

4/23/92-01060

**FINAL**  
**SAMPLING AND ANALYSIS PLAN**  
**REMEDIAL INVESTIGATION/FEASIBILITY**  
**STUDY FOR CAMP ALLEN LANDFILL**  
**(AREAS A AND B) NORFOLK NAVAL BASE,**  
**NORFOLK, VIRGINIA**  
**CONTRACT TASK ORDER 0084**

*Prepared For:*

**NAVAL FACILITIES**  
**ENGINEERING COMMAND**  
**ATLANTIC DIVISION**  
*Norfolk, Virginia*

*Under:*

**Contract N62470-89-D-4814**

*Prepared By:*

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**APRIL 23, 1992**

## TABLE OF CONTENTS

	<u>Page</u>
<b>1.0 INTRODUCTION .....</b>	<b>1-1</b>
1.1 Purpose .....	1-1
1.2 Sampling and Analysis Plan (SAP) Contents .....	1-4
<b>2.0 SITE BACKGROUND .....</b>	<b>2-1</b>
2.1 Area A .....	2-1
2.2 Area B .....	2-4
2.3 References .....	2-4
<b>3.0 FIELD ACTIVITIES .....</b>	<b>3-1</b>
3.1 Subcontractor Procurement .....	3-1
3.2 Site Investigation .....	3-1
3.2.1 Site Visit .....	3-2
3.2.2 Background Review .....	3-2
3.3 Field Activities - Area A .....	3-2
3.3.1 Geophysical Survey .....	3-2
3.3.2 Residential Well Sampling .....	3-3
3.3.3 Surface Water and Sediment Sampling .....	3-6
3.3.4 Drilling and Monitoring Well Installation .....	3-6
3.3.5 Source Characterization of Contamination from B-20W .....	3-10
3.3.6 Geologic Borings .....	3-10
3.3.7 Groundwater Sampling - Rounds 1, 2 and 3 .....	3-12
3.3.8 Air Sampling at Brig Facility .....	3-13
3.3.9 Slug Tests .....	3-14
3.3.10 Aquifer Test .....	3-14
3.3.11 Land Surveying .....	3-15
3.4 Field Activities - Area B .....	3-15
3.4.1 Surface Water/Sediment/Soil Sampling .....	3-15
3.4.2 In-situ Groundwater Sampling (Geoprobe) .....	3-16
3.4.3 Drilling and Monitoring Well Installation .....	3-19
3.4.4 Source Characterization Contamination at Area B .....	3-20
3.4.5 First Round Groundwater Sampling Event .....	3-20
3.4.6 Groundwater Sampling - Round 2 and Round 3 .....	3-21
3.4.7 Slug Test .....	3-21
3.4.8 Land Surveying .....	3-21
3.5 Sample Analysis .....	3-22
3.6 Quality Assurance/Quality Control .....	3-22
3.7 Sample Numbering .....	3-36
3.8 Groundwater Modeling .....	3-37
<b>4.0 GENERAL FIELD OPERATIONS .....</b>	<b>4-1</b>
4.1 Mobilization .....	4-1
4.2 Field Personnel and Responsibilities .....	4-1
4.3 Geophysical Survey .....	4-3
4.4 Residential Well Sampling .....	4-4
4.5 Surface Water/Sediment/Surface Soil Sampling .....	4-5
4.6 Monitoring Well Installation .....	4-6
4.7 Well Construction .....	4-6

**TABLE OF CONTENTS  
(CONTINUED)**

	<u>Page</u>
4.8 Soil Borings .....	4-7
4.9 Well Development .....	4-9
4.10 Groundwater Sampling .....	4-9
4.11 Slug Tests .....	4-10
4.12 Aquifer Testing .....	4-10
4.13 Land Surveying .....	4-11
4.14 Groundwater Modeling .....	4-12
4.15 Sample Preservation .....	4-14
4.16 Chain-of-Custody, Sample Packaging and Shipping .....	4-14
4.17 Personal Protection .....	4-15
4.18 Decontamination and Waste Handling .....	4-15
4.18.1 Sampling Equipment .....	4-15
4.18.2 Heavy Equipment .....	4-16
4.18.3 Personnel Decontamination .....	4-16
4.19 Documentation .....	4-16
4.20 Field Change and Corrective Action .....	4-16
4.21 Field Instrument Calibration .....	4-17
4.22 Contaminated Materials Handling Plan .....	4-17
4.22.1 Health and Safety Disposables .....	4-17
4.22.2 Drill Cuttings .....	4-17
4.22.3 Development and Purge Water .....	4-17
<b>5.0 STANDARD OPERATING PROCEDURES .....</b>	<b>5-1</b>
5.1 Geophysics - Borehole SOP	
5.2 Geophysics - Electromagnetic Induction SOP	
5.3 Geophysics - Ground Penetrating Radar Profiling SOP	
5.4 Geophysics - Magnetometry Profiling SOP	
5.5 Water Quality Testing SOP	
5.6 Surface Water and Sediment Sample Acquisition SOP	
5.7 Borehole and Sample Logging SOP	
5.8 Soil and Rock Sample Acquisition SOP	
5.9 Monitoring Well Installation SOP	
5.10 Photoionization Detector (PID) SOP	
5.11 Flame Ionization Detector (FID) SOP	
5.12 Water Level, Water-Product Level, and Well Depth Measurements SOP	
5.13 Groundwater Sample Acquisition SOP	
5.14 In-Situ Hydraulic Conductivity Testing SOP	
5.15 Aquifer Testing SOP	
5.16 Sample Preservation SOP	
5.17 Chain-of-Custody SOP	
5.18 Chemical Sampling and Field Analytical Equipment Decontamination SOP	
5.19 Decontamination of Drilling Rig and Monitoring Well Materials SOP	
5.20 Field Logbook SOP	
5.21 Handling of Site Investigation Wastes SOP	

## LIST OF TABLES

<u>Number</u>		<u>Page</u>
3-1	Environmental and QA/QC Sample Summary .....	3-23
3-2	Environmental Sediment/Soil Samples - Area A - Round 1 .....	3-25
3-3	QA/QC Sediment/Soil Samples - Area A - Round 1 .....	3-26
3-4	Environmental GW/SW Samples - Area A - Round 1 .....	3-27
3-5	QA/QC GW/SW Samples - Area A - Round 1 .....	3-28
3-6	Environmental and QA/QC Sediment/Soil Samples - Area B - Round 1 ..	3-29
3-7	Environmental and QA/QC SW Samples - Area B - Round 1 .....	3-30
3-8	Environmental GW Samples - Area A - Round 2 .....	3-31
3-9	QA/QC GW Samples - Area A - Round 2 .....	3-32
3-10	Environmental GW Samples - Area B - Round 2 .....	3-33
3-11	QA/QC GW Samples - Area B - Round 2 .....	3-34
3-12	Environmental and QA/QC GW Samples - Areas A and B - Round 3 .....	3-35

## LIST OF FIGURES

<u>Number</u>		<u>Page</u>
1-1	Base Location Map .....	1-2
1-2	Site Location Map .....	1-3
2-1	Existing Monitoring Wells, Areas A and B .....	2-2
2-2	Existing Surface Water and Sediment Sample Locations, Areas A and B ..	2-3
3-1	Proposed Geophysical Investigation, Areas A and B .....	3-4
3-2	Previously Sampled Residential Well Locations .....	3-5
3-3	Area A - Proposed Surface Water/Sediment Sampling Locations .....	3-7
3-4	Area A - Proposed Monitoring Well Locations .....	3-8
3-5	Area A - Proposed Test Boring Locations .....	3-11
3-6	Area B - Proposed Surface Water/Sediment/Surface Soil Locations .....	3-17
3-7	Area B - Geoprobe Sampling Area, Test Borings and Deep Well Locations	3-18
4-1	Project Organization Summary .....	4-2

## **1.0 INTRODUCTION**

This document presents the Final Sampling and Analysis Plan for the Contract Task Order-0084, Remedial Investigation/Feasibility Study at the Camp Allen Landfill Site (Areas A and B), Naval Base, Norfolk, Virginia. Baker Environmental, Inc. (Baker) is the prime contractor for the Comprehensive Long-Term Environmental Action Navy Program (Navy CLEAN) under which this CTO is being performed. Figure 1-1 presents a Base Location Map and Figure 1-2 presents a Site Location Map.

This plan has been prepared to ensure that Baker staff and subcontractors employ procedures/protocols conforming to NEESA Installation Restoration Program (IRP) requirements.

### **1.1 Purpose**

The specific objectives of the Remedial Investigation are to: (1) Conduct field investigations, including sampling, to gather necessary additional information at the two areas targeted under this study; (2) Condense data gathered in these tasks with existing data from previous investigations to facilitate formulation of comprehensive conclusions for each area; (3) Formulate monitoring plans as appropriate at each area; and (4) Present data and recommendations in a report suitable for a Technical Review Committee (TRC) review.

USEPA (EPA/540/G-89/004), and NEESA IRP guidance will be followed in conducting the RI/FS to "gather information sufficient to support an informed risk management decision" regarding the most appropriate remedial action to be taken at the site. To accomplish this overall goal, and to facilitate project planning and management, this project will be performed as a series of tasks in accordance with the framework established in the Scope of Work, as follows:

- Task 1 - Project Management
- Task 2 - Site Visit and Background Review
- Task 3 - Review/Prepare Project Plans
- Task 4 - On-Site Investigation
- Task 5 - Sample Analysis
- Task 6 - Data Validation
- Task 7 - Data Assembly/Interpretation (Optional)

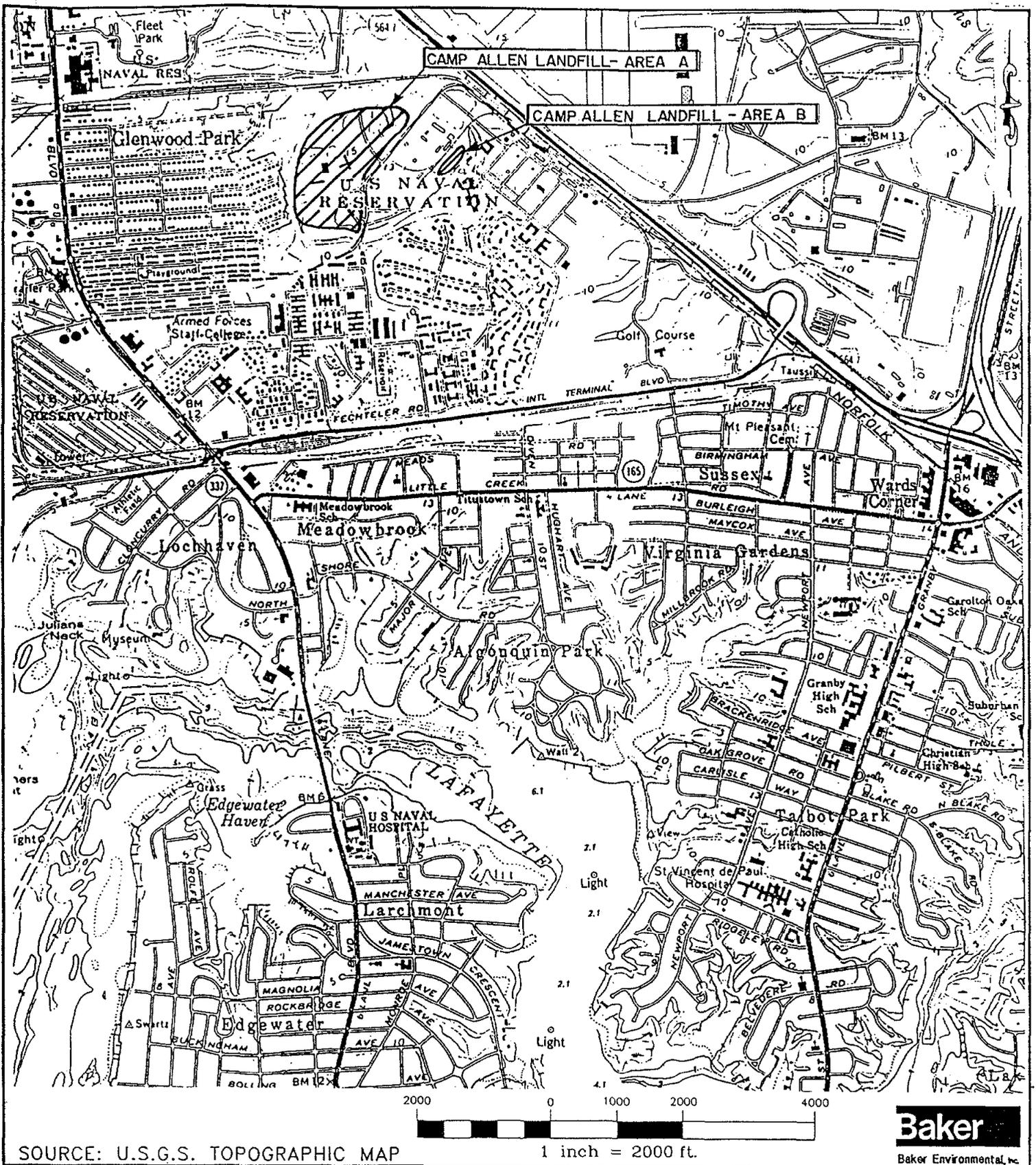
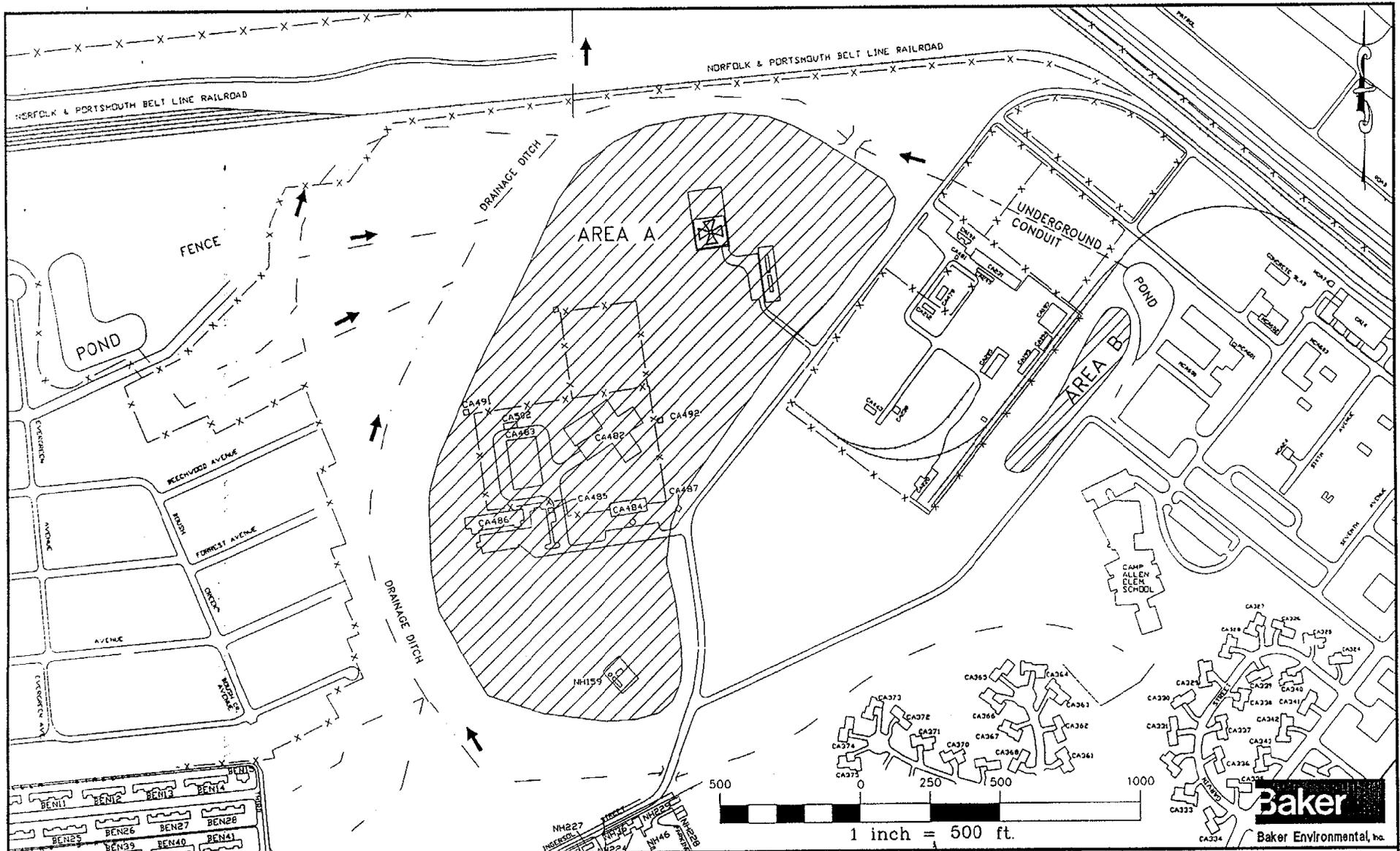


FIGURE 1-1  
 BASE LOCATION MAP  
 CAMP ALLEN LANDFILL  
 AREAS A and B  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA



**LEGEND**

 ASSUMED LANDFILL BOUNDARY  
 SURFACE WATER FLOW DIRECTION

SOURCE: LANTRIV, OCTOBER 1991

**FIGURE 1-2**  
**SITE LOCATION MAP**  
**CAMP ALLEN LANDFILL AREAS A & B**  
  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA

- Task 8 - Baseline Risk Assessment (Optional)
- Task 9 - Groundwater Modeling (Optional)
- Task 10 - Remedial Investigation Report (Optional)
- Task 11 - Feasibility Study (Optional)
- Task 12 - Feasibility Study Report (Optional)
- Task 13 - Remedial Action Plan/Record of Decision Reports (Optional)
- Task 14 - Interim Measures Design (Optional)
- Task 15 - Waste Disposal (Optional)
- Task 16 - Meetings

The primary purpose of the SAP is to provide guidance for all field activities by describing in detail the sampling and data collection methods to be used to implement the various field tasks identified in the Remedial Investigation/Feasibility Study (RI/FS) Work Plan for CTO-0084 (Baker, 1992). The guidance also helps to ensure that sampling and data collection activities are carried out in accordance with generally acceptable practices so that data obtained during the field investigation are of sufficient quantity and quality to evaluate the nature and magnitude of contamination in various media, estimate human health and environmental risks, and evaluate potential technologies for remediation of contaminated media.

## **1.2 Sampling and Analysis Plan (SAP) Contents**

Section 1.0 of this SAP identifies the objective and the contents of the report. Section 2.0 provides background information on each of the two areas to be investigated. The field activities are described in Section 3.0. General field operations activities are presented in Section 4.0. Section 5.0 provides a description of the standard operating procedures (SOPs) for each field investigation method.

## 2.0 SITE BACKGROUND

Previous investigations of hazardous waste sites at the Naval Base, Norfolk, Virginia have been conducted under an Initial Assessment Study, Confirmation Study, and Site Suitability Assessment Study. Additionally, an Interim Remedial Investigation was performed.

In April 1982, an Initial Assessment Study (IAS) was conducted at the Sewell's Point Naval Complex, Norfolk Naval Base, Norfolk, Virginia. The IAS identified 18 sites of concern with regard to potential contamination. The Camp Allen Landfill Areas A and B were included as potential areas of concern (Figure 1-2).

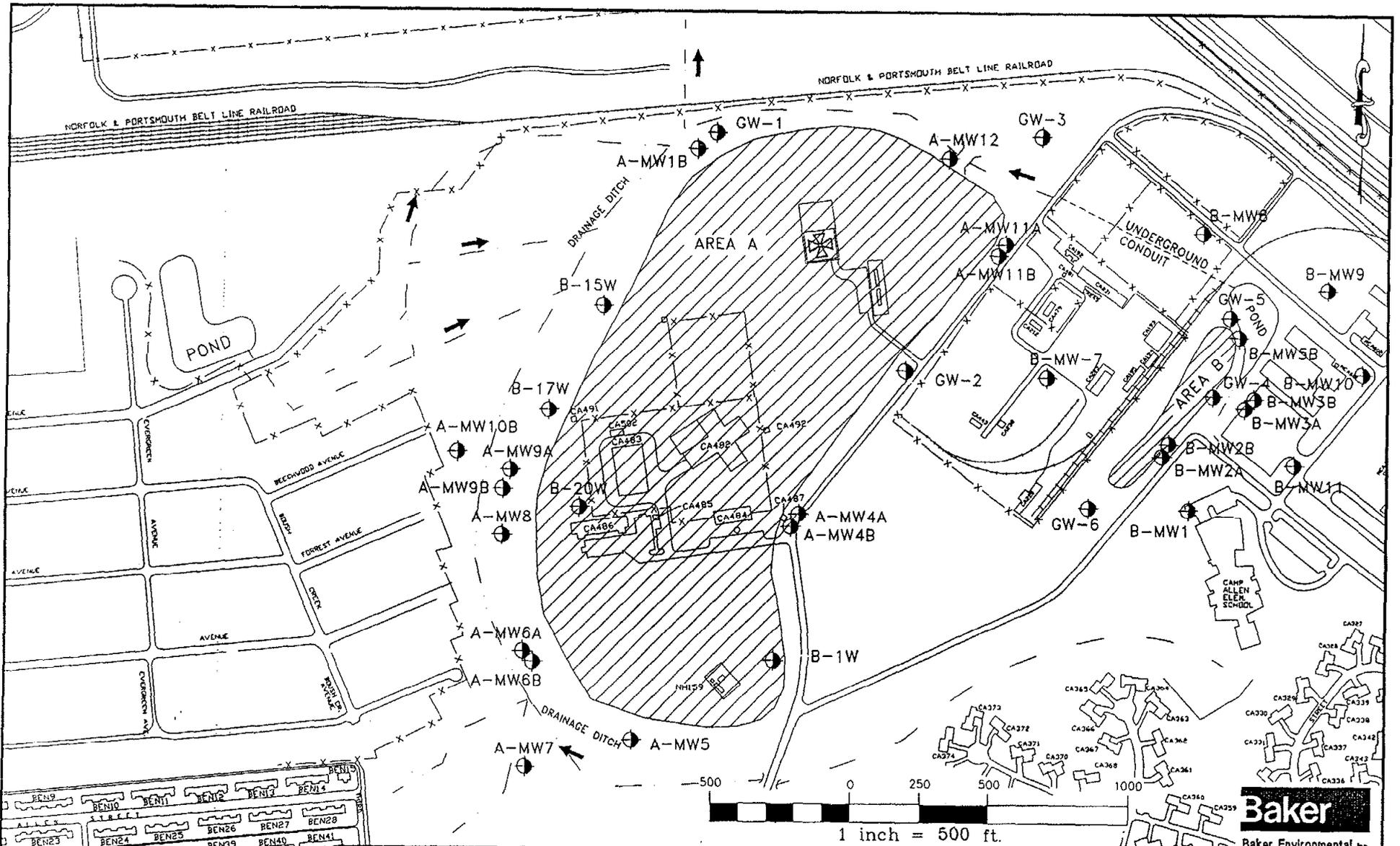
The IAS identified a high potential for migration of contaminants from the landfill to off-site areas via the shallow (surficial) groundwater and the surface water drainage ditches. Migration of contaminants to the deeper Yorktown Aquifer also was suggested since no evidence of a continuous aquitard (layer of low permeability soils which retard vertical groundwater flow) was found underlying the area. A Confirmation Study was recommended because of the potential for contaminant migration.

Malcolm Pirnie, Inc. conducted two separate (but related) investigations at the Camp Allen Landfill Site between 1983 and 1987. The investigations included a Confirmation Study (begun in 1983 and completed in 1987) and a Site Suitability Assessment (SSA) for a proposed Brig facility expansion at the site (begun in 1983 and completed in 1984).

Figures 2-1 and 2-2 present existing monitoring well locations and surface water and sediment sampling locations at Areas A and B from previous investigations, respectively.

### 2.1 Area A

The Camp Allen Landfill Site - Area A includes a large area of approximately 43 acres. Operations at the Camp Allen Landfill (Area A) were conducted from the early 1940s until about 1974 to dispose of a variety of materials. It is estimated that approximately 40,000 pounds of metal plating sludges, 60,000 pounds of parts cleaning sludges, and 400,000 pounds of paint stripping residues were disposed. Other materials disposed of at the site include incineration ash, fly and bottom ash from the Navy power plant, overage chemicals, spent chlorinated organic solvents, acids, caustics, paints, paint thinners, pesticides, asbestos, scrap metal, and construction and demolition debris.



