes half of the travel time to a central decontamination area, if required, plus the actual time spent for the decontamination. If equipment requires additional decontamination because of contact with the ground or dirty portions of other equipment, this time is not chargeable. Decontamination will be performed to the satisfaction of the WESTON supervisor.

4.11.2 Backhoe

If a backhoe is being used to excavate test pits in contaminated soils, or if analytical soil samples are to be collected from test pits, the following decontamination procedures should be followed:

Prior to excavation of any test pit and between test pits, steam clean the backhoe bucket and arm using a non-phosphate detergent (i.e., Liquinox/potable water solution).

Rinse the detergent solution from the backhoe bucket and arm by steam cleaning with potable water.

4.11.3 Soil Sampling Equipment

Sampling equipment that will be used includes stainless steel bowls, trowels, scoopulas, California split-spoons, brass tube inserts, and Teflon bailers. Equipment to be used during sampling will be decontaminated at a centralized decontamination area site at which the equipment is being used. All sampling equipment will be decontaminated after use to prevent cross-contamination between sampling points. Decontaminated equipment will then be wrapped in aluminum foil with the shiny side facing out. No sampling debris will be left on any site.

The procedure for decontaminating sampling equipment is as follows:

- Place dirty equipment on a plastic ground sheet at the head of the decontamination line.
- Rinse equipment with potable water to remove surface dirt and mud if necessary.
- Scrub equipment with a bristle brush using a non-phosphate detergent (e.g., Liquinox) and potable water. To clean the inside of a bailer, use a bottle brush pulled through the bailer with a polypropylene cord.

- Rinse off soap with potable water.
- Using a squirt bottle, rinse with 10% ultrapure nitric acid (use 1% nitric acid for metallic sampling materials) if equipment will be used for the collection of metals samples. Collect nitric acid rinsate in a tub or bucket.
- Rinse with ASTM Type II reagent-grade water.
- Rinse with pesticide-grade hexane. Collect solvent rinsate in a tub or bucket separate from the nitric acid rinsate.
- Rinse with pesticide-grade methanol. Collect solvent rinsate in a tub or bucket separate from the nitric acid rinsate.
- Rinse with ASTM Type II reagent-grade water.
- Allow equipment to air dry.
- Wrap equipment with aluminum foil (shiny side facing out).
- Sampling equipment used to collect samples for organic analyses will not be allowed to contact any type of plastic after decontamination.

At the end of the decontamination procedures, the proper disposal of the decontamination liquids will include the following steps:

- Discharge potable water in the decontamination area.
- Rinse soapy washtub in the decontamination area only.
- Dilute the detergent wash water and discharge it in the decontamination area.
- Overturn tubs to allow them to drain.
- Rinse tub bottoms and stack tubs for future use.
- The hexane, methanol, nitric acid, DI rinse liquids should be placed in a designated 55-gallon drum or other designated container for future characterization and disposal.

4.11.4 Field Parameter Equipment

- Water level indicators and transducers used for measurement of water in wells and in surface waters will be decontaminated after each use by flushing with ASTM Type II reagent-grade water prior to and after each use. If floating product or high levels of organic contamination are evident, or known to exist in a well, the full sampling decontamination procedure outlined in Section 5 will be employed.

- The HORIBA U-10, temperature, dissolved oxygen, PX and electrical conductivity probes will be flushed with ASTM Type II reagent-grade water between measurements. No solvents will be used to clean these probes.
- Turbidimeter sample vials will be wiped dry after being filled with a sample and prior to insertion into the turbidimeter. After the measurement is taken, the sample vial and the turbidimeter will be flushed with ASTM Type II reagent-grade water.
- The flow meter will be rinsed with ASTM Type II reagent-grade water between sites.

4.11.5 Submersible Pump

All submersible pumps used for sampling or for well development will be decontaminated after use to prevent cross-contamination between wells. The procedure for decontaminating submersible pumps follows:

- Scrub pump and cord in a tub of Liquinox and potable water.
- Pump at least 20 gallons of the soapy water through the pump.
- Rinse with potable water.
- Pump at least 20 gallons of rinse water through the pump.
- Rinse with DI water.
- Place pump in a decontaminated, plastic garbage can, or wrap it in clean plastic.

After decontamination, the proper disposal of the decontamination liquids includes the following steps:

- Drain wash water and rinse in decontamination area.
- Rinse decontamination containers with potable water.
- Allow containers to dry overnight.

4.12 SAMPLE CONTAINERS AND PRESERVATION

When metals are the analytes of interest, high-density polyethylene containers with polytetrafluoroethylene-lined polypropylene caps should be used (Polytetrafluoroethylene is commonly referred to using the registered name of Teflon. Polytetrafluoroethylene will be referred to as PTFE.) When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Containers should be cleaned based on the analyte of interest. The cleanliness of a batch of pre-cleaned bottles should be verified by the container supplier or in the laboratory. Residue analysis should be available prior to sampling in the field. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. Table 4-2 presents the various sample containers and sample volumes required for each sample type. Also presented is the preservative that is needed for each sample type.

Table 4-2

Required Containers, Preservation Techniques, and Holding Times

Parameter	Analytical Reference	Sample Container	Sample Volume*	Preservation ¹	Maximum Holding Time ²
Water Samples					
Volatile Organics	SW-846 Method 8260B	Glass vial with Teflon-lined septum cap	(2) 40-mL	No head space, 4 drops concentrated HCl. Cool, 4 °C	14 days
Semi-volatile Organics/Organochlorine Pesticides/PCBs/Herbicides/ Organophosphates/ Polycyclic Aromatic Hydrocarbons	SW-846 Methods 8270C, 8081A, 8150B, 8141A 8310	Amber glass with Teflon-lined cap	4 liters (1 gal.)	Cool, 4 °C	Extract within 7 days, analyze within 40 days following extraction
PCDDs/PCDFs	SW-846, Method 8280A	Amber glass with Teflon-lined cap	(2) 1-liter	Cool, 4 °C	Extract within 30 days, analyze within 45 days of collection
PCBs	SW-846 Method 8082	Amber glass with Teflon-lined cap	1 liter	Cool, 4 °C	Extract within 7 days, analyze within 40 days following extraction
Metals-except Mercury	SW-846 Method 6010B	Plastic	1 liter	Adjust to pH<2 with Nitric Acid	6 months
Cyanide	SW-846 Method 9010B	Plastic	1 liter	Adjust to pH>12 with NaOH, cool, 4 °C	14 days
Reactive Cyanide	SW-846 Method 9034	Plastic	1 liter	Adjust to pH>12 with NaOH, cool 4 °C	14 days
Sulfide	SW-846 Method 9030B	Plastic	500 mL	No head space, 15 drops 2N zinc Acetate, adjust to pH>9 with NaOH, cool, 4 °C	7 days
Reactive Sulfide	SW-846 Method 9014	Plastic	500 mL	No head space, 15 drops 2N zinc Acetate, adjust to pH>9 with NaOH, cool, 4 °C	7 days
Mercury	SW-846 Method 7470A	Plastic	500 mL	Adjust to pH<2 with 35% HNO ₃ , cool, 4 °C	28 days
Soil and Sediment Samples					
Volatile Organics	SW-846 Method 5035	EnCore sampler	5 gram	Cool, 4 °C	Transfer EnCore samples within 48 hours to preserved vial, analyze within 14 days of

Table 4-2

Required Containers, Preservation Techniques, and Holding Times (Continued)

Parameter	Analytical Reference	Sample Container	Sample Volume*	Preservation ¹	Maximum Holding Time ²
					collection
Soil and Sediment Samples (Continued)					
Semi-Volatile Organics/Organochlorine Pesticides/PCBs/Herbicides/ Organophosphates/ Polycyclic Aromatic Hydrocarbons	SW-846 Methods 8270C, 8081A, 8150B, 8141A 8310	Widemouth glass with Teflon liner	500 mL	Cool, 4 °C	Extract within 14 days, analyze within 40 days following extraction
PCDDs/PCDFs	SW-846, Method 8280A	Amber glass	250 mL	Cool, 4 °C	Extract within 30 days, analyze within 45 days of collection
Metals – except Mercury	SW-846 Method 6010B	Glass or Plastic	500 mL	Cool, 4 °C	6 months
Mercury	SW-846 Method 7471A	Glass or plastic	Analyze from metals jar	Cool, 4 °C	28 days
Cyanide	SW-846 Method 9010B	Glass or plastic	Analyze from metals jar	Cool, 4 °C	14 days
Sulfide	SW-846 Method 9030B	Glass or plastic	500 mL	Minimize head space, fill surface of soil or sediment with 2N Zinc Acetate, cool, 4 °C	7 days
Reactive Cyanide	SW-846 Method 9014	Glass or plastic	125 mL (4 oz)	Cool, 4 °C	14 days
Reactive Sulfide	SW-846 Method 9034	Glass or plastic	125 mL (4 oz)	Cool, 4 °C	7 days
Water Quality Samples – Water					
TOC	EPA Method 415.1	Plastic or glass	100 mL	Adjust to pH<2 with HCl	28 days
TDS	EPA Method 160.1	Plastic or glass	100 mL	Cool, 4 °C	7 days
TSS	EPA Method 160.2	Plastic or glass	100 ml	Cool, 4 °C	7 days
BOD ₅	EPA 405.1	Plastic or glass	500 mL	Cool, 4 °C	48 Hours
DOC	EPA 415.1	Plastic or glass	500 mL	Cool, 4 °C	NA
Hardness	EPA 130.2	Plastic or glass	500 mL	Adjust to pH <2 with HNO ₃ , Cool, 4 °C	6 months

Table 4-2

Required Containers, Preservation Techniques, and Holding Times (Continued)

Parameter	Analytical Reference	Sample Container	Sample Volume*	Preservation ¹	Maximum Holding Time ²
Orthophosphate	EPA 365.2	Plastic or glass	500 mL	Cool, 4 °C	48 hours
TKN	EPA 351.4	Plastic or glass	1 Liter	Adjust to pH<2 with H ₂ SO ₄ Cool, 4 °C	28 days
Water Quality Samples – Water (Continued)					
NH ₃	EPA 350.3	Plastic or glass	Analyze from TKN container	Adjust to pH<2 with H ₂ SO ₄ Cool, 4 °C	28 days
NO ₃	EPA 353.2	Plastic or glass	Analyze from TKN container	Adjust to pH<2 with H ₂ SO ₄ Cool, 4 °C	28 days
NO ₂	EPA 353.2	Plastic or glass	Analyze from TKN container	Adjust to pH<2 with H ₂ SO ₄ Cool, 4 °C	28 days
Total Phosphate	EPA 365.2	Plastic or glass	Analyze from TKN container	Adjust to pH<2 with H ₂ SO ₄ Cool, 4 °C	28 days
Alkalinity	EPA 310.1	Plastic or glass	250 mL	Cool, 4 °C	14 days
Turbidity	EPA 180.1	Plastic or glass	On-site	Cool, 4 °C	On-site (48 hrs)
Dissolved Oxygen	SM4500-OC	Plastic or glass	On-site	Cool, 4 °C	On-site (immed.)
PH	SW-846 9041A	Plastic or glass	On-site	Cool, 4 °C	On-site (immed.)
Geotechnical Samples – Soil					
TOC	SW-846 9060	Glass	125 mL (4 oz.)	Cool, 4 °C	28 days
Grain Size Distribution	ASTMD 422	Glass	1 Liter	Cool, 4 °C	NA
Porosity	ASA 18-2.1	Glass	125 mL (4 oz.)	Cool, 4 °C	NA
Atterberg Limits	ASTM D 4318	Glass	125 mL (4 oz.)	Cool, 4 °C	NA
Bulk Density	ASTM D 2937	Glass	125 mL (4 oz.)	Cool, 4 °C	NA

Notes:

*Additional sample volume may be required for sediment or soil samples with low percentage solids.

¹ Whenever possible, pre-preserved bottles will be used.

² Holding time measured from date of collection.

³ To be performed at laboratory, prior to EnCore Sample Transfer.

Section 5

5. SAMPLE CHAIN-OF-CUSTODY/DOCUMENTATION

5.1 FIELD DOCUMENTATION

This section describes procedures for maintaining sample control through proper sample documentation. When samples are collected for chemical or physical characteristics analysis, documentation such as chain-of-custody and sample analysis request forms, custody seals, and logbooks needs to be completed. The information presented in this section enables maintenance of sample integrity from time of collection through transportation and storage. It is this documentation that will verify that the samples were properly handled.

The following discussion outlines standard practices and procedures to be used when documenting a sampling episode. This includes identification of procedures required for field documentation, sample labeling, and the maintenance of chain-of-custody. Applicable requirements are identified in the following paragraphs. Proper completion of the logbook and supporting paperwork with indelible ink is necessary to support potential enforcement actions that may result from the sample analysis; therefore, maintaining sample integrity through proper documentation is essential.

All data collection will be documented in either a field notebook or appropriate Geologic Logging and Interpretation System (GEOLIS) forms in a bound logbook. Field notebooks will be assigned to individual field personnel for daily entries. Notes in the bound field notebooks will be written in black or blue ink, and be as detailed and descriptive as possible so that a particular situation may be recalled without reliance on the collector's memory. There should be no erasure or deletions from the field notes.

The field logbook should enable the sampling activity to be reconstructed without relying on the collector's memory. Logbooks should be kept in the field member's possession or in a secure place during field work. The following topics should be recorded in the field logbook:

- Name and title of author, date, and time of entry.
- Name and address of field contact.

- Names and responsibilities of field crew members.
- Names and titles of any site visitors.
- Sample collection method.
- Number and volume of sample(s) taken.
- Information concerning sampling changes, scheduling modifications, and change orders.
- Details of sampling location.
- Date and time of collection.
- Field observations.
- Any field measurements made.
- Sample identification number(s).
- Information from containers, labels of reagents used, de-ionized water used for blanks, etc.
- Sampling methodology.
- Sample preservation.
- Sample distribution and transportation.
- Sample documentation (e.g., chain-of-custody record numbers).
- Decontamination procedures.
- Documentation for investigation-derived wastes (IDWs) (e.g., contents and approximate volume of waste, disposal method).
- Documentation of any scope of work changes required by field conditions.
- Signature and date (entered by personnel responsible for observations).

5.1.1 GEOLIS Field Logbooks

5.1.1.1 *Borehole, Well, or Task Completion*

- A field team member must submit the original logbook to the Data Administrator for copying within 2 days after the borehole completion. The field team must clearly

indicate which logs are to be copied. The Data Administrator will copy the appropriate logs and return the logbook to the field team.

- When the logbook has been filled and all logs included have been copied, the logbook will be returned to a secure place for safekeeping.

Corrections to all documentation must be done using the following procedures:

- Use a black or blue ink pen.
- Cross out the data with a single strike mark. Ensure that the original entry being struck out is still readable.
- Initial and date the strike mark.

5.1.1.2 Drilling Documentation

All borehole lithologies are logged into the section containing GEOLIS® Borehole Logging forms. One page of these forms is required to describe each lithologic change (interval) within the sampling interval. In addition to logging the various lithologic descriptions in the appropriate overburden or bedrock section, particular care must be taken to thoroughly complete each lithologic sheet while on-site. Overall drilling method descriptions, such as borehole diameter over a specific interval, drilling method over that interval, and drill fluid, should be logged in the Borehole Location Form at the beginning of each section of the field logbook.

5.1.1.3 Borehole Logging and Well Construction

The GEOLIS® system is used to log, manage, and interpret soil boring, well completion data, sampling data, and other data collected in the field. The GEOLIS® system was developed to provide consistent, systematic, and complete descriptions of soil and rock. GEOLIS® consists of the GEOLIS® Soil/Rock Logging Procedures and the GEOLIS® Data Management Software package.

The GEOLIS® Soil/Rock Logging Procedures are standardized operational procedures to be used when drilling boreholes and logging soil samples. The procedures center on the following three forms that are used to log the pertinent borehole information:

- Borehole Location Form (see Figure (B-1, Appendix B).

- Lithologic Logging Form (see Figure B-2, Appendix B).
- Well Construction Forms (see Figures B-3 and B-4, Appendix B).

The WESTON's GEOLIS Logging Reference Manual [00-2235], provided to each field team, describes the protocols in detail. Brief descriptions of the information logged on each form are:

- **Borehole Location Form**—Provides information on borehole specifics, such as the field and location identification numbers; start and finish dates; geologist and driller information; and types of drill rig, drilling methods, and fluids used.
- **Lithologic Logging Form**—Provides a detailed checklist for describing the soil and bedrock encountered during drilling. The Lithologic Logging Form allows the geologist or soil scientist to describe the soil or bedrock encountered using a combination of standardized parameters. Information is recorded for the following data types: standard penetration, blow counts, recovery, sampling method, analytical samples collected, organic vapor readings, and lithologic data required for classification using ASTM Method D2488.
- **Well Construction Form**—Provides a detailed checklist for pertinent well completion information and provides for a graphic presentation of well completion data.

Logbooks containing the three forms are bound and assigned uniquely to each site.

Lithologic Data

All borehole lithologies are logged into the section containing the GEOLIS® Borehole Logging Forms. One page of these forms is required to describe each lithologic change while conducting the sampling interval. In addition to logging the various lithologic descriptions in the appropriate section (bedrock or overburden), the following items must be noted on each sheet:

- Header items (client, site, borehole number, date, and logger's name).
- Sampling method.
- Water entry zones.
- Rock quality determination (RQD) for bedrock cores.
- Sample ID numbers, intervals, and sample types.
- Material origin (natural or fill).
- Observed product, odor, or sheen.

- Instrument readings.
- Information not adequately addressed in any preceding section is added in the comment section, or in the blank notes section provided in each logbook.

Well Construction

In the event that a borehole is completed as a groundwater monitoring well or piezometer, all details of the construction are logged in the Well Construction Form. Detailed instructions for completing this form are found in the GEOLIS® Logging Reference Manual.

Subcontractor Work and Supplies

In addition to logging all pertinent borehole and well information, the field geologist is also responsible for noting the times of the contractor activities and quantities of all supplies provided by the subcontractor. This information is important for accurate subcontractor billing record keeping. This information is logged on the Drilling Activity Log Form (see Figure B-5, Appendix B). The form is designed to help check the driller's invoices, and must be reviewed and signed by the subcontractor. This is done daily, and a copy of the signed form is given to the On-Site Data Manager.

Well Development

Subsection 4.3.2.5 describes the procedures for well development and documenting the process using the GEOLIS Well Development Form (see Figure B-6, Appendix B). The data are recorded in well development logbooks, and the procedure for collecting and reporting the data is as follows:

- Sign out the appropriate well development logbook.
- Record the data for well development and driller activities.
- Estimate final well yields.

Additional Information

GEOLIS field logbooks contain blank pages to note additional information such as site conditions; weather; the presence of any oversight, regulatory, or other visitors; and supplemental information on each day's activities, such as technical data, sketches, drilling

difficulties, or approved changes to standard procedure (see Figures B-7 through B-9, Appendix B).

5.1.1.4 *Soil and Water Sample Documentation*

Various GEOLIS forms are used to document soil, sediment, and water samples that are collected. These forms are listed below.

Soil and Sediment Sampling

The soil/sediment sampling form contains location data and sampling data for surface soil and/or sediment. An example is presented as Figure B-10, Appendix B.

Soil Boring Sampling

The soil boring sampling form lists the various soil samples that may have been collected from a soil boring, including sample ID, sample collection time, and depth. An example is presented as Figure B-11, Appendix B.

Test Pit Logging Form

The test pit logging form is used to record samples collected from test pits, the nature of the soil within the test pit, water entry zones, and types of material observed. An example is presented as Figure B-12, Appendix B.

Water Level Form

The water level form is used to record depth to water within monitoring wells and other types of wells. It includes measurement of NAPL thicknesses and total well depth. An example is presented as Figure B-13, Appendix B.

Well Purging

The well purging form records volumes of water removed from wells during purging and field measurement parameters such as temperature, conductivity, DO, etc. An example is presented as Figure B-14, Appendix B.

Water Sampling

The water sampling form records the sampling information for either surface water samples or groundwater samples. Information includes analytical parameters, sampling method, QA samples, splits, and field parameters. An example is presented as Figure B-15, Appendix B.

5.1.2 Sampling Location Documentation

The exact locations of sampling points will be documented for purposes of generating an accurate representation of the site conditions using the data generated to date, defining data gaps, and identifying potential future data needs. This is accomplished through the use of a monument. A piece of wood should be hammered into the ground to almost ground level, making it difficult to remove, thus assuring its permanence. The stake should then be marked with flagging tape or fluorescent paint.

The project site and location identifiers are designed to provide a method of identifying sampling points and allowing them to be posted on GIS maps for future data presentation and interpretation.

The location ID, physical location description, sampling depths, split samples, and sample comments will be entered for each location as it is established and sampled on the Sample/Location Attribute Form (see Figure B-16, Appendix B).

All sampling locations will be surveyed for horizontal and vertical coordinates using field GPS units or by a licensed surveyor at the time of sampling or as soon after sampling as practical to ensure that the monuments have not been removed or covered over.

Protocols for the use of the Global Positioning System (GPS) are presented below.

5.1.2.1 Protocol for GPS Use

Use of Trimble Pathfinder Pro XL GPS

The backpack Pro XL unit is equipped with a white dome-like sensor, an 8-channel receiver (capable of monitoring 8 satellites simultaneously), and a handheld datalogger, which can be

programmed to enter positional and attribute data into one or more rover files. It may be used at distances of up to 300 km from the base station.