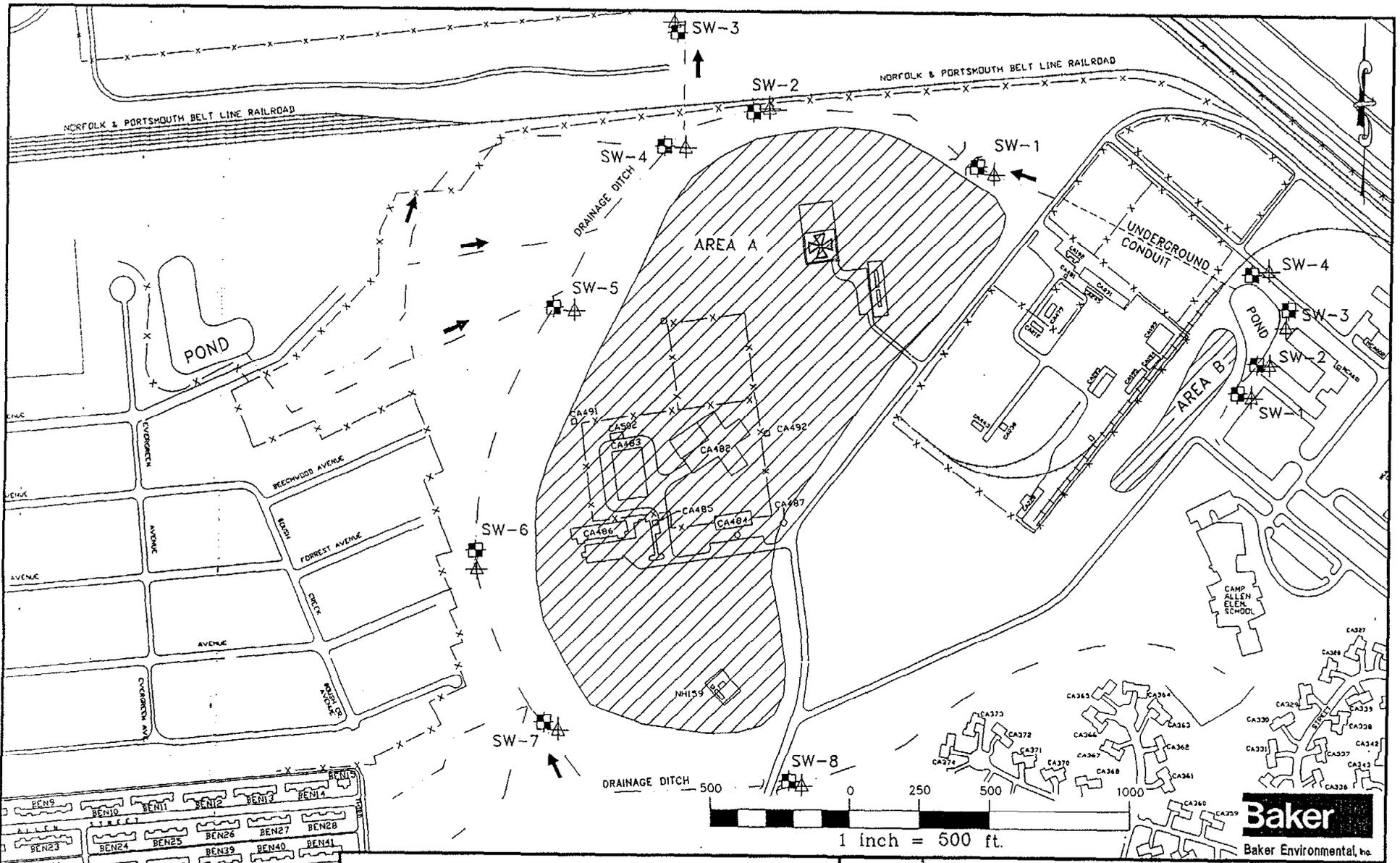
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⊗ EXISTING MONITORING WELL LOCATION

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 2-1**  
**EXISTING MONITORING WELLS**  
**CAMP ALLEN LANDFILL AREAS A & B**  
**NORFOLK NAVAL BASE**  
**NORFOLK, VIRGINIA**

2-3



**LEGEND**

- ▲ EXISTING SURFACE WATER SAMPLE LOCATION
- EXISTING SEDIMENT SAMPLE LOCATION

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 2-2**  
 EXISTING SURFACE WATER AND  
 SEDIMENT SAMPLE LOCATIONS  
 CAMP ALLEN LANDFILL AREAS A & B  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA

At present, the majority of Area A is capped with a grass cover to minimize surface erosion. Area A incorporates the Navy Brig facility in addition to a heliport built over a portion of the landfill. The area is adjacent to tidal drainage ditches that convey surface water runoff north to Willoughby Bay via the developed channel of Boush Creek. Additionally, a residential area (Glenwood Park) is located to the west of the site.

## 2.2 Area B

Area B is about two acres in size. In 1971, a fire in a salvage yard located between Landfill Areas A and B (Figure 1-2) occurred where waste lubricating oils, organic solvents, paints, paint thinners, acids, caustics, and pesticides were stored. It was reported that the burned material, smoldering residue from the fire, and residual waste, which was not burned, were buried just east of the salvage yard in Area B. Many of these wastes were reportedly drummed or otherwise containerized. The trenches used for landfilling in Area B were reportedly about 150 feet long, six to eight feet deep, and 10 feet wide.

At present, all of Area B is capped with a grass cover to minimize surface erosion. The area is adjacent to tidal drainage ditches that convey surface water runoff north to Willoughby Bay via the developed channel of Boush Creek. Additionally, the Camp Allen Elementary School is located approximately 300 feet southeast of the site.

## 2.3 References

Malcolm Pirnie, Inc. (1987), NACIP Program Confirmation Study. Sewell's Point Naval Complex, Norfolk, Virginia. Contract N62470-83-C-6079.

Malcolm Pirnie, Inc. (1984), NACIP Program Confirmation Study - Site Suitability Assessment, Proposed Brig Expansion (P-977). Naval Station, Norfolk, Virginia.

CH2M Hill (1990-1991), Raw Data and Site Summaries from Interim Remedial Investigation.

### **3.0 FIELD ACTIVITIES**

#### **3.1 Subcontractor Procurement**

Upon approval and finalization of the Project Plans, Baker will finalize the Scope of Work for selected subcontractors, including the driller, analytical laboratories, data validation subcontractor, Geoprobe subcontractor, and land surveyor. Prior to initiation of field work, Baker will finalize negotiations with the Geoprobe contractor, analytical laboratories, and drilling subcontractor.

#### **3.2 Site Investigation**

In addition to Project Management and Subcontractor Procurement, on-site work to be performed will include the following tasks:

- **Field Activities - Area A**
  - ▶ Geophysical Survey
  - ▶ Residential Well Sampling
  - ▶ Surface Water and Sediment Sampling
  - ▶ Monitoring Well Installation
  - ▶ Characterization of Contamination from B-20W Source
  - ▶ Geologic Borings
  - ▶ Groundwater Sampling/Sample Analysis
  - ▶ Air Sampling at Brig Facility
  - ▶ Slug Tests
  - ▶ Aquifer Test
  - ▶ Land Surveying
  
- **Field Activities - Area B**
  - ▶ Surface Water/Sediment/Soil Sampling
  - ▶ In-situ Groundwater Sampling (Geoprobe)
  - ▶ Drilling and Monitoring Well Installation
  - ▶ Characterize Source Contamination at Area B
  - ▶ First Round Groundwater Sampling Event
  - ▶ Groundwater Sampling - Round 2 and Round 3
  - ▶ Land Surveying
  - ▶ Slug Tests

Work at both areas will be conducted concurrently.

### **3.2.1 Site Visit**

The Baker Project Manager and Project Geologist participated in a meeting at LANTDIV and brief site visit February 7, 1992. During the meeting, sample locations were scoped and documented based on consultation with the Engineer-in-Charge (EIC). Baker also participated in a more in-depth site visit on March 24, 1992 with the EIC, and Activity personnel.

### **3.2.2 Background Review**

In addition to the site visit, a review of available background information was conducted. This review included available documents and analytical data results from previous investigations, in addition to available geologic/hydrogeologic information of both a site-specific and regional nature. The site visit and background review provided information to facilitate preparation of the project plans.

## **3.3 Field Activities - Area A**

### **3.3.1 Geophysical Survey**

At the outset of the investigation for this area, a geophysical survey will be conducted in order to assist in defining a drainage channel thought to be present below the landfill. Additionally, data will be used to modify locations of subsequent soil borings and monitoring wells. Various techniques will be utilized including electromagnetic profiling, gamma logging, and resistivity profiling.

In order to better define the location of the channel previously situated in the vicinity of Area A, the following geophysical survey tasks will be conducted:

- Three transects each of EM 31 and EM 34 data runs.
- Resistivity sounding (five sectors totaling not more than 2,000 L.F.).
- Six borehole gamma logs.

Continuity of the upper clay layer will be investigated by electromagnetic (EM) terrain conductivity profiling or resistivity constant spacing profiling along the lines of coverage as

shown on Figure 3-1. Both shallow and deep penetrating profiling will be conducted to determine the continuity of the clay layer.

Vertical electrical resistivity soundings will be used to determine the presence or absence of the clay layer. Resistivity data from these locations will be modeled to determine the subsurface strata and the thickness of the clay layer.

Natural-gamma logging in six existing deep boreholes nearest to the resistivity profiles (A-MW1B, A-MW4B, A-MW6B, A-MW9B, A-MW11B, and B-1W) will be used to identify lithology in addition to stratigraphic correlation across the site. Five deep well locations are selected in order to maximize subsurface characterization. If either of the 110-foot deep wells (A-MW1C and/or A-MW9C) are completed at the time of gamma logging, these wells will be used during the geophysical investigation instead of A-MW1B and/or A-MW9B.

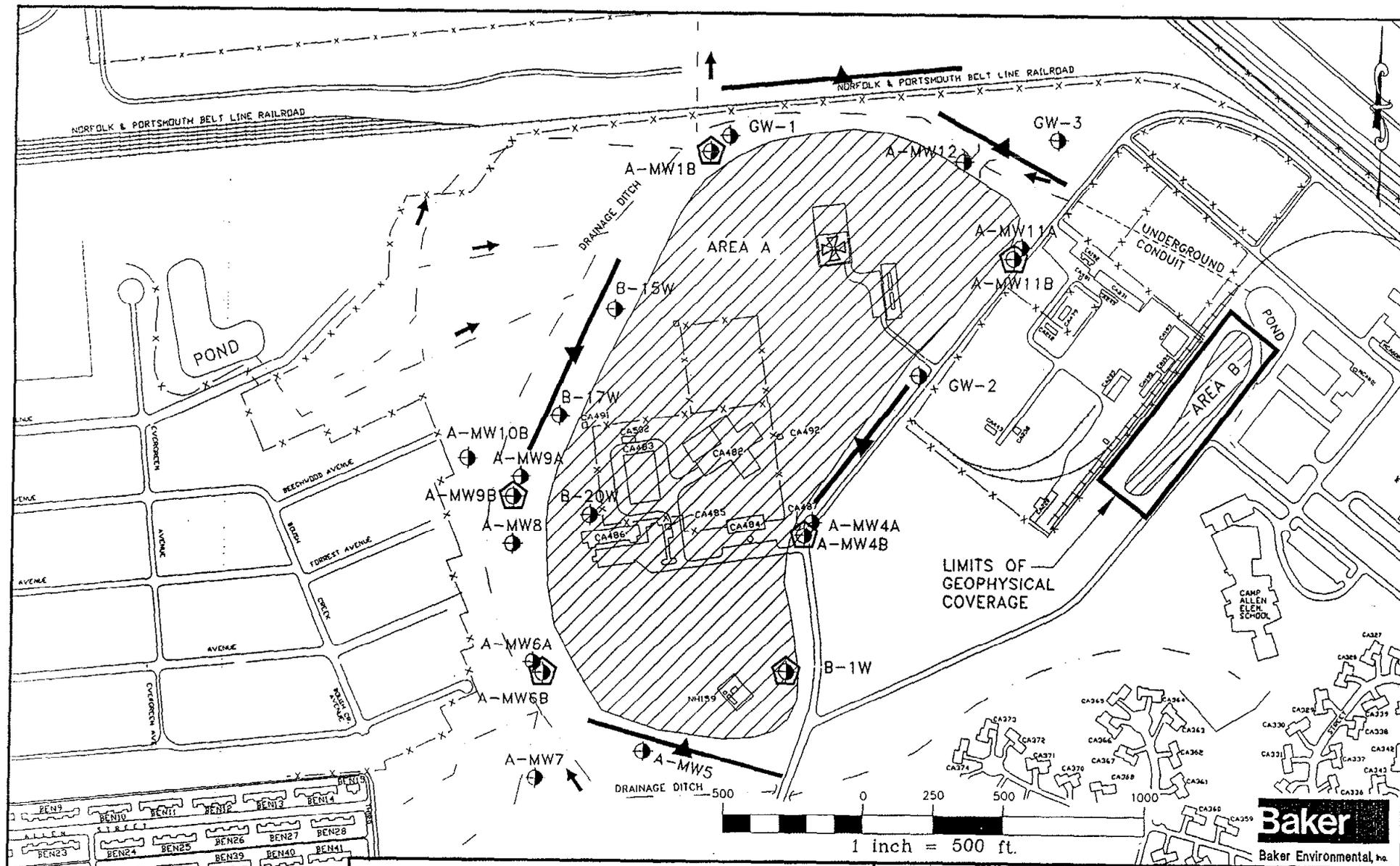
Section 4.3 presents a description of geophysical surveying procedures. Geophysical survey equipment and use is detailed in Section 5.1 - "Geophysics - Borehole;" Section 5.2 - "Geophysics - Electromagnetic Induction;" Section 5.3 - "Geophysics - Ground Penetrating Radar Profiling;" and Section 5.4 - "Geophysics - Magnetometry Profiling."

### **3.3.2 Residential Well Sampling**

It is anticipated that residential well sampling will be conducted prior to mobilization of the drilling rigs. Figure 3-2 presents previously sampled residential wells. Samples will be obtained from approximately five residential wells in the Glenwood Park area located west of the Area A landfill.

Samples will be collected from outside taps which are located closest to the well. Well water will be allowed to flow from the tap for a period of approximately 10 to 15 minutes prior to sampling to permit the lines to clear of stagnant water. During the 15 minute purge time, temperature, pH, and specific conductivity will be measured using field instrumentation.

Subsequent to purging, groundwater will be collected into the appropriate sampling containers, packaged, and shipped to the laboratory for analysis of volatile organic compounds. All sampling equipment will be removed prior to departure from the residence.



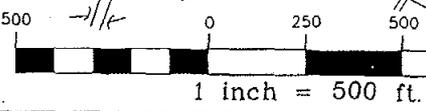
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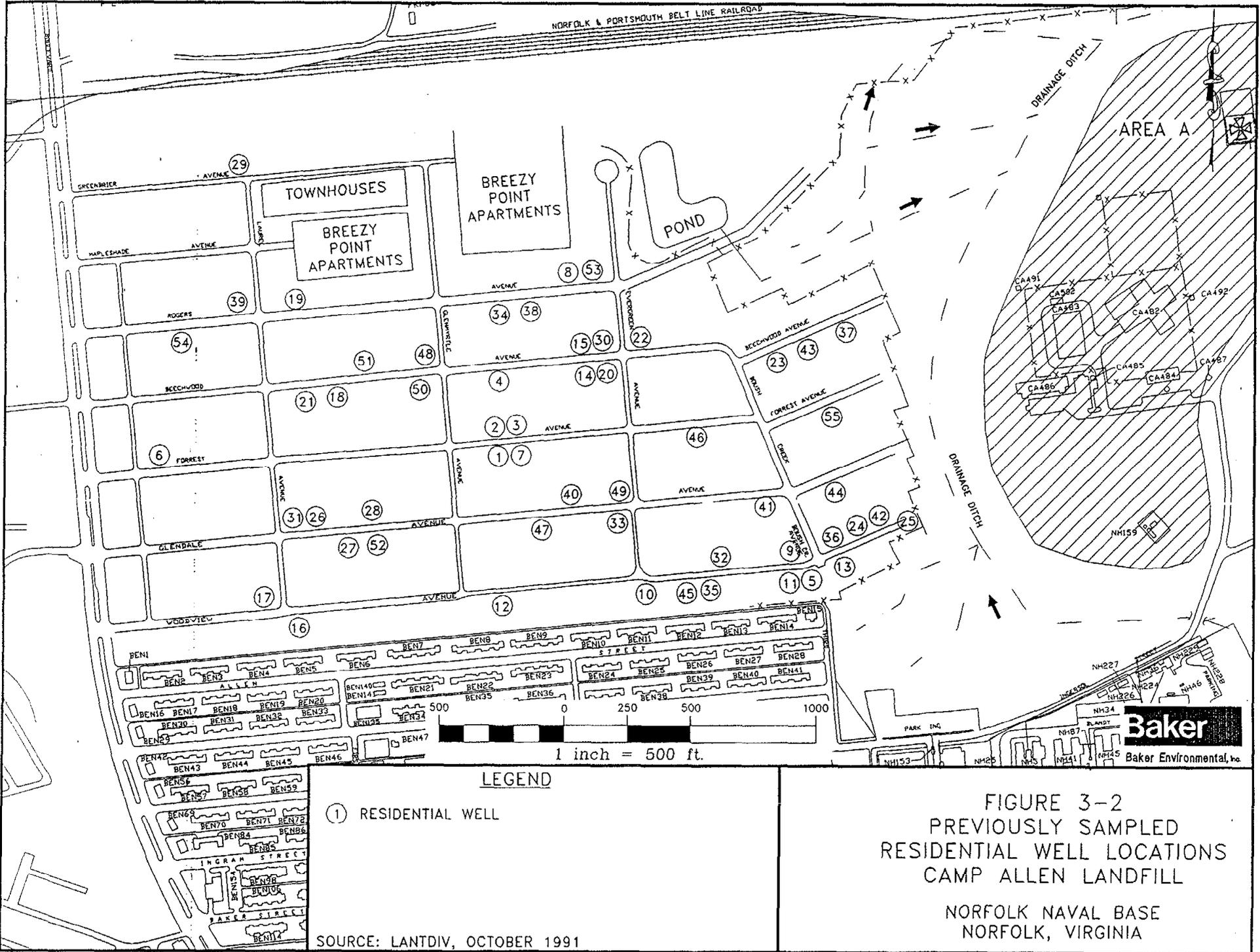
- EXISTING MONITORING WELL LOCATION
- EM PROFILE
- GAMMA LOGGING LOCATION
- RESISTIVITY SOUNDING

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-1**  
**PROPOSED GEOPHYSICAL INVESTIGATION**  
**CAMP ALLEN LANDFILL AREAS A & B**

NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA





**LEGEND**  
 (1) RESIDENTIAL WELL

**FIGURE 3-2**  
 PREVIOUSLY SAMPLED  
 RESIDENTIAL WELL LOCATIONS  
 CAMP ALLEN LANDFILL  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA

SOURCE: LANTDIV, OCTOBER 1991

Section 4.4 presents general field operations for Residential Well sampling. Stabilization of field measurements are discussed in Section 5.5 "Water Quality Testing."

### **3.3.3 Surface Water and Sediment Sampling**

Surface water and sediment will be sampled from the drainage channels in the vicinity of Area A. Sediment samples will be collected from 20 locations as presented in Figure 3-3. Eight of the 20 sample locations will be in the vicinity of surface water and sediment sampling from the previous investigation.

Surface water samples will be collected prior to sediment sampling from eight locations (Figure 3-3) and will be analyzed for TCL and TAL (dissolved only) parameters, chloride, sulfate, and alkalinity. The scope of work may be modified to include aqueous total metals analysis. Additionally, sampling locations may be modified to address other potential drainageways.

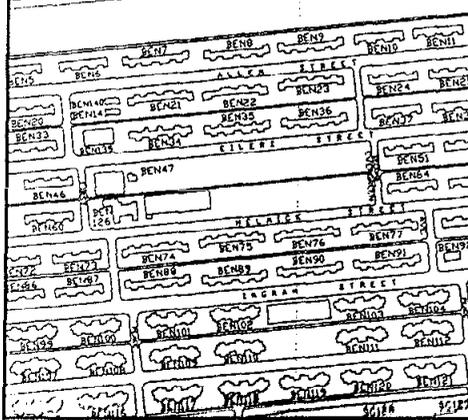
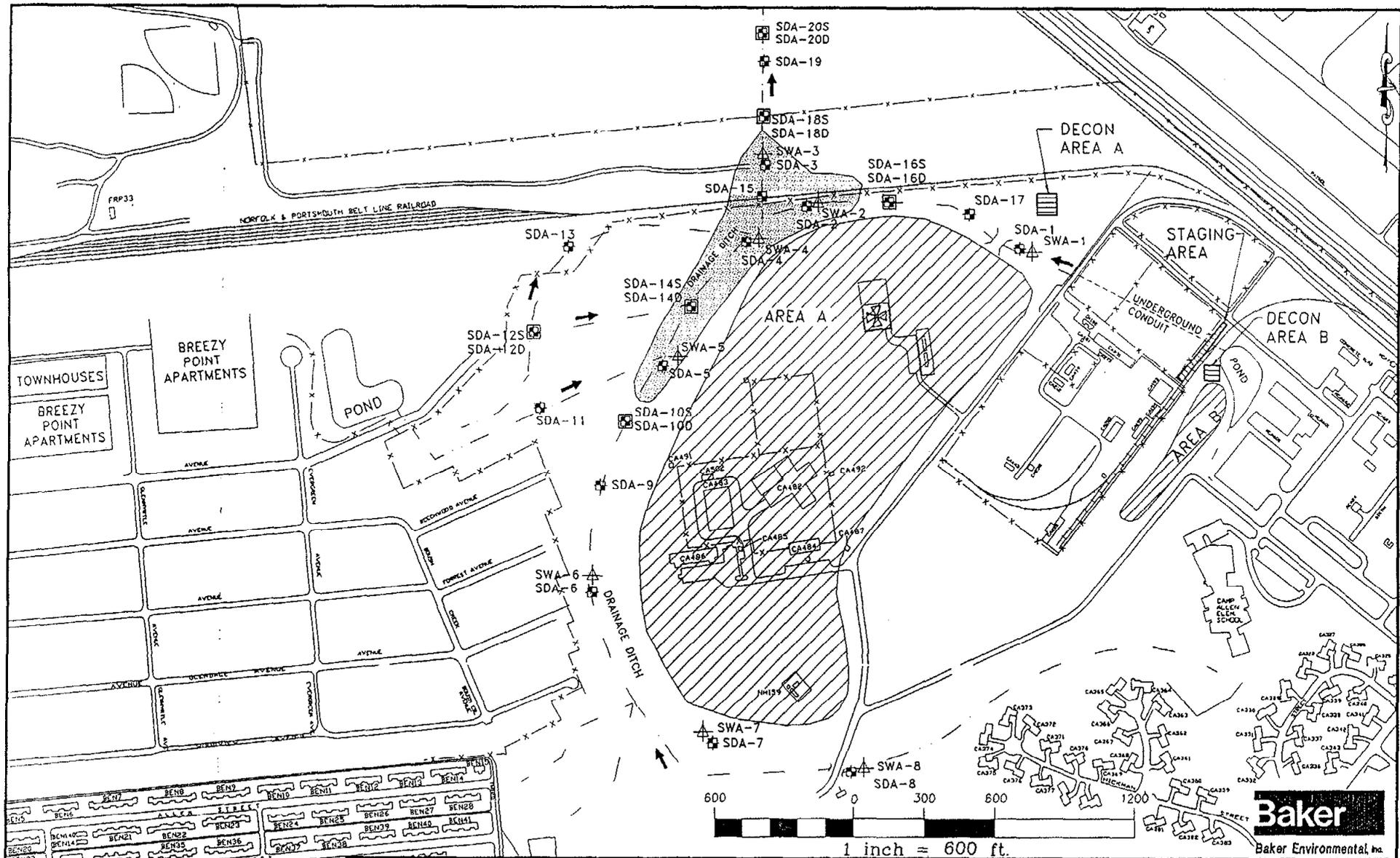
Sediment samples will be collected subsequent to surface water sampling from a depth of 0 to 0.5 feet at each location. Additionally, one sediment sample will be collected from a depth of 2 to 2.5 feet at six of the locations (Figure 3-3). All sediment samples will be analyzed for selected metals (arsenic, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and vanadium).

Sampling of surface water and sediment will be conducted from downstream to upstream to reduce the amount of turbidity in the surface water samples. Additionally, sampling will occur at times of low tide and low flow to minimize dilution of possible contaminants. Therefore, sampling activities will not occur subsequent to periods of heavy rainfall.

Section 4.5 details general field operations and Section 5.6 presents Surface Water and Sediment Sampling SOPs.

### **3.3.4 Drilling and Monitoring Well Installation**

Subsequent to the geophysical survey, residential well sampling, and surface water/sediment sampling activities, a series of monitoring wells will be installed to determine the extent of groundwater contamination in the vicinity of Area A. Monitoring well locations are presented in Figure 3-4.