1. First set up the various components to each field unit, then turn on the data logger.
 - Be sure to attach the antenna cable and the battery cables before initializing the system.
 - Connect the cable from the backpack to the datalogger.
2. One of the first things that will happen is that the satellites will beam down an “almanac” indicating the approximate positions of all satellites, and each satellite will also send down an “ephemeris” giving its own precise location.
3. You will see a Main Menu. First check some of the configuration settings by pressing Func, then Config, then GPS, and specifying Rover Options (enter):
 - Point features should be recorded at 1s intervals and line/area features at 3s intervals.
 - The minimum number of positions should be set at 150.
 - The elevation mask is set at 15° (higher than for the Base Station; the Base Station must be able to “see” all satellites seen by the rover).
 - The SNR and PDOP masks should be set to 6.0.
 - You may then exit this feature using the Clear button.
4. Now choose Data Capture from the main menu list.
 - Create the file RMMDDHHa (type in the appropriate filename, then press Enter). You should now see a screen with the file name you just created. You may now collect the first point.
 - Select the Point-Generic Option.
 - Now stand immobile with the antenna close to the sign. Record at least 150 points for this file. After the beep (minimum number of readings has been achieved), press OK to complete the data collection, then Clear and F2 (Yes) to exit the file, then press Function, then Clear to turn off the datalogger.

Note: If you hear a continuous beep while collecting, this indicates too few satellites visible; pause a moment before continuing.

Data Analysis

Once the fieldwork is complete, you need to return to the office, where you will differentially correct the rover files.

To transfer a data file from one of the rovers:

- a. Connect the yellow cable from the data logger to the serial port on your PC.
- b. Turn the rover on and highlight File Transfer (press Enter).
- c. Then enter the PFINDER package on the PC (this is done at the DOS prompt by entering pfinder).
- d. Under Comm pull down to Data Files to PC, select the file(s) to transfer, and click on Okay.
- e. A series of .SSF will be created for each of the data logger files.
- f. The newly created .SSF files may then be transferred to the WESTON office for differential correction.

Using a Remote Community Base Station

Field crews will collect GPS data on a daily basis.

At the end of each sampling day, each field crew will download the .SSF files collected that day.

All downloaded files will be sent electronically via e-mail or FTP to the WESTON office.

The WESTON office will download the base station files on a daily basis (from base stations listed below), and correct files received from Pittsfield.

NH Dept. of Transportation
Concord, NH 03302
PH: (603) 271-1600
BBS: (603) 271-6889
Contact: Kerrie Hartshorn
Password: gpsbase.

Maine Technical Source
Woburn, MA 01801
PH: (718) 932-8888
BBS: (718) 932-7981
Contact: Spencer Drake
Password:

The corrected GPS files will then be put into a GIS environment for QC/QA checks.

Any stray points would then be revisited by the sampling teams in Pittsfield and sent back for post-processing.

The GPS positions will then be posted on maps for client access.

Note: This procedure will be able to run under the following alternative plans if necessary:

- a. Files can be collected by field teams and stored by the GPS unit if a computer is not immediately available.
- b. The corresponding base station files can be acquired and stored until the GPS files are obtained (by disk, e-mail, or FTP).

Using the WESTON Base Station

- a. At the beginning of each field collection day, the base station will be put into operation.
- b. Field crews will collect GPS data on a daily basis.
- c. At the end of each sampling day, each field crew would download the .SSF files collected that day.
- d. Each field crew will then proceed to perform the differential corrections for their data.
- e. The corrected data will then be checked for accuracy in a GIS environment by the field crews, at which time non-valid points will be retaken the following day.
- f. The corrected and uncorrected files will then be sent (via e-mail or FTP) to the WESTON office.

5.2 PHOTOGRAPHIC DOCUMENTATION

Sampling points should be documented on film. A film record of a sampling event allows positive identification of the sampling point. In some cases, a photograph of the actual sample collected may be required. Photographs are the most accurate and convenient record of field personnel observations. Photographs taken to document sampling points should include two or more reference points to facilitate relocating the point at a later date. Keeping a record of photographs taken is crucial to their validity as a representation of an existing situation. Photograph documentation is invaluable if the sampling and subsequent analytical data end in litigation, enforcement, or cost recovery actions. In addition to photographs, video coverage of a sampling episode can be equally or even more valuable than photographs because it can be used to prove that samples were taken properly as well as the location at which they were taken. Video coverage can be used as a record of site conditions and can give those who have not been

on-site an idea of the circumstances. For each photograph taken, the following items should be noted in the field logbook:

- a. Date.
- b. Time.
- c. Photographer (signature).
- d. Name of site.
- e. General direction faced and description of the subject taken.
- f. Sequential number of the photograph and the roll number.
- g. Site photo map.

5.3 FIELD SAMPLE NUMBERING SYSTEM

Sample labels are required for properly identifying samples and evidence. The data obtained from samples collected for a sampling or monitoring activity may be used for remedial measures. All samples must be properly labeled with the label affixed to the container prior to transportation to the laboratory. It is also recommended that samples be photographed so that labels are clearly readable. Information on sample labels should be limited to the following:

- **Field Sample Identification Number**—Each sample, including field control samples, collected for a project should be assigned a unique 18 character name (see below).
- **Samplers**—Each sampler's name and signature or initials.
- **Preservative**—Whether a preservative is used and the type of preservative.
- **Analysis**—The type of analysis requested.
- **Date/Time**—Identify the date and time the sample was taken.
- **Type of Sample**—The type of sample should be identified as discrete or composite.

5.3.1 Field Sample Identification Number

The field sample ID includes site, location, sample type, and depth or date collected information. A sample attribute form will be used to record some of the more-detailed attributes of the sample, and the form will function as a field chain-of-custody. The sample attribute information will be explicitly recorded on a sample attribute field form (i.e., field sample ID, location ID, physical location description, sampling depths, split samples, and sample comments). The field

sample ID and its corresponding attribute information will be captured electronically on the day of collection and linked within the database.

The field sample ID will be 18 characters long and be composed of four parts:

XX - XXXXXXXX - X - XXXX
 [Site - Location ID - QC Type - Depth/Date]

Field Sample ID Part 1: Site

Part 1 of the field sample ID will be two characters representing a site within an OU or “PE” for PE samples. The list of available values follows and can be expanded as needed:

Site	Site Description	OU Number
AS	Allendale School	OU 3
E1	East Street Area 1	OU 1
E2	East Street Area 2	OU 1
H0	East Branch Housatonic River - Upstream of Newell Street	OU 2
H1	East Branch Housatonic River - Newell to Lyman Streets	OU 2
H2	East Branch Housatonic River - Lyman to Confluence with West Branch	OU 2
H3	Housatonic River - Confluence to Woods Pond	OU 2
H4	Woods Pond	OU 2
H5	Housatonic River - Woods Pond to Rising Pond	OU 2
H6	Housatonic River - Downstream of Rising Pond	OU 2
H7	Housatonic River - Other	OU 2
H8	Housatonic Tributary	OU 2
H9	Reference Locations - Outside Housatonic Drainage Basin	OU 2
HL	Hill 78 Site	OU 1
LS	Lyman Street Area	OU 1
N1	Newell Street Area I	OU 5
N2	Newell Street Area II	OU 5
O1	General OU 1 - Not site specific	OU 1
O5	General OU 5 - Not site specific	OU 5
O6	General OU 6 - Not site specific	OU 6
OA	Oxbow A	OU 6
OB	Oxbow B	OU 6
OC	Oxbow C	OU 6
OJ	Oxbow J	OU 6
OK	Oxbow K	OU 6
PE	PE Sample - Not site specific	None
SL	Silver Lake	OU 4
UB	Unkamet Brook Area	OU 1

Field Sample ID Part 2: Location ID

Part 2 of the field sample ID will be eight characters/numbers representing the location ID. Location IDs will be unique identifiers representing geographic *x, y* coordinates for all sample types except for tissue and PE samples. There will be four different location ID systems depending on what type of sample is being collected:

- Transect samples.
- Non-transect samples.
- Tissue samples.
- PE samples.

The list of available location codes follows:

Location Code	Description
AR	Air/Meteorology Monitoring Location
BH	Soil Boring
BS	Non-Transect: River Bank: Surface/Shallow Soil Sampling
F	Transect: Floodplain: Surface/Shallow Soil Sampling
FL	Non-Transect: Floodplain: Surface/Shallow Soil Sampling
PR	Piezometer
PW	Pore Water Sampling Location
RB	Transect: River Bank: Surface/Shallow Soil Sampling
SD	Transect: Sediment Sampling Location
SE	Non-Transect: Sediment Sampling Location
SL	Non-Transect: Surface/Shallow Soil Sampling
SP	Sump/Pipe/Tank Sampling Location
SW	Surface Water/Seep Sampling Location
TB	Bird Tissue Sampling Location
TD	Duck Tissue Sampling Location
TF	Fish Tissue Sampling Location
TI	Invertebrate Tissue Sampling Location
TM	Mammal Tissue Sampling Location
TP	Test Pit
WD	Waste/Disposal Location
WL	Well
WM	Surface Water Measurement Location

A. Transect Samples:

The transect location codes are F, RB, and SD. The location ID consists of four parts:

- The first part will be two characters (or one character for floodplain) that are the location code.
- The second part will be two numbers that are the river mile (the Newell Street Bridge is the zero river mile; upstream of the bridge will be N1, N2, N3, etc. indicating negative miles).
- The third part will be three numbers that are the sequential transect number.
- The fourth part will be one number (or two numbers for floodplain) that indicates position along the transect.
 - The fourth part for SD location codes will be “1” for left stream (facing upstream), “2” for mid stream, and “3” for right stream.
 - The fourth part for RB location will start at “1” for the top of slope on the left bank (facing upstream), “2” for the mid slope on the left bank, “3” for the toe of slope on the left bank, “4” for the toe of slope on the right bank, “5” for mid slope on the right bank, and “6” for the top of slope on the right bank.
 - The fourth part for F location codes will be a numerical sequence not necessarily relating to left or right position.

A table showing the left to right sequence and some location ID examples follows.

	<u>↑Upstream↑</u>														
Location Code	<i>F</i>			<i>RB</i>			<i>SD</i>			<i>RB</i>			<i>F</i>		
4th Part of Location ID	unique number sequence			1	2	3	1	2	3	4	5	6	unique number sequence		

SD000173: The right stream sediment location on transect 17 between river mile 0 and 1.

RB030932: The middle of slope left bank location on transect 93 between river mile 3 and 4.

F1391028: The 28th floodplain location on transect 910 between river mile 13 and 14.

B. Non-Transect Samples:

The location ID consists of two parts:

- The first part will be two characters that are the location code.
- The second part will be six numbers that are a numerical sequence for each location code.

Some examples follow:

SL000023: The 23rd surface/shallow soil location.

SW000016: The 16th surface water/seep location.

C. Tissue Samples:

The location ID consists of four parts:

- The first part will be two characters that are the location code.
- The second part will be two numbers that are the river mile or two characters for a water body code.
- The third part will be two characters that are species type.
- The fourth part will be two numbers that are a numerical sequence for each location code and species combination. Composite samples will have a "C" and a number.

A table of the species codes, water body codes, and some location ID examples follows.

Species Code	Description	Species Code	Description
AE	American Eel	LB	Largemouth Bass
BB	Brown Bullhead	LS	Longnose Sucker
BC	Black Crappie	NP	Northern Pike
BD	Blacknose Dace	PS	Pumpkin Seed
BG	Bluegill	RB	Rock Bass
BM	Bluntnose Minnow	RS	Redbreasted Sunfish
BT	Brown Trout	RT	Rainbow Trout
CC	Common Carp	SB	Smallmouth Bass
CH	Creek Chub	WC	White Catfish
CP	Chain Pickerel	WP	White Perch
CS	Common Shiner	WR	White Crappie
FF	Fallfish	WS	White Sucker
FM	Fathead Minnow	YB	Yellow Bullhead
GF	Goldfish	YP	Yellow Perch
GS	Golden Shiner		

Site	Site Description	OU Number
3M	3-Mile Pond	OU 2
GP	Goodrich Pond	OU 2
RP	Rising Pond	OU 2
WP	Woods Pond	OU 2

TF05CS06: The sixth common shiner sample from between river mile 5 and 6.

TFGPGF15: The fifteenth goldfish sample from Goodrich Pond.

TFWPBBC6: The sixth composite brown bullhead sample from Woods Pond.

D. PE Samples:

The location ID consists of one part:

- The location code will be the Lot Number for the PE sample. Zeros will be added to Lot Numbers with fewer than 8 characters.

Field Sample ID Part 3: Sample QC Type

Part 3 of the field sample ID will be a single number representing the sample QC type. The list of available values follows.

QC Code	Description
0	Normal Sample
1	Field Duplicate Sample
2	Equipment Blank Sample
3	Trip Blank Sample
4	Ambient Blank Sample
5	Filtered Sediment Sample
6	Performance Evaluation (PE) Sample

Field Sample ID Part 4: Starting Sample Depth or Collection Date

Part 4 of the field sample ID will vary depending on whether the sample has associated depth or not. Samples with associated depth will have this part as a starting depth, and it will be expressed in tenths of feet (e.g., 0105 represents a starting depth of 10.5 feet). This part will indicate date collected for all other samples.

The 4 character date code will be:

- Position one equals the last number of the year.
- Position two equals a letter corresponding to a month (J=January, F=February, M=March, A=April, Y=May, U=June, L=July, G=August, S=September, C=October, N=November, D=December).
- Position three and four equal the day of the month.

(e.g., 8S19 is the code for 19 September 1998).

A sample attribute form will be used to record location description codes, physical location descriptions, starting and ending depths, and, if a sample is split, then to whom it is split and what the split sample ID is. The sample attribute form will also be used as a field chain-of-custody, and “Relinquished by,” “Received by,” “Date,” and “Time” will be entered on the form. This covers custody of samples from the sample collection location to the Pittsfield staging area.

Examples of Field Sample IDs

H1-RB000191-1-0010: This represents a field duplicate river bank soil sample collected at 1.0 feet starting depth at the top of the left bank along transect 19 in the East Branch of the Housatonic River from Newell to Lyman Streets between river mile 0 and 1.

H3-SD030592-0-0000: This represents a normal sediment sample collected at 0 feet starting depth at mid stream along transect 59 in the Housatonic River from the Confluence to Woods Pond between river mile 3 and 4.

H3-SD030592-0-0005: This represents a normal sediment sample collected at 0.5 feet starting depth at mid stream along transect 59 in the Housatonic River from the Confluence to Woods Pond between river mile 3 and 4.

E2-BH000023-0-0015: This represents normal soil boring sample number 23 collected at 1.5 feet starting depth in East Street Area 2.

E2-BH000023-1-0015: This represents a field duplicate of soil boring sample number 23 collected at 1.5 feet starting depth in East Street Area 2.

E2-BH000023-2-0015: This represents a soil boring equipment blank collected on the same day as soil boring sample **E2-BH000023-0-0015**.

E2-BH000023-3-0015: This represents a trip blank packed with soil boring sample **E2-BH000023-0-0015**.

H4-TFWPCC21-0-8C06: This represents the 21st common carp sample from Woods Pond collected on 6 October 1998.

PE-TT008890-6-8G28: This represents a PE sample with Lot Number TT00889, and it was analyzed with samples collected on 28 August 1998.

5.4 SAMPLE DOCUMENTATION

5.4.1 Sample Labels

Sample labels will be consistent with the requirements of EM 200-1-3. Sample tags will not be used.

Field personnel will be responsible for identifying, labeling, providing proper preservation, and packaging samples to preclude breakage during shipment.

Every sample will be labeled and labels will include:

- Project number and site name.
- Unique sample number.
- Sampling date and time.
- Initials of sampling technician.
- Method of sample preservation/conditioning.

5.4.2 Chain-of-Custody Records

Chain-of-custody records provide documentation of the handling of each sample. Sample custody will be initiated by WESTON upon collection of samples. Chain-of-custody forms will be placed in waterproof plastic bags and taped to the inside lid of the cooler. The cooler will be sealed with chain-of-custody seals. Chain-of-custody forms will be used for recording pertinent information about the types and numbers of samples collected and shipped for analysis. Sample identification numbers will be included on the chain-of-custody form to ensure that no error in identification is made during shipment. Chain-of-custody procedures shall be carried out in accordance with Appendix F of EM 200-1-3.

5.4.2.1 Chain-of-Custody

Chain-of-custody procedures provide documentation of the handling of each sample. Chain-of-custody procedures are implemented so that a record of sample collection, transfer of samples between personnel, sample shipping, and receipt by the laboratory that will analyze the sample is maintained. The chain-of-custody (COC) record serves as a legal record of possession of the sample. The COC record is initiated with the acquisition of the sample. The COC record remains with the sample at all times and bears the name of the person (field investigator) assuming responsibility for the samples. The field investigator is tasked with ensuring secure and appropriate handling of the bottles and samples. To simplify the COC record and eliminate potential litigation problems, as few people as possible should handle the sample or physical evidence during the investigation. A sample is considered to be under custody if one or more of the following criteria are met:

- a. The sample is in the sampler's possession.
- b. The sample is in the sampler's view after being in possession.
- c. The sample was in the sampler's possession and then was locked up to prevent tampering.
- d. The sample is in a designated secure area.

In addition to the COC record, there is also a COC seal. The COC seal is an adhesive seal placed in areas such that if a sealed container is opened, the seal would be broken. The COC seal ensures that no sample tampering occurred between the field and the laboratory analysis.

5.4.2.2 Transfer of Custody and Shipment

All sample sets should be accompanied by a COC record. When transferring possession of samples, the individual receiving the samples should sign, date, and note the time that he/she received the samples on the COC record. This COC record documents transfer of custody of samples from the field investigator to another person, other laboratories (including any on-site laboratory), or other organizational units. Samples must be properly packaged for shipment and delivered or shipped to the designated laboratory for analyses. Shipping containers must be

secured by using nylon strapping tape and custody seals. The custody seals must be placed on the container so that it cannot be opened without breaking the seals. The seal must be signed and dated by the field investigator. When samples are split with a facility, state regulatory agency, or other government agency, the agency representative must sign the COC record, if present. All samples should be accompanied by the COC record. As previously discussed, the U.S. Army Corps of Engineers (USACE) tracking number (e.g., LIMS number) that is used in conjunction with the government QA sample shipment must be written on the QA sample's COC record. The original and one copy of the record will be placed in a plastic bag taped to the inside lid of the secured shipping container. One copy of the record will be retained by the field investigator or project leader. The original record will be transmitted to the field investigator or project leader after samples are accepted by the laboratory. This copy will become a part of the project file. If sent by mail, the package should be registered with return receipt requested. If sent by common carrier, an air bill should be used. Receipts from post offices and air bills should be retained. The air bill number or registered mail serial number should be recorded in the remarks section of the COC record.

5.4.3 Potential Problems

Although most sample labels are made with water-resistant paper and are filled out using waterproof ink, inclement weather and general field conditions can affect the legibility of sample labels. It is recommended that, after sample labels are filled out and affixed to the sample container. This will preserve the label and keep it from becoming illegible. In addition to label protection, chain-of-custody and analysis request forms should be protected when samples are shipped in iced coolers. Typically, these forms should be placed inside a ziplock bag or similar waterproof protection and taped to the inside lid of the secured shipping container with the samples.

5.5 DOCUMENTATION PROCEDURES

Prior to sample collection, labels will be affixed to sample containers. Ink will be used for all logbook, chain-of-custody, and sample label entries.

5.6 CORRECTIONS TO DOCUMENTATION

All original data recorded in field logbooks, sample labels, chain-of-custody records, and receipt for sample forms will be written in waterproof ink. If an error is made, a single line should be drawn through the entry, and the entry initialed and dated. The erroneous information should not be obliterated. Any errors found in documentation should be corrected by the person who made the entry.

Section 6

6. SAMPLE PACKING AND SHIPPING

This section describes procedures for properly packaging and shipping environmental and hazardous waste samples. The procedures described in this section are performed after samples have been collected and placed in the proper containers and correctly preserved. Guidelines for proper container and preservative selection can be found in Subsection 4.12.

The following are procedures for packaging and shipping requirements of environmental and hazardous waste samples. *All on-site personnel overseeing sample shipping are required to have current certification in the Dangerous Goods Shipping Course.*

6.1 ENVIRONMENTAL SAMPLES

Environmental samples are defined as those samples collected from environmental matrices such as soil, groundwater, or sediments. Environmental samples should be packaged for shipment as follows:

- a. Sample container is adequately identified with sample labels. Sample labels are placed on samples at this time if required.
- b. All bottles are taped shut with custody seals.
- c. Each sample bottle is placed in a separate plastic bag, the air removed as much as possible, and is then sealed. For water samples, each VOA vial is wrapped in a paper towel, and the two vials are placed in one bag. If a trip blank is submitted, it should be wrapped and placed in the bag with the two VOA vials. Bags may be sealed with evidence tape or custody seals for additional security.
- d. A picnic cooler (such as a Coleman or other sturdy cooler) is typically used as a shipping container. In preparation for shipping samples, the drain plug is taped shut from the outside. Approximately 3 in. of inert packing material, such as asbestos-free vermiculite, perlite, or Styrofoam beads, is placed in the bottom of the liner. Other commercially available shipping containers may be used; however, the use of such containers (cardboard or fiber boxes complete with separators and preservatives) should be specified in the sampling plan and pre-approved.
- e. The bottles are placed upright in the lined picnic cooler in such a way that they do not touch and will not touch during shipment. Cardboard separators may be placed between the bottles at the discretion of the shipper.