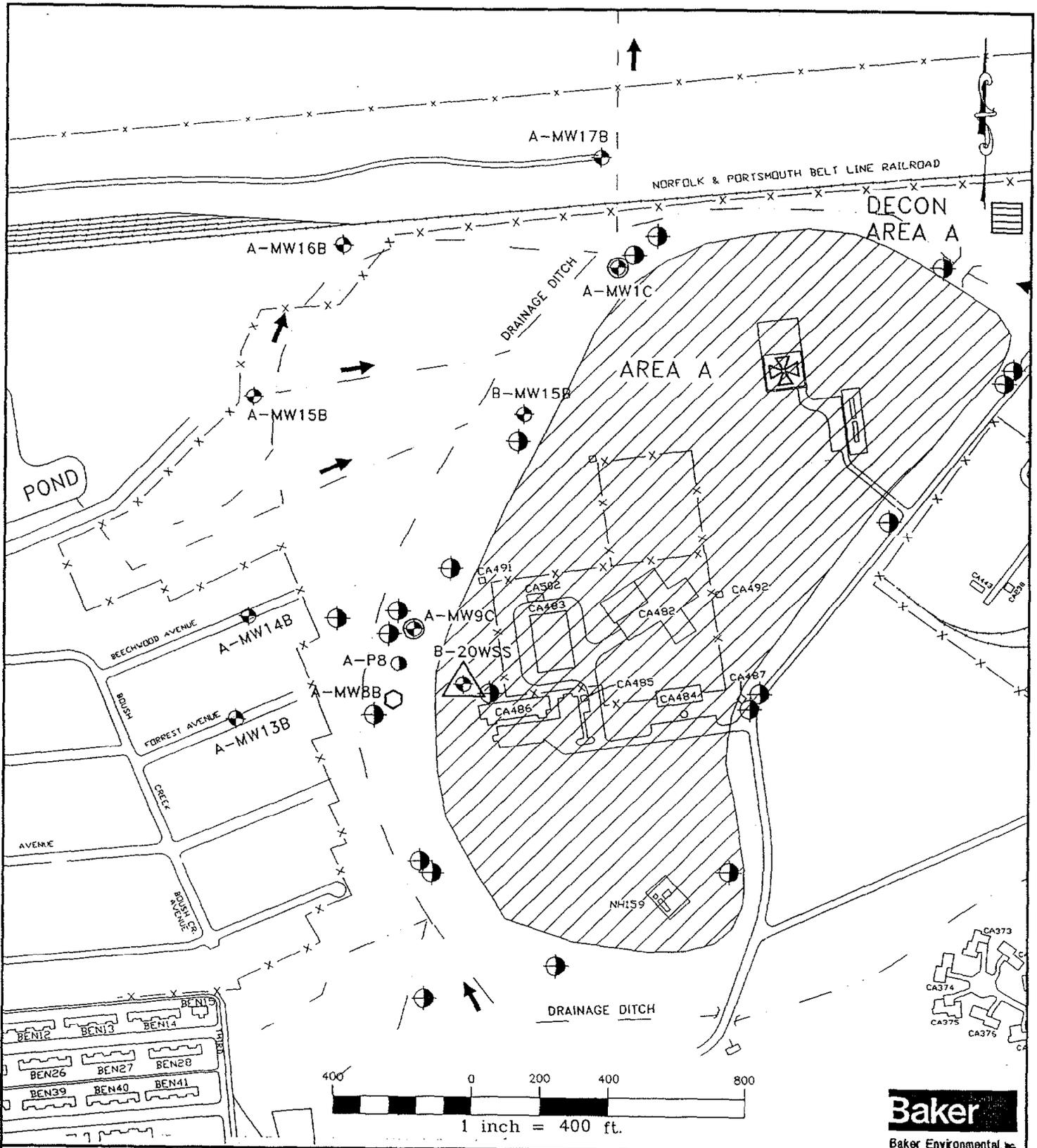


**LEGEND**

- ☒ PROPOSED SEDIMENT SAMPLE LOCATION  
DEPTH 0 - 0.5 ft.
- ☒☒ PROPOSED SEDIMENT SAMPLE LOCATION  
DEPTH 0 - 0.5 ft. AND 2.0 ft. - 2.5 ft.
- ☒ AREA OF ELEVATED METALS CONCENTRATIONS  
(SEDIMENTS)

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-3**  
**PROPOSED SURFACE WATER AND**  
**SEDIMENT SAMPLE LOCATIONS**  
**CAMP ALLEN LANDFILL - AREA A**  
**NORFOLK NAVAL BASE**  
**NORFOLK, VIRGINIA**



**Baker**  
Baker Environmental, Inc.

**LEGEND**

- ⊙ PROPOSED TYPE III MONITORING WELL LOCATION ( DEPTH 65 ft.)
- ⊕ PROPOSED TYPE III MONITORING WELL LOCATION ( DEPTH 110 ft.)
- ⊖ PROPOSED TYPE III PUMPING WELL LOCATION (DEPTH 65 ft.)
- ⊙ PROPOSED PIEZOMETER LOCATION (DEPTH 65 ft.)
- ⊙ EXISTING MONITORING WELL LOCATION (DEPTH 30ft.)
- ⊙ PROPOSED STAINLESS STEEL (TYPE II) WELL LOCATION (DEPTH 30ft.)

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-4**  
**PROPOSED MONITORING WELL LOCATIONS**  
**CAMP ALLEN LANDFILL - AREA A**

NORFOLK NAVAL BASE  
NORFOLK, VIRGINIA

Two 110-foot deep wells will be installed at A-MW9 and A-MW1. These two wells will be set at 110 feet, but drilling is anticipated to reach 150 feet depth to define the bottom elevation of the Yorktown Aquifer. These two wells will be installed prior to installation of the 65-foot deep wells. If contaminants exist at deeper levels than 65 feet, the total depth of the seven 65-foot deep wells to be drilled downgradient from the landfill will be evaluated and modified, as necessary.

Seven 65-foot deep monitoring wells will be installed subsequent to the installation of the two 110-foot deep wells. Two 65-foot deep wells will be installed on site at locations A-MW8 and B-15W. The well at A-MW8 will be 4-inches in diameter to facilitate conducting an aquifer test (Section 3.3.10). Five wells will be installed downgradient of the landfill on the other side of the western drainage channel to characterize horizontal migration of contaminants in the Yorktown Aquifer. Additionally, these wells will be placed in locations which may be used to measure groundwater elevations during the aquifer test.

- One well will be installed on Forrest Avenue (within the Glenwood Park housing plan) approximately midway between the Base fence and the intersection of Forrest Avenue and Boush Avenue.
- One well will be installed approximately 150 feet west of the Base fence on Beechwood Avenue.
- One well will be located approximately 800 feet west of existing well B-15W and east of an existing dirt pile east of the Breezy Point Apartment complex.
- One well will be located approximately 600 feet west of existing well A-MW1B.
- One well will be located approximately 300 feet north of existing well nest A-MW1A/B at the end of the gravel road along the Norfolk and Portsmouth Railroad Right-of-Way.

One 65-foot deep piezometer will be installed near A-MW8 (approximately 50 feet south or west, as accessible) to be utilized during the aquifer test.

It is estimated that wells will be screened from 110 to 100 feet below ground surface in the two 110-foot deep wells, and from 65 to 55 feet below ground surface in the seven 65-foot deep wells. However, these screen depths are subject to change depending upon field conditions and Round 1 analytical results.

Sections 4.6 and 4.7 detail general field operations for well installation and well construction. Sections 5.7 and 5.8 present "Borehole and Sample Logging" and "Monitoring Well Installation," respectively.

### **3.3.5 Source Characterization of Contamination from B-20W**

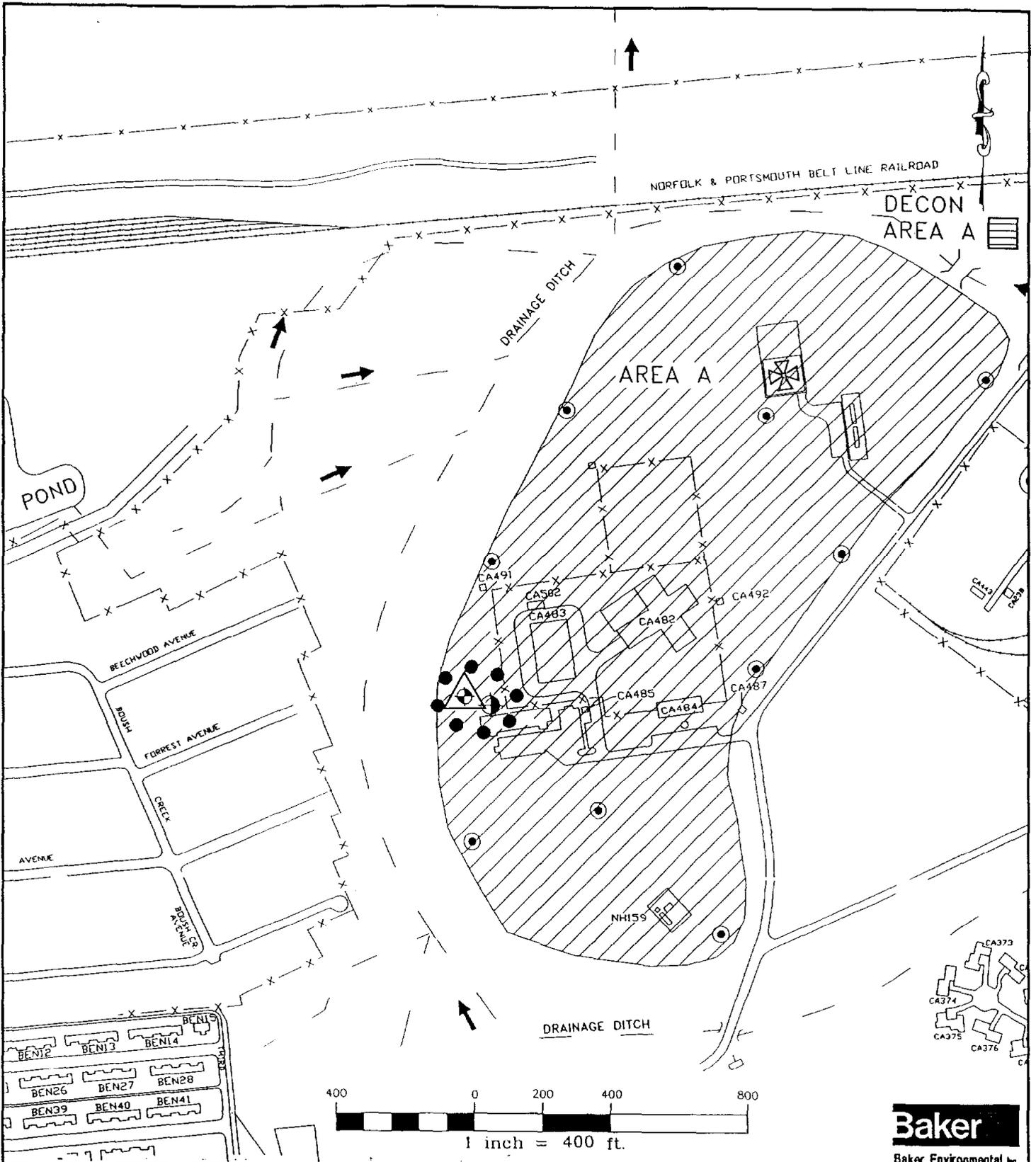
The extent of contamination at monitoring well B-20W (see Figure 3-4) will be characterized by installing one stainless-steel monitoring well to the bottom of the surficial aquifer (approximately 30 feet below ground surface) to evaluate the presence of Dense, Nonaqueous Phase Liquids (DNAPLs) at this location. It is assumed that drilling will be performed in elevated levels of personal protective equipment (Level C or Level B) during this activity, as previous analytical results indicate high concentrations of volatile organic compounds (VOCs) in the groundwater.

Eight soil borings will be drilled to a depth of 20 feet near B-20W, as shown in Figure 3-5, in order to evaluate the extent of the source contamination in the soil surrounding this well. Subsurface soil samples from the borings will be screened with an HNu photoionization detector to measure volatile organic vapors. One subsurface soil sample from each boring will be submitted for analysis of TCL parameters. These samples will be obtained from just above the water table. Additionally, one groundwater sample from the stainless-steel well will be submitted for analysis of TCL and TAL parameters. It is assumed drilling will be performed in elevated levels of personal protective equipment (Level C or Level B).

Section 4.8 details general field operations for Soil Borings. Sections 5.7, 5.9, 5.10, and 5.11 present Baker's SOPs for "Borehole and Sample Logging," "Soil and Rock Sample Acquisition," "Photoionization Detector," and "Flame Ionization Detector," respectively.

### **3.3.6 Geologic Borings**

Ten subsurface borings will be drilled in and around the landfill at Area A (Figure 3-5) to better define the distribution of the clay layer underlying the surficial aquifer. The clay layer



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**LEGEND**

- ⊙ PROPOSED GEOLOGIC BORING (DEPTH 40 ft.)
- PROPOSED SOURCE CHARACTERIZATION BORINGS (DEPTH 20 ft.)
- ⊕ B-20W
- ⚠ B-20WSS

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-5**  
**PROPOSED TEST BORING LOCATIONS**  
**CAMP ALLEN LANDFILL - AREA A**

NORFOLK NAVAL BASE  
NORFOLK, VIRGINIA

is assumed to begin at a depth of approximately 30 feet and extend to a depth of about 60 feet. The borings will be advanced to an estimated depth of 40 feet. However, when the clay unit is encountered, drilling will advance no further than two to four feet into the clay to prevent possible penetration through the unit.

It is assumed that drilling on the landfill will be performed in elevated levels of personal protective equipment (Level C or Level B).

One sample of clay each will be collected from five of the ten borings (to be determined in the field) and submitted to a laboratory for physical parameter testing including:

- Grain size by sieve and hydrometer (D422)
- Atterberg limits
- Bulk density
- Moisture content (D2216)

Subsequent to drilling and sample collection each boring will be backfilled with a cement/bentonite grout to the ground surface. Section 4.8 describes general field operations for soil borings. Section 5.7 presents "Borehole and Sample Logging" SOPs.

### **3.3.7 Groundwater Sampling - Rounds 1, 2, and 3**

Three separate groundwater sampling events will be conducted as part of the investigation. The results of the first round will be used to help determine if the extent of the contamination has been defined by the newly installed wells. Wells will be developed and sampled not less than 24 hours after installation, as per LANTRDIV's directive.

Round 1 - Subsequent to well development of each of the seven newly-installed, 65-foot deep wells, groundwater will be collected and analyzed for chlorinated volatile organic compounds (VOCs) by EPA Method 601. A local laboratory (non-NEESA certified) will be used to analyze the samples from the 65-foot deep wells on a two- to three-day accelerated turn around basis.

Additionally, the two 110-foot deep monitoring wells will be sampled and analyzed via EPA Method 624. Two samples will be collected from each of the 110-foot deep wells. The local laboratory will be used to analyze the first set of samples from the 110-foot deep wells on a two- to three-day accelerated turn around basis. Additionally, a field Gas Chromatograph, to be

used during the Geoprobe investigation at Area B may be available to "field screen" the second set of groundwater samples from the two 110-foot deep wells using EPA Method 601 (modified).

Round 2 - Sixteen shallow wells and 15 deep wells will be sampled and samples submitted to the laboratory to be analyzed for the TCL and TAL compounds, chloride, sulfate, and alkalinity. Additionally, the 30-foot deep stainless steel well will be sampled and analyzed for TCL parameters only. Contract Laboratory Program (CLP) protocols (Level D QA/QC) will be used during analysis. TAL metals (dissolved) analysis may be modified to include total metals.

Round 3 (Optional) - Fifteen deep wells will be sampled no less than three months (90 days) after the second sampling event (Round 2). These samples will be analyzed for the TCL volatile organic compounds only. It is assumed that the other compounds will not be detected in significant concentrations to require continued monitoring. CLP protocols (Level D QA/QC) will be used during analysis. If elevated concentrations of contaminants other than volatile organic parameters are present in the Round 2, Baker will recommend increasing the analytical program in Round 3 to include additional parameters, as necessary.

Static water level will be measured in all existing and newly installed wells during each sampling event. Measurements will be obtained from top of casing to determine groundwater elevation.

Sections 4.9 and 4.10 details general field operations for well development and groundwater sampling activities, respectively. Sections 5.12 and 5.13 present "Water Level, Water-Product Level, and Well Depth" and "Groundwater Sample Acquisition" SOPs, respectively.

### **3.3.8 Air Sampling at Brig Facility**

Air sampling activities will be conducted according to the LANTDIV SOW and the Air Sampling Plan Addendum to be developed by Baker. Eight air samples will be collected in the vicinity of the Brig Facility at Area A and will be analyzed for TCL volatile organic compounds only.

Three samples will be collected inside the facility at a location nearest to monitoring well B-20W to characterize the effect the well has on interior ambient air conditions. Three

samples will be collected from outside the facility (in the vicinity of monitoring well B-20W) to characterize ambient air conditions in the immediate area. Additionally, one background sample will be collected from inside the building and one background sample will be collected from outside the building at points farthest from well B-20W.

It is anticipated that two eight-hour sampling periods will occur during this activity. The Air Sampling Plan Addendum will detail the Air Sampling Program including interior and exterior sampling locations, parameters to be analyzed, sampling protocols, etc.

### **3.3.9 Slug Tests**

An in-situ hydraulic conductivity test (slug test) will be conducted on eight of the 11 newly installed wells (six 65-foot and two 110-foot deep) at Area A. The 4-inch well, stainless steel well, and piezometer, will not be included in this task. One rising head test and one falling head test will be conducted on each well.

The rising-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically downward at the initiation of the test; the decay of this artificially depressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

The falling-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically upward at the initiation of the test; the decay of this artificially impressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Section 4.11 details general field operating procedures for slug tests. Section 5.12 presents the "In-situ Hydraulic Conductivity Testing" SOP.

### **3.3.10 Aquifer Test**

The aquifer test will be conducted by the drilling subcontractor to determine the Yorktown Aquifer hydraulic parameters. Monitoring well A-MW8B will be pumped for a 24-hour period and will be allowed to recover for a period of 24-hours. Water levels will be monitored at seven well locations and the newly installed piezometer during the 48-hour test.

Section 4.12 details general field operations for conducting an aquifer test. Section 5.15 presents the "Aquifer Testing" SOP.

### **3.3.11 Land Surveying**

Thirty-two existing monitoring wells, ten newly installed wells, one piezometer, and existing staff gauges will be surveyed for vertical and horizontal control. A registered land surveyor will determine the elevations and locations of all monitoring wells and site structures (i.e., staff gauges). Soil borings, surface water/sediment sampling locations, and geophysical survey points will not be surveyed, but will be referenced to existing structures and mapped.

Section 4.13 presents general land surveying procedures.

## **3.4 Field Activities - Area B**

Field activities will include a geophysical survey, surface water/sediment/surface soil sampling, installation of groundwater monitoring wells with associated groundwater sampling, soil borings with associated subsurface soil sampling, slug tests, and land surveying.

### **3.4.1 Surface Water/Sediment/Soil Sampling**

A total of eight sediment samples will be submitted for analysis of parameters from the TCL and TAL. Sediment samples will be collected from six locations at a depth of 0 to 0.5 feet. Additionally, one sediment sample will be obtained from a depth of 2 to 2.5 feet at two of the locations. Samples will be collected in the vicinity of previous sediment sampling activities at the pond and drainage channel located adjacent to Area B.

Surface water samples will be obtained from five locations at the pond and drainage channel and will be analyzed for TCL and TAL parameters.

Near-surface soil samples will be collected from a depth of about two feet below ground surface in the vicinity of the schoolyard adjacent to Area B. Due to a Technical Review Committee (TRC) member request, a total of three grab samples will be submitted to the laboratory for analysis of TAL metals only. All analytical work under this task will be conducted using CLP protocols (Level D QA/QC).

Figure 3-6 presents surface water/sediment sampling locations and surface soil sampling locations at Area B. Soil sample locations at the school were selected to address the schoolyard area as a whole.

Section 4.5 details general field operations for surface water and sediment sampling. Section 5.6 presents Baker's "Surface Water and Sediment Sampling Acquisition" SOP.

#### **3.4.2 In-situ Groundwater Sampling (Geoprobe)**

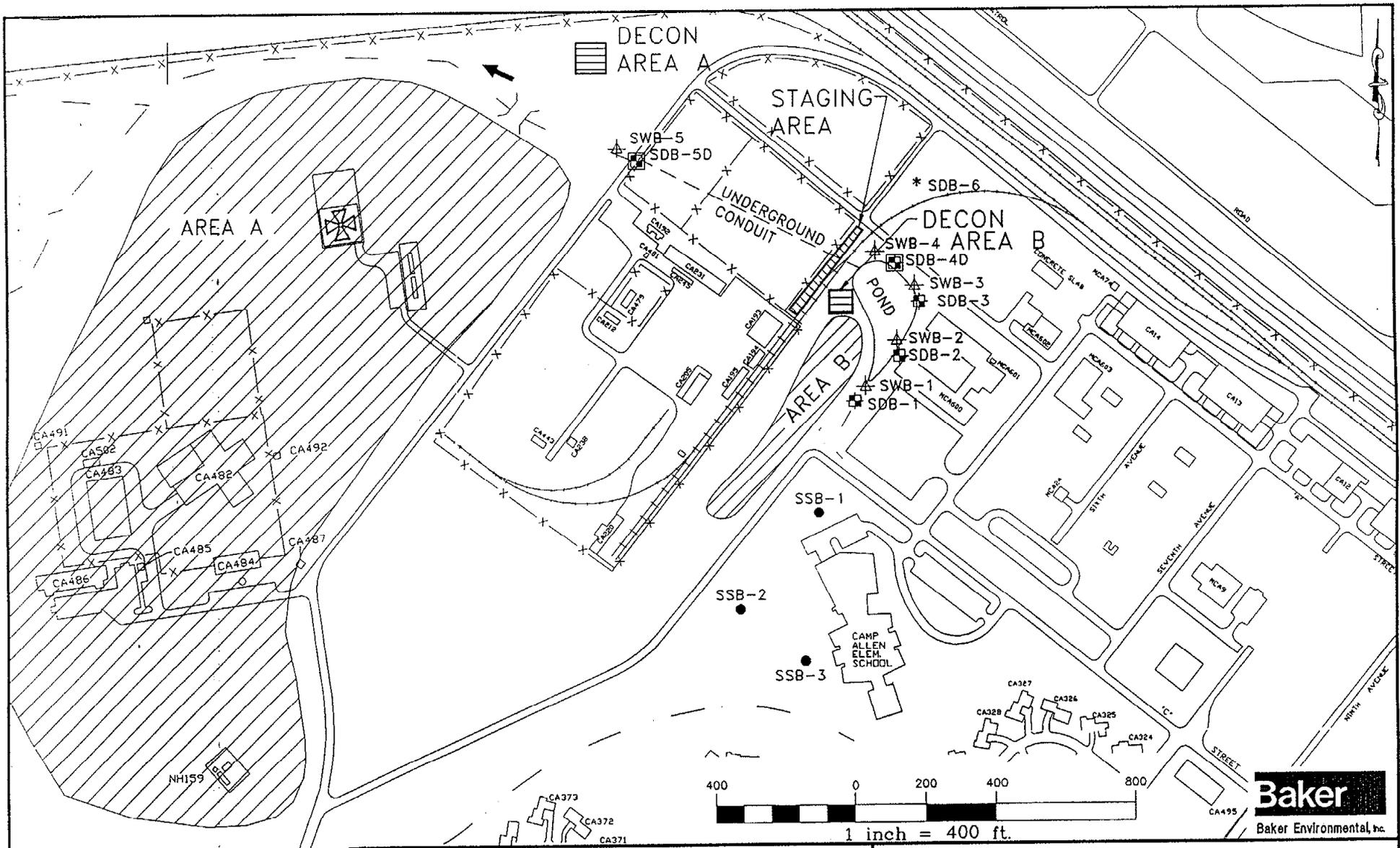
The Geoprobe sampling technique can sample and analyze subsurface contamination in soil gas, soil, and/or groundwater. During the initial phase of the investigation at Area B, the Geoprobe system will be utilized to collect and analyze groundwater samples to assist in determining the extent of contamination in the surficial aquifer, as well as the direction of migration. This information will aid in determining optimum locations for the five shallow monitoring wells to be installed downgradient of Area B.

Prior to well installation, groundwater samples will be collected from 25 locations in a "crescent shaped" area approximately 450 feet wide as presented in Figure 3-7. Due to the presence of volatile organic contaminants in the existing wells, the area downgradient of the wells will be investigated.

Two sets of groundwater samples will be collected at each sampling location. The first set of samples will be collected and analyzed by a gas chromatograph (GC) in an on-site laboratory equipped van. The on-site GC will be used to scan the groundwater samples and will be able to relay results to the field crew on a same-day basis so that field decisions can be made regarding the placement of shallow monitoring wells. EPA Method 601 (modified) will be used to analyze selected VOCs based on previous analytical results.

The second set of groundwater samples will be shipped to a local laboratory (non-NEESA certified) and will be analyzed within a two- to three-day time frame for chlorinated volatile organic compounds using Method 601.

Subsequent to collecting the groundwater sample, the probe will be removed and the hole will be backfilled to the ground or surface with a cement/bentonite grout mixture. It is anticipated that the Geoprobe will be advanced in both paved and grass-covered areas.



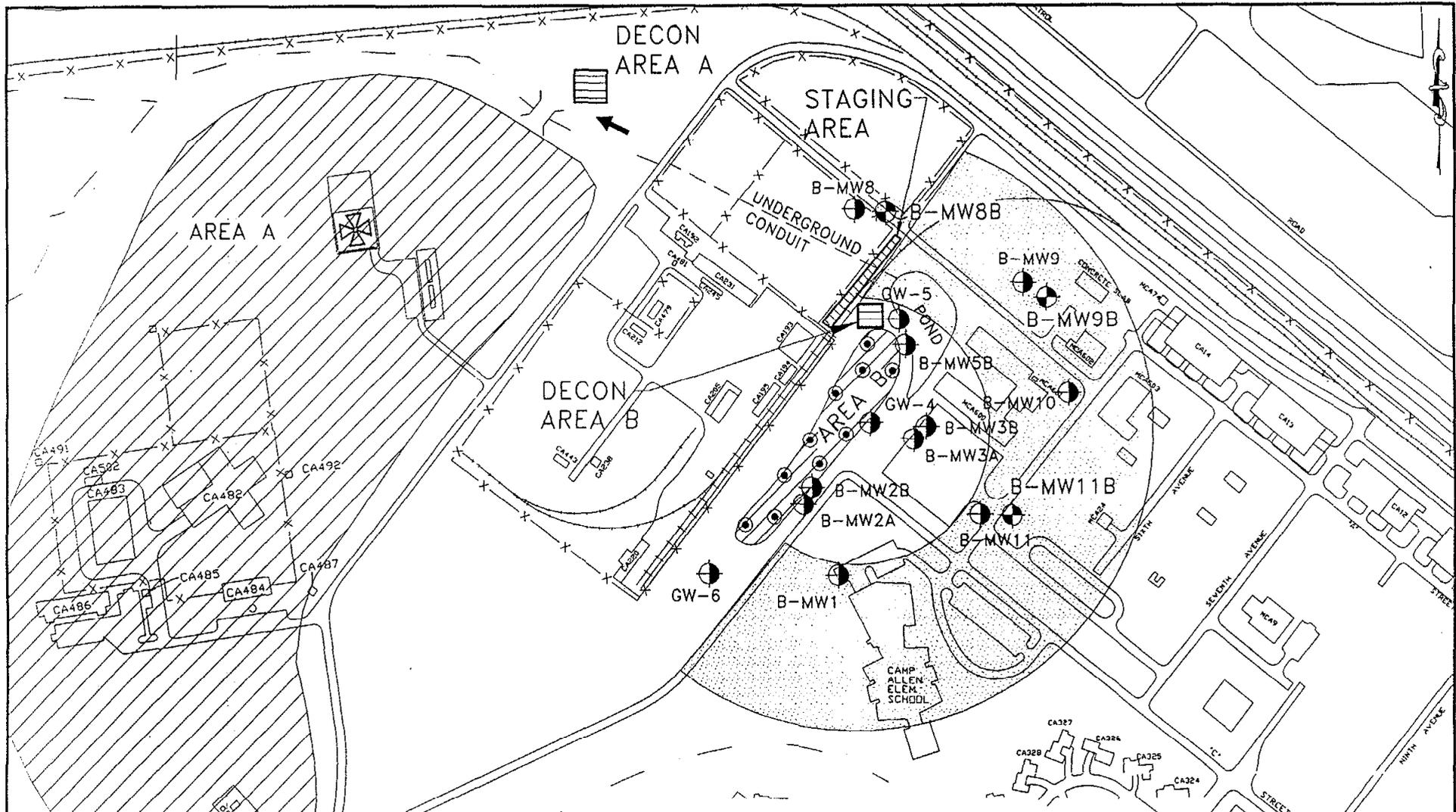
**LEGEND**

- ▲ PROPOSED SURFACE WATER SAMPLE LOCATION
- PROPOSED SEDIMENT SAMPLE LOCATION (DEPTH 0-0.5 ft.)
- ◻ PROPOSED SEDIMENT SAMPLE LOCATION (DEPTH 0-0.5 ft. AND 2.0 ft.-2.5 ft.)
- PROPOSED SURFACE SOIL SAMPLING LOCATION
- \* SDB-6 SAMPLE LOCATION IS RESERVED FOR FIELD CONFIRMATION

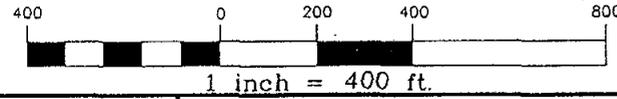
SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-6**  
 PROPOSED SURFACE WATER/SEDIMENT/  
 SURFACE SOIL SAMPLING LOCATIONS  
 CAMP ALLEN LANDFILL - AREA B  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA

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NOTE:  
 TYPE III MONITORING WELL LOCATION  
 DEPENDANT ON GEOPROBE SAMPLING  
 RESULTS.



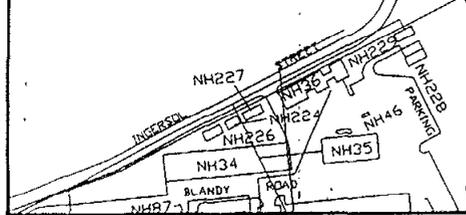
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LEGEND

- PROPOSED TYPE III MONITORING WELL LOCATION (DEPTH 65 ft.)
- PROPOSED TEST BORING LOCATION
- EXISTING MONITORING WELL LOCATION
- PROPOSED GEOPROBE SAMPLING AREA

SOURCE: LANTDIV, OCTOBER 1991

**FIGURE 3-7**  
 PROPOSED GEOPROBE SAMPLING AREA,  
 TEST BORINGS AND DEEP WELL LOCATIONS  
 CAMP ALLEN LANDFILL - AREA B  
 NORFOLK NAVAL BASE  
 NORFOLK, VIRGINIA



The Geoprobe system will be used to collect and analyze groundwater samples at approximately 10 locations per day. If contamination is present, proposed monitoring well locations (tentatively located during the site visit) will be adjusted in order to better define the contamination plume.

### **3.4.3 Drilling and Monitoring Well Installation**

A total of eight monitoring wells will be installed to determine the extent of groundwater contamination in both the surficial and Yorktown aquifers. Locations will be determined during the site visit and by in-situ groundwater sampling (Geoprobe) results.

Five 25-foot deep monitoring wells will be installed at locations determined by the results of the Geoprobe sampling activity. These wells will be constructed using 2-inch diameter PVC riser and 10-foot screen length. The shallow wells will be screened from approximately 25 feet to 15 feet below ground surface. It is anticipated that the majority of the shallow wells will be completed with flush-mount protective casing in traffic areas.

Three 65-foot deep monitoring wells will be installed adjacent to existing shallow wells B-MW7, B-MW8, and B-MW11.

These wells will be constructed using 2-inch diameter PVC riser and 10-foot screen length. The deep wells will be screened from approximately 65 feet to 55 feet below ground surface. It is anticipated that the majority of the deep wells will be completed with a 5-foot length of protective casing and guard posts in nontraffic areas.

Figure 3-7 also presents Area B proposed monitoring well locations.

Sections 4.6 and 4.7 detail general field operations for monitoring well installation and construction, respectively. Sections 5.7, 5.8, and 5.9 presents Baker's "Borehole and Sample Logging," "Soil and Rock Sample Acquisition," and "Monitor Well Installation" SOPs, respectively.

#### **3.4.4 Characterize Source Contamination at Area B**

As part of the Source Characterization Task, a magnetometer or Ground Penetrating Radar (GPR) survey will be performed to determine if any drums or buried metal are present (Figure 3-1).

Based on the results of the geophysical survey at Area B, ten borings will be drilled to a depth of approximately 10 feet. Figure 3-7 shows proposed test boring locations at Area B based on the results of a previous soil gas survey. Actual soil boring locations will be adjusted in the field subsequent to review of the geophysical survey at Area B. It is assumed drilling on the landfill will be performed in elevated levels of personal protective equipment (Level C or Level B).

Subsurface soil samples will be screened for volatile organic vapors using an HNu photoionization detector (PID). One subsurface soil sample from each borehole will be submitted to the laboratory for chemical analysis. Most likely this sample will be collected just above the water table or at a depth determined by the site geologist based on evidence of visual and/or measured contamination. Analytical parameters will include TCL and TAL parameters.

Sections 4.3 and 4.9 detail general field operations for geophysical survey and soil boring activities. Sections 5.3 and 5.4 present "GPR" and "Magnetometry Profiling," respectively. Sections 5.7 and 5.9 present "Borehole and Sample Logging" and "Soil and Rock Sample Acquisition," respectively.

#### **3.4.5 First Round Groundwater Sampling Event**

Subsequent to well development, three newly installed 65-foot deep wells will be sampled during this event. Samples will be analyzed for VOCs using EPA Method 601.

A local (non-NEESA certified) laboratory will be used to analyze the samples on a two- to three-day accelerated turnaround basis. Wells will be developed and sampled not less than 24 hours after installation per LANTDIV's directive.

### **3.4.6 Groundwater Sampling - Round 2 and Round 3**

Round 2 - During the Area B investigation sixteen shallow and six deep monitoring wells will be sampled and analyzed for the TCL and TAL compounds, chloride, sulfate, and alkalinity. Contract Laboratory Program protocols (Level D QA/QC) will be used during analysis.

Round 3 (Optional) - Twenty-two wells (fourteen existing and eight newly installed wells) will be sampled during this event. Samples will be analyzed for the TCL volatile organic compounds only. Contract Laboratory Program protocols (Level D QA/QC) will be used during Round 3 analysis. It is assumed that the other compounds will not be detected in significant concentrations to require continued monitoring. However, if other compounds are detected in significant concentrations during Round 2, a modification to the scope of work regarding Round 3 may be requested to include additional parameters, as necessary.

Static water level will be measured in all existing and newly installed wells at Area B during each sampling event. Measurements will be obtained from top of casing to determine groundwater elevation.

Section 4.9 details general field operations for groundwater sampling. Section 5.13 presents Baker's "Groundwater Sample Acquisition" SOP.

### **3.4.7 Slug Test**

An in-situ hydraulic conductivity test (slug test) will be performed on six of the eight newly installed monitoring wells at Area B. The six wells at Area B will be selected in the field. One rising head test and one falling head test will be conducted on each well. Refer to Section 3.3.9 for a description of rising and falling head tests.

Section 4.11 details general field operating procedures for slug tests. Section 5.14 presents the "In-situ Hydraulic Conductivity Testing" SOP.

### **3.4.8 Land Surveying**

Fourteen existing monitoring wells and eight newly installed monitoring wells will be surveyed for vertical control and horizontal control at Area B.

Section 4.13 details general field operations for land surveying.

### **3.5 Sample Analysis**

All samples will be analyzed following NEESA standard methods. The appropriate number of field QA/QC samples, including field blanks, rinsate blanks, and duplicates/replicates will be analyzed in addition to laboratory QA/QC samples, including matrix spike and matrix spike duplicate samples.

A subcontracted NEESA-certified laboratory will be used to perform the sample analysis. Baker personnel will be responsible to track analysis of the samples and obtain results from the laboratory. Three sampling events are anticipated for each area under investigation, with a minimum time of three months (90 days) between the second and third event.

Table 3-1 presents sample summaries for environmental and QA/QC samples. Tables 3-2 to 3-12 present parameters, number of samples, bottle requirements, preservation, and holding time requirements for each area for each sampling round.

Hydrochloric acid will be used to adjust aqueous volatile organic samples to a pH of less than 2. Each aqueous sample obtained for TAL metals analysis will be preserved with nitric acid to a pH of less than 2. The nitric acid ( $\text{HNO}_3$ ) will be added to the dissolved metals sample aliquot subsequent to filtering. Groundwater samples obtained for cyanide analysis will be preserved with sodium hydroxide ( $\text{NaOH}$ ) to a pH of greater than 12. Sample analysis for metals may be modified to include total metals analysis.

Section 4.15 details general field operations for sample preservation. Section 5.16 presents "Sample Preservation" SOPs.

The type of container used for each sampling effort, as well as a summary of preservation requirements also are described in the QAPP.

### **3.6 Quality Assurance/Quality Control**

The appropriate number of field QA/QC samples, including field blanks, rinsate blanks, and duplicates will be analyzed in addition to laboratory QA/QC samples, including matrix spike

TABLE 3-1

## SUMMARY OF ENVIRONMENTAL SAMPLES\*

Site Location	Sample Type	Media/No. of Locations	No. of Samples per Location	VOCs (Method 601)	VOCs (Method 624)	TCL VOCs	TCL Semi-volatiles	Pesticide/PCBs	TAL (Dissolved) Metals	TAL <sup>(1)</sup> (Total) Metals	Selected Metals <sup>(2)</sup>	Chloride	Sulfide	Alkalinity	
Area A	Residential Wells	Aqueous/5 <sup>(3)</sup>	1			5									
	Subsurface Soil	Solid/8	1			8	8	8							
	Surface Water	Aqueous/8	1			8	8	8	8	8		8	8	8	
	Sediment	0-.5'	Solid/20	1								20			
		2-2.5'	Solid/6	1								6			
	Groundwater														
Round 1 <sup>(4)</sup>	Aqueous/9	1	7	2					31	32		31	31	31	
Round 2 <sup>(5)</sup>	Aqueous/32	1				32	32	32							
Round 3 (opt.) <sup>(5)</sup>	Aqueous/15	1				15									
Total Samples Area A				7	2	88	48	48	39	40	26	39	39	39	
Area B	Subsurface Soil	Solid/10	1			10	10	10		10					
	Surface Water	Aqueous/5	1			5	5	5	5	5					
	Sediment	0-.5'	Solid/6	1			6	6	6		6				
		2-2.5'	Solid/2	1			2	2	2		2				
	Surface Soil	Solid/3	1							3					
	Geoprobe	Aqueous/25	1	25											
	Groundwater														
Round 1 <sup>(4)</sup>	Aqueous/3	1	3												
Round 2 <sup>(5)</sup>	Aqueous/22	1				22	22	22	22	22		22	22	22	
Round 3 (opt.) <sup>(5)</sup>	Aqueous/11 <sup>(6)</sup>	1				11									
Total Samples Area B				28		56	45	45	27	48		22	22	22	
Total Areas A and B				35	2	144	93	93	66	102	26	61	61	61	

TABLE 3-1 (Continued)  
QA/QC SAMPLE SUMMARY

Task	Media	No. of Environmental Samples	Duplicate (Aqueous)	Replicate (Solid)	Matrix Spike/Matrix Spike Duplicate	Equipment Rinsate	Trip Blanks	Field <sup>(7)</sup> Blanks
Area A								
Residential Wells	Aqueous	5	1				2	
Subsurface Soil	Solid	8		1	2	4	4	2
Surface Water	Aqueous	8	1		2	1	4	2 <sup>(8)</sup>
Sediment: 0-5' 2-2.5'	Solid	20		2	1	1		
		6		1	1	1		2
Groundwater								
Round #1 <sup>(4)</sup>	Aqueous	9	1				9	
Round #2 <sup>(5)</sup>		32	4		4	6	18	2
Round #3 <sup>(5)</sup>		15	2		2	2	2	2
<b>TOTAL AREA A</b>		<b>103</b>	<b>9</b>	<b>4</b>	<b>12</b>	<b>15</b>	<b>39</b>	<b>10</b>
Area B								
Subsurface Soil	Solid	10		1	2	5	8	
Surface Water	Aqueous	5	1		2	1	3	
Sediment: 0-5' 2-2.5'	Solid	6		1				
		2		1	1	1	1	
Surface Soil	Solid	3		<sup>(9)</sup>	1	<sup>(9)</sup>	<sup>(9)</sup>	
Geoprobe	Aqueous	25	3				3	
Groundwater								
Round #1 <sup>(4)</sup>	Aqueous	3	1				3	
Round #2 <sup>(5)</sup>		22	3		4	4	17	
Round #3 <sup>(5)</sup>		22	3		2	3	3	
<b>TOTAL AREA B</b>		<b>87</b>	<b>10</b>	<b>3</b>	<b>14</b>	<b>14</b>	<b>38</b>	
<b>TOTAL AREAS A AND B</b>		<b>190</b>	<b>19</b>	<b>7</b>	<b>26</b>	<b>29</b>	<b>77</b>	<b>10</b>

\* Optional air samples at Brig - 15 samples to be determined.

- (1) Forty (40) samples at Area A and 27 samples at Area B for total metals analysis reflect the Mod. 2 scope of work.
- (2) Selected metals analysis will include: arsenic, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and vanadium.
- (3) Residential wells (Area A) - Number of samples changed from 25 to 5 to reflect Mod. 2 scope of work.
- (4) Round 1 GW - Areas A & B - non-NEESA QA/QC
- (5) Analysis will be performed (in Rounds 2 and 3) under Level D QA/QC.
- (6) Area B - Round 3 samples changed from 22 to 11 to reflect Mod. 2 scope of work.
- (7) Two sources of water (potable and deionized) will be analyzed for each parameter/each round.
- (8) Metals only.
- (9) Surface soil replicate, rinsate and trip blanks at Area B are included in sediment QA/QC totals.

**TABLE 3-2  
ENVIRONMENTAL - SEDIMENT/SOIL SAMPLES  
AREA A - ROUND 1**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (3)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	8	glass teflon lined cap	Cool to 4°C	10 days	CLP	1 x 50 gm
Semi-Volatile Organic Compounds (SVOA)	8	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	1 x 50 gm
PCB/Pesticides	8	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm
Selected Metals Aqueous (1) Sediment	-- 26	plastic/glass	Cool to 4°C	<u>Mercury is 28 days</u> 180 days	CLP	1 x 50 gm

**SELECTED METALS (below) (2)**

Arsenic	26	plastic/glass	Cool to 4°C	180 days	EPA 206.2 (Furnace)	1 x 50 gm
Beryllium	26	plastic/glass	Cool to 4°C	180 days	EPA 200.7 (ICAP)	
Cadmium	26	plastic/glass	Cool to 4°C	180 days	EPA 200.7 (ICAP)	
Chromium	26	plastic/glass	Cool to 4°C	180 days	EPA 200.7 (ICAP)	
Lead	26	plastic/glass	Cool to 4°C	180 days	EPA 239.2 (Furnace)	
Mercury	26	plastic/glass	Cool to 4°C	28 days	EPA 245.1 (Cold Vapor)	
Selenium	26	plastic/glass	Cool to 4°C	180 days	EPA 270.2 (Furnace)	
Silver	26	plastic/glass	Cool to 4°C	180 days	EPA 200.7 (ICAP)	
Vanadium	26	plastic/glass	Cool to 4°C	180 days	EPA 200.7 (ICAP)	

(1) Dissolved

(2) A total of 26 sediment samples will be analyzed for the metals indicated.

(3) VTSR - Validated time of sample receipt.

**TABLE 3-3  
QA/QC - SEDIMENT/SOIL SAMPLES  
AREA A - ROUND 1**

Parameter	Duplicate Samples	Trip Blanks (1)	Equipment Rinsate (1)	Field Blank (1)	MS/MSD	Holding Time (2)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	1	4	4	2	2	10 days	CLP	1 x 50 gm (solid) 2 x 40 ml (aqueous)
Semi-Volatile Organic Compounds (SVOA)	1	--	4	2	2	Extraction within 7 days Analyze 40 days	CLP	1 x 50 gm (solid) 2 x 1 liter (aqueous)
PCB/Pesticides	1	--	4	2	2	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm (solid) 2 x 1 liter (aqueous)
Selected Metals Aqueous	--	--	2	2	2	Mercury is 28 days	CLP	1 x 50 gm (solid) 1 x 1 liter (aqueous)
Sediment	3					180 days		

**SELECTED METALS (below)**

Arsenic	3	--	2	2	2	180 days	EPA 206.2 (Furnace)	1 x 50 gm
Beryllium	3	--	2	2	2	180 days	EPA 200.7 (ICAP)	
Cadmium	3	--	2	2	2	180 days	EPA 200.7 (ICAP)	
Chromium	3	--	2	2	2	180 days	EPA 200.7 (ICAP)	
Lead	3	--	2	2	2	180 days	EPA 239.2 (Furnace)	
Mercury	3	--	2	2	2	28 days	EPA 245.1 (Cold Vapor)	
Selenium	3	--	2	2	2	180 days	EPA 270.2 (Furnace)	
Silver	3	--	2	2	2	180 days	EPA 200.7 (ICAP)	
Vanadium	3	--	2	2	2	180 days	EPA 200.7 (ICAP)	

(1) Aqueous sample

(2) VTSR - Validated time of sample receipt

**TABLE 3-4  
ENVIRONMENTAL - SW SAMPLES  
AREA A - ROUND 1**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (2)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	8	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semi-Volatile Organic Compounds (SVOA)	8	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	8	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Selected Metals Aqueous (1) Sediment	8 --	plastic/glass	HNO <sub>3</sub> to pH <2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 1 liter

**OTHER ANALYTES (below)**

Chloride	8	plastic/glass	None required	28days	EPA 325.3	1 x 1 liter
Sulfate	8	plastic/glass	None required	28days	EPA 375.4	
Alkalinity	8	plastic/glass	Cool to 4°C	14 days	EPA 310.1	

(1) Dissolved

(2) VTSR - Validated Time of Sample Receipt

**TABLE 3-5  
QA/QC - SW SAMPLES  
AREA A - ROUND 1**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate (2)	Field Blank (2,3)	MS/MSD	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	1	4	1	--	2	10 days	CLP	2 x 40 ml
Semi-volatile Organic Compounds (SVOA)	1	--	1	--	2	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	1	--	1	--	2	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous (1)	1	--	1	2	2	Mercury is 28 days	CLP	1 x 1 liter
Sediment	--	--	--	--	--	180 days		

**SELECTED METALS (below)**

Chloride	1	--	1	2	2	28 days	EPA 325.3	1 x 1 liter
Sulfate	1	--	1	2	2	28 days	EPA 375.4	
Alkalinity	1	--	1	2	2	14 days	EPA 310.1	

- (1) Dissolved
- (2) Aqueous sample
- (3) Field Blank Round 1 assumed as one event with two (potable/D.I.) water sources
- (4) VTSR - validated time of sample receipt

**TABLE 3-6  
ENVIRONMENTAL - SEDIMENT/SOIL SAMPLES  
AREA B - ROUND 1**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	18	glass teflon lined cap	Cool to 4°C	10 days	CLP	1 x 50 gm
Semi-Volatile Organic Compounds (SVOA)	18	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	1 x 50 gm
PCB/Pesticides	18	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm
Metals (TAL) Aqueous (1) Sediment	-- 21	plastic/glass	HNO <sub>3</sub> to pH < 2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 50 gm

**QA/QC - SEDIMENT SOIL SAMPLES  
AREA B ROUND 1**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate (2)	Field Blank (2,3)	MS/MSD	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	2	9	6	--	4	10 days	CLP	1 x 50 gm (solid) 2 x 40 ml (aqueous)
Semi-volatile Organic Compounds (SVOA)	2	--	6	--	4	Extraction within 7 days Analyze 40 days	CLP	1 x 50 gm (solid) 2 x 1 liter (aqueous)
PCB/Pesticides	2	--	6	--	4	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm (solid) 2 x 1 liter (aqueous)
Metals (TAL) Aqueous Sediment	-- 3	-- --	4	--	6	<u>Mercury is 28 days</u> 180 days	CLP	1 x 50 gm (solid) 1 x 1 liter (aqueous)

(1) Dissolved

(2) Aqueous sample

(3) Field Blank - assumes Round 1 assumed as one event with two (potable/DI) water sources

(4) VPSR - Validated time of sample receipt

**TABLE 3-7  
ENVIRONMENTAL - SW SAMPLES  
AREA B - ROUND 1**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	5	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semi-Volatile Organic Compounds (SVOA)	5	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	5	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous (1) Sediment	5 --	plastic/glass	HNO <sub>3</sub> to pH <2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 1 liter

**QA/QC - SW SAMPLES  
AREA B - ROUND 1**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate (2)	Field Blank (2,3)	MS/MSD	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	1	3	1	--	2	10 days	CLP	2 x 40 ml
Semi-volatile Organic Compounds (SVOA)	1	--	1	--	2	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	1	--	1	--	2	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous Sediment	1 --	-- --	1	--	2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 1 liter