- f. All samples should be shipped to the laboratory on ice and chilled to 4 °C except for the geotechnical samples, which do not require shipment with ice.
- g. Additional inert packing material is placed in the cooler to partially cover the sample bottles (more than halfway). If samples are required to be shipped to the laboratory with ice, ice in a bag must be placed around, among, and on top of the sample bottles. If chemical ice is used, it should be placed in a double plastic bag. The cooler should then be filled with inert packing material and the liner taped shut.
- h. The paperwork going to the laboratory is placed inside a plastic bag. The bag is sealed and taped to the inside of the cooler lid. A copy of the COC form should be included in the paperwork sent to the laboratory. The air bill must be filled out before the samples are handed over to the carrier. The laboratory should be notified if another sample is being sent to another laboratory for dioxin analysis or if the shipper suspects that the sample contains any other substance that would require laboratory personnel to take additional safety precautions.
- i. The cooler is closed and taped shut with strapping tape (filament-type).
- j. At least two signed custody seals are placed on the cooler, one on the front and one on the side. Additional seals may be used if the sampler or shipper thinks more seals are necessary.
- k. The cooler is handed over to the overnight carrier. A standard air bill is necessary for shipping environmental samples. The shipper should be aware of carrier weight or other policy limitations.

6.2 HAZARDOUS SAMPLES

Hazardous samples are defined as those that are typically highly contaminated, such as oils (LNAPL and DNAPL), sludges, discarded products, and other materials. Hazardous samples must be packaged as follows:

- a. Sample container is adequately identified with sample. Sample tags are placed on samples at this time if required.
- b. All bottles, except the VOA vials, are taped closed with electrical tape (or other tape as appropriate). Evidence tape or custody seals may be used for additional security.
- c. Each sample bottle is placed in a plastic bag, and the bag is sealed. As much air as possible is squeezed from the bags before sealing. Evidence tape or custody seals may be used to seal the bags for additional security.

- d. Each bottle is placed upright in a separate paint can, the paint can is filled with vermiculite, and the lid is fixed to the can. The lid must be sealed with metal clips or with filament or evidence tape; if clips are used, the manufacturer typically recommends six clips.
- e. Up arrows are placed on the can to indicate which end is up.
- f. The outside of each can must contain the proper Department of Transportation (DOT) shipping name and identification number for the sample. The information may be placed on stickers or printed legibly. A liquid sample of an uncertain nature is shipped as a flammable liquid with the shipping name "FLAMMABLE LIQUID, N.O.S." and the identification number "UN1993." A solid sample of uncertain nature is shipped as a flammable solid with the shipping name "FLAMMABLE SOLID, N.O.S." and the identification number "UN1325." If the nature of the sample is known, 40 CFR 171-177 is consulted to determine the proper labeling and packaging requirements.
- g. The cans are placed upright in a cooler that has had its drain plug taped shut inside and out, and has been lined with a garbage bag. Vermiculite is placed on the bottom. Two sizes of paint cans are used: half-gallon and gallon. The half-gallon paint cans can be stored on top of each other; however, the gallon cans are too tall to stack.
- h. All hazardous samples should be shipped to the laboratory on ice and chilled to 4 °C.
- i. Additional inert packing material is placed in the cooler to partially cover the sample bottles. If samples are shipped to the laboratory with ice, bags of ice must be placed around the cans. The cooler must be filled with packing material and the liner taped shut.
- j. The paperwork going to the laboratory is placed inside a plastic bag and taped to the inside of the cooler lid. A copy of the COC form should be included in the paperwork sent to the laboratory. The sampler keeps one copy of the COC form. The laboratory should be notified if a parallel sample is being sent to another laboratory for dioxin analysis, or if the sample is suspected of containing any substance for which laboratory personnel should take safety precautions.
- k. The cooler is closed and sealed with strapping tape. At least two custody seals are placed on the outside of the cooler (one on the front and one on the back). More custody seals may be used at the discretion of the sampler.

The following markings are placed on the top of the cooler:

- Proper shipping name (49 CFR 172.301).
- DOT identification number (49 CFR 172.301).
- Shipper's or consignee's name and address (49 CFR 172.306).

- “This End Up” legibly written if shipment contains liquid hazardous materials (49 CFR 172.312).
1. The following labels are required on top of the cooler (49 CFR 172.406(e)):
 - Appropriate hazard class label (placed next to the proper shipping name).
 - “Cargo Aircraft Only” (if applicable as identified in 49 CFR 172.101).
 - m. An arrow symbol(s) indicating “This Way Up” should be placed on the cooler in addition to the markings and labels described above.
 - n. Restricted-article air bills are used for shipment. The “Shipper Certification for Restricted Articles” section is filled out as follows for a flammable solid or a flammable liquid:
 - Number of packages or number of coolers.
 - Proper shipping name: if unknown, use:
 - Flammable solid, N.O.S.
 - Flammable liquid, N.O.S.
 - Classification; if unknown, use:
 - Flammable solid, N. O. S.
 - Flammable liquid, N.O.S.
 - Identification number; if unknown, use:
 - UN1325 (for flammable solids).
 - UN1993 (for flammable liquids).
 - Net quantity per package or amount of substance in each cooler.
 - Radioactive materials section (Leave blank).
 - Passenger or cargo aircraft. (Cross off the non-applicable. Up to 25 lb of flammable solid per cooler can be shipped on a passenger or cargo aircraft. Up to 1 qt of flammable liquid per cooler can be shipped on a passenger aircraft, and up to 10 gal of flammable liquid per cooler can be shipped on a cargo aircraft.)
 - Name and title of shipper (printed).
 - An emergency telephone number at which the shipper can be reached within the following 24 to 48 hours.
 - Shipper’s signature.

Subsection 4.12 provides information concerning sample containers and preservatives.

Section 7

7. INVESTIGATION DERIVED WASTES (IDW)

The purpose of this section is to describe the requirements for residuals management. The requirements of these procedures are applicable to residuals management for wastes generated as a result of field sampling and characterization activities. The goal of residuals management is to minimize the amount of waste generated while following applicable regulations.

Prior to commencing sampling of remediation, the field team leader will select an area, preferably secure, for drum storage in consultation with the FTL.

Any drum used will be a U.S Department of Transportation (DOT) approved drum that will be required to containerize waste. Drums will be stored in rows not larger than 2 drums wide with labels facing outward for identification. Decontamination fluids and other low-volume fluids may be temporarily stored and transported in 5-gallon buckets with lids.

Different residual materials (e.g., soil and water) will not be drummed together, but will be placed in separate drums. Field screening will be used to drum materials with similar levels of contamination together, if possible.

7.1 RESIDUALS MANAGEMENT

The determination as to whether residual waste must be placed in drums will be made based on the following questions:

- Is there visual evidence of contamination, previous analytical results that indicate elevated levels of contamination, or in an area where soil contamination is expected?
 - If yes, place materials in a drum.
 - If no, check a representative sample for elevated instrument reading on field instruments (PID or FID).
- Are elevated instrument readings obtained?
 - If yes, place the material in drums.
 - If no, spread discharge to the ground surface.

If there are any questions, it is better to containerize.

7.1.1 Residual Soil

If it is determined that soil cuttings and excess samples must be drummed, they will be placed in DOT-approved drums with drum liners, and will be sealed and labeled in accordance with labeling practice.

7.1.2 Residual Liquids

If it is determined that residual liquid such as water from well development and decontamination water must be containerized, it will be placed in a temporary holding tank or DOT-approved 55-gallon drums as appropriate. Drums will be sealed and labeled in accordance with labeling procedures. Decontamination solvents and test kit solvents will be segregated from aqueous material and allowed to evaporate as much as possible before being containerized in solvent-specified drums. Liquids drums will contain removable bungs. Funnels will be used to prevent spillage when adding liquids to the drums.

7.1.3 Residual Disposables

All non-contaminated disposable wastes, such as bags, washed gloves, and material scrap, will be kept separate from other wastes. This material will be bagged or otherwise contained and disposed of in a dumpster or other appropriate location.

Contaminated disposable wastes may include disposable PPE and contaminated equipment. This material will be placed in wrangler type boxes unless field screening results of soil and/or waste residuals indicate non-elevated results.

7.2 DISPOSAL

Wastes that have been drummed based on field criteria may be sampled for laboratory analysis to determine the appropriate type of disposal facility. The number of samples collected will depend on the homogeneity of the drummed material, the nature of the source areas, and the requirements of the disposal facility.

IDW characterized or listed as hazardous waste will be disposed in a manner consistent with all local, state, and federal guidelines.

7.3 LABELING

Drums will be labeled on the side with the following information:

- Sampling location identification.
- Sampling area designation.
- Type of material.
 - OB—Overburden soil and cuttings
 - GW—Groundwater from wells
 - DW—Decontamination water
 - DS—Disposables
 - BR—Bedrock cuttings
 - SO—Decontamination solvents
- Water content.
 - SAT—saturated
 - UNSAT—unsaturated
- For drums containing liquids, indicate the approximate fill line on the outside of the drum. Do not fill more than two-thirds full with liquids.
- Range of field screening results and instrument type.
- Date the drum was filled and sealed.

Example label:

MW-1010
E1-OB-UNSAT
10– 30 OVM
12-AUG-98

Section 8

8. CONTRACTOR CHEMICAL QUALITY CONTROL (CCQC)

WESTON is required to ensure that quality is maintained throughout all field work. WESTON will utilize experienced field personnel to perform soil, product, and groundwater sampling.

8.1 PREPARATORY PHASE

The Site Quality Control (QC) Manager will review all pertinent sections of the Scope of Work during the preparatory meeting to ensure that field personnel are cognizant of data quality objectives (DQOs). The Site QC Manager, in conjunction with the WESTON Project Management and sampling team, will also review all work requirements, examine all materials and equipment, examine work areas, and demonstrate all field activities. If new sampling personnel arrive on-site during the work effort, the Site QC Manager must repeat this phase before new personnel begin work.

8.1.1 Project-Specific Checklist

Field equipment list includes the following:

- Sampling and analysis plan.
- Example tables for recording all data.
- QA sample table to match up QC and QA samples.
- Field screening instruments.
- Calibration standards.
- Instrument operating manuals.
- Backup instrument(s) for field screening.
- Decontamination materials.
- Sample collection equipment.
- Labels for sample containers.
- Examples of completed sample shipping documents.

- Sample containers.
- Chain-of-custody forms.
- Chain-of-custody seals.
- Sample shipping coolers.
- Sample packing materials.
- Ice packs.
- Sample preservatives.
- Laboratory information.
- Copy of a phone log showing QA samples have been scheduled.

Checklist of activities:

- Review data quality objectives (DQOs) and specific analytical method - required sampling, sample holding, and analysis requirements.
- Review sampling and analysis plan.
- Calibrate all instruments.
- Review decontamination procedures.
- Review sample custody forms.
- Review sample numbering system.
- Discuss analytical test methods.
- Review sampling techniques.

8.2 INITIAL PHASE

The Site QC Manager is responsible for overseeing every step of work when that work is first initiated.

8.3 FOLLOW-UP PHASE

The Site QC Manager is responsible for continued daily contract compliance until completion of the particular feature of work.

Section 9

9. DAILY CHEMICAL QUALITY CONTROL REPORTS (DCQCR)

9.1 DEPARTURE FROM APPROVED PLANS

WESTON will document and report all major departures from approved plans. The report will address the following:

- Reasons for departures.
- Problems identified.
- Corrective actions.
- Effect of the departure on scope and results.
- Instructions from CENAE personnel for re-sampling and/or re-analysis.

These reports of significant problems will be sent to the contracting officer's representative within 48 hours of the occurrence.

9.2 DATA REPORTS

The quality control reporting requirements for laboratory reporting are addressed in Sections 11 and 14 of the QAPP. The quality control information will be submitted together with the analytical data packages, as they are received from the contract laboratory (approximately 7 days following completion of laboratory analyses). No additional quality control reports will be required.

Section 10

10. CORRECTIVE ACTIONS

10.1 FIELD CORRECTIVE ACTION

The initial responsibility for monitoring the quality of field measurements and observations lies with the field personnel. The Site QC Manager is responsible for verifying that QC procedures are followed. This requires that the Site QC Manager assess the correctness of field methods and the ability to meet QA objectives. If a problem occurs that might jeopardize the integrity of the project or cause some specific QA objective not to be met, the Site QC Manager will notify the Project Manager. An appropriate corrective action will then be decided upon and implemented. The Site QC Manager will document the problem, the corrective action, and results in the field logbook. Copies of the logbook will be provided to the Project Manager and the appropriate QC Manager.

10.2 LABORATORY CORRECTIVE ACTION

The initial responsibility to monitor the quality of an analytical system lies with the analyst. The analyst will verify that all QC procedures are followed and that results of an analysis of QC samples are within acceptance criteria. This requires that the analyst assess the correctness of all of the following items as appropriate:

- Sample preparation procedure.
- Initial calibration.
- Calibration verification.
- Method blank result.
- Laboratory control standard.
- Duplicate analysis.
- Fortified sample result.

If the assessment reveals that any of the QC acceptance criteria are not met, the analyst must immediately assess the analytical system to correct the problem. The analyst notifies the appropriate supervisor and laboratory QA coordinator of the problem, and, if possible, identifies potential causes and corrective action.

The nature of the corrective action obviously depends on the nature of the problem. For example, if a continuing calibration verification is determined to be "out of control," the corrective action may require re-calibration of the analytical system and re-analysis of all samples since the last acceptable continuing calibration standard.

When the appropriate corrective action measures have been defined and the analytical system is determined to be "in control," the analyst documents the problem and the corrective action. Data generated concurrently with an "out-of-control" system will be evaluated for usability in light of the nature of the deficiency. If the deficiency does not impair the usability of the results, data will be reported, and the deficiency noted in the case narrative. Where sample results are impaired, the laboratory QA coordinator is notified, and appropriate corrective action (e.g., re-analysis, etc.) is taken.

Other laboratory corrective actions are discussed in the QAPP.

Section 11

11. SEQUENCE OF ACTIVITIES

The sequence of the various field activities will be outlined in work plans that are submitted.

Section 12

12. SAMPLING APPARATUS AND FIELD INSTRUMENTATION

A list of the field equipment, containers, and supplies anticipated to possibly be needed for this project is provided below. A listing of field screening instrument calibration procedures is contained in Appendix C.

Field Equipment:

- Cameras
- Duct Tape
- Film
- Fire Extinguisher
- Garbage Bags
- Indelible Ink
- OVM
- Combustible Gas Indicator (CGI)
- MiniRAM
- Submersible Pump
- Transducers
- Data Logger
- Paper Towels
- Razor Knife
- Sample Containers Provided by Laboratory

Decon Equipment:

- Liquinox
- Methanol
- Hexane
- Distilled Water
- Decon Tubs
- Scrub Brushes
- Spray Bottles
- Squeeze Bottles
- Plastic Sheeting
- DOT Drums

Personal Protective Equipment:

- Safety Goggles
- Nitrile Gloves
- ANSI Boots
- Hard Hats

- Hearing Protection
- Tyvek Suits
- Level C protective gear
- Level B protective gear

Sampling Equipment:

- Vermiculite or bubble wrap
- Scoops
- Scoopulas
- Stainless steel bowls
- Hand auger
- Tape measure
- Folding ruler
- Hazard shipping labels
- Strapping tape
- Ice
- Site plans and forms
- Sampling pumps
- Two-inch submersible pumps with controllers
- Electronic water level indicators
- Dedicated Teflon tubing for each monitoring well
- Disposable Teflon bailers
- Surgical-grade silicon tubing for sampling pumps
- 250-ml graduated cylinders
- Stop watches to check/adjust purge rates
- Dedicated nylon rope
- Calibrated bucket

- Sample containers and preservatives
- Flow-through polyethylene containers for monitoring groundwater parameters during purging
- Wide range pH test paper to ensure proper sample preservation
- Generator to supply electricity at remote sampling locations
- Extension cords
- Large pipe wrenches to remove well caps
- Polyethylene sheeting
- Coolers for sample shipment
- Conductivity meter and KCl calibration standard solutions
- Turbidity meter and calibration standards
- Thermometer
- pH meter with standard pH buffer solutions of pH 4, 7, and 10
- Dissolved oxygen meter
- Oxidation reduction potential (ORP) meter
- Photo-ionization detector (PID) and calibration standard
- Decontamination supplies including non-phosphate detergent, tap water, de-ionized water, brushes, decontamination tubs, and sprayers

This is not intended to be a complete list, but to present probable equipment needs. Specific equipment not reference in this document will be described in individual work plans and/or addendums to the FSP.

Appendix A

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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Appendix B

APPENDIX B

STANDARD FORMS

Figure B-1

GEOLIS[®] Location Identification Form

CLIENT: _____ PROJECT: _____ PROPERTY: _____ SITE / AREA: _____ LOCATION ID: _____ BEGIN DATE: _____ END DATE: _____ LOGGER: _____	QUALITY LEVEL: 1 - 2 - 3 UNIT SYSTEM: ENGLISH - METRIC 	
LOCATION TYPE: BOR - PIZ - WEL - PIT - _____ TEST PIT: LENGTH: _____ FT/M WIDTH: _____ FT/M BOREHOLE COMPLETED IN: OVERBURDEN - BEDROCK BEDROCK CONFIRMED: NOT - DRL - SPS - AUG - COR - CUT TOTAL DEPTH: _____ FT/M BGS DEPTH TO BEDROCK: _____ FT/M BGS		
BOREHOLE DIAMETER No. 1: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS METHOD: HSA SSA BKA JET DRT RRT COR DAW CBT DCD DHH SON OTHER: _____ FLUID: AIR - WATER - MUD - FOAM - NONE		
BOREHOLE DIAMETER No. 2: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS METHOD: HSA SSA BKA JET DRT RRT COR DAW CBT DCD DHH SON OTHER: _____ FLUID: AIR - WATER - MUD - FOAM - NONE		
BOREHOLE DIAMETER No. 3: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS METHOD: HSA SSA BKA JET DRT RRT COR DAW CBT DCD DHH SON OTHER: _____ FLUID: AIR - WATER - MUD - FOAM - NONE		
DRILLING/EXCAVATING CO.: _____ DRILLER/OPERATOR: _____ EQUIPMENT/RIG: _____		
COMMENTS: _____ _____ _____ _____ _____		
DATA ENTRY BY: _____ DATE ENTERED: _____ QC REPORTS PRINTED ? YES - NO	QC REVIEW BY: _____ REVIEW DATE: _____ APPROVED WITH - WITHOUT REVISIONS	QA REVIEW BY: _____ REVIEW DATE: _____ APPROVED WITH - WITHOUT REVISIONS

Figure B-2

GEOLIS[®] Borehole Logging Form

COMPANY: _____		LOCATION ID: _____		
CLIENT: _____		DATE: _____		
PROJECT: _____		LOGGER: _____		
SITE / AREA: _____		SIGNATURE: _____		

SAMPLING METHOD: SPS - CSS - STB - CTS - CUT - COR - NS		FLUID ENTRY/ LOSS ZONES: _____ FT/M BGS _____ GPM	
OTHER: _____		ANALYTICAL SAMPLE ID _____ INTERVAL (FT/M BGS) _____	
SAMPLING INTERVAL: _____ TO _____ FT/M BGS			
RECOVERY: _____ / _____ FT/M NA			
BLOW COUNT: / IN/CM NA		TYPE / LAB: UND - DIS - CMP / MOB - GEO - CHM - _____	
RQD: _____ % NA		TYPE / LAB: UND - DIS - CMP / MOB - GEO - CHM - _____	

SAMPLING INTERVAL No.: _____		LITHOLOGY ARCHIVED? YES - NO NO RECOVERY	MATERIAL: NATURAL - FILL - UNCERTAIN	
LITHOLOGIC INTERVAL No.: _____			OBSERVED: STN - SHN - ODR - PRD - NA - OTHER: _____	
LITHOLOGIC INTERVAL: _____ TO _____ FT/M BGS			INSTRUMENT 1 TYPE: _____ READING: _____	
			INSTRUMENT 2 TYPE: _____ READING: _____	

OVERBURDEN SECONDARY TYPE: NA - BED - CLS - MIX COLOR: MUN - GSA _____ COLORATION: UNI - STN - MOT - VAR BOULDERS: _____ % MAX DIAM: _____ IN COBBLES: _____ % MAX DIAM: _____ IN TEXTURE: C - M - F GRAVEL: _____ % _____ % SAND: _____ % _____ % SILT: _____ % _____ % CLAY: _____ % _____ % ORGANIC: _____ % _____ % ROUNDNESS: GRAVEL: FAC - STR - ANG - SUB - RND - NA SAND: ANG - SUB - RND - NA SORTING: WEL - MOD - POR - NA PLASTICITY: NON - LOW - MOD - HGH - NA MOISTURE: DRY - MST - WET - SAT - NA CEMENTATION: NON - SLT - MOD - WEL - NA GRAIN TYPE: QTZ - FRG - FOS - BIO - NA MATRIX: MSM - CSM - CAL - OXD - ARG - SIL - NA STRENGTH: COHESIVE: VSF - SFT - FRM - STF - VST - HRD NONCOHESIVE: VDN - DEN - FIR - LSE - NA UPPER CONTACT: SHP - GRD - DIF - SME - NA BEDDING THICK: _____ IN/CM No.: _____ TYPE: XBD - RPL - HOR - INC - NA MAS - LNS - LAM - GRU - GRD	GRAPHIC LOG	BEDROCK SECONDARY TYPE: NA - BED - VEN - MIX COLOR: MUN - GSA _____ ROCK TYPE: OTHER: _____ SED: SHL - SLT - SST - CGL - LST - DOL - COL MET: SLA - PHY - SHS - GNS - HRN - QZT - MBL IGN: GRN - RHY - BSL - GBR - TUF - BRC TEXTURE: C - M - F NA GRAVEL: _____ % _____ % SAND: _____ % _____ % SILT: _____ % _____ % CLAY/LIME MUD: _____ % _____ % GRAIN TYPE: QTZ - FRG - FOS - BIO - NA MATRIX: CAL - MIC - OXD - ARG - SIL - ORG - NA STRENGTH: EWK - VWK - WEK - MOD STR - VST - EST UPPER CONTACT: SHP - GRD - DIF - SAM - NA SECONDARY VUG - FRC - BED - NA - OTHER POROSITY: HGH - MOD - LOW WEATHERING: FRS - SLT - MOD - HGH - CPL - NA
---	-------------	---