(1) Dissolved

(2) Aqueous sample

(3) Field Blank - assumes Round 1 assumed as one event with two (potable/DI) water sources

(4) VPSD - Validated time of sample receipt

**TABLE 3-8  
ENVIRONMENTAL - GW SAMPLES  
AREA A ROUND 2**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (2)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	32	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semi-Volatile Organic Compounds (SVOA)	32	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	32	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous (1) Sediment	31 --	plastic/glass	HNO <sub>3</sub> to pH <2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 1 liter

Chloride	31	plastic/glass	None required	28days	EPA 325.3	1 x 1 liter
Sulfate	31	plastic/glass	None required	28days	EPA 375.4	
Alkalinity	31	plastic/glass	Cool to 4°C	14 days	EPA 310.1	

(1) Dissolved

(2) VTSR - Validated Time of Sample Receipt

**TABLE 3-9  
QA/QC - GW SAMPLES  
AREA A - ROUND 2**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate (2)	Field Blank (2,3)	MS/MSD	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	4	18	6	2	4	10 days	CLP	2 x 40 ml
Semi-volatile Organic Compounds (SVOA)	4	--	6	2	4	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	4	--	6	2	4	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous (1)	4	--	6	2	4	Mercury is 28 days	CLP	1 x 1 liter
Sediment	--	--				180 days		

Chloride	4	--	6	2	4	28 days	EPA 325.3	1 x 1 liter
Sulfate	4	--	6	2	4	28 days	EPA 375.4	
Alkalinity	4	--	6	2	4	14 days	EPA 310.1	

- (1) Dissolved  
(2) Aqueous sample  
(3) Field Blank Round 2 assumed as one event with two (potable/D.I.) water sources  
(4) VTSR - validated time of sample receipt

**TABLE 3-10**  
**ENVIRONMENTAL - GW SAMPLES**  
**AREA B - ROUND 2**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (2)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	22	glass teflon lined cap	Cool to 4°C 1:1 HCl pH < 2	10 days	CLP	2 x 40 ml
Semi-Volatile Organic Compounds (SVOA)	22	glass teflon lined cap	Cool to 4°C	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	22	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAI) Aqueous (1) Sediment	22 --	plastic/glass	HNO <sub>3</sub> to pH < 2	<u>Mercury is 28 days</u> 180 days	CLP	1 x 1 liter

Chloride	22	plastic/glass	None required	28days	EPA 325.3	1 x 1 liter
Sulfate	22	plastic/glass	None required	28days	EPA 375.4	
Alkalinity	22	plastic/glass	Cool to 4°C	14 days	EPA 310.1	

(1) Dissolved

(2) VTSR - Validated Time of Sample Receipt

**TABLE 3-11**  
**QA/QC - GW SAMPLES**  
**AREA B - ROUND 2**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate (2)	Field Blank (2,3)	MS/MSD	Holding Time (4)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	3	17	4	--	4	10 days	CLP	2 x 40 ml
Semi-volatile Organic Compounds (SVOA)	3	--	4	--	4	Extraction within 7 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	3	--	4	--	4	Extraction within 10 days Analyze 40 days	CLP	2 x 1 liter
Metals (TAL) Aqueous (1)	3	--	4	--	4	Mercury is 28 days	CLP	1 x 1 liter
Sediment	--	--				180 days		

3-34

Chloride	3	--	4	--	4	28 days	EPA 325.3	1 x 1 liter
Sulfate	3	--	4	--	4	28 days	EPA 375.4	
Alkalinity	3	--	4	--	4	14 days	EPA 310.1	

- (1) Dissolved
- (2) Aqueous sample
- (3) Field Blank Round 2 assumed as one event with two (potable/D.I.) water sources
- (4) VTSR - validated time of sample receipt

**TABLE 3-12  
ENVIRONMENTAL - GW SAMPLES  
AREA A - ROUND 3 (Optional)**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (5)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	15	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml

**QA/QC - GW SAMPLES  
AREA A - ROUND 3**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate	Field Blank (3)	MS/MSD	Holding Time (5)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	2	2	2	2	2	10 days	CLP	2 x 40 ml

- (1) Aqueous Sample  
 (2) Field Blank - Round 3 assumed as one event with two (potable/DI) water sources  
 (3) VTSR - Validated time of sample receipt

**ENVIRONMENTAL - GW SAMPLES  
AREA B - ROUND 3 (Optional)**

Parameter	# of Samples	Bottle Requirements	Preservation Requirements	Holding Time (5)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	22	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml

**QA/QC - GW SAMPLES  
AREA B - ROUND 3**

Parameter	Duplicate Samples	Trip Blanks (2)	Equipment Rinsate	Field Blank (3)	MS/MSD	Holding Time (5)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	3	4	4	--	4	10 days	CLP	2 x 40 ml

- (1) Aqueous Sample  
 (2) Field Blank - Round 3 assumed as one event with two (potable/DI) water sources  
 (3) VTSR - Validated time of sample receipt

and matrix spike duplicate samples. A subcontracted laboratory will be used to perform sample analysis.

QA/QC samples will be collected at the following frequencies, which are standard to the IRP.

- Trip Blanks - one per shipping cooler containing samples for volatile organic analysis
- Field Blank (Ambient Conditions Blank) - two samples per sampling event (one potable and one deionized water)
- Equipment Blank - one sample per day for subsurface soil (split-spoon sampler) sampling, sediment (hand auger and/or trowel) sampling, and groundwater (bailer) sampling.
- Field Duplicate - one sample for every 10 (10%) environmental groundwater samples collected at each site.
- Field Replicate - one sample for every 10 (10%) environmental soil/sediment samples collected at each site.

Additional samples for internal laboratory QA/QC (i.e., matrix spikes, etc.) will be collected.

Refer to Table 3-2 for a presentation of QA/QC sample requirements.

### **3.7 Sample Numbering**

In order to identify and accurately track the various samples to be collected during this investigation, a numbering system must be developed. A two letter designation will be used to denote sampling media (i.e., SB for soil collected from soil borings, SE for sediment samples, SW for surface water samples, SS for surface soil samples, RW for residential well samples, GW for groundwater samples, GP for samples collected during the Geoprobe investigation, and GB for soil collected from the geologic borings at Area A).

Sample locations then will be addressed using the letter A or B to designate the site location (Area A or B, respectively).

Three numbers will follow the media and site location description to characterize sample location and depth. The numbers will describe the sampling round (1, 2 or 3) and the sample location (i.e., 01 denotes sample location number one, 02 denotes sample location number two, etc.) In the case of two or more sample depths collected at a sample location, a letter designation will follow (S will indicate a shallow sample and D will indicate a deep sample). Therefore, a groundwater sample from Well B-MW11B (say, location number 8) during the Round 2 sampling event will be designated as GWB-208. Well numbers will be described in the field logbook.

Duplicate samples will be denoted by the next number in the series for a particular media. Therefore, if the last number for surface water sampling at Area B is SWB-05, then the duplicate associated with one of the samples (SWB-01 to 05) will be designated as SWB-06. The field log book will include with which sample the duplicate is associated. This will ensure sample anonymity at the laboratory.

Rinsate samples and Trip Blanks will be designated as RSA/B (Rinsate Sample Area A or B) and TBA/B (Trip Blank Area A or B) - 01, 02, 03, etc.

### **3.8 Groundwater Modeling (Optional)**

USGS MODFLOW software will be used to simulate groundwater conditions at the site in the unconfined surficial aquifer and in the confined Yorktown Aquifer. In general, the models will be used to help evaluate the effectiveness of potential remediation alternatives. The models will be established by defining appropriate groundwater boundary values, field determined aquifer conditions and other identifiable hydrogeologic features. The selection of the boundary surfaces and conditions will be the primary step in conceptualizing and developing models of the subject groundwater systems.

Section 4.14 presents general groundwater modeling procedures.

## **4.0 GENERAL FIELD OPERATIONS**

### **4.1 Mobilization**

The field investigation will be initiated through mobilization activities such as equipment procurement, procurement of the field trailer and utility clearances, and location of decontamination areas and drum storage areas. All drilling and decontamination equipment and associated equipment and materials will be mobilized by Baker's drilling subcontractor. Remaining sampling equipment and other supplies will be collected and provided by the Baker field team.

### **4.2 Field Team Personnel and Responsibilities**

Baker intends to staff the investigation with a Project Manager, a Project Geologist serving as the Field Team Supervisor, a Health and Safety Officer trained in Industrial Hygiene, as well as additional team members (geologists, engineers, environmental scientists, and technicians), as needed. Additionally, administrative and technical support staff will be available off site for various tasks of the project. Figure 4-1 presents the Project Organization Summary.

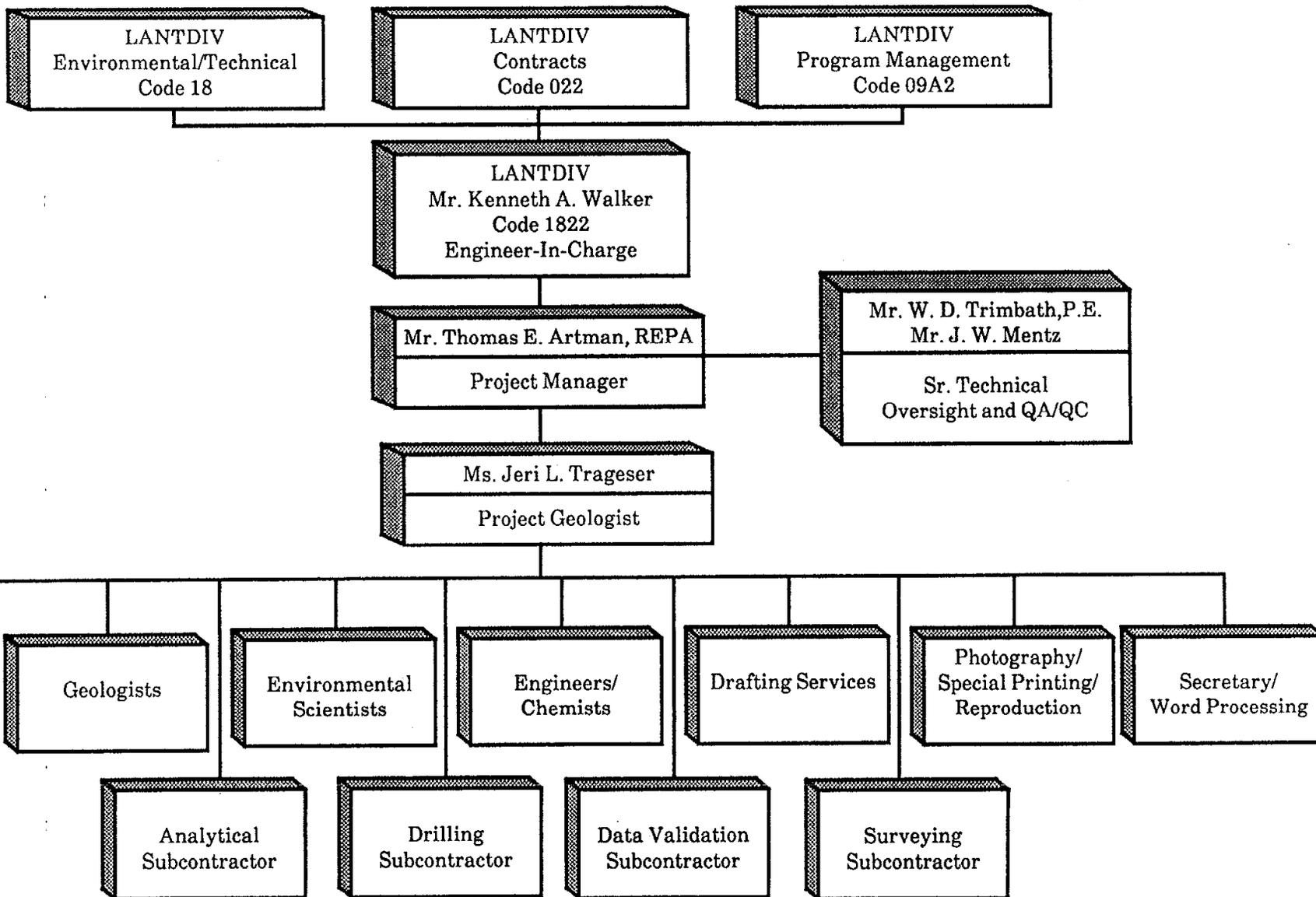
The Project Manager will provide technical support and oversight during the project, including budget and schedule review, preparation and review of invoices, project-specific personnel resources planning, and coordination with LANTDIV, the Activity, and subcontractors.

The Project Geologist will locate the soil borings and monitoring wells, and is responsible for the technical aspects of the project during the field program as well as during report preparation. As Field Team Supervisor, the Project Geologist also will be responsible for all logistical planning and be the primary point of contact with Base personnel.

The Field Team Supervisor will be responsible for directing all drilling and sampling activities, and accomplishing the work in accordance with the Sampling and Analysis Plan, as well as working with the Health and Safety Officer to assure compliance with the Health and Safety Plan.

FIGURE 4-1

PROJECT ORGANIZATION



4-2

The Health and Safety Officer will be responsible for assuring that the investigation is conducted in accordance with the Health and Safety Plan. Additionally, he/she will use air monitoring instruments when on site to indicate whether or not an upgrade in the level of personal protection is necessary and will be the central point of contact for all health and safety issues. When the Health and Safety Officer is not on site, the Field Team Supervisor will be responsible for health and safety issues.

The Site Geologist(s) will determine subsurface soil sample locations, maintain the field log book, maintain all sample documentation (i.e., Chain-of-Custody, sample labels, sample tags, etc.) take project photographs (if permitted by the Activity), and assist sampling technicians with soil and groundwater sample collection, as well as sample packaging. Additionally, the Site Geologist will monitor the ambient air during drilling and sampling operations in the absence of the Health and Safety Officer.

The Environmental Scientists/Sampling Technicians will perform subsurface soil and groundwater sampling during field activities. Additionally, this person(s) will assist the Site Geologist with sample packaging activities.

#### 4.3 Geophysical Survey

Electromagnetic (EM), ground penetrating radar (GPR), gamma logging, resistivity sounding, and magnetometry techniques will be utilized to define potential areas of buried wastes, and/or utilities at the areas under investigation, as well as the underlying clay layer at Area A. Data will be used to modify the locations of subsequent soil borings and monitoring wells and to characterize the condition of the subsurface.

Electromagnetic terrain conductivity profiling is a non-invasive method of obtaining subsurface information through inductive electric measurements made at the ground surface. The EM survey is a rapid, cost effective reconnaissance tool for identifying lateral changes in subsurface conductivity. Areas of higher than background conductivity are often associated with surficial and/or buried wastes, contaminants, or metals (i.e., underground storage tanks, product lines). Conductivity measurements will be obtained with a Geonics Model EM-31 instrument for an effective depth of penetration to 15 feet.

Ground penetrating radar (GPR) is an active geophysical system which transmits high frequency EM waves into the ground and detects the energy reflected back to the surface. GPR

operates on a similar principal as seismic reflection, except, instead of acoustic waves, electromagnetic waves of radio and microwave frequencies (80 MHZ to 1,000 MHz) are utilized. Reflections typically occur at lithologic changes, subsurface discontinuities, and internal soil structures.

Borehole geophysical techniques (also called logging) are a group of active and passive geophysical methods used to provide detailed measurements of soil, rock, and water properties. This is done by lowering tools into the borehole to measure the electrical, acoustical, or radioactive properties of the materials surrounding the borehole. The surveys are nondestructive and can often be run in existing boreholes and water supply wells with no modifications.

Two borehole techniques will be used during the Camp Allen Landfill investigation: natural gamma, which yields a measure of potassium- 40 content in rocks; and resistivity profiling, which provides a measure of clay content in geological materials.

Magnetometry measurements detect local perturbations in the earth's magnetic field. Both naturally-occurring and man-made magnetic materials can modify the ambient field. Shallow buried ferrous objects, such as drums, tanks, and product lines, usually produce a detectable magnetic anomaly. Magnetic measurements will be obtained with a Geometrics Model G-856 proton precession magnetometer operated in the total field mode.

Both electromagnetic and magnetic data will be digitally recorded and downloaded to a PC for processing and analysis. Measurements will be contoured over the area of investigation to facilitate identification of anomalously high/low conductivity and magnetic intensities. Areas interpreted to represent buried waste, contaminants, or metals will be delineated.

Sections 5.1 to 5.4 present SOPs for "Geophysics - Borehole," "Geophysics - Electromagnetic Induction," "Geophysics - Ground Penetrating Radar," and "Geophysics - Magnetometry Profiling," respectively.

#### **4.4 Residential Well Sampling**

Approximately five residential wells are proposed to be sampled. Samples will be collected from outside taps which are located closest to the well. Well water will be allowed to flow from the tap for a period of approximately 10 to 15 minutes prior to sampling to permit the lines to

clear of stagnant water. Water will be collected into a bucket at the tap and will be disposed of periodically by pouring the water onto the ground surface no less than 30 feet away from the tap.

During the 15 minute purge time, temperature, pH, and specific conductivity will be measured using field instrumentation. Stabilization of field measurements are discussed in Section 5-5 "Water Quality Testing."

Subsequent to purging, groundwater will be collected into the appropriate sampling containers, packaged, and shipped to the laboratory for analysis of volatile organic compounds. All sampling equipment will be removed prior to departure from the residence.

#### **4.5 Surface Water/Sediment/Surface Soil Sampling**

A stainless steel hand auger (or other appropriate tool) will be used to obtain each sediment samples. Sediment collected into the hand auger will be transferred into a stainless steel sampling bowl or bucket. Samples for volatile organic analysis will be transferred by trowel directly from the sampling bowl into the appropriate sample container. The remaining sample will be homogenized by thorough mixing and then will be transferred into the appropriate sampling containers (see Tables 3-3, 3-4 and 3-6). Sediment sampling will be conducted from downstream to upstream sampling points.

Surface water samples for TCL volatile organic analysis will be collected directly into the 40 milliliter glass sample container according to Section 5.6 "Surface Water and Sediment Sampling." Surface water for the remaining analyses will be collected into a clean, stainless steel bucket. The water then will be poured (in equal portions) into the appropriate sample container. If more water is needed, the bucket again will be filled and equal portions of surface water will be poured into the sample containers. This procedure will ensure a uniform sample.

Near-surface soil samples will be collected from a depth of about two feet below ground surface in the vicinity of the schoolyard adjacent to Area B. A total of three grab samples will be submitted to the laboratory for analysis of TAL metals only. All analytical work under this task will be conducted using CLP protocols (Level D QA/QC).

#### **4.6 Monitoring Well Installation**

A total of 17 groundwater monitoring wells and one piezometer will be installed during this RI as described above. Well borings will be advanced using a truck mounted or all-terrain (ATV) type vehicle drill rig. The well borings will not be sampled for chemical analysis during this investigation. Instead, subsurface soil will be sampled for lithologic information only. Each well boring will be continuously split-spoon sampled to the water table and then (at 3 to 5-foot intervals) advanced to final depth. Well borings that will penetrate into the Yorktown aquifer will be "cased off" to eliminate the potential of downward migration of contaminants from the surficial aquifer into the lower aquifer. A monitoring well will be installed subsequent to the advancement of the well boring.

One shallow well (approximate depth of 30 feet below ground surface) will be installed in the vicinity of existing well B-20W at Area A.

Five shallow wells (approximate depth of 25 feet below ground surface) will be installed downgradient from the Area B landfill using Geoprobe sampling results. The well screen will be placed to intercept the water table. Therefore, wells will be advanced approximately seven feet below the water table to account for seasonal fluctuation in groundwater elevation.

Ten deep wells (seven at Area A and three at Area B) and one piezometer (approximate depth of 65 feet below ground surface) will be installed. These wells will be screened to intercept the upper Yorktown Aquifer.

Additionally, two deep wells (approximate depth of 110 feet below ground surface) will be installed at Area A during this RI. These wells will be screened to intercept the lower Yorktown Aquifer. A 30-foot deep stainless steel well will be constructed in the vicinity of existing well B-20W as part of the source characterization task.

Section 5.8 presents "Monitoring Well Installation" SOPs.

#### **4.7 Well Construction**

The well to be located adjacent to existing well A-MW8 (see Figure 3-4) will be constructed to facilitate conducting the aquifer test. Therefore, this well will be constructed of 4-inch inside diameter (I.D.), Schedule 40, PVC, 0.010 machine slot well screen and solid polyvinyl chloride

(PVC) riser pipe extending from the screen to the ground surface. The well to be located in the vicinity of existing well B-20W (Figure 3-4) to characterize source contamination in Area A will be constructed of 2-inch I.D. stainless steel riser and screen. The remaining wells will be constructed of 2-inch I.D., Schedule 40, PVC, 0.010 machine slot screen (ten feet length) and solid PVC riser.

In order to prevent the possible migration of the surficial aquifer into the lower Yorktown Aquifer, the 110-foot and 65-foot deep wells will be "cased off." First, drilling will advance to the clay unit located at approximately 30 feet below ground surface. Next, a 6-inch diameter steel surface casing will be installed one to two feet into the clay. Grout will be tremied around the outer annular space. The grout will be allowed to set for a minimum period of 8 to 12 hours. Then, drilling will continue to the targeted depth of the well. The well will be constructed such that the top of the screened interval is placed three to five feet below the bottom of the clay unit.

A gravel pack of clean quartz sand will be placed in each well to a minimum of one foot above the screen. A bentonite pellet seal will be installed a minimum of two feet above the gravel pack. After the bentonite seal has been hydrated, a cement/bentonite grout will be installed to one foot below ground surface. A flush mounted protective casing with locking cap will complete the well for wells constructed in high traffic areas. A cement apron will be placed so that surface water does not collect at the well. Additionally, a 3" x 3" x 4" concrete pad will be installed in the asphalt or concrete to reinforce the shallow wells.

A 5-foot length of "stick up" protective casing with locking cap will complete the well for wells that are constructed in areas with no vehicular traffic. A concrete pad (3" x 3" x 4") will be placed so that surface water does not collect at the well. Additionally, four 5-foot long concrete-filled steel posts will be installed around the pad to prevent damage to the well and protective casing.

#### 4.8 Soil Borings

A total of 28 soil borings will be drilled during this RI. Eight borings will be advanced to an approximate depth of 20 feet near existing well B-20W (Area A) to evaluate the extent of the source contamination (landfill material) in the soil. Ten borings will be advanced to an approximate depth of 40 feet in the vicinity of the landfill at Area A to characterize the extent and continuity of the underlying clay unit. Additionally, ten soil borings will be drilled to an

approximate depth of 10 feet at the landfill in order to evaluate the extent of the source contamination (landfill material) in the soil at Area B.

Soil borings will be advanced using a truck mounted drill rig. The borings at each Area (A and B) are to be sampled continuously to the water table and then at 3-foot intervals to depth (if necessary) for lithologic characterization using a 1-3/8 inch inside diameter split barrel sampler in accordance with ASTM Method D-1586.

A Baker geologist will observe the drilling and sampling operations. During advancement of the augers, soil cuttings and split-spoon samples will be monitored using an HNu photoionization detector (PID) for volatile organic contamination. Stratigraphic horizon descriptions, discolorations, odors and other visual observations will be described and recorded on a Field Test Boring Record.

Each subsurface soil sample will be analyzed as described in Section 3.3. Subsurface soil samples will be collected for laboratory analyses from each boring as follows:

**Area A:**

- One sample will be collected at just above the water table from each of the eight borings adjacent to existing well B-20W.
- One sample from each of the 10 geological borings will be collected from the clay unit at a depth of approximately 30 to 40 feet below ground surface but not deeper than 2 to 4 feet into the clay.

**Area B:**

- One sample will be collected at just above the water table from each of the ten borings located on the landfill.

Upon completion of sampling, each boring will be backfilled with a grout mixture of cement and bentonite powder. All auger cuttings will be containerized. It is assumed that this task will require elevated levels of personal protective equipment (Level B or Level C).

Refer to Sections 5.7 and 5.8 for Drilling SOPs.

#### **4.9 Well Development**

Prior to groundwater sampling, the newly installed monitoring wells will be developed by removing water from each well into 55 gallon drums using a teflon bailer and clean rope, air lift unit, submersible pump, and/or bladder pump. Dedicated sampling equipment also may be utilized. If dedicated sampling equipment will not be used, equipment will be decontaminated between wells.

Well development will be performed only after the grout used to construct the well has been allowed to adequately set (typically 24 hours or more). It is assumed that the existing wells scheduled to be resampled during this RI will not require redevelopment.

Groundwater levels will be measured to the nearest 0.01 foot from the top of the PVC casing. Development will continue until temperature, pH, and specific conductivity stabilized. A sample of the development water will be containerized after the groundwater has stabilized to document final silt content.

All monitoring wells will be purged using a teflon bailer and clean rope. A total of three to five well volumes will be removed prior to sampling. Temperature, pH, and specific conductivity measurements will be collected during purging as well as after sampling. Additionally, groundwater level measurements will be obtained prior to purging and just after groundwater sampling. This information will assist in determining well recovery rates.

Sections 5.5, and 5.12 present SOPs for "Water Quality Testing" and "Water Level, Product Level and Well Depth Measurements," respectively.

#### **4.10 Groundwater Sampling**

Groundwater sampling will occur immediately after purging the wells. One groundwater sample will be collected from each well using a clean teflon bailer. The sample will be transferred from the bailer into properly labeled, laboratory prepared sampling containers; cooled to approximately 4°C; and shipped to the analytical laboratory under appropriate Chain-of-Custody documentation procedures.

Section 5.13 presents Baker's "Groundwater Sample Acquisition" SOP.

#### 4.11 Slug Tests

An in-situ hydraulic conductivity test (slug test) will be conducted on eight of the 11 newly installed wells (six 65-foot and two 110-foot deep) at Area A. The 4-inch well, stainless steel well and piezometer are not included in this task.

An in-situ hydraulic conductivity test (slug test) will be performed on six of the eight newly installed monitoring wells at Area B. The six wells at Area B will be selected in the field. One rising head test and one falling head test will be conducted on each well.

Section 5.14 presents the "In-situ Hydraulic Conductivity Testing" SOP.

#### 4.12 Aquifer Testing

The aquifer test will be conducted to determine aquifer parameters. Monitoring well A-MW8B will be pumped for a 24-hour period and will be allowed to recover for a period of 24 hours. Water levels will be monitored at seven or more locations during the 48-hour test.

Aquifer characterization tests will be performed to evaluate the hydraulic characteristics of the Yorktown aquifer. Tests will include a step drawdown, a 24-hour drawdown, and a 24-hour recovery. The 4-inch Type III well (A-MW8B) will be used as the pumping well location and observation wells will be selected from surrounding monitoring wells and the nearby piezometer. Observation locations will be verified in the field. A maximum of eight locations will be observed using pressure transducers. Other locations may be manually monitored using water level indicators.

The step drawdown test will be performed in order to establish the constant flow rate to be used during the 24-hour drawdown test. Based on hydrogeologic information of the area, the maximum flow rate is not anticipated to exceed 5-10 gallons per minute. All discharged groundwater will be containerized for proper disposal. The drilling subcontractor will supply required tanker trucks for groundwater containment.

The drawdown test will be an aquifer test in which a constant discharge rate will be maintained for a 24-hour interval. Water level measurements via pressure transducers and

water level indicators will be recorded at prescribed time intervals. Flow rates will be periodically recorded as well.

At the conclusion of the drawdown phase of the testing, the pump will be shut down and water level recovery measurements will be recorded for a period of 24-hours or until water levels have reached  $\pm 10\%$  initial water level elevations.

Section 5-15 presents Baker's "Aquifer Test" SOP.

#### 4.13 Land Surveying

Area A: Thirty-one monitoring wells from the Interim Remedial Investigation, the nine newly installed wells, the new piezometer, and well A-MW10B will be surveyed for vertical control and horizontal control.

Area B: Fourteen existing monitoring wells and eight newly installed monitoring wells will be surveyed for vertical control and horizontal control.

The following specific activities are associated with the land survey.

1. The elevations of 18 groundwater monitoring wells (ten at Area A and eight at Area B), one piezometer (Area A), and soil borings (to an accuracy of 0.01 feet, referenced to Mean Sea Level [MSL]) will be determined from an on-base USGS benchmark. Benchmarks may not be readily accessible to the survey sites.
2. The elevation point for each well and boring will be established at the top of the inner PVC well casing and a permanent mark designating the elevation point shall be established on each well. In addition, the ground surface elevation for each well and boring shall be established to an accuracy of 0.1 feet. Horizontal control shall be established to the nearest foot. (Note: Some monitoring wells will be flush-mounted level with the pavement; thus, the land surface elevation will be above the "top of casing" elevation for these wells.)
3. The location of each well and boring will be tied to permanent land monuments (e.g. building corners). A reproducible, legible property drawing will be provided with the

wells and borings located on the drawing and a table listing the well designation, "top-of-casing" and ground surface elevations for each well and boring.

4. The surveyor will provide one legible copy of the field survey notes used to determine the elevation and location of the wells.
5. The surveyor will perform these services in accordance with standard, acceptable surveying practices as required by the State of Virginia.
6. All work will be conducted under the supervision of a Registered Land Surveyor, duly licensed to work in the State of Virginia.

#### **4.14 Groundwater Modeling (Optional)**

This task consists of the development of a mathematical computer model of the geologic and hydrogeologic conditions of the surficial and Yorktown aquifers in the vicinity of the Camp Allen Landfill. The purpose of this exercise is to aid in the evaluation of potential groundwater remedial alternatives through the development and use of this model. It is likely that the USGS MODFLOW software will be used for this task. However, the use of other computer models will be considered if the geologic and hydrogeologic configuration and boundary conditions so warrant.

The USGS MODFLOW software is a three-dimensional finite-difference groundwater flow model. This software package allows for the simulation of multiple unconfined and/or confined aquifers. Various "add-on modules" allow for the simulation of surface water flows, flows to and from wells, recharge, and other hydrologic stresses which may effect an aquifer.

The groundwater flow modeling will be conducted in four principle steps:

- Review of geologic and hydrogeologic information to develop a conceptual model of the site.
- Input of the conceptual model into the computer software.
- Calibration of the computer software.

- Evaluation of potential remedial alternatives.

The first step is the review of the geologic and hydrogeologic information collected during the site investigation to develop a conceptual model of the site. Surficial conditions, as well as conditions documented in the subsurface investigations, will be used in the development of the conceptual model. Some of the specific items that will be considered include surficial topography; surface water characteristics; depth to and thickness of each formation; formation properties such as hydraulic conductivity, storativity, porosity, etc.; piezometric surfaces; recharge/evapotranspiration and constant head; and, constant flux or head dependent boundary conditions around the area selected for simulation. The development of the conceptual model will be performed as a part of and in conjunction with the evaluation of the field information for the remedial investigation report.

Input of the conceptual model parameters into the MODFLOW software constitutes the second step of this exercise. Information developed for the conceptual model will be input into the modeling software through the use of Modelcad software (Computer-Aided Design for Ground-Water Modeling, Geraghty & Miller, Inc.). This software allows for the graphical input of the groundwater system configuration including aquifer geometries, aquifer parameters, and boundary conditions. Digitized site base maps created in Autocad will be used as the initial basis for input of the conceptual model.

The third step consists of calibration of the MODFLOW software. Calibration refers to the adjustment of the model input parameters so that various computer simulations reflect measured field conditions. Two principal calibration scenarios will be tested. The first scenario is the simulation of "static" conditions (i.e., simulation of groundwater flow conditions without induced stresses such as pumping wells). The results of this simulation will be compared to the static water level measurements collected from the monitoring wells. The second calibration scenario will be the simulation of the aquifer test which is to be conducted on one of the deep wells completed in the Yorktown aquifer (A-MW8B). The results of this simulation will be compared to water level measurements collected from both shallow and deep wells during the aquifer tests. The results of each of these scenarios will be evaluated to ascertain whether the model is appropriately calibrated. Additional aquifer testing may be required for a more thorough model calibration.

The final step of this modeling exercise is the use of the calibrated model to simulate various remedial action alternatives. Although specific remedial alternatives have not yet been

developed, it is likely that groundwater control remedies will be considered. The model will be used to evaluate various groundwater control remedies by estimating potential well locations, recovery (and/or injection) rates, and the effectiveness of various hydraulic and physical groundwater flow barriers.

Summary input to and output from the MODFLOW software will be presented in graphical format (graphs, maps or tables) in the RI and/or the FS Reports, as applicable. If requested, complete input and output files will be provided on 5 1/2- or 3 1/4-inch computer diskettes.

#### **4.15 Sample Preservation**

All samples will be preserved with ice to a temperature of 4°C prior to transportation to the analytical laboratory. Aqueous samples to be analyzed for Target Compound List (TCL) volatile organic compounds will be preserved with hydrochloric acid (HCl) to a pH of less than 2. Additionally, filtered aqueous samples to be analyzed for Target Analyte List (TAL) dissolved metals will be preserved with Nitric Acid (HNO<sub>3</sub>) after filtering to a pH of less than 2.

Baker's SOP for "Sample Preservation and Handling" has been included in Section 5.16. Section 3.5 above and the QAPP each present summaries of sample containers, preservation, and holding times for groundwater and soil samples.

#### **4.16 Chain-of-Custody, Sample Packaging and Shipping**

Proper chain-of-custody documentation will be maintained for all samples from the time of collection until they are shipped to the analytical laboratory. Chain-of-custody sheets accompanying the samples will contain the following information: project number, sampler(s) name, sample numbers, number of containers, method(s) of preservation of samples, date and time of sample collection, analysis(es) requested, date and time of transportation to the laboratory, method of transportation, and any other information pertinent to the samples. Baker's SOP for sample Chain-of-Custody has been included in Section 5.20.

Samples will be shipped via an overnight courier to arrive before 12:00 noon the following day. The only exception is that samples shipped on Saturday will not arrive at the laboratory until Monday. In some cases, depending on the proximity of the local laboratory, the samples may be driven directly to the laboratory.

#### **4.17 Personal Protection**

Baker currently anticipates that most investigation activities at the Camp Allen Landfill Site will be conducted in Level D personal protection with upgrading to Level C or B personal protection during drilling activities on the landfills. Level D includes hard hats; steel-toed, chemical-resistant boots; and chemical-resistant gloves. Level C includes, but is not limited to: a OSHA/NIOSH-approved full-face, canister-equipped, air-purifying respirator; coveralls, or a one-piece or two-piece chemical-resistant splash suit; chemical-resistant inner and outer gloves; steel-toed, chemical-resistant boots; and hard hats. Level B includes chemical resistant clothing, airline respirator escape pack, self-contained breathing apparatus (SCBA) for rescue, chemical-resistant gloves (inner disposable and outer), safety shoes/boots, chemical-resistant over boots, and hard hat. Based on air monitoring conducted during investigation activities, it may be necessary to upgrade the level of personal protection. Additional details concerning the level of personal protection are contained in the Health and Safety Plan (Attachment A of the Work Plan).

#### **4.18 Decontamination and Waste Handling**

Prior to drilling, two temporary decontamination pads will be constructed of high density polyethylene and wood with elevated sides and a sump to collect fluids. Depending on accessibility, one pad will be constructed immediately adjacent to Area A on the eastern boundary and the second pad will be constructed on the eastern or southern boundary of the landfill at Area B. The location of the decon pads will be finalized during mobilization as directed by LANTDIV.

##### **4.18.1 Sampling Equipment**

Sampling equipment (i.e., split-spoons, sampling trowels, bucket augers, bailers, etc.) will be decontaminated prior to sampling and between samples, according to the sequence established in Section 5.18. Waters generated during decontamination of sampling equipment will be contained in 55-gallon drums pending receipt of analytical results and final disposition recommended to the Activity.

Section 5.18 presents "Chemical Sampling and Field Analytical Equipment Decontamination" SOP. Section 5.19 presents "Handling of Site Investigation Wastes" SOP.

#### **4.18.2 Heavy Equipment**

All heavy equipment, including the drilling rig, rods and augers, and other downhole equipment used during site investigation activities will be decontaminated prior to beginning work and between all boreholes using a high-pressure steam wash at a location designated by the EIC and the Activity. The water to be used during steam-cleaning will be from a potable source. Monitoring well casing and screen also will be steam-cleaned using the same procedure, unless it is precleaned and wrapped in plastic prior to arrival at the site. Well casings and screen wrapped in the manufacturer's packaging will be steam-cleaned prior to installation. A decontamination pad will be constructed of high density polyethylene and wood with elevated sides and a central sump for fluid collection at each area.

Baker's SOP for "Decontamination of Drilling Rig and Monitoring Well Materials" has been included in Section 5.20.

#### **4.18.3 Personnel Decontamination**

Personnel decontamination is discussed in the Health and Safety Plan.

#### **4.19 Documentation**

A single notebook will be dedicated to the investigation, and will serve as a daily logbook detailing the weather and activities of the day, including work accomplished, those present on site for the day, as well as technical issues such as sample numbers, descriptions of sample locations, any problems encountered during their collection, and sample handling and preservation methods. Each individual in the field crew will maintain a logbook which documents his/her field activities.

Baker's SOP for "Field Logbook" has been included in Section 5.21.

#### **4.20 Field Change and Corrective Action**

If changes become necessary due to field conditions (e.g., weather problems, obstructions to drilling or sampling), the proposed change will be communicated from Baker's Field Team Supervisor to Baker's Project Manager and then on to the Engineer-in-Charge (EIC) for the

project. Upon agreement of the best method of solving the problem and after consultation with the Activity (if necessary), the method will be implemented and the change will be documented, with the documentation placed in the project file.

#### **4.21 Field Instrument Calibration**

Equipment calibration will be performed at the frequency and using the directions recommended by the manufacturer of each respective piece of equipment. Daily calibration will be performed in the morning prior to initiation of site investigation activities.

#### **4.22 Contaminated Materials Handling Plan**

##### **4.22.1 Health and Safety Disposables**

Health and safety disposables, such as sampling gloves, outer boots, Tyvek coveralls, paper towels, plastic sheeting, or other materials which may come in contact with potentially contaminated materials will be placed in large, clear plastic bags during the day. These bags will be marked "Potentially Contaminated Materials" to prevent their confusion with ordinary trash. At the end of each day, these bags will be collected and placed in open-top drums in a secure drum storage area. The drums containing these materials will be likewise marked.

##### **4.22.2 Drill Cuttings**

Soil cuttings and excess split-spoon soil samples generated during drilling will be containerized in 55-gallon drums and staged in a designated area pending receipt of analytical results and final disposition recommended to the Activity. These drums will be clearly marked with a grease pencil or other water-resistant marker to indicate the borehole from which the cuttings were removed. The word "soils" also will appear to differentiate between drummed cuttings and drummed purge water or development water.

##### **4.22.3 Development and Purge Water**

All water generated during well development and purging of the wells prior to groundwater sampling will be containerized in 55-gallon drums and will be staged in a designated area pending receipt of analytical results and final disposition recommended to the Activity. These

drums will be clearly marked similarly to drummed soil cuttings, except that the well number will be marked on the drums, along with the word "water."

Section 5.20 presents "Handling of Site Investigation Wastes" SOP.

## **5.0 STANDARD OPERATING PROCEDURES**

This section contains standard operating procedures (SOPs), divided by cover sheets, for the subjects as follows:

- Geophysics - Borehole SOP
- Geophysics - Electromagnetic Induction SOP
- Geophysics - Ground Penetrating Radar Profiling SOP
- Geophysics - Magnetometry Profiling SOP
- Water Quality Testing SOP
- Surface Water and Sediment Sample Acquisition SOP
- Borehole and Sample Logging SOP
- Soil and Rock Sample Acquisition SOP
- Monitoring Well Installation SOP
- Photoionization Detector (PID) SOP
- Flame Ionization Detector (FID) SOP
- Water Level, Water-Product Level, and Well Depth Measurements SOP
- Groundwater Sample Acquisition SOP
- In-Situ Hydraulic Conductivity Testing SOP
- Aquifer Testing SOP
- Sample Preservation SOP
- Chain-of-Custody SOP
- Chemical Sampling and Field Analytical Equipment Decontamination SOP
- Decontamination of Drilling Rig and Monitoring Well Materials SOP
- Field Logbook SOP
- Handling of Site Investigation Wastes SOP

**Section 5.1**  
**Geophysics - Borehole SOP**

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## GEOPHYSICS: BOREHOLE

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using borehole geophysical logging. Calibration and operation, along with field maintenance, will be included in this SOP.

### 2.0 SCOPE

This SOP indicates the normal suite of logging that may be used, as well as certain supplemental logs. The description of logging techniques includes the type of device, the physical property responding to or recorded by the device, and the general pattern of interpretation and correlation related to the device or the suite of logs.

### 3.0 DEFINITIONS

Active technique - A technique in which a stress is applied to the material under study and the resultant response is measured. Stresses can include electrical current, sound waves or neutron or gamma ray bombardment.

Calibration - The process of checking and adjusting the tool reading to a standard of known value.

Lithology - The physical character of a rock or rock type; also often used for describing overburden material (e.g., sand, clay, till).

Measuring point - The point, on a probe or sonde device, where the reading is taken (e.g., the tips of the caliper arms, the detector on a gamma-ray tool).

Non-unique response - Tool response that is not unique to a specific rock characteristic. For example, several different rock types exhibit low gamma-ray counts; water-filled fractures and clay layers both have low resistivity values.

Passive technique - A technique which measures properties inherent to the material; examples include self-potential, gamma-ray, temperature.

Probe - The downhole electronics and detecting/measuring apparatus of the logging system, usually encased in a stainless steel jacket.

Reference elevation - The surface elevation which acts as a common measuring point for all correlations, commonly ground surface or top of casing.

Resolution (vertical) - Ability to see thin layers.

Sonde - same as probe.

Total depth - The deepest point in the boring as determined by geophysical logs.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the borehole technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the borehole logging activities have been briefed and trained to execute these procedures.

#### 5.0 PROCEDURES

##### 5.1 Overview

Borehole geophysical techniques (also called logging) are a group of active and passive geophysical methods used to provide detailed measurements of soil, rock and water properties.

This is done by lowering tools into the borehole to measure the electrical, acoustical or radioactive properties of the materials surrounding a borehole. The surveys are non-destructive and can often be run in existing boreholes and water supply wells with no modifications.

The techniques are based on counterpart surface geophysical methods, adapted to the borehole environment (Table 1). Typically, these adaptations include the reduction of equipment size (most techniques will fit inside a two-inch diameter hole), reduction and standardization of the fixed source to receiver spacing (and a corresponding reduction in how deep the technique looks into the formation), protection of tools from pressure and temperature effects, and interpretation of data with respect to vertical rather than horizontal changes.

The relation of techniques as investigative suites, and the responses interpreted, are indicated on Table 2 for the usual and some unusual applications.

## **5.2 Applications**

### **5.2.1 Self-Potential**

- Identification of zones of water loss or gain (streaming potential)
- Qualitative indication of clay content/determination of clay layers
- Qualitative indication of water salinity
- Rock type correlation/layer thickness

### **5.2.2 High-Resolution Caliper**

- Used in open borehole geophysics
- Provides rock density in grams per cubic centimeter
- Provides borehole diameter

### **5.2.3 Natural Gamma**

- Yields a measure of potassium-40 content in rocks

### **5.2.4 Resistivity Profiling**

- Provides a measure of clay content in geologic materials
- Can be used as an olimeter

### **5.2.5 Temperature Log**

- Yields temperature at a specific vertical location in a borehole to presence of groundwater

**TABLE 1**  
**COMPARISON OF SURFACE AND BOREHOLE TECHNIQUES**

Surface Technique	Borehole Technique	Remarks
SP (Self-Potential)	SP	--
Resistivity Profiling	Normal or Single Point Resistivity Tools	--
Resistivity Sounding	None applicable	--
Electromagnetic Induction	Electromagnetic Induction	--
Seismic Refraction	Acoustic Velocity and VSP (Vertical Seismic Profiling)	Used primarily in consolidated rock; groundwater applications limited typically to bedrock.
Ground Penetrating Radar	None applicable	---
Magnetometry	None applicable	--
Gravity	Borehole Gravimeter	Groundwater applications not investigated.

**TABLE 2**  
**BOREHOLE SUITES AND TECHNIQUES**

Suite	Sonde	Response
Lithology	High-resolution caliper Natural gamma Resistivity	Density Borehole diameter Potassium-40 content Clay content
Groundwater	Temperature log Fluid conductivity meter Resistivity Self-Potential	Temperature Iron content ohms Salinity Zones of water loss or gain
Porosity	Neutron tool	Porosity
Flow	Long-space density Flow meter	Vertical flow Horizontal flow
Seismic	None applicable	--
Gravimetric	None applicable	--

- Measures inflow and outflows of a borehole/well

#### **5.2.6 Fluid Conductivity Meter**

- Yields direct iron content of groundwater by measuring conductivity of the fluid in which the probe is immersed

#### **5.2.7 Neutron Tool**

- Measures porosity of geologic materials by sending neutrons into the materials. Higher porosity will be indicated by return of fewer neutrons to the tool.

#### **5.2.8 Long-Space Density**

- Measures vertical flow in a borehole/well

#### **5.2.9 Flow Meter**

- Measures flow across a borehole/well

### **6.0 QUALITY ASSURANCE RECORDS**

Data will be recorded in log books or on data log sheets attached to the monitoring device. All data will be entered with the following: date, location, personnel on site, start and end time (in military time), Contract Task Order number, and weather.

### **7.0 REFERENCES**

Drobin, M.B., 1976, Introduction to Geophysical Prospecting, 3rd edition: New York, McGraw-Hill, 630 p.

Keys, W.S., and MacCary, L.M., 1971, Application of Borehole Geophysics to Water-Resources Investigations: U. S. Geological Survey, Techniques of Water-Resources Investigations, Book 2, Chapter E1, 126 p.

Labo, J., 1987, A Practical Introduction to Borehole Geophysics - An overview of wireline well logging principles for geophysicists: Tulsa, Society of Exploration Geophysicists, 330 p.

Taylor, T.J., 1983, Interpretation and Application of Borehole Televiewer Surveys, in 24th Annual Logging Symposium Transactions: Houston, Society of Professional Well Log Analysts, Paper QQ, 19 p.

Zemanek, J., Caldwell, R. ., Glenn, E.E., Jr., Holcomb, S.W., Norton, L.J., and Straus, A.J.D., 1968, The Borehole Televiewer - A new logging concept for fracture location and other types of borehole inspection: Dallas, Society of Petroleum Engineers, 43rd Annual meeting (Houston) preprint SPE-2402. Later published in 1969, Journal of Petroleum Technology, V. 21, No. 6, p. 762-774.

TABLE 1

COMPARISON OF GEOPHYSICAL METHODS FOR HAZARDOUS WASTE APPLICATION

Geophysical Method	Cost	General Applications	Relative Depth of Investigation	Advantages	Disadvantages	Accuracy
Seismic Refraction	Moderate	Determine depths to bedrock and water table. Identify zones of fractured weathered bedrock.	0 to 10 meters	Accurately identifies groundwater and rock layering.	Sensitive vibration, construction activities and electrical noise.	± 10% of depth to interface
Electrical Resistivity	Inexpensive	Determine depths to water table, clays, and bedrock.	10 to 100+ meters	Easy to operate. Equipment is inexpensive.	Dipping strata complicates interpretation.	± 25% of total depth
Self Potential	Inexpensive	Identify groundwater flow and area of contamination.	0 to 20 meters	Equipment is inexpensive. Easy to operate. Highly qualitative interpretation.	Susceptible to interference from lithological and vegetation differences.	
Electromagnetic	Moderate	Plume detection and tracing. Depths to water table, bedrock, clays, etc.	0 to 5 meters	Walk over method.	Lacks the resolution and depth.	± 25% accuracy
Ground Penetrating radar (GPR)	Moderate	Buried metals detection and general identification.	0 to 10 meters	Tow-along method. Radar commercially available. Easy to operate and high resolution.	Depth of penetration limited by conductivity of material (drum, tank, debris, etc.).	± 20% accuracy
Magnetics Equipment	Inexpensive	Buried ferrous detection.	0 to 10 meters	Easy to operate and equipment commercially available.	Sensitive to fences, power lines, pipes, and cultural metal ferrous objects.	
Gravity	High	Detection of joints, fault scapes, buried river channels, collapse or fill areas.	10 to 100 meters	Data can be acquired in highly developed urban areas. Field work done by one person. Equipment is portable.	Instrument and survey equipment expensive. Geologic data necessary for interpretation. Also, requires highly trained field personnel.	
Borehole Measurement	Moderate	Drill to known depth of measurement.	5 to 100+ meters	Very good vertical resolution. Most equipment easy to operate. Little data reduction.	Borehole construction may limit techniques. Radioactive tools need special licensing.	

Note: All methods can be operated in a non-intrusive manner.

**Section 5.2**  
**Geophysics - Electromagnetic**  
**Induction SOP**

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## GEOPHYSICS: ELECTROMAGNETIC INDUCTION METHOD

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using electromagnetic induction (EM) methods.

### 2.0 SCOPE

This SOP provides a description of field procedures, equipment, and interpretation methods necessary to fully utilize this procedure.

### 3.0 DEFINITIONS

Conductivity - Inverse of resistivity.

Horizontal dipole mode - Transmitter and receiver coils oriented vertically.

Vertical dipole mode - Transmitter and receiver coils oriented horizontally.

Vertical sounding - Multiple EM measurements centered at a point with varying coil spacings.