NATURAL FRACTURE SETS				
INTERVAL (FT/M BGS)	#/FT-M	DIP	DIR	FILL/SHAPE/ROUGH/SURFACE
---				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
---				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
---				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
---				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH

STRAT UNIT:		NOT SAMPLED	NO RECOVERY
NOTE LINE:			

SAMP/LITH No.	DEPTH INTERVAL	NOT SAMPLED	NO RECOVERY
_____ / _____	_____ TO _____		

COMMENTS: (1) _____

(2) _____

GEOLIS[®] Well Construction Form

Sheet _____ of _____

COMPANY: _____		LOCATION ID: _____		
PROJECT: _____		DATE: _____		
PROPERTY: _____		LOGGER: _____		
SITE/AREA: _____ / _____		SIGNATURE: _____		

START DATE: _____	SURVEYED ELEVATIONS (MSL)	DEPTH TO WATER	DATE / TIME
COMPLETION DATE: _____	GROUND LEVEL: _____ FT/M	_____ FT/M(TOC)	
WELL STATUS: PMP - ABN - COL - NOR	MEASURING POINT (TOP OF CASING): _____ FT/M	_____ FT/M(TOC)	
STATUS DATE: _____		_____ FT/M(TOC)	

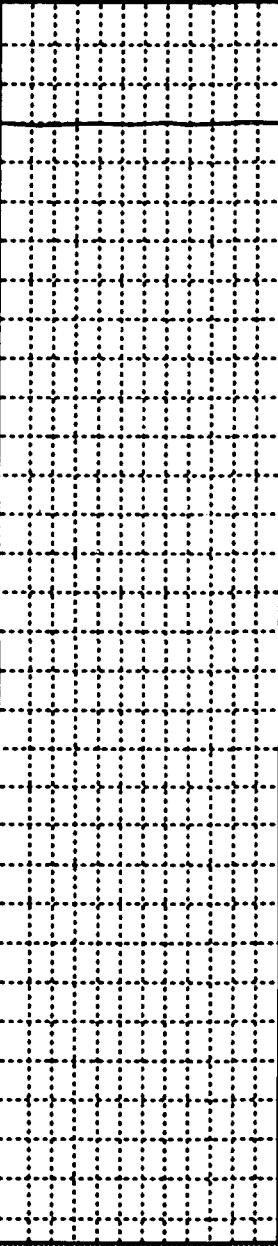
WELL DIAGRAM - NOT TO SCALE	DEPTH (FT BGS)	WELL CODE	WELL TYPE	
	0	GRS	SCREEN - MULTIPLE SCREEN - OPEN HOLE - NESTED - PROBE	
			CASING: SINGLE - DOUBLE - TRIPLE COMPLETION: FLUSH - PROT - VAULT - CAP - NA	
			TOTAL NO. OF SCREENS/WELLS: _____ SCREEN/WELL NO: _____	
			WELL USE: DOM - PUB - IRR - FIR - MON - HYD - EXT - DEW - RCH - VEW - INJ - OTH	
			WELL DESIGN CONSTRUCTION	
			CASING #1 (INNERMOST): DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS	
			TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____	
			CASING JOINTS: FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: _____	
			CASING #2: DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS	
			TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____	
CASING #3 (OUTERMOST): DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS				
TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____				
STICK UP: INNER CASING _____ FT/M OUTER CASING _____ FT/M				
GROUT: TYPE: CMT - C/B - BEN - HSB - OTH: _____				
INTERVAL: _____ TO _____ FT/M BGS				
PLACEMENT: TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: _____				
SEAL: TYPE 1: _____ INTERVAL: _____ TO _____ FT/M BGS				
TYPE 2: _____ INTERVAL: _____ TO _____ FT/M BGS				
SAND PACK: TYPE: _____ INTERVAL: _____ TO _____ FT/M BGS				
SCREEN OR DEVICE: DIAMETER: _____ IN/MM INTERVAL: _____ TO _____ FT/M BGS				
TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: _____				
SLOTS: CON - SLH - SLV - BRG - CUT - OTH: _____				
SLOT SIZE: 6 - 10 - 20 - 30 - 40 - _____ SLOT: _____				
STRAT UNIT MONITORED: _____				
ESTIMATED WELL YIELD: _____ GPM/LPM DRAWDOWN: _____ FT/M BMP				
WATER SAMPLING SYSTEM: NON - PMP - PKR - MLS TYPE: _____				
SEAL INTERVAL: _____ TO _____ FT/M BGS INTAKE DEPTH: _____ FT/M BGS				
NOTES: _____				
OPEN HOLE: DIAMETER 1: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS				
DIAMETER 2: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS				
SILT TRAP/SUMP: YES - NO INTERVAL: _____ TO _____ FT/M BGS				
INSIDE WELL T D: _____ FT/M BGS COLLAPSE/BACKFILL: COL - BFL - BTH - NON				
COLLAPSE INTERVAL: _____ TO _____ FT/M BGS				
BACKFILL INTERVAL: _____ TO _____ FT/M BGS TYPE: _____				
WELL CONSTRUCTION CODES				
GRS = GROUND SURFACE TSC = TOP OF SCREEN BPC = BOTTOM OF PROTECTIVE CASING TST = TOP OF SILT TRAP TBS = TOP OF BENTONITE SEAL WTD = TOTAL DEPTH INSIDE WELL TBR = TOP OF BEDROCK BTD = BOREHOLE TOTAL DEPTH BOC = BOTTOM OF OUTER CASING TOC = TOP OF CASING (INNER) TSP = TOP OF SAND PACK BGS = BELOW GROUND SURFACE				
COMMENTS: _____				

Figure B-4

GEOLIS® Multi-Screen Well Form

Sheet _____ of _____



COMPANY: _____		LOCATION ID: _____	
PROJECT: _____		DATE: _____	
PROPERTY: _____		LOGGER: _____	
SITE/AREA: _____ / _____		SIGNATURE: _____	

WELL DIAGRAM - NOT TO SCALE	DEPTH (FT. BGS)	WELL CODE	MULTIPLE SCREEN CONSTRUCTION	SCREEN No.: _____
			CASING #1 (INNERMOST) DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS	
			TYPE PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____	
			CASING JOINTS FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: _____	
			GROUT: TYPE: NON - CMT - C/B - BEN - HSB - OTH: _____	
			INTERVAL: _____ TO _____ FT/M BGS	
			PLACEMENT TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: _____	
			SEAL: TYPE 1: _____ INTERVAL: _____ TO _____ FT/M BGS	
			TYPE 2: _____ INTERVAL: _____ TO _____ FT/M BGS	
			SAND PACK: TYPE: _____ INTERVAL: _____ TO _____ FT/M BGS	
			SCREEN OR DEVICE DIAMETER: _____ IN/MM INTERVAL: _____ TO _____ FT/M BGS	
TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: _____				
SLOTS CON - SLH - SLV - BRG - CUT - OTH: _____				
SLOT SIZE 6 - 10 - 20 - 30 - 40 - _____ SLOT				
STRAT UNIT MONITORED: _____				
ESTIMATED WELL YIELD: _____ GPM/LPM DRAWDOWN: _____ FT/M BMP				
WATER SAMPLING SYSTEM: NON - PMP - PKR - MLS TYPE: _____				
SEAL INTERVAL: _____ TO _____ FT/M BGS INTAKE DEPTH: _____ FT/M BGS				
NOTES: _____				
COMMENTS: _____				
			MULTIPLE SCREEN CONSTRUCTION	
			SCREEN No.: _____	
			CASING #1 (INNERMOST) DIAMETER: _____ IN/CM INTERVAL: _____ TO _____ FT/M BGS	
			TYPE PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____	
			CASING JOINTS FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: _____	
			GROUT: TYPE: NON - CMT - C/B - BEN - HSB - OTH: _____	
			INTERVAL: _____ TO _____ FT/M BGS	
			PLACEMENT TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: _____	
			SEAL: TYPE 1: _____ INTERVAL: _____ TO _____ FT/M BGS	
			TYPE 2: _____ INTERVAL: _____ TO _____ FT/M BGS	
SAND PACK: TYPE: _____ INTERVAL: _____ TO _____ FT/M BGS				
SCREEN OR DEVICE DIAMETER: _____ IN/MM INTERVAL: _____ TO _____ FT/M BGS				
TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: _____				
SLOTS CON - SLH - SLV - BRG - CUT - OTH: _____				
SLOT SIZE 6 - 10 - 20 - 30 - 40 - _____ SLOT				
STRAT UNIT MONITORED: _____				
ESTIMATED WELL YIELD: _____ GPM/LPM DRAWDOWN: _____ FT/M BMP				
WATER SAMPLING SYSTEM: NON - PMP - PKR - MLS TYPE: _____				
SEAL INTERVAL: _____ TO _____ FT/M BGS INTAKE DEPTH: _____ FT/M BGS				
NOTES: _____				
COMMENTS: _____				

[illegible]



COMPANY: _____
PROJECT: _____
PROPERTY: _____
SITE/AREA: _____

LOCATION NO.: _____

DATE: _____

LOGGER: _____

SIGNATURE: _____

[illegible]

GEOLIS_R Sketches Form

COMPANY: _____ PROJECT: _____ PROPERTY: _____ SITE/AREA: _____	LOCATION NO.: _____ DATE: _____ LOGGER: _____ SIGNATURE: _____	
--	--	---

GEOLIS_® Notes and Sketches Form

COMPANY: _____ PROJECT: _____ PROPERTY: _____ SITE/AREA: _____	LOCATION NO.: _____ DATE: _____ LOGGER: _____ SIGNATURE: _____
--	--



GEOLIS® Soil/Sediment Sampling Form

COMPANY: _____ LOCATION ID: _____
 PROJECT: _____ DATE: _____
 PROPERTY: _____ SAMPLER: _____
 SITE/AREA: _____ / _____ SIGNATURE: _____

ESTIMATED / GPS SURVEYED
 SURFACE ELEVATION: _____
 N. COORDINATE: _____
 E. COORDINATE: _____
 LOCATION TYPE: SSS - SED - BOR - PIT - OTH: _____
 GRID COORD.: _____ / _____ GRID ID: _____ NA
 GROUND SLOPE: FLT - SLI - MOD - STP - NA
 WATER BODY/SOIL SERIES NAME: _____

WATER TYPE: LAK - PND - EST - RVR - STP - STI - LAG - PIP - CHN - WET
 NA - OTH: _____ FLOW: FLD - FUL - LOW - POO - DRY - NA
 WATER DEPTH: _____ FT-M BMP VELOCITY: NON - LOW - MOD - HGH

SAMPLING INFORMATION

SAMPLE ID: _____
 COLLECTION TIME (24:00) _____
 SAMPLE DEPTH INTERVAL: _____ TO _____ FT-M BGS
 SAMPLE TYPE: DISCRETE - COMPOSITE - OTH: _____
 PURPOSE: BKG - RSK - GEO - EXP - CHR - REM - OTH: _____
 ASSOCIATED WATER SAMPLE ID: _____
 SAMPLING METHOD: TRL - SPT - BLP - DRG - BUC - SPS - CSS - STS
 CUT - CTS - COR - OTH: _____
 SAMPLER DECONTAMINATION: DED - LAB - FLD - NON
 (1)DET - (2)STM - (3)ACE - (4)HEX - (5)MET - (6)DIW - (7)POT - (8)NO3
 (9)OTH: _____ SEQUENCE: _____
 SAMPLING PROCEDURES USED: NON - SAP/QAPP - SOP - OTH
 REFERENCE: _____
 CHAIN-OF-CUSTODY No.: _____
 QA SAMPLES: MS/MSD SAMPLE COLLECTED: YES - NO
 DUPLICATE ID: _____
 TRIP BLANK ID: _____
 AMBIENT/RINSE BLANK ID: _____

SITE SKETCH**SAMPLE DESCRIPTION**

MATERIAL: NAT - FIL - PRD - SDG - UNC - OTH: _____
 ODOR: NOR - SEW - PET - CHM - ANB - NON - OTH: _____
 SHEEN/STAIN (2): NON - SLI - MOD - HVY PET - IRN - BAC - OTH
 INST. 1 TYPE: _____ READING: _____ UNITS: _____
 INST. 2 TYPE: _____ READING: _____ UNITS: _____
 SURFACE LAYER: SOL - GRS - LVS - VEG - GVL - ASP - CMT - FIL
 OTHER: _____
 THICKNESS (IN/CM): _____ REMOVED - SAMPLED
 SECONDARY TYPE: NA - BED - CLS - MIX
 OVERALL COLOR: MUN - GSA - NON WET - DRY

 COLORATION: UNI - STN - MOT - VAR
 TEXTURE: % C - M - F - VF
 GRAVEL: _____ % _____ %
 SAND: _____ % _____ %
 SILT: _____ % _____ %
 CLAY: _____ % _____ %
 ORGANIC: _____ % _____ %
 ROUNDNESS:
 GRAVEL: FAC - ANG - SBA - SBR - RND - NA
 SAND: ANG - SBA - SBR - RND - NA
 SORTING: BIM - WEL - MOD - POR - NA
 PLASTICITY: NON - LOW - MOD - HGH - NA
 MOISTURE: DRY - MST - WET - SAT
 STRENGTH: NONCOHESIVE: LSE - FIR - DEN - VDN
 COHESIVE: VSF - SFT - FRM - STF - VST - HRD

ANALYTICAL PARAMETERS

LAB NAME

CHM: VOC - BNA - PES - PCB - HRB - PHE - TOC - TPH - MET - OTH: _____
 CHM: VOC - BNA - PES - PCB - HRB - PHE - TOC - TPH - MET - OTH: _____
 TCLP: VOC - BNA - PES - HRB - MET - OTH: _____
 RAD/OTH: GAL - GBT - GGM - SAL - TRT - ASB - OTH: _____
 GEOTECH: GRA - SPG - ATL - POR - PRM - CON - CMP - SHR - OTH: _____

SPLIT SAMPLES: NON - CLI - OWN - OVR - OTH: _____ SPLIT SAMPLE ID NO.: _____
 ORGANIZATION NAME: _____ PARAMETERS: SAME - OTHER: _____
 REPRESENTATIVES NAME: _____ QA/QC SAMPLES: NON - DUP - RNS - TRP - MSD

COMMENTS: _____

GEOLIS® Soil Boring Sampling Form

COMPANY _____ PROJECT _____ PROPERTY _____ SITE/AREA _____ / _____	LOCATION ID: _____ DATE: _____ SAMPLER: _____ SIGNATURE: _____	
---	---	---

SAMPLING INFORMATION

SAMPLER DECONTAMINATION: _____	DED - LAB - FLD - NON	QA SAMPLES										
(1)DET - (2)STM - (3)ACE - (4)HEX - (5)MET - (6)DIW - (7)POT - (8)NO3												
(9)OTH _____ - (10)OTH: _____												
SEQUENCE <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td></tr></table>												
SAMPLING PROCEDURES USED: _____	NON - SAP/QAPP - SOP - OTH											
REFERENCE _____												
CHAIN-OF-CUSTODY No: _____												

	DUPLICATE ID	
	TRIP BLANK ID	
	RINSE BLANK ID	

SAMPLE ID	COLLECTION TIME (24:00)	DEPTH INTERVAL FT/M BGS	SAMPLE TYPE	SAMPLE PURPOSE	SAMPLING METHOD	ANALYTICAL PARAMETER CODES OR SET No
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			
			DIS - CMP			

SAMPLING METHOD	SAMPLE PURPOSE
SPS - CSS - STS - CUT - CTS - COR - OTH _____	BKG - RSK - GEO - EXP - CHR - REM - OTH _____

ANALYTICAL PARAMETERS	LAB NAME
#1 VOC - BNA - PES - PCB - HRB - PHE - TOC - TPH - MET - OTH _____	_____
#2 VOC - BNA - PES - PCB - HRB - PHE - TOC - TPH - MET - OTH _____	_____
#3 VOC - BNA - PES - PCB - HRB - PHE - TOC - TPH - MET - OTH _____	_____
#4 TCLP VOC - BNA - PES - HRB - MET - OTH _____	_____
#5 RAD GAL - GBT - GGM - SAL - TRT - OTH _____	_____
#6 GEOTECH GRA - SPG - ATL - POR - PRM - CON - CMP - SHR - OTH _____	_____

SPLIT SAMPLES NON - CLI - OWN - OVR - OTH _____	SPLIT SAMPLE ID NO:
ORGANIZATION NAME: _____	PARAMETERS SAME - OTHER _____
REPRESENTATIVES NAME: _____	QA/QC SAMPLES: NON - DUP - RNS - TRP - MSD

COMMENTS _____

Figure B-12

GEOLIS_R Test Pit Logging Form

COMPANY: _____		LOCATION ID: _____		
CLIENT: _____		DATE: _____		
PROJECT: _____		LOGGER: _____		
SITE/AREA: _____		SIGNATURE: _____		

SOIL SERIES: _____		TOTAL DEPTH: _____ FT-M	
PARENT MATERIAL: ALL - RES - COL - LOS - OTHER: _____		DEPTH DETERMINED BY: PRU - WAT - CFR - MRB - OTH	
SOIL DRAINAGE CLASS: VPD - PRD - SPD - MWD - WLD - SED - EXD		DEPTH TO STANDING WATER: _____ FT-M	
PROPOSED USE: _____		WATER ENTRY ZONES	
LIMITING ZONE:		DEPTH FT/M BGS FLOW RATE GPM/LPM WALL	
TYPE: BED - MOT - FRG - HCF - WAT - NON			
DEPTH: _____			

SOIL HORIZON No.: _____		MATERIAL: NATURAL - FILL - UNCERTAIN	
SOIL HORIZON		APPEARANCE: SHN - ODR - PRD - NA - OTHER: _____	
INTERVAL: _____ TO _____ FT-M BGS		INSTRUMENT 1 TYPE: _____ READING: _____	
HORIZON DESIGNATION: _____		INSTRUMENT 2 TYPE: _____ READING: _____	

SAMPLE ID	INTERVAL (FT-M BGS)	TIME	TYPE	PARAMETERS
_____	_____	_____	TYPE: SMP - COL - SPL - RNS - LCS - OTH _____	
_____	_____	_____	DESTINATION: CHM - RAD - GEO - ARC - OTH _____	
_____	_____	_____	TYPE: SMP - COL - SPL - RNS - LCS - OTH _____	
_____	_____	_____	DESTINATION: CHM - RAD - GEO - ARC - OTH _____	

SECONDARY TYPE: NA - BED - CLS - MIX OVERALL COLOR: _____ MUN - GSA WET - DRY COLORATION: UNI - STN - MOT - VAR DRAINAGE MOTTLING: NONE INTERVAL: _____ TO _____ FT/M BGS ABUNDANCE: FEW - CMN - MNY CONTRAST: FNT - DIS - PRM COLOR: HIGH CHROMA: _____ LOW CHROMA: _____ 50/50 MATRIX: YES - NO PEDON STRUCTURE: TYPE: PLT - PRS - COL - BLK - ABK SBK - GRN - SGR - MAS GRADE: SLI - WEK - MOD - STR DRY CONSISTENCE: LSE - SFT - SLH HRD - VHD - EHD MOIST CONSISTENCE: LSE - VFB - FRB FRM - VFM - EFM TEXTURE: COARSE MATERIAL: _____ % SAND: C - M - F _____ % SILT: _____ % CLAY: _____ % ORGANIC: _____ %	GRAPHIC LOG	COARSE FRAGMENTS: ROUNDED: GRA - COB - STN - BLD FLAT: CHN - FLG - STN - BLD ROUNDNESS: GRAVEL: FAC - STR - ANG - SUB - RND - NA SAND: ANG - SUB - RND - NA SORTING: WEL - MOD - POR - NA PLASTICITY: NON - LOW - MOD - HGH - NA MOISTURE: DRY - MST - WET - SAT CEMENTATION: NON - SLT - MOD - WEL GRAIN TYPE: QTZ - FRG - FOS - NA MATRIX: CAL - OXD - ARG - SIL - NA STRENGTH: NONCOHESIVE: DNS - FRM - LSE COHESIVE: STF - FRM - SFT - HRD LOWER CONTACT: DISTINCTNESS: ABT - CLR - GRD - DIF TOPOGRAPHY: SMT - WYV - IRR - DIS BEDDING: THICKNESS: _____ IN/CM NUMBER: _____ TYPE: XBD - RPL - HOR - INC - NA MAS - LNS - LAM - GRU - GRD STRAT UNIT: _____ NOTE LINE: _____
---	-------------	---

COMMENTS: _____

GEOLIS_R Water Level Form

Figure B-13

COMPANY		LOCATION ID (SEE FIRST COLUMN ON THE LEFT)			
CLIENT		DATE			
PROJECT		MEASURED BY			
SITE/AREA		SIGNATURE			

LOCATION ID	TIME	DEPTH TO WATER (ft)	DEPTH TO PRODUCT (ft)	DEPTH TO BOTTOM (ft)	BOTTOM CONDITION CODE	LEVEL STATUS CODE	LOCATION TYPE CODE	MEASURING POINT CODE	FIELD MEASURE CODE

COMMENTS:

BUC - UNCASSED BORING WOH - OPEN HOLE WELL WSC - SCREENED WELL OR PIEZOMETER TPO - OPEN TEST PIT STR - RIVER/STREAM SPR - SPRING/SEEP OTH -	STA - STATIC WDV - DURING DEVELOPMENT PPR - POST PURGE TPP - PUMP TEST/PUMPED WELL TPO - PUMP TEST/MONITOR WELL TSR - SLUG TEST/RISING HEAD TSF - SLUG TEST/FALLING HEAD TAP - PACKER TEST/PUMPED ZONE TAO - PACKER TEST/OBSERVED ZONE OTH -	TIC - TOP OF INNER CASING TOC - TOP OF OUTER CASING ELM - ELEVATION MARKER GRS - GROUND SURFACE OMP - OTHER FRM - FIRM BOTTOM SFT - SOFT BOTTOM DRY - DRY BOTTOM NO WATER	MTP - TEMPERATURE MSC - SPECIFIC CONDUCTANCE MPD - PHOTOIONIZER (e.g. HNU) MFD - FLAME IONIZER (e.g. OVA) MOO - DISSOLVED OXYGEN MPH - pH MEH - Eh MO1 - Other MO2 - Other
--	---	--	--

Figure B-14

GEOLIS® Well Purging Form

COMPANY _____ CLIENT _____ PROJECT _____ SITE / AREA _____	LOCATION ID _____ DATE _____ SAMPLER _____ SIGNATURE _____	
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WELL OBSERVATIONS

CASING & LID: OK - DAMAGED - HEAVED - NO LID LOCKED: YES - NO KEY NO. _____ STICKUP: _____ FT-M
 WELL DIAMETER: 2" - 4" - 6" - 8" - OTH: _____ BOREHOLE DIAMETER: _____ IN-CM MEASURING POINT: TIC - TOC - GRS
 VAPOR READINGS: PID - FID - OTHER: _____ BACKGROUND: _____ INSIDE WELL: _____
 CHECKED FOR NAPL LAYER: YES - NO OBSERVED NON - FLT - SNK THICKNESS: _____ IN-CM SHEEN YES - NO

PURGING CALCULATIONS

(A) DEPTH TO WELL BOTTOM _____ FT-M BMP	Casing Factor (GPF for inches) = $0.041(\text{Well Diameter})^2$ 2" = 0.16; 4" = 0.65; 6" = 1.47; 8" = 2.61 GPF
(B) DEPTH TO WATER: _____ FT-M BMP	
(C) SAND PACK LENGTH _____ FT-M	Sand Pack Factor (GPF for inches) = $[0.041(\text{Hole Diameter})^2 - 0.041(\text{Well Diameter})^2] 0.45$
(D) WATER COLUMN HEIGHT (A - B): _____ FT-M	
(E) CASING VOLUME FACTOR: _____ GPF-LPM	(I) TOTAL WELL VOLUME (G + H) _____ GAL-L
(F) SAND PACK VOLUME FACTOR: _____ GPF-LPM	(J) VOLUMES TO BE PURGED: _____
(G) CASING VOLUME (D x E): _____ GAL-L	(K) TOTAL PURGE VOLUME (I x J): GAL-L
(H) SAND PACK VOLUME (C x F): _____ GAL-L	

PURGING INFORMATION

PURGE ENDPOINT: VOLUME - TIME - PARAMETER STABILIZATION - TURBIDITY CRITERIA: _____
 PURGING METHOD: BAILER - SUB. PUMP - CENT. PUMP - PACKER & PUMP - OTHER: _____
 DEVICE DESCRIPTION: _____ DEVICE No.: _____
 PUMP/BAILER INTAKE: SCREEN TOP - SCREEN/WELL BOTTOM - MID SCREEN/WELL - WATER LEVEL - MOVED UP/DOWN
 PURGE WATER: DISCHARGED - TREATED - STORED ONSITE STORED IN: TANKS - DRUMS NO. _____
 FIELD MEASUREMENTS IN: FLOW THRU CHAMBER - OPEN JAR CASCADING WATER: YES - NO DEPTH: _____ FT-M BMP
 WELL PURGING INTERVAL: _____ TO _____ FT-M BMP PURGE DEPTH TO WATER (MAX): _____ FT-M BMP

TIME	DEPTH TO WATER (FT-M BMP)	PURGE RATE or VOLUME (GPM-GAL)	TURBIDITY (NTU)	FIELD MEASUREMENTS AND UNITS						COMMENTS
				MTP						
				°C.						
										Pre Purge Readings
										Post Purge Readings

TOTAL PURGE TIME: _____ HRS TOTAL PURGE VOLUME: _____ GAL - L RECOVERY: FAST - SLOW - V. SLOW

FIELD MEASUREMENT CODES

MTP - Temperature (°C.)	MCL - Color	MDO - Dissolved Oxygen (mg/L)	MD1 - DTW in Well _____
MSC - Specific Conductance (mS/cm)	MPH - pH	MO1 - Other: _____	MD2 - DTW in Well _____
MPD - Photoionizer (e.g., HNu)	MEH - Eh	MO2 - Other: _____	MD3 - DTW in Well _____
MFD - Flame Ionizer (e.g., OVA)	MAL - Alkalinity	MO3 - Other: _____	MD4 - DTW in Well _____

GEOLIS® Water Sampling Form

Figure B-15

COMPANY _____ PROJECT _____ PROPERTY _____ SITE/AREA _____ / _____	LOCATION ID _____ DATE _____ SAMPLER _____ SIGNATURE _____																																																					
SITE SKETCH 	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 60%;"></th> <th style="width: 20%;">ESTIMATED/GPS</th> <th style="width: 20%;">SURVEYED</th> </tr> <tr> <td>SURFACE ELEVATION</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>N COORDINATE</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>E COORDINATE</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>WELL PERMIT No.</td> <td colspan="2">_____</td> </tr> <tr> <td>MEASURING POINT</td> <td colspan="2">TOC - TSG - WAT - OTH _____</td> </tr> </table>			ESTIMATED/GPS	SURVEYED	SURFACE ELEVATION	_____	_____	N COORDINATE	_____	_____	E COORDINATE	_____	_____	WELL PERMIT No.	_____		MEASURING POINT	TOC - TSG - WAT - OTH _____																																			
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WELL PERMIT No.	_____																																																					
MEASURING POINT	TOC - TSG - WAT - OTH _____																																																					
SAMPLING INFORMATION SAMPLE ID: _____ COLLECTION TIME (24 00) _____ : _____ DURATION HRS:MIN _____ : _____ SAMPLE DEPTH FT-M BMP _____ SAMPLING QTR/ROUND _____ SAMPLE PURPOSE: BKG - SCR - RSK - RND - SDW - CON - OTH _____ SAMPLE TYPE: DISCRETE - COMPOSITE - OTHER: _____ SAMPLING METHOD GROUNDWATER: BLO - BLC - PSB - PPR - PCN - PBL - NLF - MLS SURFACE WATER: BOT - KEM - BCB - SCP - TGS OTHER: _____ SAMPLER DECONTAMINATION: DED - LAB - FLD - NON (1)DET - (2)STM - (3)ACE - (4)HEX - (5)MET - (6)DIW - (7)POT - (8)NO3 (9)OTH: _____ SEQUENCE: _____ SAMPLING PROCEDURES USED: NON - SAP/QAPP - SOP - OTH REFERENCE: _____ QA SAMPLES: _____ MS/MSD SAMPLE COLLECTED: YES - NO DUPLICATE ID: _____ TRIP BLANK ID: _____ AMBIENT - RINSE BLANK ID: _____ CHAIN-OF-CUSTODY No.: _____ 48 HOUR PRECIPITATION: NON - LTE - MOD - HVY CUR - 8 - 16 - 24 - _____ HOURS PRIOR TO SAMPLING WELL PURGE RECOVERY: _____ % OF INITIAL WATER LEVEL	SAMPLE DESCRIPTION GROUNDWATER: WOS - WBS - WBO - SUP - RES - BOR - HYD - SPR SEP - PIT - SMP - OTH: _____ SURFACE WATER: TAL - LAK - PND - RVM - RVB - RVS - STP - STI - WET OUB - INB - LAG - PIP - SWR - CUL - CHN - DCH - OTH _____ SAMPLED: WATER - NAPL/PRODUCT - OTH _____ WATER BODY/FORMATION NAME: _____ FLOW: FLD - FUL - LOW - POO - DRY - NA WIDTH _____ FT-M DEPTH: _____ FT-M VELOCITY _____ FT/S-M/S VELOCITY METHOD: MMB - PYG - DYE - OBJ - EST WATER COLOR: CLR - LBN - MBN - DBN - TUR - GRE - STN NAPL LAYER PRESENT: NO - FLT - SNK THICKNESS _____ IN-CM SHEEN YES - NO DESCRIPTION: _____																																																					
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">FIELD PARAMETERS:</th> <th style="width: 10%;">UNITS</th> <th style="width: 20%;">BEFORE</th> <th style="width: 20%;">AFTER</th> </tr> </thead> <tbody> <tr><td>TIME</td><td>24 00</td><td></td><td></td></tr> <tr><td>WATER LEVEL (BMP)</td><td>FT-M</td><td></td><td></td></tr> <tr><td>TEMPERATURE</td><td></td><td></td><td></td></tr> <tr><td>SP CONDUCTANCE</td><td></td><td></td><td></td></tr> <tr><td>pH</td><td></td><td></td><td></td></tr> <tr><td>EH</td><td></td><td></td><td></td></tr> <tr><td>DISS. OXYGEN</td><td></td><td></td><td></td></tr> <tr><td>PID / FID</td><td></td><td></td><td></td></tr> <tr><td>ALKALINITY</td><td></td><td></td><td></td></tr> <tr><td>TURBIDITY</td><td></td><td></td><td></td></tr> <tr><td>FERROUS IRON (Fe2+)</td><td></td><td></td><td></td></tr> <tr><td>CARBON DIOXIDE (CO2)</td><td></td><td></td><td></td></tr> </tbody> </table>			FIELD PARAMETERS:	UNITS	BEFORE	AFTER	TIME	24 00			WATER LEVEL (BMP)	FT-M			TEMPERATURE				SP CONDUCTANCE				pH				EH				DISS. OXYGEN				PID / FID				ALKALINITY				TURBIDITY				FERROUS IRON (Fe2+)				CARBON DIOXIDE (CO2)			
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ANALYTICAL PARAMETERS CHM VOC - BNA - PES - PCB - HRB - PHE - TOC - UMT - FMT - ION - SOL - INO - OTH CHM VOC - BNA - PES - PCB - HRB - PHE - TOC - UMT - FMT - ION - SOL - INO - OTH RADIO/TH GAL - GBT - GGM - SAL - TRT - ASB - OTH _____		LAB NAME _____ _____																																																				
SPLIT SAMPLES: NON - CLI - OWN - OVR - OTH: _____ ORGANIZATION NAME: _____ REPRESENTATIVES NAME: _____		SPLIT SAMPLE ID NO.: _____ PARAMETERS: SAME - OTHER: _____ QA/QC SAMPLES: NON - COL - RNS - TRP - MSD																																																				
COMMENTS: _____ _____																																																						

SAMPLE ATTRIBUTE FORM**LOCATION ID**

--	--	--	--	--	--	--	--

GPS:	Yes	GPS Comment:
	No	

Location Description Codes (circle one)			
BB	Soil Boring – TD in Bedrock	MUA	Monitoring Well – Screens Upper Alluvium
BF	Soil Boring – TD in Fill	MW	Monitoring Well – Screens Water Table
BG	Soil Boring – TD in Glacial Till	MWT	Monitoring Well – Screens Water Table and Till
BL	Soil Boring – TD in Lower Alluvium	PW	Public/Residential Well
BM	Soil Boring – TD in Middle Alluvium	RW	Recovery Well
BT	Soil Boring – TD in Top of Till	SF	Surface/Shallow Soil – Floodplain
BU	Soil Boring – TD in Upper Alluvium	SP	Surface/Shallow Soil – Paved/Covered
BW	Soil Boring – TD at Water Table	SR	Surface/Shallow Soil – Riverbank
DL	Sediment – Lake or Pond	SU	Surface/Shallow Soil – Unpaved
DO	Sediment – at Sewer/Pipe Outfall	TB	Tissue Sample – Brain
DR	Sediment – River/Stream	TF	Tissue Sample – Fillet
MB	Monitoring Well – Screens Bedrock	TL	Tissue Sample – Liver
MFW	Monitoring Well – Screens Fill and Water Table	TO	Tissue Sample – Offal
MG	Monitoring Well – Screens Within Till	TR	Tissue Sample – Breast
MLU	Monitoring Well – Screens Lower Alluvium	TW	Tissue Sample – Whole Body
MMA	Monitoring Well – Screens Middle Alluvium	WS	Surface Water Sample
MT	Monitoring Well – Screens Top of Till	WSD	Surface Water Suspended Sediment Sample – Multiple Depths
Physical Location Description (e.g., Riverbank: Top of Slope)			

<u>Site</u>	<u>Location ID</u>	<u>QC type</u>	<u>Start Depth or Date collected</u>	<u>Depth</u>		<u>If the Sample is Split:</u>
				<u>(in Tenths of Feet)</u> <u>Starting</u>	<u>Ending</u>	
_____	_____	_____	_____	_____	_____	Split To:
Comments: (e.g., refusal below this depth)						Split Sample ID:
_____	_____	_____	_____	_____	_____	Split To:
Comments:						Split Sample ID:
_____	_____	_____	_____	_____	_____	Split To:
Comments:						Split Sample ID:
_____	_____	_____	_____	_____	_____	Split To:
Comments:						Split Sample ID:
_____	_____	_____	_____	_____	_____	Split To:
Comments:						Split Sample ID:
Relinquished By		Received By		Date	Time	

Appendix C

APPENDIX C

FIELD SCREENING INSTRUMENT CALIBRATION PROCEDURES

APPENDIX C

FIELD SCREENING INSTRUMENT CALIBRATION PROCEDURES

The field equipment will be properly calibrated, charged, and in good general working condition prior to the start of each workday.

All field instruments will be appropriately protected against inclement weather during the field investigation. Each instrument is especially designed to maintain its operating integrity during variable temperature ranges representative of those that will be encountered at the site. At the end of each workday, all field equipment will be stored in a cool, dry room. Prior to the start of work each day, the LM will inspect all equipment for fluid leaks. If a leak is detected, the equipment will be removed from service for repair or replacement, and the action will be documented in a field logbook.

This procedure outlines the technical requirements and operational use of the field instruments that will be used for air, soil, and water monitoring during field screening and characterization activities. This section addresses standard operating procedures (SOPs) associated with the following air monitoring instruments:

- HNu PI101/MicroTip photo-ionization detectors.
- Organic vapor analyzer (OVA).
- Combustible gas indicator (CGI)/oxygen detector.
- Colorimetric detector tubes/Draeger bellows pump.
- Miniram aerosol monitor.
- Monitor detectors.

C.1 AIR MONITORING EQUIPMENT

C.1.1 HNu PHOTOIONIZATION ANALYZER AND MICROTIP

The HNu photo-ionization analyzer and MicroTip are designed to measure the concentrations of trace gases in air. These analyzers employ the principle of photo-ionization for detection. A sensor, consisting of a sealed ultraviolet light source, emits photons that are energetic enough to

ionize many chemical agents, particularly organics. In general, the HNu will be calibrated as follows:

- Identify the type of lamp being used to determine the relative value of the calibration gas.
- Turn instrument switch to the standby position and check the electronic zero.
- Adjust the zero point with the Zero control.
- Set the function switch in the 0- to 200-ppm range.
- Connect the probe to one end of the calibration humidifier and the calibration gas to the other end.
- Open the valve on the pressured calibration container until a slight flow is indicated. The instrument will draw in the volume required for detection.
- Adjust the span potentiometer so that the instrument is reading the relative value of the calibration gas as determined by the type of probe. This will be done only if the instrument fails to read the calibration gas value labeled on the side of the Cal Gas Cylinder.
- Record on the provided form all original and readjusted settings as specified by the form.
- Calibration on the 0- to 200-ppm range allows for a linear response in the 0- to 20-ppm range; thus, a separate calibration is not required.
- If the span setting resulting from calibration is 0.0 or if calibration cannot be achieved, then the lamp must be cleaned.
- When the observed readings are within the required tolerances, the instrument is fully calibrated.

The HNu instrument will be calibrated daily.

The MicroTip must be calibrated for it to display concentration in units equivalent to parts per million. First, a supply of zero gas, which contains no ionizable gases or vapors, is used to set MicroTip's point. Then, span gas containing a known concentration of an ionizable gas or vapor is used to set the response factor.

Usually clean, outdoor air is a suitable zero gas. If there is any doubt, use a commercial source of zero-grade gas and a second sampling bag. A supply of span gas of the desired compound and concentration must be obtained for calibration. Observe proper handling techniques for all gases.

Isobutylene at 100 ppm in air is recommended for use as span gas. To calibrate the instrument, use the calibration kit as follows:

- Connect the supplied regulator to the span gas cylinder. Hand-tighten the fittings.
- Open the valve on the gas bag by turning the valve stem fully counterclockwise.
- Attach the gas bag adapter nut to the regulator. Hand-tighten the fittings.
- Turn the regulator knob counterclockwise about half a turn to start the flow of gas.
- Fill the gas bag about half full and then close the regulator fully clockwise to turn off the flow of gas.
- Disconnect the bag from the adapter and empty it. Flush the bag a few times with the span gas and then fill it.
- Close the gas bag by turning the valve clockwise.
- Press Setup and select the desired Cal Memory with the arrow keys and press Enter. Press Exit to leave Setup.
- Press Cal and expose the MicroTip to zero gas. Press Enter and MicroTip sets its zero point.
- MicroTip then asks for the span gas concentration. Enter the known span gas concentration and then connect the span gas bag adapter to the inlet.
- Press Enter and the MicroTip sets its response factor.
- When MicroTip's display reverts to normal, MicroTip is calibrated and ready for use.
- Remove the span gas bag from the inlet.

MicroTip has five calibration memories (Cal Memories) and can be calibrated with five different span gases if desired. Only one Cal Memory may be used at a time. Each memory stores a different zero point and response factor. Use the following procedure to program the Cal Memories:

- Press Setup and select the desired Cal Memory (1 to 5) with the arrow keys.
- Exit from Setup and press the Cal key.
- Follow the displayed calibration instructions. When the calibration is completed, it is automatically stored in the selected Cal Memory.

Whenever the instrument is calibrated, MicroTip updates the selected Cal Memory. The instrument should be calibrated once per day.

MicroTip can also be used as a high-sensitivity leak detector. When High Sensitivity is selected in Setup, only zero gas is required for calibration. MicroTip does not read directly in parts per million, but shows a reading proportional to the concentration of ionizable gases and vapors in the sample. During calibration in High Sensitivity, MicroTip does not ask for span gas, but automatically sets itself to the maximum response factor.

C.1.2 Organic Vapor Analyzer

The Century portable organic vapor analyzer (OVA) is designed to detect and measure gases and organic vapors in the atmosphere. The instrument uses the principle of hydrogen flame ionization for detection. The OVA measures gases and vapors by producing a response to an unknown sample that can be related to a gas of known composition to which the instrument has been previously calibrated. The instrument is normally calibrated to methane gas. To calibrate the instrument, the following steps are followed in order:

1. Place the instrument in normal operation with the Calibrate switch set to X10 and the Gas Select control set to 300. Allow the instrument to warm up for at least 5 minutes before attempting calibration.
2. Introduce zero air and use the Calibrate Adjust (zero) knob and adjust the meter reading to zero.
3. Attach the end of a T assembly to the calibration gas cylinder and the other to the probe.

4. Open the calibration gas cylinder until a slight flow is detected exiting the open end of the T assembly. (Caution: If the calibration gas is toxic or highly flammable, calibration should occur inside a hood.)
5. Adjust trimpot R-32 on the internal circuit board so that the meter reads equivalent to the known sample (methane). This sets the instrument gain for methane with the panel-mounted gain adjustment (Gas Select) set at a reference number of 300.
6. Turn off the hydrogen Supply Valve to put out the flame.
7. With the Calibrate switch on X10, use the Calibrate Adjust (zero) knob to adjust the meter reading to 4 ppm.
8. Place the Calibrate switch in the X1 position, and, using trimpot R-31 on the internal circuit board, adjust the meter reading to 4 ppm.
9. Move the Calibrate switch to the X10 position again. Use the Calibrate Adjust (zero) knob to adjust the meter to a reading of 40 ppm.
10. Move the Calibrate switch to the X100 position and use trimpot R-33 on the internal circuit board to adjust the meter reading to 40 ppm.
11. Move the Calibrate switch to the X10 position and use the Calibrate Adjust (zero) knob to adjust the meter reading to zero.
12. The unit is now balanced range to range, calibrated to methane, and ready to be placed into normal service.

Calibration will be performed in a well-ventilated area prior to daily use of the instrument.

C.1.3 Explosimeter/Combustible Gas Indicator

The explosimeter or combustible gas indicator (CGI) is an air monitoring device designed to indicate a flammable/explosive atmosphere and the level of oxygen present. The CGI registers combustible gas or vapors in terms of their lower flammability limit (LFL), which is the lowest

concentration at which a combustible gas may ignite (or explode) under normal atmospheric conditions. Since the instrument measures both the level of oxygen in the atmosphere and the level a combustible gas reaches before igniting, the calibration of the instrument comprises a two-step process.

The oxygen portion of the instrument is calibrated by placing the meter in normal atmospheric air and rotating the Cal. Oxygen control knob until the oxygen meter reads exactly 20.8% oxygen. This calibration will be done once daily when the instrument is in use.

The CGI is calibrated to pentane at the laboratory to indicate directly the percentage LEL of pentane in air. It is recommended that the CGI be calibrated daily and whenever the detector filament is replaced.

The calibration kit included with the CGI contains a calibration gas cylinder, a flow control, and an adaptor hose.