Vertical profiling - EM measurements along a traverse with a fixed coil spacing and coil orientation.

### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the borehole technique and equipment to be used. It is the responsibility of the Field Team Leader

to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the borehole logging activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the field investigation personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and the Project Manager. Field personnel are responsible for the proper acquisition of geophysical data.

## 5.0 PROCEDURES

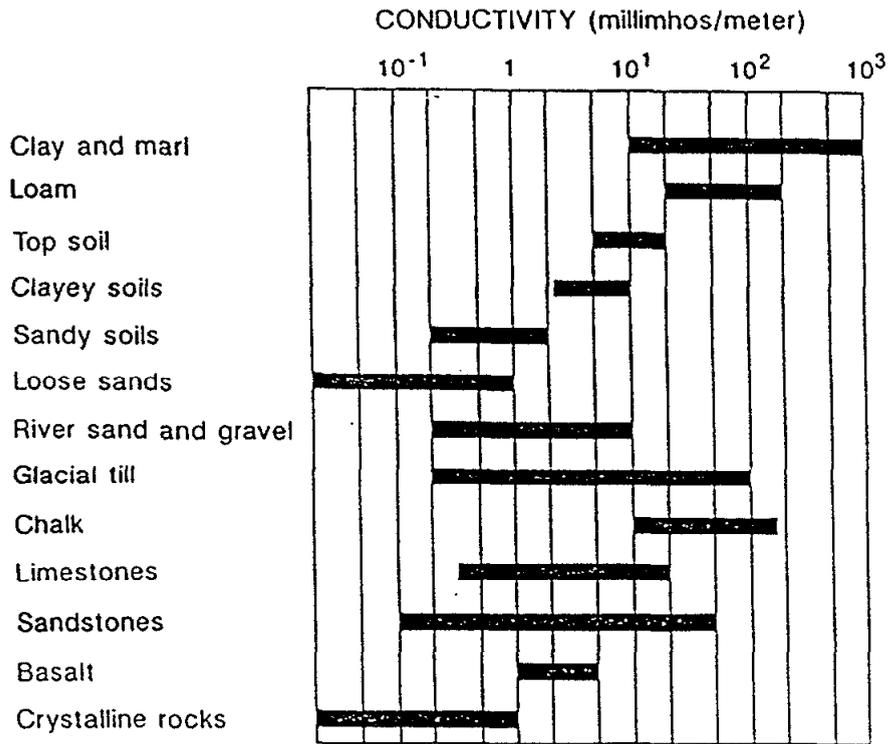
### 5.1 Overview

Electromagnetic Induction (EM) methods are non-destructive geophysical techniques of measuring the apparent conductivity of the subsurface materials. Electrical conductivity values of subsurface materials are determined by transmitting a high frequency electromagnetic (primary) field into the earth and measuring the secondary electromagnetic field produced by the eddy current as illustrated in Figure 1. The transmitter and receiver coils do not require direct ground contact thus permitting continuous profiling and rapid data acquisition.

The strength of the secondary field is a function of the inter coil spacing, operating frequency and ground conductivity. The ratio of the secondary to the primary magnetic field is directly proportional to the terrain conductivity which enables direct instrument readout of apparent conductivity values (measured conductivity values are the bulk average conductivity for the area or volume of earth sampled). Conductivity ranges typical of various earth materials are shown on Figure 2. EM conductivity values are usually expressed in units of milliohms per meter. Conductivity values are converted to resistivity values in ohm-meters by use of the following relationship:

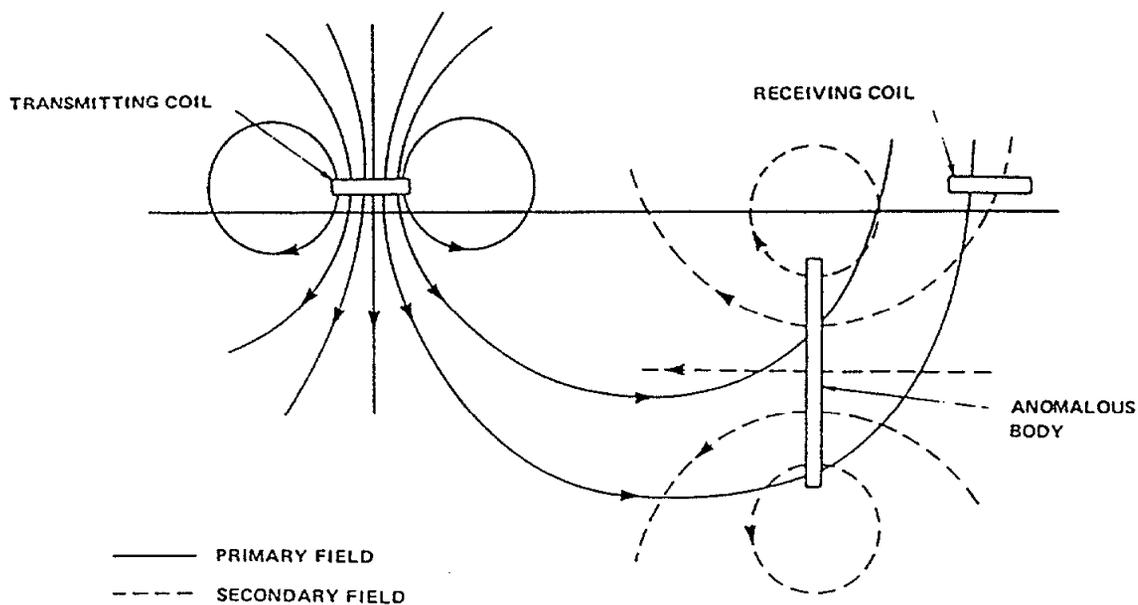
$$\text{resistivity (ohm- meters)} = \frac{1,000}{\text{EM instrument readout (milliohms per meter)}}$$

Figure 1



(after Culley et al.)

Figure 2



Source: Griffith and King, 1981

The apparent conductivity of the subsurface materials is dependent upon subsurface conditions such as:

- Lithology
- Porosity
- Permeability
- Conductivity of subsurface pore fluids

Changes in these parameters causing measurable variations in electromagnetic conductivity can result from:

- Contaminant plumes
- Abandoned trenches and lagoons
- Lateral changes such as pockets of material
- Bedrock fracture zones
- Lithological variations
- Buried metallic objects

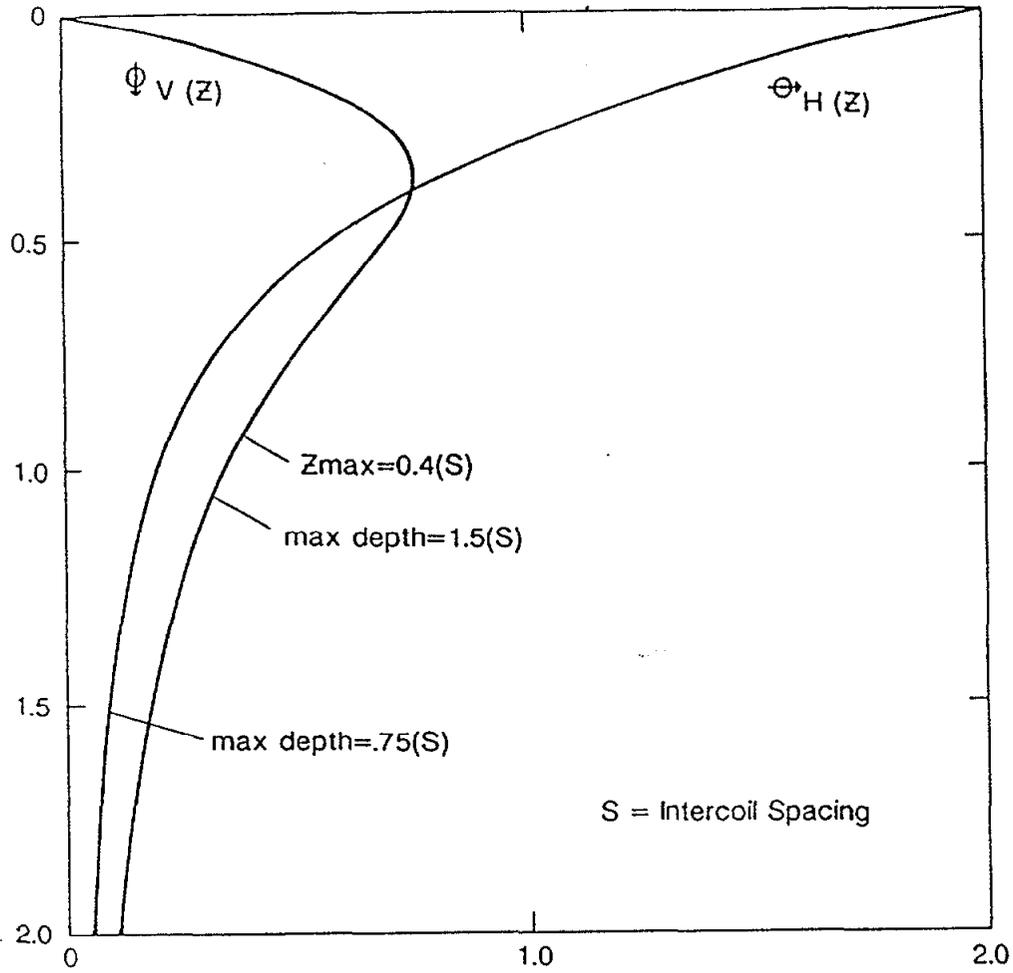
The sampling depth or depth of investigation is related to the coil spacing and coil mode. The two coil modes used are the vertical dipole mode (coils horizontal) and the horizontal dipole mode (coils vertical). Figure 3 shows the relationship of the coil spacings, mode and relative responses.

Vertical sounding and horizontal profiling are the two EM survey techniques. Vertical profiling is accomplished by multiple measurements about a point with varying coil spacing. Horizontal profiling is performed by making measurements along traverses with a fixed coil spacing. General discussions of electromagnetic induction methods are presented in texts by Grant and West (1965), Telford and others (1976), and Griffiths and King (1981).

## 5.2 Applications

The measurement of subsurface conductivity at a hazardous waste site provides a valuable contribution to site characterization. The conductivity (resistivity) of the hydrogeologic section is predominantly influenced by the pore fluids. Consequently, conductivity measurements provide indirect information on the porosity and permeability of subsurface materials, the degree of saturation, and the conductivity of the pore fluids. The conductivity of the pore fluid is influenced by the presence of dissolved electrolytes. Contaminant plumes in the unsaturated and saturated zones can be mapped provided there is a sufficient change in

Figure 3



COMPARISON OF RELATIVE RESPONSES FOR  
VERTICAL AND HORIZONTAL DIPOLES

the conductivity to be detected by the EM instrument. Generally, contaminant plumes of inorganic waste are easily detected because the pore fluids often have conductivity values as much as three orders of magnitude above background values. Figure 4 illustrates an EM anomaly associated contamination plume. EM conductivity measurements can also be used to detect the presence of buried waste; filled disposal trenches, and buried metal objects such as drums, tanks or metal debris. Figure 5 illustrates an EM anomaly over a buried metal object. Electromagnetic surveys can be used to locate conductive as well as and non-conductive bodies. The many applications include:

- Contaminant plume mapping
- Locating abandoned trenches and lagoons
- Delineating bedrock fracture zones
- Determining thickness of weathered layers
- Lithology mapping
- Locating buried metallic objects
- Lateral anomalies such as pockets or pits of different materials

Examples of EM applications at sites where groundwater is contaminated are presented by Duran (1982), Greenhouse (1983), and Greenhouse and Slaine (1983).

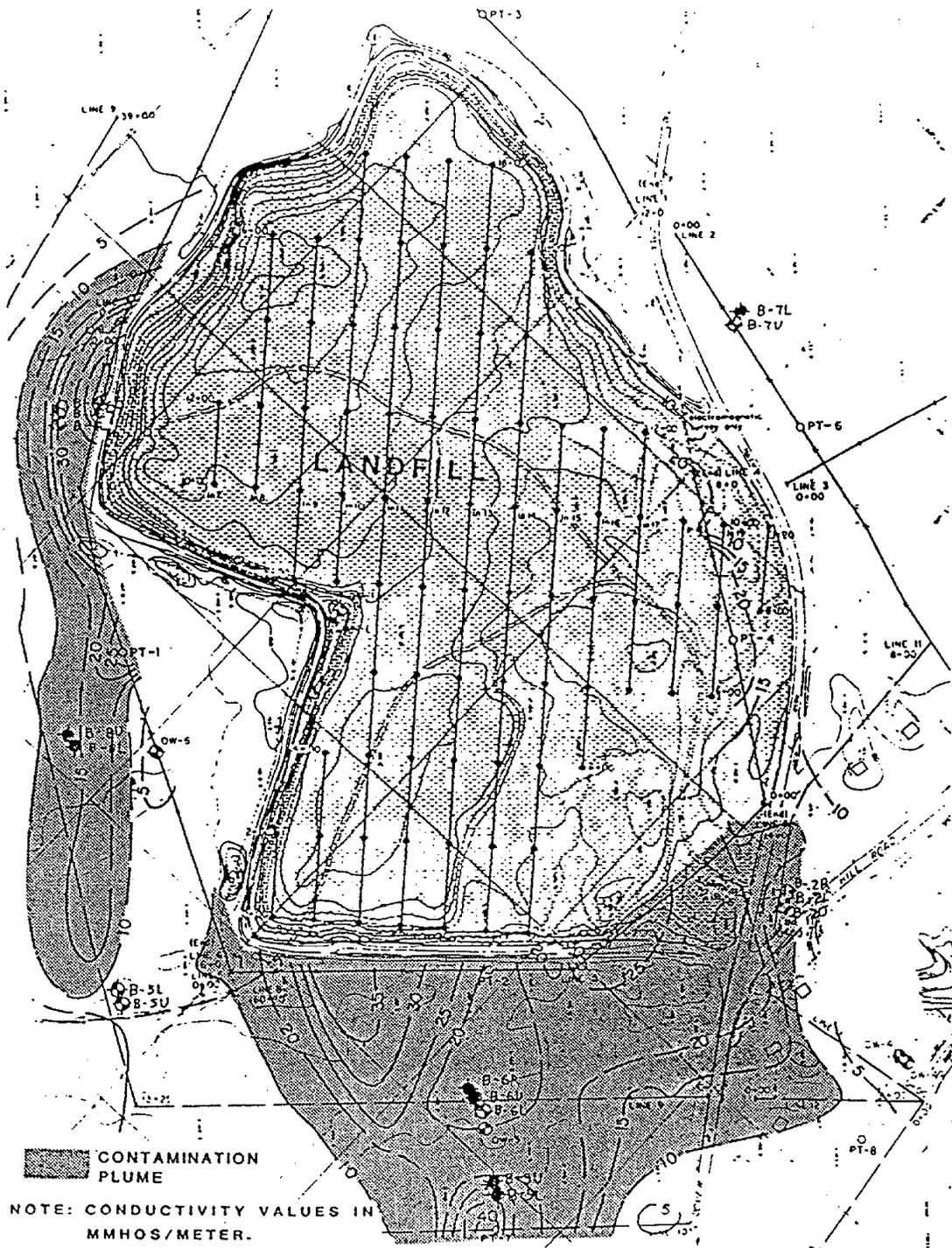
### 5.3 Equipment

The VLF (very low frequency) and two-coil instrument are basically the two different types of electromagnetic surveying instruments in use; each is capable of sensing to different depths. There are several models and manufacturers of EM equipment.

The VLF instrument is a receiver which relies on specialized, very low frequency communication antennas for induction of an electromagnetic field. Surveying with the VLF or equivalent instrumentation is commonly referred to as VLF surveying.

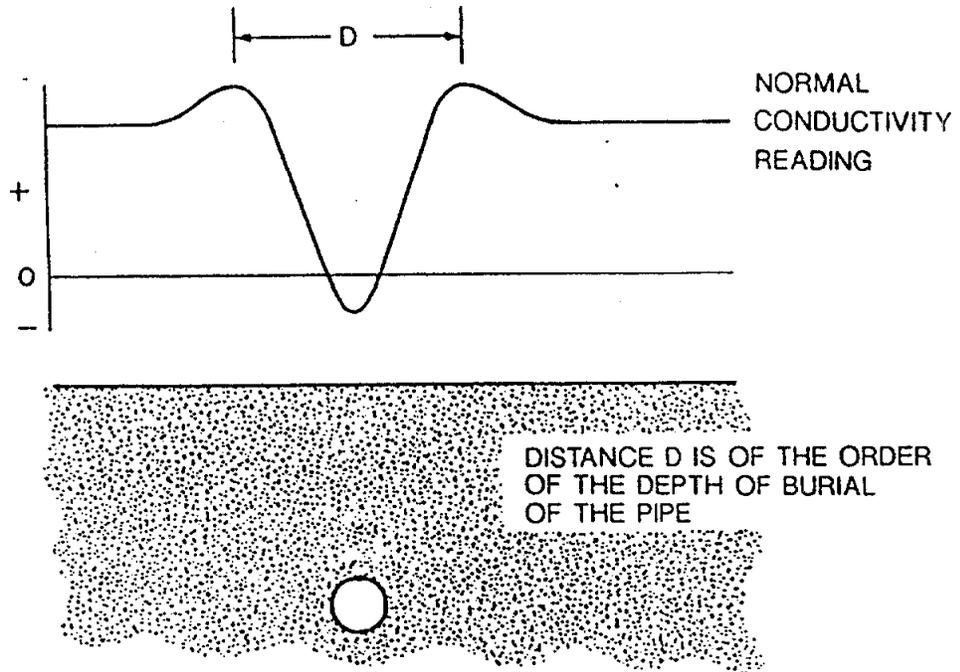
The VLF Instrumentation is a small, lightweight hand-held instrument which can be operated by one person. Principal components of the instrument are a pair of mutually perpendicular coils and a receiving crystal with a frequency specific to a transmitting antenna. The two receiving coils are used to measure local characteristics of the primary induced field and any secondary fields emanating from bodies of variable conductivity. Typical sources of induced electromagnetic fields for VLF surveying are the very low frequency antennas used for submarine communications.

Figure 4



CONDUCTIVITY CONTOUR MAP

Figure 5



Source: Geonics Limited, Operating Manual for  
EM31 Terrain Conductivity Meter, 1979

TYPICAL EM RESPONSE OVER A METAL PIPE

The two-coil system, consists of a transmitter coil and a receiver coil. Figure 1 illustrates the basics of a two-coil electromagnetic induction apparatus. The transmitter coil induces an electromagnetic field of known strength and the receiver coil measures the resulting quadrature, or ratio of primary to secondary fields resulting from subsurface features. Each instrument is read directly in units of milliohms per meter (conductivity). EM readings represent the average bulk conductivity at a point halfway between the two coils.

#### 5.4 Data Acquisition

The advantage of the EM survey method is the speed and accuracy with which lateral changes of terrain conductivity can be measured. The EM conductivity data can be acquired using sounding and profiling techniques similar to those used in electrical resistivity. EM profiling is accomplished by traversing an area with a fixed coil spacing and orientation; EM sounding is accomplished by expanding the inter-coil spacings in a manner similar to that used by electrical resistivity soundings. Some commonly used EM equipment is limited in the number of available inter-coil spacings that can be used; however, there are other EM instruments available that can operate at many coil spacings and frequency ranges to provide numerous sounding data points necessary for accurate computer modeling and profiling.

The factors determining which instrument is used and what the grid spacing should be at particular sites are:

- Depth to target and size of target
- Accessibility of the site
- Effects of manmade structures and utilities, such as electric power lines
- Conductivity of the earth materials

EM induction instruments may have a depth of investigation of up to 200 feet depending upon coil spacing and orientations used (see Figure 3). The very low frequency VLF device has the greatest depth of investigation and is generally used to evaluate large geologic structures.

In conducting a VLF survey, VLF readings should be acquired with the instrument oriented perpendicular to a straight line from the site to the transmitter antennas. This orientation is necessary to ensure optimum data quality. All readings from a particular VLF station must be obtained with the instrument oriented in the same direction.

For an EM induction survey, a regular pattern of survey stations will provide coverage of the area in question. Typically, use of a grid spacing which is approximately equal to the size of the target sought by the survey, and a coil spacing with a maximum response for the depth of interest will produce satisfactory results. Specific needs for local detail, however, may require a refined coverage. The chosen spacing should always be site and target specific.

In conducting an EM survey, the field operator must avoid or note any potential sources of anomalous (noise) conductivity values such as power lines, buildings, fences, buried pipelines or any other large metal objects. Noise sources should be noted on the profiles or contour maps so that anomalies due to these known sources can be accounted for.

Important information that should be known for planning and before conducting an EM conductivity survey are: assumed hydrogeologic characteristics of the site, potential source locations and migration paths, characteristics of the hazardous substance of interest, and depths of interest. The level of detail necessary (size of object of interest and detail of resolution) determines the number of lines and station spacings of readings required.

EM data, if not recorded on a strip chart or digital recording instrument, should be recorded on standardized data sheets. At a minimum all data (strip chart, digital disks, or standard forms) should have the following information listed:

- Project/site location identification
- Company
- Date and time
- Operators name
- Instrument make, model
- Coil spacings and configuration
- Line and station numbers
- Instrument reading scales
- Weather conditions/temperature

## 5.5 Interpretation

### 5.5.1 Data Analysis

In general, electromagnetic survey data require relatively little processing before they can be interpreted. This is especially true for fixed coil spacing surveys because the data are recorded

in units of conductivity; preliminary interpretations are made by comparison of conductivity values. A contour map can be prepared from the data and compared with results of other surveys. EM instruments also can be used for vertical soundings similar to resistivity sounding. Vertical sounding with EM equipment, however, has lower resolution than that performed with the resistivity technique. As a result, EM data are generally more useful for continuous profiling surveys.

VLF instruments do not read directly in units of conductivity. The in-phase measurement (the tilt of primary induced field) is read in terms of the tangent to the angle of tilt and is given as a percentage. Quadrature measurements, which are the ratios of voltage required to equalize the primary to secondary signal strengths, are also given as percentages. For field interpretation these two sets of data can be plotted in profile form, percentage versus distance. Greenhouse and Slaine (1983) describe a simple mathematical conversion so that VLF data can be presented in contour format and compared to other available data such as resistivity and magnetics. Digital data acquisition systems are now available that allow calculation of conductivity.

Data acquired during two-coil surveys are easier to work with because the instruments read directly in units of conductivity. A contour map can be prepared from the data and compared with results of other surveys.

#### **5.5.2 Presentation of Results**

Results of an EM conductivity survey can be presented in profile and/or contour map form. The orientation of the traverses should be indicated on profiles in lines of coverage on contour maps. Locations of observed surface metal and other cultural features such as topography, buildings, fences, power lines etc. should be noted on both the profiles and the contour maps.

#### **5.5.3 Interpretation**

EM conductivity data can be analyzed qualitatively and quantitatively. Generally, profiling data are presented as a contour map or profiles. Profile lines should be stacked and aligned. A qualitative analysis of the contour map or aligned profiles usually can allow an interpreter to identify any conductivity trends that may be indicative of buried metal, groundwater flow and contaminant transport. A comparison of available geologic data, cultural ferrous metal and

debris maps prepared during data acquisitions should be made to evaluate the causes of any conductivity trends observed.

Computer or chart comparisons of EM sounding data with available theoretical models can be made. This type of interpretation is similar to that used in electrical resistivity, but in EM sounding it is limited to relatively simple hydrogeologic conditions.

## **5.6 Advantages and Limitations**

Advantages of the electromagnetic induction method include:

- No ground contact required
- Rapid data acquisition (faster than resistivity)
- Lightweight, one or two man operation
- Wide range of applications
- High lateral resolution
- Field interpretation possible

Limitations of the electromagnetic induction method include:

- Limited dynamic range 1-1,000 milliohm/meter
- Susceptible to effects of man-made structures, utilities, etc.
- Less vertical resolution than resistivity
- Limited penetration
- Does not distinguish even simple layering, without more complex application and interpretation
- Setting and maintaining instrument at zero

## **6.0 QUALITY ASSURANCE RECORDS**

Field data will be recorded in log books and/or data recording sheets accompanying the monitoring equipment. Data recorded in a field log book will be entered with the following data: date, site location, Contract Task Order number, personnel conducting the investigation, time (military time), start time and end time, weather.

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**Section 5.3**  
**Geophysics - Ground Penetrating**  
**Radar Profiling SOP**

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## **GEOPHYSICS: GROUND PENETRATING RADAR (GPR)**

### **1.0 PURPOSE**

The purpose of this SOP is to provide general reference information and technical guidance on the methods and techniques of ground penetrating radar (GPR).

### **2.0 SCOPE**

These procedures provide overall technical guidance.

### **3.0 DEFINITIONS**

Bistatic Antenna - An antenna system in which transmitting and receiver coils are housed in separate antenna units.