Recalibration Instructions

- Attach the flow control to the recommended calibration gas tank (pentane).
- Connect the adapter hose to the flow control.
- Open the flow control valve.
- Connect the adapter hose fitting to the inlet of the instrument. After about 15 seconds, the LEL meter pointer should be stable and within the range specified on the calibration sheet accompanying the calibration equipment. If the meter pointer is not in the correct range, stop the flow, and remove the right hand side cover. Turn on the flow and adjust the "S" control with a small screw driver to obtain a reading as specified on the calibration sheet.
- Disconnect the adaptor hose fitting from the instrument and replace the side cover.

C.1.4 MSA Sampler Pump/Draeger Pump and Gas Detector Tubes

In areas where benzene and/or vinyl chloride is suspected to exist, an MSA sampler pump or Draeger gas detector tubes will be used for monitoring in addition to the HNu and OVA. For MSA universal sampling pumps, the pump filter disk should be removed and cleaned

periodically by gently tapping or blowing on the surface to remove any foreign matter. Every 6 months, the pump piston should be relubricated with high-vacuum silicone grease. Tube holders should be replaced when they show signs of wear or loss of elasticity. The test for leaks after an extended period of idleness, or periodically during use, is as follows:

- Lock the rotating head in orifice no. 4. Insert the tube into the tube holder. Pull the handle back to lock the piston into the 100 cc position. Wait 2 minutes. Rotate the handle to release the locking mechanism. The piston should then return to the 0 cc position. If this does not occur, another test should be performed. Adjust the rotating head so that the locking button is positioned halfway between any two index numbers. Lock the piston into the 100 cc position. Wait 2 minutes and unlock it. The piston should return to the 0 cc position if the seal between the piston and cylinder is adequate.
- For a Draeger pump, check the pump for leaks every time it is used by sealing the pump with an unopened Draeger tube and completely compressing the bellows. If the bellows has not expanded completely after 30 minutes, the pump is sufficiently airtight and will deliver the required volume. Every 4 weeks, the wire mesh sieve under the rubber bung in the pump head must be cleaned. A special spanner is necessary to remove the rubber bung. The sieve should be taken out and cleaned with a brush under running water. Every time the pump is used, it should be flushed out with air by pumping a few times without a detector tube.

C.1.5 Low-Volume Air Sampler - Miniram Aerosol Monitor

This procedure outlines the technical requirement and operational use of the Miniram aerosol monitor.

The requirements of this procedure are applicable to all activities that include use of the Miniram aerosol monitor. The instrument is used to determine the relative concentrations of airborne particulates in a worker's breathing zone or general area that may cause a respiratory hazard. Information is used to establish the levels of protection and other control measures such as action levels.

MODE OF OPERATION

Startup and Field Calibration Procedures

- Check initial read-out conditions. A blank display indicates that the Miniram has not been in the measurement mode for 48 hours or more, and is in the “minimum power off” mode. An OFF display indicates that the Miniram has been in the OFF mode for less than 48 hours.
- If the Miniram shows a blank display, press OFF and wait until the display reads OFF (approximately 5 seconds after pressing OFF).

Calibration Procedures

The unit is factory-calibrated against a filter gravimetric reference using a standard test dust. Recalibration of the instrument is conducted every 6 months. The equipment storage facility should check the Miniram against a reference scatterer after calibration at the factory and after each usage. No other field calibration is warranted.

Operational Check

- Follow the startup procedures.
- Observe the three bar indicators on the Miniram display. If the OVR bar is displayed at any time during operation in the measurement mode, the Miniram detection circuit has been overloaded. A momentary overload can be caused by insertion of an object into the sensing chamber or sudden exposure to sunlight, etc. If the cause of the overload is eliminated, the OVR bar will disappear during the next 10-second display period, unless the overload persists for more than 1½ minutes over an 8-hour measurement cycle. The ID bar display is activated only for display identification purposes and not for error conditions. The BAT bar is displayed when the battery voltage becomes insufficient, indicating that the battery charger should be plugged into the Miniram.
- Place the Zero Bag on a flat surface with the red flow fitting facing up. Flatten the bag and then unzip it.
- Insert the ribbed elbow connection (attached to the filter cartridge) into the red flow fitting of the plastic bag until the connector is flush with the bottom of the red flow fitting.
- The Miniram should be in its OFF condition (observe display). If the display is blank, or the Miniram is in the MEAS mode, key OFF.

- Open the Zero Bag and place the Miniram in the center of it.
- Key ZERO through the open end of the Zero Bag. Immediately zip close the Zero Bag and begin to pump the hand bulb. The zero concentration is automatically subtracted from the measurement readings.
- The Zero Bag should inflate as the hand pumping continues, up to a height of approximately 5 inches. Continue pumping gently to maintain the bag interior pressure until the Miniram displays OFF again.
- Unzip the Zero Bag and remove the Miniram.
- Store the Zero Bag flattened and zipped closed, with the ridded elbow connector plugged in to ensure cleanliness of the bag's interior.

Operation

- Follow the startup, operational check, and calibration procedures.
- If the Miniram shows a blank display, press OFF and wait until the display reads OFF.
- If the Miniram displays OFF, press MEAS to initiate the measurement cycle (there is no need to press OFF first in this case). A concentration display that changes or blinks once every 10 seconds is in the measurement mode.
- The first read-out display is either GO or CGO if TIME is also pressed.
- Approximately 36 seconds after pressing MEAS, the first new 10-second averaged concentration reading is displayed. All subsequent readings are concentration values in mg/m^3 , updated every 10 seconds.
- The Miniram will now run in the measurement mode for 500 minutes, after which it will stop, displaying the OFF reading, retaining in storage the concentration averaged and elapsed time information. If both MEAS and TIME are pressed at the same time (press Time first while depressing MEAS), the Miniram will display CGO. The Miniram will then operate for an 8.3-hour run and will restart automatically and continue to measure for an indefinite number of 8.3-hour runs.
- ID: Pressing NO. during the measurement period provides a momentary display of the identification number stored within the Miniram memory. The ID key, in combination with other keys, is used for several additional programming functions.
- PKB: With the Miniram in the OFF mode, the stored information can be displayed back by pressing PKB. When the PKB key is initially pressed, the display will indicate "P" for 1 second. If PKB continues to be pressed for more than 1 second, the stored data are automatically played back through the Miniram display. First, the identification number is displayed with the ID indicate bar on. Next, the shift or run

number (7 through 1, starting with the last one) is shown (with the OVR indicator bar on as identification); followed by the monitoring time in minutes for that run, followed by the off time between the last and next run (in tens of minutes). Finally, the average concentration is shown in mg/m^3 . An average reading of 9.99 indicates that a significant overload condition occurred during that run. If PBK is pressed for less than 1 second, PA will be displayed, and the stored data will be fed out the digital output jack for printout or computer storage.

- TWA: This key stands for time-weighted average. During the measurement mode, if TWA is pressed, the display will indicate the average concentration in mg/m^3 up to that instant, from the start of the last run.
- SA: This key stands for shift average. During the measurement mode, pressing SA will provide a display of the aerosol concentration up to that moment, averaged over an 8-hour shift period.
- TIME: During the measurement mode, if TIME is pressed, the display will show the elapsed time, in minutes, from the start of the last measurement run.

Shutdown Procedures

- Pressing the OFF key will discontinue whatever mode is underway, displaying GCA followed by the display segments CHECK and finally OFF.

Cleaning Procedures

- The interior walls and the glass windows of the sensing chamber should be cleaned when the zero reference reading exceeds $3 \text{ mg}/\text{m}^3$.
- Open the sensor chamber with both thumbs by gently pushing the sensing chamber away from the display/control panel end. This will expose the two round lenses and a rectangular lens.
- Clean the lenses with lens tissue or a Q-tip and a small amount of isopropyl alcohol. Rinse thoroughly to remove any residue from the lenses.
- Allow the sensing chamber to dry completely and reinsert the chamber back onto the Miniram with minimal pressure.

C.1.6 Monitor Detectors

When monitoring the breathing zone for hydrogen sulfide (H_2S) and hydrogen cyanide (HCN) gases, the COMPUR 4100 SD monitor will be used. The unit will be calibrated in the field and

will provide an audible alarm when the alarm threshold concentration of hydrogen sulfide or hydrogen cyanide gas is present in the work area. The instrument is calibrated as follows:

- Battery test—Switch to the battery position. If the unit has enough power for 8 hours of use, an intermittent tone will sound. The absence of this tone indicates that a change of batteries is required. Make the test as short as possible to save power.
- When the tone is heard, switch to on.
- Place the unit onto the gas generator, and remove the unit when the alarm sounds. The generator releases gas at levels capable of setting off the alarm within 10 seconds. If the alarm does not sound, the detector needs to be checked and/or serviced.
- Once the unit has passed the calibration check, attach the unit to personal clothing in the breathing zone, being careful not to cover the filter cap.

C.2 WATER CHEMISTRY MONITORING EQUIPMENT

C.2.1 Temperature, pH, Electrical Conductivity, Turbidity, and Dissolved Oxygen

The instrument used to measure temperature, pH, electrical conductivity, turbidity, and dissolved oxygen is the HORIBA U-10 water quality checker. The HORIBA U-10 water quality checker is an instrument designed for simultaneous, multiparameter measurements of water quality using one probe. Measurements are displayed sequentially on the hand-held digital LCD readout. The following procedure is used for taking analytical measurements of water sampled with the HORIBA U-10:

- Press the POWER key to turn the instrument on.
- Gently place the probe into the water sample collected in a 5-gallon bucket. Never throw or drop the probe into the water.
- Use the SELECT key to move the upper cursor on the readout to each parameter to be measured.
- To obtain a uniform reading, slowly move the probe up and down to circulate water through it.
- Use the EXP key to select the expanded readout mode to display measurements with one additional decimal place of accuracy.
- Record measurements in the GEOLIS logbook.

- After the measurement, turn power OFF. Rinse the probe with ASTM Type II reagent-grade water.

The HORIBA U-10 will be calibrated daily by only the on-site field logistics technician. If an instrument failure occurs, field personnel will return the instrument to the on-site technician for repairs. An inventory of replacement parts will be maintained on-site to facilitate quick field repairs. Individual sensors in the probe can be replaced by the on-site technician. Note: The meter should not be used when it is known that product is present in the water sample.

In the event that the HORIBA U-10 becomes totally inoperative, field analytical measurements will be taken with the following or equivalent instruments:

- pH—Analytical Measurements' Model 107 portable pH meter.
- Temperature and electrical conductivity—YSI Model 33 meter.
- Turbidity—HF Scientific Model DRT 15 turbidimeter.
- Dissolved oxygen—YSI Model 50 B DO meter.

C.2.2 Electrical Conductivity Meter

The YSI Model 33, or equivalent, is a portable, battery-operated, transistorized instrument with a standard probe used to measure salinity, electrical conductivity, and temperature in surface water, groundwater, and wastewater. The meter is calibrated daily, or each time the meter is turned on. Setup and calibration procedures follow.

Set up the instrument as follows:

- Adjust meter zero, if necessary, by turning the screw on the meter face so that the meter needle coincides with the zero on the conductivity scale.
- Calibrate the meter by turning the mode control to Redline and adjusting the Redline control so that the meter needle lines up with the redline on the meter face. If this cannot be accomplished, replace the two "D" batteries.

Check the probe for cleanliness as follows:

- Plug the probe into the probe jack on the side of the instrument.
- Place the probe into the solution and measure on the X100 or X10 scales.

- Depress the Cell Test button. The meter reading should be less than 2%; if it is greater, the probe must be cleaned.

Clean the probe as follows:

- Spray Dow Chemical's Bathroom Cleaner with Scrubbing Bubbles into the holes in the terminal end of the probe. You may also use Lysol brand Basin, Tub, and Tile Cleaner.
- Soak the probe for 5 minutes.
- Gently spray rinse the probe with DI water.
- Do not touch the electrodes inside the probe.

For a loose or slipping temperature knob:

- Read the temperature and conductivity of a solution.
- Determine the salinity of the solution from the calibration by running a line vertically from the conductance value to the appropriate °C line. From this intersection, extend a line horizontally to the edge of the graph and read the salinity value.
- Remove the °C knob.
- Switch to the salinity function knob.
- Turn shaft under the °C function knob until the meter needle reads the salinity value determined previously.
- Switch to the temperature function knob.
- Place the °C knob on the shaft without turning the shaft, with the knob pointer indicating the meter temperature reading.
- Tighten both set screws securely.
- Return meter for factory calibration as soon as possible.

C.2.3 pH Meter

Analytical Measurements' Model 107 pH meter is a portable pH monitoring instrument for determining the pH value of groundwater, surface water, and wastewater.

This instrument requires a daily function and accuracy check prior to being issued for field use.

This test is performed as follows:

- Connect the probe to the BNC connector provided on the unit.
- Move the selector switch to the check position.
- Using the buffer knob, move the meter pointer over the full scale. If full-scale deflection cannot be obtained, the battery must be replaced before continuing.
- Move the selector switch to pH position.
- Immerse the probe in pH 7 buffer solution.
- Adjust the buffer knob so that the pointer indicates pH 7.
- Rinse the probe in distilled water.
- Immerse the probe in pH 4 buffer solution.
- Adjust the temperature knob so that the pointer indicates pH 4.
- Immerse the thermometer into pH 4 buffer solution and take a reading.
- Compare the thermometer reading to the temperature indicated by the temperature knob on the instrument. If these two values do not match, the instrument must be returned to a qualified service technician for calibration of the internal temperature compensation circuitry.

After the unit has been calibrated, the following method is used to take field measurements:

- Immerse the thermometer into the sample and take a reading.
- Adjust the temperature knob to match the thermometer reading.
- Turn the selector switch to check position.
- Adjust the buffer knob to match the reading that was recorded during the calibration procedure.
- Turn the selector switch to the pH position and take a reading of the sample.
- Rinse the probe in distilled water.
- Record the results in the field logbook.

C.2.4 Turbidimeter

The Fisher Model DRT-15 turbidimeter, or equivalent, is a portable instrument designed to measure the turbidity of samples of water, wastewater, liquid fuels, cooling water, and colored liquids. The instrument provides linear turbidity measurements over four switch-selectable ranges: 0 to 1.0, 10, 100, and 200 nephelometric turbidity units (NTU). It is sensitive to a change of 0.02 NTU on the 0 to 1 NTU scale.

The turbidimeter requires verification of calibration daily or each time the meter is turned on (if more than once per day). A reference standard of 0.1 NTU is required for verification of calibration. If measurement of the reference standard indicates that recalibration is necessary, or if the electronic PC board, the photodetectors, or the light source have been replaced, the turbidimeter should be recalibrated as follows.

Solutions with formalin suspension values of 198, 19.8, and 2.0 NTU are necessary for calibration as follows:

- Fill, cap, and label a separate cuvette sample of each.
- Always mix the contents of each cuvette by inverting several times before placing in the optical well for a reading.
- Keep the outside surface of cuvette clean.
- When placing any standards in the well, always use the light shield to cover the well to keep out ambient light.

To gain access to the tripods, remove the accessories from the foam holder. Proceed as follows:

1. Center the reference adjust control on top of the instrument.
2. Insert the reference standard, and turn the range control on the DRT-1SC to the 20 range. Adjust the Coarse Zero trimpot until a reading of 0.10 NTU is obtained.
3. Replace the reference standard with the 2.0 NTU formalin standard, and adjust the “20 Range Adjust” trimpot to obtain a reading of 2.0 ± 0.1 NTU.

4. Replace the 2.0 NTU formalin standard with the reference standard, and adjust the control to obtain a reading of 0.10 NTU.
5. Repeat steps 3 and 4 until no further adjustments are required.
6. Insert the 19.8 NTU formalin standard, and adjust the “20 Range Adjust” trimpot to obtain a reading of 19.8 ± 0.1 NTU.
7. Turn the range control on the DRT-150 to the 200 range. Insert the 198 NTU formalin standard, and adjust the “200 Range Adjust” trimpot to obtain a reading of 198 NTU.

Additional calibration by EPA Method 180.1 will be performed after the aforementioned calibration is performed to check the accuracy of the calibration scales. The following steps will be conducted:

- For turbidities less than 40 units: shake the sample to thoroughly disperse the solids. Wait until air bubbles disappear, then pour the sample into the sample cuvette. Read the turbidity directly from the instrument scale or from the appropriate calibration curve.
- For turbidities greater than 40 units: dilute the sample with one or more volumes of turbidity-free water until the turbidity falls below 40 units. The turbidity of the original sample is then computed from the turbidity of the diluted sample and the dilution factor. For example, if 5 volumes of turbidity free water were added to 1 volume of sample, and the diluted sample showed a turbidity of 30 units, then the turbidity of the original sample was 180 units.
- **Calculation**—Multiply the sample readings by the appropriate dilution to obtain a final reading.

Report the results as follows:

NTU	Record to Nearest
0.0 to 1.0	0.05
10 to 40	1
100 to 400	10
400 to 1,000	50
> 1,000	100

C.2.5 Dissolved Oxygen Meter

Total dissolved oxygen (DO) will be measured using a YSI 50B or YSI 51B DO meter (or equivalent). The meter will be calibrated at the beginning of each day and checked periodically during sampling. Before the YSI Model 50B DO meter can be used, the sampling team must initially set up the instrument as follows:

- Connect the probe to the meter, then place the probe in a constant oxygen environment, such as a BOD bottle or the calibration bottle supplied.
- Set the function switch to the C position. An audible tone will sound. This is a signal that the microprocessor's Power On Self Testing (POST) diagnostic mode has been activated. Observe the display to ensure all meter segments appear. A second tone will sound in about 7 seconds to signal the end of the POST diagnosis, and the display will blank briefly.
- If the POST diagnosis uncovers a fault in the instrument operation, the display will not appear, or will freeze. Should this occur, it is necessary to return the instrument for repair to the dealer or to YSI.
- Temperature will be displayed after the second tone. Observe the reading for stability. Temperature equilibration may take up to 5 minutes.
- Set the function switch to the mg/L position and allow 15 minutes for the system to stabilize. If calibration is attempted prematurely, calibration values will drift and may be out of specification.
- It is not necessary or desirable to turn the instrument off after each measurement. In normal field use, the meter may be left on in any switch position between measurements, and turned off only at the end of the day.
- Each start-up from the OFF position could require a 5- to 15-minute wait for probe stabilization.
- Once the meter has been set up initially, the following procedures should be used for best results. Because the oxygen level in the layer of liquid sample at the membrane surface of the probe is continuously being depleted, it is essential that water movements of 1 foot per second or greater be maintained when recording measurements. A moving stream will usually provide this motion, as will moving the probe through the sample by hand. Make oxygen measurements as follows:
 - Perform the initial setup and calibration procedures as described previously.
 - Collect sample in a clean, 8-ounce jar.

- Set the function switch to the position appropriate to the sample and the readout described (% or mg/L). Allow 3 to 5 minutes for the probe to come to temperature equilibration with the sample.
- Begin stirring at least 30 seconds before taking the reading. Observe the reading when the display has stabilized.
- The rightmost DISPLAY SET key is a toggle switch for showing or suppressing the last digit of the reading in both % and mg/L modes. The default mode displays the last digit. When the last digit is suppressed, the measurement will still be as accurate as it is when the last digit is displayed.
- After the CAL key is pressed, a tone will sound when the reading is stable. This does not affect the instrument's measurement in any way. The autoread function is off in the autodefault mode and works only for DO measurements. Note: If the instrument is operated in a LOBAT (low battery) condition and it is not possible to replace the batteries immediately, confirm your reading by repeating the INITIAL SETUP procedures.
- Record all readings in the GEOLIS field logbook.
- Properly dispose of water for DO measurement with containerized purge water or by another appropriate method.

Before the YSI Model 51B DO meter can be used, the sampling team must initially set up the instrument as follows:

- Place the instrument in its intended operating position. Recalibration may be necessary if instrument operating position is changed.
- With the switch in the OFF position, adjust the meter to zero using the screw in the bottom center of the meter panel.
- Switch the function knob to the ZERO setting and adjust the meter to zero using the zero control knob located beneath the meter panel.
- Switch the function knob to the FULL SCALE setting, and adjust the meter using the full scale knob beneath the meter panel (full scale is achieved whenever the meter needle aligns with the "15" mark on the mg/L scale).
- Attach the probe to the meter.
- Before calibrating, allow the probe to stabilize for 15 minutes.

The YSI Model 51B DO meter should be calibrated between each sampling point in the following manner:

- Switch the function knob to the CALIB O2 position.
- Slip the small plastic bottle (used to prevent the membrane from drying out) over the probe. Ensure that the plastic bottle contains a damp tissue or sponge in the tip.
- Allow the temperature to stabilize for 10 minutes.
- Use the CALIB knob located beneath the meter panel to adjust the meter to read the correct DO value based on the following table.

Solubility of Oxygen in Water (mg/L) at Various Temperatures (°C)

Temp.	DO*	Temp.	DO	Temp.	DO	Temp	DO	Temp.	DO
0	14.60	11	11.00	22	8.72	33	7.16	44	6.04
1	14.19	12	10.76	23	8.56	34	7.05	45	5.95
2	13.81	13	10.52	24	8.40	35	6.93	46	5.86
3	13.44	14	10.29	25	8.24	36	6.82	47	5.78
4	13.09	15	10.07	26	8.09	37	6.71	48	5.70
5	12.75	16	9.85	27	7.95	38	6.61	49	5.62
6	12.43	17	9.65	28	7.81	39	6.51	50	5.54
7	12.12	18	9.45	29	7.67	40	6.41		
8	11.83	19	9.26	30	7.54	41	6.31		
9	11.55	20	9.07	31	7.41	42	6.22		
10	11.27	21	8.90	32	7.28	43	6.13		

*DO value is based on atmospheric pressure of 760 mm Hg (at sea level).

When measuring DO with the YSI Model 51B meter, these steps should be followed:

- Place the probe in your sample and set the function knob to temperature. Allow sufficient time for the temperature to stabilize.
- Record the temperature and adjust the O2 SOLUBILITY FACTOR dial to the observed reading.
- Set the function knob to read O2. If an automatic stirrer is not attached to the probe, the probe will have to be manually stirred by raising and lowering the probe approximately 1 foot per second.
- Allow sufficient time for the DO reading to stabilize.
- Record the reading on the GEOLIS form.

Field Alkalinity Measurement

Alkalinity is defined as the measurement of the ability of a solution to resist or buffer a change in pH. Alkalinity is measured by progressively lowering the pH of a solution by titrating with a strong acid such as HCl or H₂SO₄.

- The Hach Model AL-DT titration device, which measures alkalinity at two end points (P-alkalinity and total alkalinity), is used. To accurately measure alkalinity, the conductivity of the water must be known. Alkalinity may be approximated as half the conductivity value when conductivity is expressed in units of umhos as with the YSI Model 33 meter (e.g., water with a conductivity of 100 umhos would be expected to have a total alkalinity of approximately 50 mg/L as CaCO₃). Alkalinity may be approximated from conductivity values measured with the HORIBA Water Quality Checker using the following formula:

$$\text{Estimated alkalinity} = [\text{conductivity ms/cm} \times 1,000]/2$$

For example, water with a conductivity of 0.1 mS/cm would be expected to have a total alkalinity of approximately 50 mg/L as CaCO₃.

All information collected during the alkalinity test is recorded on the Field Alkalinity Worksheet. The measurement of alkalinity involves the following procedure:

- Water samples must be collected in 250-mL plastic or glass bottles, with no headspace, and capped tightly.
- Samples should be analyzed as soon as possible.
- Maximum storage time is 24 hours on ice.
- Samples should be allowed to reach room temperature before analysis.
- If possible, the samples should be kept at the original sample temperature while being transported from the field to the area where the titration will occur.
- Estimate the alkalinity, as described previously.
- Select the sample volume and the respective sulfuric acid titration cartridge from the following table:

Estimated Alkalinity Range	Sample Volume (mL)	Cartridge (NH ₂ SO ₄)	Multiplier	pH	Color
10 to 40	100	0.16	0.1	5.1	Blue-gray
40 to 160	25	0.16	0.4	5.1	Blue-gray
100 to 400	100	1.6	1.0	4.8	Violet-gray
200 to 800	50	1.6	2.0	4.5	Light pink
500 to 2,000	20	1.6	5.0	4.5	Light pink
1,000 to 4,000	10	1.6	10.0	4.5	Light pink

- Insert a clean delivery tube into the titration cartridge and twist the cartridge onto the titrator body.
- Flush out the delivery tube by turning the small knob until a few drops drip from the tube, wipe the tip, and reset the counter to zero.
- Measure the aforementioned sample volumes into a 250-mL flask and dilute to 100-mL with de-ionized water, if necessary.
- Add the contents of one phenolphthalein pillow and swirl to mix.
- If the solution turns pink (normally it does not), titrate to a colorless end point and record the number of drops required to calculate P-alkalinity.
- P-Alkalinity = Drops x multiplier in mg/L CaCO₃ (from previous table)
- Add one bromocresol green-methyl red indicator pillow and swirl. Titrate from green to the color listed in the previous table and record the number of drops required to calculate total alkalinity. The color can be judged against a 50 mL solution containing 1 indicator pillow and 1 pH buffer pillow.
- Total alkalinity = Drops x multiplier in mg/L CaCO₃ (from previous table). Record all values and final color on the alkalinity form.
- Example: A water sample has an alkalinity of approximately 100 mg/L (conductivity of 200 umhos or 0.2 mS/cm). Place 100 mL in a flask and add the phenolphthalein pillow. If the solution turns pink, add 1.6N H₂SO₄ buffer, and titrate until clear. Add 1 bromocresol green-methyl red indicator pillow, titrate solution to a light violet-gray end point (pH 4.8), and calculate the total alkalinity. If 120 drops are necessary, total alkalinity is 120 mg/L (120 x 1). If fewer than 30 drops with the 1.6N H₂SO₄ cartridge or more than 300 drops with 0.16N H₂SO₄ are required, the sample should be re-titrated with the other cartridge and both results reported. If the alkalinity result falls outside the estimated alkalinity range, the sample should be re-titrated using the appropriate H₂SO₄ cartridge and/sample volume.

- Properly dispose of all liquids and decontaminate equipment according to procedures outlined in Subsection 4.11.
- Properly dispose of liquids in either purge water containers or by other appropriate methods. Decontaminate equipment according to Subsection 4.11 if elevated readings were detected with the PID. If there are no elevated readings, then rinse with distilled water.

FIELD SCREENING INSTRUMENT CHECKLISTS

FIELD SCREENING INSTRUMENT CHECKLISTS

CGI/O ₂ DETECTOR MSA MODEL 260		
ID/Serial No.:	Date:	Time:
Signature:		
ITEM	DONE	PROCEDURES
Start-up Procedures		Attach the sample hose to the inlet of the instrument.
		Open the instrument lid. Turn the center ON-OFF control to the far right HORN-OFF position. Both meter pointers will move and one or both alarm lights may light.
		Allow the instrument to warm up until the meter stabilizes (about a minute).
		If the % oxygen stabilizes at a value other than 20.9 %, set to 20.9% by using the CALIBRATE O ₂ control.
		Set the % LEL to zero by adjusting the ZERO LEL control.
		If either the alarm lights are lighted, press the Alarm Reset button.
		Momentarily place a finger over sample inlet fitting or end of the sample line probe. Flow indicator float should drop out of sight indicating no flow. If float does not drop, check system for leaks.
		Press the CHECK button and observe the % LEL meter. The pointer must read at 80% LEL or higher as marked by the BATTERY zone on the meter. Battery OK? If reading is less, batteries must be recharged. No tests should be attempted as the instrument will not perform properly.
Operation Check		Follow the start-up procedures, operational check and the calibration procedures. Ensure the alarm is in the ON position. Observe response values for various gases indicated in the instrument manual.
		For LEL and oxygen reading hold the hose inlet at point to be tested.
Calibration Procedures		Follow the start-up procedures.
		Connect the regulator to the calibration gas.
		Connect the adapter hose from the regulator to the inlet of the CGI/O ₂ meter.
		Open the cylinder valve.
		Observe the meter on the instrument. Readings will increase, then stabilize. As soon as the reading is stable compare with the value on the calibration gas cylinder. If calibration cannot be accomplished proceed to the calibration instructions in the MSA 260 instruction manual.
		If readings are within $\pm 10\%$, quickly close regulator valve and disconnect the tube from instrument inlet.
Comments		Carefully remove the right side/end of the instrument case (the side opposite the inlet). With the Cal Gas attached, use a small (jewelers) screwdriver to adjust the "S" potentiometer until the meter scale reads 50% LEL. Instrument is now calibrated. If Oxygen needle does not adjust to 20.9% during initial start-up, or is greater than $\pm 10\%$ of potentiometer for the oxygen scale.

CGI/O₂ DETECTOR Gastec MODEL 1314

ID/Serial No.:	Date:	Time:	Signature:
ITEM	DONE	PROCEDURES	
Start-up Procedures		Check function switch on the control panel to ensure that it is in the OFF position. Attach sample hose to instrument by means of the quick release fitting.	
		LEL-PPM range button (top right) in LEL or OUT position, with black indicator showing (when the switch is IN, an orange indicator dot shows and circuit is in the sensitive PPM range). OXY (top left) button in the OUT position (in the IN position Oxygen reads-oxygen scale instead of LEL or PPM. A colored indicator dot shows when the switch is IN).	
		Press the power switch to turn the instrument on. Orange indicator dot should show. Alarm will sound momentarily.	
		Press battery check button and note the meter is OK. If reading is close to or below Battery Check mark on the meter, recharge the battery, is recharge needed?	
		In gas free location, allow instrument to warm up until meter stabilizes (about a minute). Turn PPM/LEL zero Knob to bring meter to "O".	
		Push the OXY (top left) switch IN so that the orange indicator shows. Meter should read 20.9% O ₂ . If not, adjust Oxygen Knob so meter reads 20.9% O ₂ .	
	Operation Check		Breathe into hose inlet and allow the instrument to sample expired air (do not put your mouth directly on the hose). Reading should come down to 16%. Alarm sounds at 19.5% oxygen. Allow reading to return to 20.9%, then put the switch back in the OUT position.
Calibration		Record date of last WESTON ES, factory, or supplier calibration.	
Calibration Procedures using a Sample Bag (option)		Cal gas Hexane? Cylinder concentration of hexane divided by 1.1 = _____%LEL. Open pinch clamp on airbag (push the latch forward to open)	
		Connect tubing by attaching short piece of flexible plastic tubing from the Y valve onto the regulator. Place the longer tube with the pinch clamp onto the instruments inlet probe.	
		Allow pump to evacuate bag until flat. Close pinch clamp (squeeze parallel faces together until tight/latched).	
		Open cylinder valve slightly so sampling bag begins to expand. Quickly open pinch clamp. As instrument takes sample, bag will start to expand further or deflate. Adjust cylinder valve so the bag remains half inflated.	
		Observe meter. Readings will increase, then stabilize. As soon as reading is stable, record:_____. Compare with value on the cal gas cylinder. Reading within ±10% of the cal gas concentration.	
		Quickly close the regulator valve and disconnect the tube from the instrument inlet.	
Calibration using a Rotometer		With instrument on and zeroed, use a piece of tubing to attach inlet of instrument to top part of rotometer. Attach another piece of tubing to bottom part of the rotometer. Do not connect to regulator on the calibration gas cylinder yet. Note position of rotometer ball.	
		Connect calibration gas cylinder regulator to the bottom tubing and open the cylinder valve.	
		Adjust cal gas regulator so rotometer reads at same level as above (about 2 cubic feet/hour (cfh). Observe meter reading. Reading will increase, then stabilize. As soon as reading is stable record:_____. Compare with value on the cal gas cylinder. Instrument reading should be within ±10% of the cal gas.	

CGI/O₂ DETECTOR Gastec MODEL 1314

ID/Serial No.:		Date:	Time:	Signature:
ITEM	DONE	PROCEDURES		
Internal Calibrate		Calibrate internally when initial reading is $> \pm 10\%$ of cal gas concentration. Loosen top of unit by unscrewing knob on front ledge of instrument. Lift on handle, taking care not to pull wiring. Find LEL pot. With cal gas flowing, use a small screwdriver and adjust to make meter coincide with cal gas cylinder % LEL. Record%:_____. Maintenance needed when calibration can't be accomplished.		
Operation		Follow the start-up procedures, operational check, and the calibration procedures.		
		PPM/LEL Range switch in the LEL (out) position, with black indicator showing, and OXY-PPM/LEL switch also in LEL (out) position.		
		For LEL readings in the 0-100% range, hold hose inlet at point to be tested. For oxygen readings move the OXY-PPM/LEL switch to the IN position.		
Comments				

FID/PID TVA 1000			
ID/Serial No.:	Date:	Time:	Signature:
ITEM	DONE	PROCEDURES	
Start-up Procedure	1.	Install hydrogen tank in side pack, turning counterclockwise until hand tight. Record pressure in tank from the gauge on top of tank: _____. Will need about 300 psi/hour of work anticipated.	
		Attach probe/readout assembly (sample line and electrical cable to TVA). Sample line - push in until hear latch, electrical cable-line up grove in housing with ridge inside coupling on TVA. Don't force.	
		Turn red hydrogen supply valve on. Quarter turn. Record pressure from output gauge: _____. Should be 11-14.	
		Wait 2-3 minutes for hydrogen fuel cell to fill.	
		Press ON Pad firmly. Screen should display: Battery Ok, NV LAN OK; Date time OK, Self Test. Wait for Beep.	
		Press the Control Key. Screen should show: 1=Turn pump on, 2=Ignite, 3=Turn PID off.	
		Press 1 to turn on pump. Should hear/feel pump turn on.	
		Press Control key. Screen should show: 1=Turn pump off, 2=Ignite, 3=Turn PID off.	
		Press 2 to ignite.	
		Flame-out indicator does not activate. Flame is lit. If Flame-out indicator activates, wait one minute and press Control key and 2 to ignite. Display on TVA should show: Main Menu. Display on Readout should show: Off.	
		When sure flame is lit, Press 1 to Run; Display on TVA should show: PID: -X.XX; FID: -X.XX/ Exit=stop. Display on Readout should show: Either PID reading or FID reading.	
		Allow at least 15 minutes for instrument to warm before attempting to calibrate.	
	Calibration	2.	Record date of last WESTON ES/Factory calibration: _____. Within 12 months? Return for calibration if over 12 months. If instrument not on, follow start-up procedures.
		At least 15 minutes elapsed since instrument turned on, pump turned, on and flame ignited?	
		Exit to Main menu; Screen on TVA should read: Main Menu.	
		Choose 2=Setup. Screen should read: Set up: 1=calibration; etc.	
		Choose 1=calibration; Screen should read; Calibration menu: 1=zero; 2=bckgrnd; etc.	
		Is humidity <50%? If yes. Choose 1=zero. Screen will indicate Zero Cal.	
		From calibration menu choose - 1=zero; Screen should read: 1=Both; 2=PID;3=FID. Choose 1=Both. Screen reads Apply zero gas. Enter=start. Exit=cancel.	
		Apply Zero gas to probe using T or Gas Bag, open zero gas regulator or gas bag valve and Press Enter: Screen will show: Calibrating PID FID zero gas.	
		Zero is completed when screen displays - Accepted. Watch closely; accepted appears for very brief time. Screen will pop back to Calibration menu after Accepted appears.	
		Is humidity > 50%? If yes, choose 2=Bckgrnd; Screen will read: 1=Both; 2=PID; 3=FID. Choose 1=both. Screen will read: Bkgrnd calibration. Enter=start. Exit=cancel. Press Enter: Screen will show: Calibrating PID FID Bkgrnd.	
		Zero is completed when screen displays - Accepted. Watch closely; accepted appears for very brief time. TVA Screen will pop back to Calibration menu when accepted.	
		From the calibration menu, choose - 3=SPAN; Screen should read: 1=both, 2=PID, etc.	
		Choose 2=PID. Record PID SPAN gas concentration: _____. Screen will read Apply Span Gas. Enter=Start. Exit=Cancel.	
	Apply PID SPAN Gas to probe using T or Gas Bag, open zero gas regulator or gas bag valve and press Enter; Screen will show: Calibrating Span PID.		

FID/PID TVA 1000			
ID/Serial No.:	Date:	Time:	Signature
ITEM	DONE	PROCEDURES	
		PID Calibration is completed when screen displays Accepted. Watch closely accepted appears very briefly. Turn off PID span gas valve or close gas bag valve. Screen will pop back to Calibration Menu.	
		EXIT to main menu screen will read: Main Menu 1=Run. Press 1.	
		Reapply PID Span Gas and record reading on readout display for PID: _____. Within 5% of PID span gas conc? _____. If yes, continue. If no, troubleshoot until does.	
		Reconfirm Span Definition by exiting to calibration menu; Should read: 1=zero, .4=gascon.	
		Choose 4=GASCON. Readout will show PID=XX.X; FID=XX.X Span Gas: 1=both; 2=PID; 3=FID. If readout is the same as the concentration indicated on the PID SPAN gas. Press Exit.	
		If readout is not the same, press 2=PID. Screen will display series of dashes followed by units (ppb/ppm/etc.). Reset units using up and down arrows to choose ppm and use number keys to enter numeric value of the span gas. Then press Enter.	
		Exit to calibration menu. Screen will read: Calibration Menu 1=zero, 2=bkgrnd, 3=span.	
		Choose 3=SPAN. Screen will read: 1=both, 2=PID; 3=FID. Choose 3=FID. Record FID SPAN gas concentration: _____. Screen will read: Apply span gas Enter=start. Exit=cancel.	
		Apply PID SPAN Gas to probe using T or Gas Bag, open zero gas regulator or gas bag valve and press Enter; Screen will show: Calibrating Span FID.	
		FID Calibration is completed when screen displays Accepted. Watch closely for accepted. Turn off FID span gas valve or close gas bag valve. Screen will pop back to Calibration Menu.	
		EXIT to main menu screen will read: Main Menu 1=Run. Press 1.	
		Reapply FID span gas and record reading on readout display for FID: _____. Within 5% of FID span gas conc? _____. If yes, continue. If no, troubleshoot until does.	
		Reconfirm Span Definition by exiting to calibration menu; Should read: Calib. Menu 1=zero; 2=bkgrnd; 3=span; 4=gascon.	
		Choose 4=Gascon. If readout is same as concentration indicated on the PID SPAN gas, press Exit.	
		If the readout is not the same, press 3=FID. Screen will display series of dashes followed by units (ppb/ppm/etc.). Reset units using up and down arrows to choose ppm and use number keys to enter numeric value of the span gas. Then press Enter.	
Shut-Down Procedures	3.	Press off button.	
		Turn off red hydrogen button.	
		If end of day or preparing to recharge, remove the hydrogen tank from the sidepack by turning clockwise. Set cylinder in case or secure place where it can not fall.	
Filling Hydrogen Cylinder	4.	Remove cylinder from side pack if not already done.	
		Verify hydrogen supply is high-grade and pressure is 2,200 psi or less.	
		Attach fill assembly to hydrogen tank. Ensure fill assembly valve is in off position.	
		Attach other end of fill assembly to TVA hydrogen cylinder.	
		Open hydrogen supply cylinder valve and then move fill assembly valve to fill.	
		Allow pressure to equalize in TVA hydrogen cylinder.	
		When full, move fill assembly valve to off.	
		Close hydrogen supply cylinder valve and disconnect fill assembly.	

OVA FLAME IONIZATION ANALYZER DETECTOR CENTURY FOXBORO OVA		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Start-up Procedures		Check the function switch on the control panel to ensure that it is in the "off" position.
		Attach probe by hand tightening the screw fitting into the interface on the side of the instrument. Attach snap-in cord. Use care in aligning the prongs in the probe cord with the socket: don't force.
		Move INSTR Switch to ON and allow five minutes for warm up.
		Move INSTR/BATT test switch to BATT position and ensure battery is charged by reading the indication on readout meter. Battery OK _____. Move INSTR back to the ON position.
		Move calibrate switch to X10 and adjust the meter reading to zero with the calibrate adjust (zero) knob.
		Turn pump switch on. Observe the sample flow rate indicator. Should be approximately 2 units.
		Cover tip of probe. If flow does not drop to zero, tighten fittings/re-seat probe until it does.
		Open hydrogen tank valve one turn and observe reading on hydrogen tank pressure indicator (about 150 psi pressure is needed for each hour of operation). Record hydrogen tank pressure reading: _____. If insufficient or below 500 psi, refill following procedure below. Refill required? _____.
		Open hydrogen supply valve ½ to 1 turn and observe reading on hydrogen supply pressure indicator. Should be between 8 and 12 psi. Record reading: _____.
		Confirm that OVA meter is still reading zero.
		Depress and hold red igniter button on left side of OVA for no more than 6 seconds. There will be a slight "pop" as hydrogen ignites and meter pointer will move upscale of zero. Immediately after ignition, release igniter button. Do not depress igniter button for more than 6 seconds. If burner does not ignite, let instrument run for several minutes and try again. After ignition, meter pointer will indicate background concentration. Record: _____.
		To set audible alarm to action level: 1) turn on; 2) adjust meter pointer to desired alarm level, using cal adjust (zero) knob; 3) turn alarm level adjust knob on back of readout assembly until alarm just comes on; 4) adjust speaker volume with volume knob; 5) reset to 0. High level alarm set at: _____.
		To set zero/flame out alarm: With instrument on and in X10 scale, 1) use calibrate adjust knob to set needle on readout assembly to 0; 2) turn alarm level adjust knob on back of readout assembly until alarm just comes on; 3) move needle slightly above zero to stop alarm sound; 4) use calibrate adjust to test alarm, leaving needle just above 0. Zero Alarm set: _____.
		Move instrument to a clean area and zero using cal adjust knob. The adjustment to 1 ppm (rather than 0) is necessary in X1 range because of sensitivity of OVA. This permits minor downward fluctuations in normal background level without dropping below 0, which would actuate the flame-out alarm. It is important to remember during the subsequent survey that 1 ppm must be subtracted from all readings.
Operation Check		Following start-up procedures. With instrument set on X10 scale, hold a solvent-based marker cap near probe tip. If meter deflects upscale, instrument is working.
Calibration		Single Point, using methane. Follow the start-up procedures and operational check. Record date of last WESTON ES, supplier/factory calibration: _____. Less than 12 months ago? If no, return to ES, factory or supplier for check and calibration.
		Ensure calibration gas is methane. Should be slightly less than 100 ppm. Cal gas Concentration: _____.

OVA FLAME IONIZATION ANALYZER CHECKLIST		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
		Follow start-up procedure and operation check. Set function switch to 10 x scale.
		Attach a regulator to a cylinder of methane gas. Connect regulator to OVA probe with a piece of clean tygon tubing and "t" or "y" connector. Turn the valve on the regulator on.
		Observe meter reading. Reading will increase, then stabilize. As soon as reading is stable, compare with value on cal gas cylinder. Record reading: _____. Instrument reading should be within 10% of cal gas concentration.
		If readings deviate by more than 10% from cal gas concentration, internally adjust as follows:
		Turn off cal gas, disconnect probe assembly and remove unit from case.
		Locate trim pots on end of gray plastic block.
		Re-attach probe assembly; attach cal gas and turn on.
		Using trim pot R-32, adjust until readout coincides with cal gas concentration.
		Turn off cal gas and disconnect. Record final/calibration reading: _____.
		If R-32 Pot is needed for calibration, perform Bias Adjust as follows:
Bias Adjust		After calibration is complete, turn of hydrogen supply valve to put out flame.
		With switch in X10 position, use the calibrate adjust knob to adjust the meter reading to 4 ppm.
		Turn calibrate switch to X1 and use trim pot R-31 to adjust meter reading to 4 ppm.
		Set switch to X10 again and use calibrate adjust knob to meter reading to 40 ppm.
		Set the switch to X100 and use trim pot R-33 to adjust meter reading to 40 ppm.
		Set switch to X10 and use calibrate adjust knob to zero.
OVA FLAME IONIZATION DETECTOR CHECKLIST		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
H ₂ Filling		Completed as needed.
		Inspect ends of hydrogen fill hose to ensure they are free of grease and obstruction.
		Ensure hydrogen cylinder is secure. Attach fill assembly to hydrogen cylinder. Tighten with wrench.
		Remove OVA fill port cover. Attach fill assembly to OVA fill port. Tighten carefully with wrench.
		Ensure OVA Hydrogen Fill and Cylinder Valves are closed. Place three-way switch in closed position.
		Check around area for ignition sources. When there are none, then proceed.
		Open hydrogen cylinder valve and quickly change three-way valve from off to bleed position.
		Move fill assembly three-way valve to fill position.
		Open OVA Hydrogen Fill Valve and fill OVA Hydrogen Cylinder.
		When OVA Hydrogen Cylinder is full, close OVA Hydrogen Fill valve.
		Move Fill Assembly three way switch to Closed position. Close Hydrogen Cylinder Valve.
		Move fill assembly three-way valve to: 1) bleed position until release stops; 2) fill position; 3) bleed position until release stops again; and 4) closed position.
		Disconnect fill assembly from OVA. Disconnect fill assembly from hydrogen cylinder.
		Recap and store Hydrogen Cylinder properly.
Comments		

PHOTOIONIZATION DETECTOR - ORGANIC VAPOR METER (OVM)			
ID/Serial No.:	Date:	Time:	Signature:
ITEM	DONE	PROCEDURES	
Start-up Procedure	1.	Power-up the instrument using the power plug.	
		Depress ON/OFF Key to ignite lamp and start pump. Depress the MODE/STORE Key.	
		a. Depress -/CRSR Key in response to LOG THIS VALUE? Prompt.	
		b. Depress -/CRSR Key to select Parameters Mode from the main Menu.	
		c. Depress +/INC Key to advance through the Run Mode selection parameter prompt.	
		d. Depress +/INC Key to advance through Auto Logging Mode selection parameter prompt.	
		e. Depress +/INC Key to advance through the Average Time selection parameter prompt.	
		f. Depress +/INC Key to advance through the Alarm Setting parameter prompt.	
		g. Depress +/INC Key to advance through the Lamp Selection parameter prompt.	
		h. Depress +/INC Key to advance through the Response Factor Setting parameter prompt.	
		i. Depress Mode/Store Key to display readout. Check with marker for response.	
Calibration Procedures	2.	Follow start-up procedures above. After completing. 1. h. (Depress +/INC Key to advance through Response Factor Setting parameter):	
		a. Depress +/INC Key again. Display will indicate "RESET" to Calibrate.	
		b. Depress RESET Key to initiate calibration sequence.	
		c. Depress -/CRSR Key to decline restoration of the backup calibration.	
		d. Connect the outlet of the calibration tubing assembly to the detector inlet.	
		e. Introduce Zero Air to the OVM by opening the flow regulator.	
		f. Depress the RESET Key to "Zero" the OVM. Screen will indicate zeroing.	
		g. Close the flow regulator. When Reset to Calibrate appears again, ready to continue.	
		The LCD should now read: Span PPM = 0250 (or other calibration gas). "+" TO CONTINUE.	
		h. Check Cylinder Concentration. If concentration is 250 ppm, continue with next row (2.i.). If concentration is not 250 ppm, go to 4. Calibration Reset, below. Record Cal Gas Conc: _____.	
		i. Depress +/INC to accept span concentration value. Screen will indicate "Reset to Calibrate."	
		j. Connect the isobutylene cylinder to the calibration tubing assembly.	
		k. Connect the outlet of the calibration tubing assembly to the OVM inlet.	
		l. Introduce the Isobutylene standard to the OVM by opening the flow regulator.	
		m. Push Reset key to "CALIBRATE" OVM, screen will indicate "Calibrating." When screen returns to Reset to Calibrate, close the flow regulator. Depress +/INC Key.	
		n. Depress MODE/STORE to return to the Run Mode.	
	3.	Operation Check	
		a. Use cap of solvent-based marker to check. If LCD display increases, instrument is operating.	
		b. Open cal gas cylinder regulator and watch LCD readout. Should stabilize at cal gas Concentration. Verify: _____; Record Reading: _____.	
		c. Close regulator and disconnect calibration assembly.	
	d. Let instrument clear and return to background. Record background if any: _____.		
4.	Resetting Calibration Parameter		
	a. Simultaneously depress the RESET and -/CRSR Keys to activate the movable cursor. Repeat this until the cursor is at the ones place.		
	b. Simultaneously depress RESET and +/INC Keys to increment the ones place value. Repeat this step until the ones place value reads the value of the concentration of isobutylene in the calibration gas (i.e., if the cylinder reads 250 ppm isobutylene, the ones place value is 0).		

PHOTOIONIZATION DETECTOR - ORGANIC VAPOR METER (OVM)		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
		c. Simultaneously depress RESET and -/CRSR Keys. Repeat this until the cursor is at the tens place. Simultaneously depress RESET and =/INC Keys to increment the tens place value (i.e., if the cylinder reads 250 ppm isobutylene, the tens place value is 5).
		d. Simultaneously depress the RESET and -/CRSR Keys to activate the movable cursor. Repeat this until the cursor is at the hundreds place.
		e. Simultaneously depress RESET and +/INC Keys to increment the hundreds place value. Repeat this step until the hundreds place value reads the value of the concentration of isobutylene in the calibration gas (i.e., if the cylinder reads 250 ppm isobutylene, the hundreds place value is 2).
		f. Simultaneously depress the RESET and -/CRSR Keys to activate the movable cursor. Repeat this until the cursor is at the thousands place.
		g. Simultaneously depress RESET and +/INC Keys to increment the hundreds place value. Repeat this step until the hundreds place value reads the value of the concentration of isobutylene in the calibration gas (i.e., if the cylinder reads 250 ppm isobutylene, the thousands place value is 0).
		h. The LCD should now read: Span PPM = the new value, 0250 in this example). "+ TO CONTINUE. Record reading: _____. Depress +/INC to accept span concentration value.
Parameter Setting	5.	a. Following parameters also have features, which can be reset or used using manufacturers' procedures in manual: Run mode; Autologging Selection; Location Mode Selection; Average Time Selection; Alarm Setting; Lamp Selection; Response Factor Setting; Free Space Indication.
Comments		

HNU PHOTOIONIZATION ANALYZER		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Start-up Procedures		Before attaching the probe, check the function switch on the control panel to ensure that it is in the "off" position.
		Attach the probe by plugging it into the interface on the top of the readout module. Use care in aligning the prongs in the probe cord with the socket: do not force it.
		Turn the function switch to the battery check position. The needle on the meter should read within or above the green area on the scale. If not, recharge the battery.
		Turn the function switch to any range setting. Listen for the hum of the fan motor.
		To zero the instrument, turn the function switch to the standby position and rotate the zero adjustment until the meter reads zero. A calibration gas is not needed since this is an electronic zero adjustment. If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted, if necessary. Wait 15 to 20 seconds to ensure that the zero reading is stable. If necessary, readjust the zero.
Operational Check		Follow start-up procedures. With the instrument set on the 0 - 20 range, hold a solvent-based magic marker cap near the probe tip. If the meter deflects upscale, the instrument is working.
Calibration Procedures		Follow the start-up procedure and the operational check. Record date of last WESTON ES, supplier/factory calibration: _____. Less than 12 months ago? If no, return to ES, factory, or supplier for check and calibration.
		Set the function switch to the range setting for the concentration of the calibration gas.
		Attach a regulator to a cylinder of isobutylene gas. Record cal gas concentration: _____. Attach the humidifier to the instrument probe. Connect regulator to the humidifier with a piece of clean tygon tubing. Turn the valve on the regulator to the on position. Record the initial reading after it stabilizes: _____.
		After 15 seconds, adjust the span dial until the meter reading equals the concentration of the calibration gas used in benzene equivalents. Do not calibrate the HNU to the actual concentration of isobutylene on the cal gas container. For the 10.2 eV probe (approximately 55 ppm benzene equivalent) and for the 11.7 eV probe (approximately 65 ppm benzene equivalent). Therefore, if the cal gas container label indicates 100 ppm isobutylene, the instrument should be calibrated to .55 X 100 or 55 (10.2 probe) and .65 X 100 or 65 (11.7 probe). Be careful to unlock the span dial before adjusting it. Record Span Setting after Cal: _____. If the span has to be set below 3.0, lamp and ion chamber should be inspected and cleaned. Was instrument calibrated and inspected? The 10.2 eV probe lamp can be cleaned in the field following procedures in the manual. Lamp cleaned? _____. The 11.8 eV lamp must be returned to Equipment Stores for cleaning. Comments: Record reading and span after adjustment: _____.

HNU PHOTOIONIZATION ANALYZER		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
		The instrument reading should be within $\pm 10\%$ of the calibration gas. The instrument needs maintenance when calibration cannot be accomplished.
		Turn the calibration gas off and remove the tubing from the instrument inlet and regulator.
Comments		

REALTIME AEROSOL MONITOR - MINIRAM		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Start-up Procedures		Check initial readout condition: Blank display indicates the Miniram has not been in the measurement mode for 48 hours or more and is in the minimum power off mode. "OFF" display indicates the Miniram has been in the off mode for less than 48 hours.
		If Miniram display is blank, press OFF. Wait until display reads OFF (about 5 seconds).
		If Miniram shows OFF, press MEAS directly to initiate the measurement cycle) there is no need to press OFF first, in this case). A concentration display that changes or blinks once every 10 seconds is in the measurement mode.
Operational Check		Follow the start-up procedures.
		Observe the three bar indicators on the Miniram display. OVR displayed? _____ If no, continue. If yes, the Miniram detection circuit has been overloaded. Watch the display. A momentary overload can be caused by the insertion of an object into the sensing chamber, sudden exposure to sunlight, etc. If the cause of overload is eliminated, the OVR bar will disappear during the next 10-second display period. Display cleared? _____ If no, continue. If yes, the overload has persisted for more than a total of 1 1/2 minutes over an 8 1/3-hour measurement cycle. Clean the lenses as described in manual. If this does not correct, contact Equipment Stores for instruction. If the OVR bar is displayed at any time during operation in the measurement mode the Miniram detection circuit has been overloaded.
		ID bar display is activated only for display identification purposes and not for error conditions.
		BAT bar displayed? _____ If no, continue. If yes, battery voltage is insufficient. Recharge.
		Place Zero Bag on a flat surface with the red flow fitting facing up. Flatten bag and then unzip it.
		Insert the ribbed elbow connector (attached to the filter cartridge) into the red flow fitting of the plastic bag, until the connector is flush with the bottom of the red flow fitting.
		The Miniram should be in its OFF condition (observe display). If the display is blanked, or if the Miniram is in the MEAS mode, key OFF.
		Open the Zero Bag then place the Miniram in the center of the Zero Bag.
		Key ZERO through the open end of the Zero Bag. Immediately zip close the Zero Bag and begin to pump the hand bulb. The zero concentration is automatically subtracted from the measurement readings.
		The Zero Bag should inflate as the hand pumping continues, up to a height of about five inches. Continue pumping gently to maintain the bag interior pressure, until the Miniram displays OFF again.
		Unzip the Zero Bag and remove the Miniram from it.
		Press MEAS button. Display will show reading displayed while pumping the Zero Bag for up to two cycles or 20 seconds. After 20-30 seconds, display should be background below 1.0.
		Store the Zero Bag flattened and zipped closed, with the ribbed elbow connector plugged in to ensure cleanliness of the bags interior.

REALTIME AEROSOL MONITOR - MINIRAM		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Cleaning Procedures		The interior walls and the glass windows of the sensing chamber should be cleaned when the zero reference reading exceeds 3 mg/m ³ .
		Open the sensor chamber with both thumbs by gently pushing the sensing chamber away from the display/control panel end. This will expose the two round lenses and a rectangular lens.
		Clean the lenses with lens tissue or Q-tip and small amounts of isopropyl alcohol. Rinse thoroughly to remove any residues from the lenses.
		Allow the sensing chamber to dry completely and re-insert the chamber back onto the Miniram with minimal pressure.
Calibration Procedures		The Miniram is factory calibrated against a filter gravimetric reference using a standard test dust. Recalibration of the instrument is conducted every 12 months. Last calibration date: _____.
Operational Procedures		Follow the start-up procedures, operational check, and calibration procedures.
		The Miniram will now run in the measurement mode for 500 minutes, after which it will stop, displaying the OFF reading, retaining in storage the concentration average and elapsed time information. If both MEAS and TIME are pressed at the same time (press TIME first while depressing MEAS) the Miniram will display CGO. The Miniram will then operate for an 8.3-hour run and will restart automatically and continue to measure for an indefinite number of 8.3-hour runs.
		ID: Pressing ID# during the measurement period provides momentary display of identification number stored within the Miniram memory. The ID key in combination with other keys, is used for several additional programming functions.
		PKB: With the Miniram in the OFF mode, the stored information can be played back by pressing PKB. When the PKB key is initially pressed the display will indicate "P" for 1 second. If PKB continues to be pressed for more than 1 second then the stored data is automatically played back through the Miniram display: first, the identification number is displayed with the ID indicator bar on; next the shift or run number (7 through 1, starting with the last one) is shown (with the OVR indicator bar on as identification) followed by the monitoring time in minutes for that run; followed by the off-time between the last and next run (in tens of minutes); finally, the average concentration in mg/m ³ . An average reading of 9.99 indicates that a significant overload condition occurred during that run. If PKB is pressed for less than one second, PA will be displayed and the stored data will be fed out through the digital output jack of the Miniram for printout or computer storage.
		TWA: This key stands for time-weighted-average. During the measurement mode, if TWA is pressed the display will indicate the average concentration in mg/m ³ up to that instant, from the start of the last run.
		SA: This key stands for shift average. During the measurement mode, pressing SA will provide a display of the aerosol concentration, up to that moment, averaged over an 8-hour shift period.
		TIME: During the measurement mode, if TIME is pressed the display will show the elapsed time, in minutes, from the start of the last measurement run.
Comments		

DETECTOR TUBES - DRAGER		
ID/Serial No.:	Date:	Time:
Signature:		
ITEM	DONE	PROCEDURES
Start-up Procedures		Leak check the bellows pump by compressing the bellows then inserting an uncut tube into the inlet orifice. After a minute, observe the bellows pump. A pump that has not lost its deflated shape indicates no leak, a fully extended pump indicates a leak. Some drager pumps have a chain. A loose chain indicates no leaks, a taut chain indicates a leak. The manufacture recommends a 30-minute leak check. Remove the tube.
Calibration Procedures		No field calibration is required. Calorimetric tubes are factory prepared. The pump requires quarterly volumetric calibration by the manufacturer.
Operational		Reset the pump counter to zero (not all drager pumps have a pump counter).
		Select the pump counter to zero (not all pumps have a stroke counter).
		Select the colorimetric tube box required for monitoring. Record the tube expiration date(s). Do not use tube if after expiration date.
		Observe the different layers, ampoules, and colors in the sample tube. Observe the markings on the tube.
		Read the instruction sheet provided by the manufacturer.
		Using the instruction sheet, identify the color change indicating a positive response of the chemical of interest.
		Using the instruction sheet, identify markings on the pump.
		Break both ends of the tube and insert into the pump. Observe directional arrows.
		Direct the tube inlet near the test source. Pump the number of pump strokes required by the manufacturer (see instructions). Record on data sheet.
		Identify the cross sensitivities identified by the manufacturer.
		Remove the tube from the pump. Dispose of the tube in an appropriate manner.
Comments		

DETECTOR TUBES - MSA KWIK DRAW		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Start-up Procedures		Leak check the bellows pump by compressing the bellows then inserting an uncut tube into the inlet orifice. After a minute, observe the bellows pump. A pump that has not lost its deflated shape indicates no leak, a fully extended pump indicates a leak. Some drager pumps have a chain. A loose chain indicates no leaks, a taut chain indicates a leak. The manufacture recommends a 30-minute leak check. Remove the tube.
Calibration Procedures		No field calibration is required. Colormetric tubes are factory prepared. The pump requires quarterly volumetric calibration by the manufacturer or WESTON Equipment Stores.
Operation		Reset the pump counter to zero (not all pumps have a stroke counter).
		Select the colormetric tube box required for monitoring. Record the tube expiration date(s). _____, _____, _____, _____. Do not use tube if after expiration date.
		Observe the different layers, ampules, colors in the sample tube. Observe the markings on the tube.
		Read the instruction sheet provided by the manufacturer.
		Using the instruction sheet, identify the color change indicating a positive response of the chemical of interest.
		Using the instruction sheet, identify markings on the tube.
		Break off both ends of the tube and insert into the pump. Observe directional arrows.
		Direct the tube inlet near the test source. Pump the number of pump strokes required by the manufacturer (see instructions). Record readings on data sheet.
		Identify the cross sensitivities identified by the manufacturer.
		Remove the tube from the pump. Dispose of the tube in an appropriate manner.
Comments		

MONITOX - HCN			
ID/Serial No.:	Date:	Time:	Signature:
ITEM	DONE	PROCEDURES	
Start-up Procedure		Turn Switch to BATT position. Fluctuating tone heard within 10 seconds?	
		If yes, immediately turn switch to On when tone sounds.	
Operation Check		Check HCN Generator. Remove cap from generator well. Is filter Pad moist?	
		Place HCN generator on top of HCN Monitox so detector housing fits into generator well and body of generator rests on top of Monitox. Push down.	
		Green light on side of generator on? ____ If yes, HCN being generated. Monitox alarm should activate within 10 seconds. If yes, record reading on Monitox: ____ then continue.	
		Red light on side of generator on? ____ If yes, replace battery. If no, continue.	
Calibration		Calibration is performed only by a trained technician. Follow the start-up procedures and operational check. Record date of last WESTON ES, supplier/factory calibration. Less than 12 months ago? If no, return to ES, factory, or supplier for check and calibration. Daily Operation checks are performed per above.	
Replace Battery - Monitox	a.	1. Turn Switch OFF. Remove three screws (two at bottom corners, one at top inside belt clip) on back.	
		2. Turn detector over and separate two halves taking care not to pull wires.	
		3. Lift out battery housing and disconnect plug.	
		4. Unscrew and remove battery lids. Replace batteries with new (2 x PX 23 (5.6V)) batteries.	
		5. Replace battery lids. Plug in battery plug ensuring cable and cable socket align properly.	
		6. Replace battery housing and front cover, carefully adjust the cable of the front panel, so it is not damaged by replacing front panel and tightening screws.	
		7. Replace front. Tighten screws and repeat battery test.	
Replace Filter Cap	b.	1. Follow steps a.1. and a.2. above as if replacing battery.	
		2. Carefully remove sensor along with filter cap and pull filter cap off.	
		3. Attach new filter cap (must have identical gas label HCN) put sensor back in position.	
		4. Follow a. 6. and a.7. above.	
Replace Battery Generator	c.	1. Replace battery with Mallory (or equivalent) 9V battery. Remove four screws on rear housing and carefully separate halves. Disconnect old battery replace with new. Close two halves of case being careful not to pull or pinch wires. Replace four screws.	
Replace Sensor Cell	d.		
Comments			

MONITOX - COCL		
ID/Serial No.:	Date:	Time: Signature:
ITEM	DONE	PROCEDURES
Start-up Procedure		Turn Switch to BATT position. Fluctuating tone heard within 10 seconds?
		If yes, immediately turn switch to On when tone sounds.
Operation Check		Check COCL ₂ Generator. Remove cap from generator well. Is filter Pad moist?
		Place COCL ₂ generator on top of COCL ₂ Monitox so detector housing fits into generator well and body of generator rests on top of Monitox. Push down.
		Green light on side of generator on? ____ If yes, COCL ₂ being generated. Monitox alarm should activate within 10 seconds. If yes, record reading on Monitox: then continue.
		Red light on side of generator on? ____ If yes, replace battery. If no, continue.
Calibration		Calibration is performed only by a trained technician. Follow the start-up procedures and operational check. Record date of last WESTON ES, supplier/factory calibration _____. Less than 12 months ago? If no, return to ES, factory, or supplier for check and calibration.
Replace Battery	a.	1. Turn Switch OFF. Remove three screws (two at bottom corners, one at tope inside belt clip) on back.
		2. Turn detector over and separate two halves taking care not to pull wires.
		3. Lift out battery housing and disconnect plug.
		4. Unscrew and remove battery lids. Replace batteries with new (2 x PX 23 (5.6V)) batteries.
		5. Replace battery lids. Plug in battery plug ensuring cable and cable socket align properly.
		6. Replace battery housing and front cover, carefully adjust the cable of the front panel, so it is not damaged by replacing front panel and tightening screws.
		7. Replace front. Tighten screws and repeat battery test.
Replace Filter Cap	b.	1. Follow steps a.1. and a.2. above as if replacing battery.
		2. Carefully remove sensor along with filter cap and pull filter cap off.
		3. Attach new filter cap (must have identical gas label COCL ₂) put sensor back in position.
		4. Follow steps a. 6. and a.7. above.
Replace Battery Generator	c.	1. Replace battery with Mallory (or equivalent) 9V battery. Remove four screws on rear housing and carefully separate halves. Disconnect old battery replace with new. Close two halves of case being careful not to pull or pinch wires. Replace four screws.
Replace Sensor Cell	d.	1. Will be done by vendor or equipment stores.
Comments		