Deconvolution - A computer processing method. The process of undoing the effect of another filter (in this instance the "earth"). A process that removes ringing, multiples, ghosts, and some background noise (Sheriff, 1973).

Dielectric Permittivity - (Also known as the relative dielectric permittivity): 1. A complex number consisting of a real and imaginary part, which uniquely describes the propagation and attenuation of electromagnetic energy in every material. The real dielectric permittivity (dielectric constant) characterizes the propagation and reflection of electromagnetic (EM) waves, while the imaginary part (dielectric loss) characterizes the attenuation of EM signal (Kutrubes and Olhoeft, 1987). 2. A measure of the capacity of a material to store charge when an electric field is applied (Sheriff, 1973).

Electromagnetic Waves - One of the waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include radio waves, infrared, visible light, ultraviolet, X-rays and gamma rays (Webster's New Collegiate Dictionary, 1979).

Migration - here velocity varies laterally, data will migrate (relative to the time versus antenna distance plot), and ray tracing is used to determine migrated positions (Sheriff, 1973).

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the borehole technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the borehole logging activities have been briefed and trained to execute these procedures.

#### 5.0 PROCEDURES

##### 5.1 Overview

Ground penetrating radar (GPR) is an active geophysical system which transmits high frequency electromagnetic (EM) waves into the ground and detects the energy reflected back to the surface. GPR operates on a similar principle as seismic reflection, except, instead of acoustic waves, electromagnetic waves of radio and microwave frequencies (80 MHz to 1,000 MHz) are utilized. Electromagnetic signals are reflected back to the surface from interfaces with differing electrical properties, such as dielectric permittivity and conductivity. The greater the contrast in the real dielectric permittivity (dielectric constant) between two materials, the more energy is reflected to the surface. Reflections typically occur at lithologic changes, subsurface discontinuities, and internal soil structures, such as:

- Top of bedrock surfaces
- Soil and rock stratification
- Water table
- Seepage and leachate zones
- Buried metal objects such as drums and utilities
- Open and water filled voids

- Bedrock fractures
- Archaeological structures

The depth of penetration of GPR is site specific, being limited by the attenuation of the electromagnetic energy. Signal attenuation is controlled by four different mechanisms listed below, any or all of which may be present at a site.

- Scattering losses
- Conduction losses
- Water losses
- Clay losses

Energy losses due to scattering occur when signals are dispersed in random directions, away from the receiving antenna, by large irregularly shaped objects, such as boulders and tree stumps.

Signal attenuation due to conduction is a function of the conductivity of a material, which varies with mineral composition, the amount of water, and the total dissolved solids (salt, heavy metals) within the water. The greater the electrical conductivity values of materials at a site, the more signal attenuation (hence less penetration) there will be.

Energy losses attributed to water occur when water molecules polarize in the presence of the applied electromagnetic field. Electromagnetic energy is lost to the radar system when it is converted to kinetic and thermal energy as a result of the rotation of water molecules.

Signal attenuation due to clay losses occurs when electrochemically charged ions polarize along clay surfaces in the presence of the electromagnetic field induced by the radar system. The migration and subsequent collision of these charged particles causes electromagnetic energy to be converted to kinetic and thermal energy, which is lost to the radar system.

Signal penetration is also dependent on the frequency of the transmitting antenna used in the radar system. Higher frequency antennas produce waves with shorter wave lengths, which are attenuated more rapidly with depth, but give better resolution. Specially designed 2 MHz antennas have been used to detect the ice-rock boundary of a 2 km thick glacier. Penetration of up to 75 feet has been reported for water saturated, clean sands in a Massachusetts glacial

delta using a commercial antenna. Signal penetration in saturated clays, on the other hand, is on the order of magnitude of a few inches. Olhoeft (1986a) determined that even 5% clay added to a clean sand and gravel will cause a decrease in penetration by a factor of 20. Salt water is also a high loss substance, as signal penetration in sea water is less than a foot. It is important to note that in a layered medium a single, highly reflective layer alone can limit signal penetration by preventing the propagation of energy through it. In this instance the apparent loss of energy is caused by reflection rather than by signal attenuation.

## 5.2 Applications and Uses

Ground penetrating radar (GPR) is a shallow penetrating geophysical profiling system used where rapid and accurate surveys are desired. GPR can be used for both area and source detection studies. GPR has been used to locate underground pipes, buried drums, foundations, voids in rock and concrete, lithologic contacts, determine stratigraphy, depth to the water table, and depth to bedrock, locate buried archaeological artifacts, excavations, filled pits and lagoons, and numerous other site specific applications. GPR has been used successfully to delineate the lateral extent of plumes. Haeni et al. (1985) used GPR to investigate the thickness, type, and extent of sediments beneath a frozen lake with a 80 MHz antenna. The information acquired with GPR was used to help map the lateral extent of an aquiclude, and better estimate inputs to the mass balance equation for water budget calculations.

A GPR system can be used to determine depths to reflecting discontinuities by conducting a depth calibration. Typically, calibration is performed by moving the radar antenna over a metal target of known depth, such as a buried metal plate. Also, if transmitting and receiving antennas are housed in different units, designated as a bistatic antenna system, a common depth point (CDP) survey, identical to surveys conducted with seismic reflection, can be used to calculate the velocity of the medium, and hence depth to the reflector. Sakayama and others (1988) describe another method to calculate velocity from bistatic antennas where the receiving antenna is continually moved away from the stationary transmitting antenna. The velocities of the direct arrival and the first strong reflector are recalculated from the inverse slope of the time-distance display (antenna separation) on the GPR record in a similar manner as seismic refraction.

To verify GPR results, other geophysical or ground truth methods can be utilized. Haeni et al. (1985) utilized seismic refraction to correlate calculated depths of stratigraphic horizons and

water tables with radar reflections. Magnetometry and electromagnetic induction methods have been utilized to verify the presence of buried drums and fuel tanks. Electromagnetic induction and electrical resistivity have been utilized to verify the lateral extent of conductive plumes. The depth to a particular reflector or target can also be verified by boreholes and/or test pit excavation.

### 5.3 Equipment

A ground penetrating radar system, shown on Figure 1, consists of:

- AC/DC power supply
- Control unit (pulse transmitter)
- Antenna(s)
- Graphic recorder
- Digital recorder (optional)
- Magnetic tape recorder (optional)
- Coaxial cable which connects the control unit to the antenna

Typically, radar antennas contain both the transmitter and receiver within one fiberglass unit. Once a radar impulse is transmitted, the antenna switches to the receiver mode and records reflected radar impulses. The pulse receiver contains an amplifier which increase the amplitude of reflected signals. Bistatic antennas (transmitter-receiver are separate) allow the coverage of larger areas with one pass, and multi-receiver combinations allow the "stacking" of radar data which increases the signal to noise ratio.

Field data are generally printed by a graphic recorder and simultaneously can be stored on magnetic tape or diskette. The 8.7-5 6/10/88 graphic recorder produces a continuous time (vertical) versus distance (horizontal) profile of the subsurface for field quality control and qualitative interpretations. Radar impulses are synchronized with the swept-stylus type graphic recorder, producing a dark band proportional to the amplitude of reflected radar signal. Because the antenna is moving, each pass of the stylus represents a slightly different antenna position. Gradually, as the recorder paper advances under the moving stylus, a pattern of reflective interfaces emerges.

Storage of data on diskette or magnetic tape allows opportunity of additional printing and/or computer processing for the refinement of data. Deconvolution of stored data enhances stratigraphic reflections from the water table and soil structures (Olhoeft, 1988). Migration of

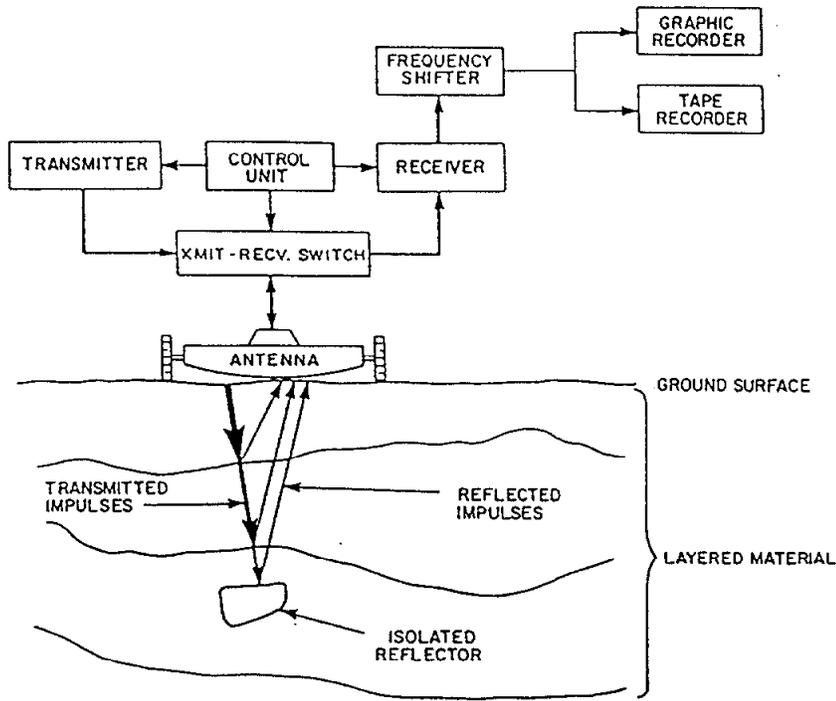
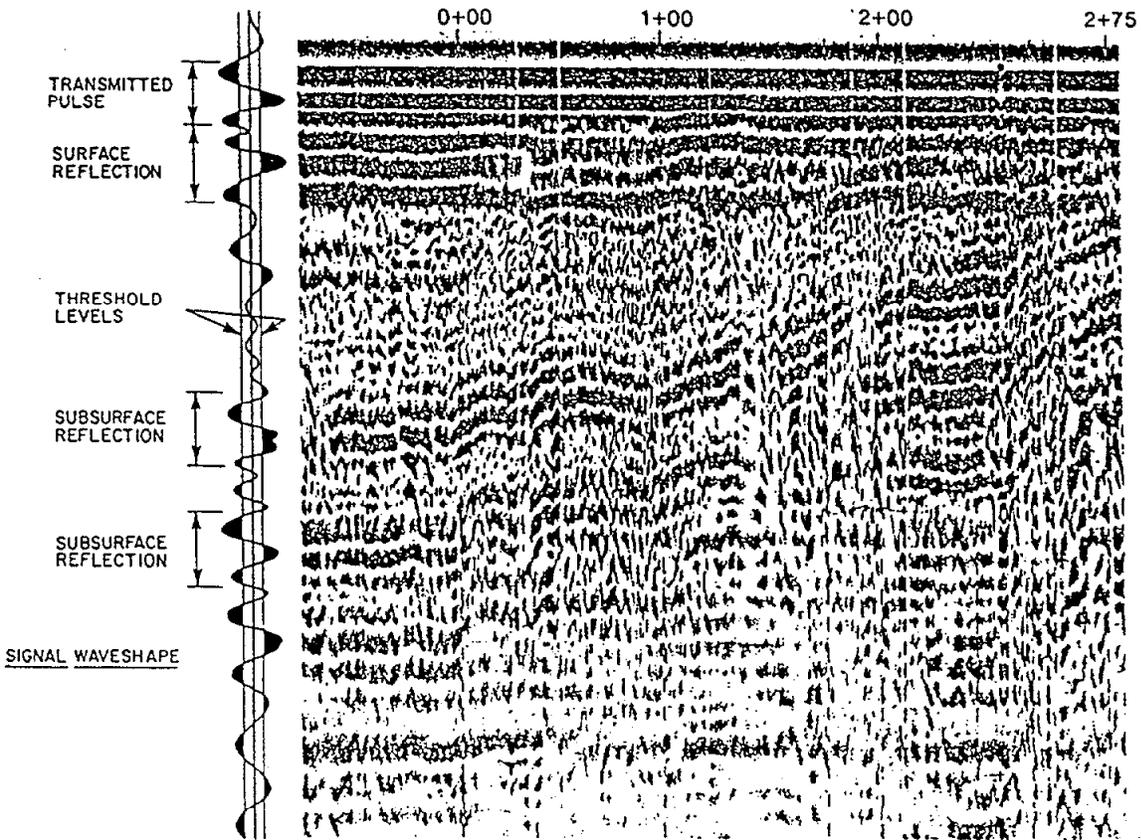


FIGURE 1

RADAR SYSTEM BLOCK DIAGRAM



TYPICAL RADAR RECORD

GROUND PENETRATING RADAR SET-UP

data allows easier resolution of metallic targets, such as buried drums, and delineation of excavations and sinkholes (Hogan, 1988).

Radar systems are designed to use antennas of various electrical characteristics. Selection of the antenna is dictated by the requirements of the survey. If high resolution, near-surface data is desired, a small, high frequency antenna is used; if the survey requires deeper probing, a larger, lower frequency antenna is used (80, 120, 250, 300, 400, 500, 900, and 1,000 MHz antennas are commercially available). The drawback of using the lower frequency antennas is that resolution of data is sacrificed for penetration. Also, the low frequency antennas (less than 250 MHz) are generally not shielded, making them susceptible to overhead power line noise and spurious reflections from passing cars. The 900 and 1,000 MHz antennas are used almost exclusively for short penetration projects such as the detection of rebar in concrete, as their penetration is generally limited to 2 to 3 feet.

#### 5.4 Field Procedures

The majority of time involved with any GPR survey is spent establishing survey lines in the area of investigation so that detected anomalies can be easily located and excavated. Survey lines should be set to maximize coverage, while maintaining a grid spacing proportional to the presumed target dimensions. A minimum survey line spacing of 10 feet is desired when looking for a 1,000 gallon fuel tank, while a larger spacing of 50 feet or more may be used to define the lateral extent of a conductive plume.

At the onset of any GPR survey the radar control unit should be adjusted for the anticipated depth of penetration. Adjustments of the time window of exploration should be made by estimating the velocity of the medium and desired depth of penetration. Assuming 8.7-66/10/88 a soil velocity of 0.4 times the speed of light and a target that is buried 10 feet below ground surface, a minimum time window of 50 nanoseconds is needed.

Accurate determination of the depth to any layer requires calibration of the radar system, as described in Section B. The easiest way of calibrating the GPR system to specific settings is by burying a plate at a measured depth, and moving the antenna slowly along the survey line. The plate will produce on the GPR record a thick, dark band, parabolic or flat in shape, with many multiple reflections beneath it. Once a certain confidence level is attained from depth calibration, the survey is conducted by slowly pulling the antenna along survey lines. A slow

walking pace increases the horizontal resolution as radar signals are propagated in a 15 to 45 degree cone from the bottom of the antenna. A slow walking pace is recommended for hazardous waste investigations as targets are better defined and easier to resolve. On the other hand, the radar antenna can be towed from the back of a car or truck at speeds up to 10 miles an hour if the "target" is a continuous reflector, such as the water table.

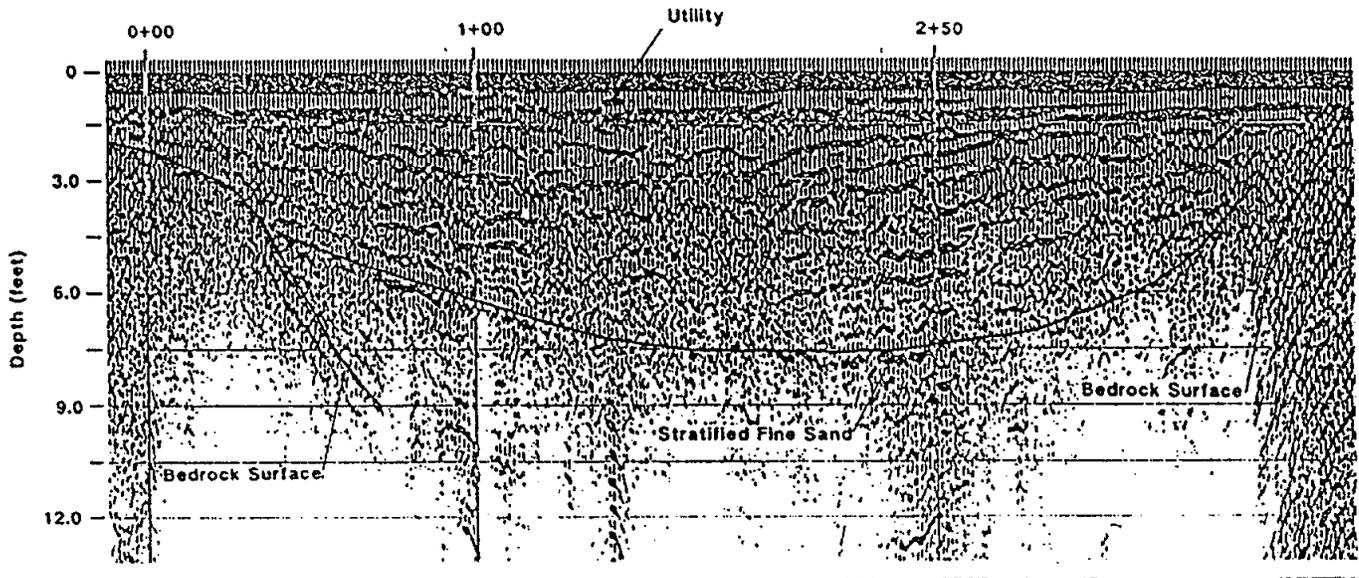
### 5.5 Interpretation

Typical GPR records produced on the graphics recorder are shown on Figures 2 and 3. A representation of a single GPR signal pulse is shown along the side of Figure 2. The horizontal scale of the record is maintained by marking on the record the locations of survey stations as they are reached by the antenna. Accurate determination of the vertical scale (i.e., conversion of a time into a depth) requires calibration of the radar system, as discussed in Section B. If the depth to a known reflector can not be determined through calibration or verification using boreholes and test pits, the velocity of the medium can be approximated from relationships involving the velocity of the medium, and the dielectric constant (real dielectric permittivity) of the medium. Values of the dielectric constant can be found in GSSI (1974), and Kutrubes (1986). The depth to the reflector can be calculated from time and velocity values. It is important to note that the relationship is no longer valid when signal losses are great.

Interpretation of GPR data is subjective, even among experienced interpreters. The strength of a reflected signal and/or the continuity of that reflector across the record may be indicative of a stratigraphic contact. The water table in an unconfined sand and gravel aquifer may also produce a similar signature on the GPR record. The strong continuous reflector shown in Figure 2 delineates the contact between bedrock and unconsolidated materials. Point targets, such as buried drums, pipes, boulders, tree stumps, etc., create a distinctive parabolic feature on GPR 8.7-8 6/10/88 records. Positive identification of point targets are subjective, as the GPR signature of a pipe is similar to that of a large boulder.

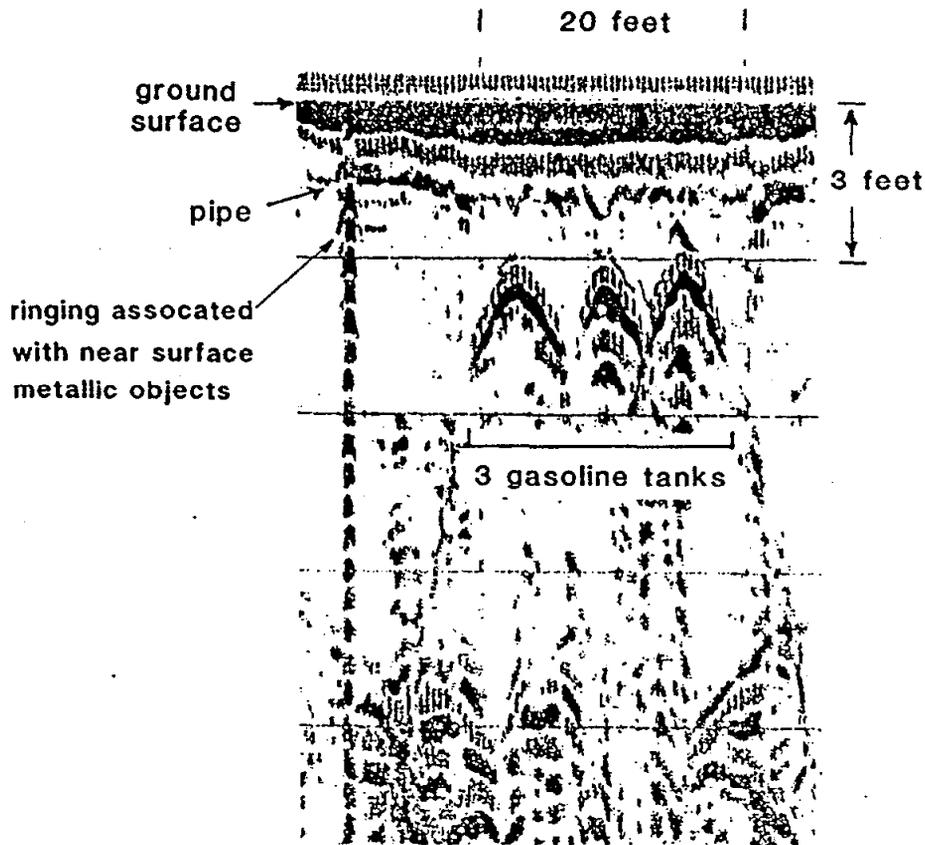
Figure 3 shows the characteristic parabolic signal created by a point target, a clay pipe in this instance, which is situated in a clean sand and gravel deposit. Metallic objects, such as buried drums and pipes, also produce a characteristic parabolic signal on the record, and sometimes produces a "ringing" noise, denoted by the heavy, dark banding, as shown in Figure 4.

FIGURE 2



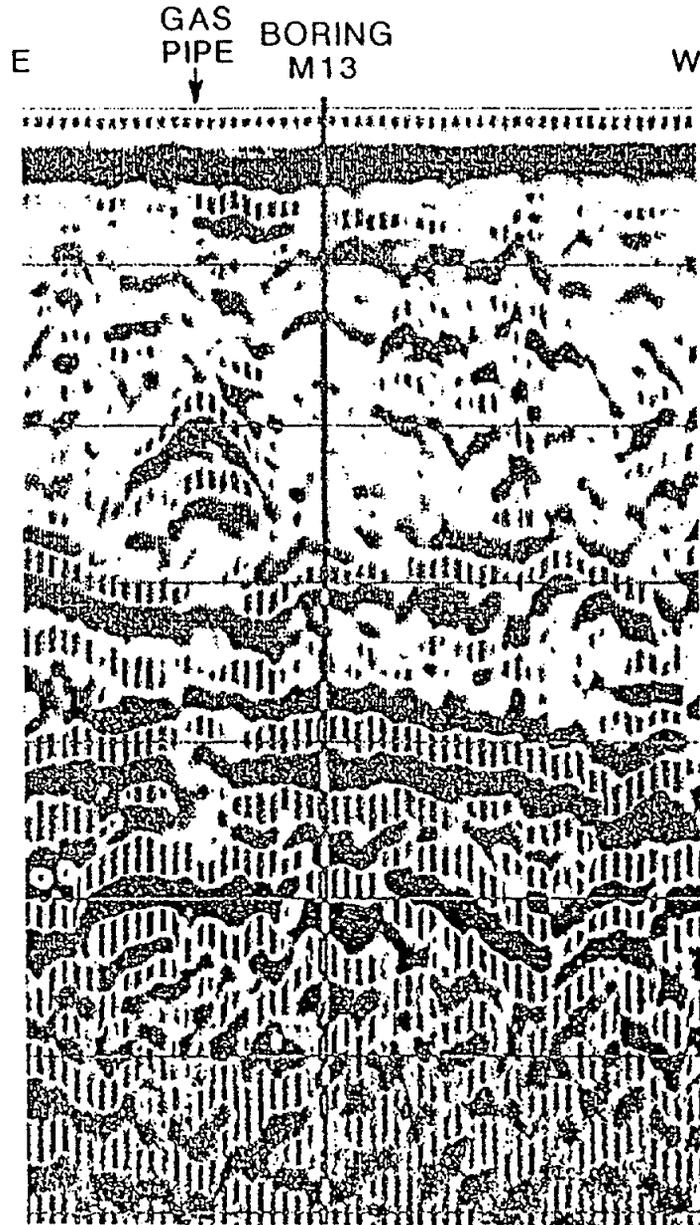
GROUND PENETRATING RADAR RECORD  
OF A BURIED RIVER CHANNEL

FIGURE 3



GROUND PENETRATING RADAR RECORD  
OF BURIED FUEL TANKS

FIGURE 4



GROUND PENETRATING RADAR RECORD  
OF A BURIED PIPE

Recorded data from diskettes or magnetic tapes can be enhanced using numerous computer processing methods to remove constant noise problems, such as ringing, or to sharpen up geologic contact features and point target boundaries. Such methods are described in detail by Hogan (1988) and Olhoeft (1988). Computer processing is costly and generally not necessary in most instances.

## 5.6 Advantages/Disadvantages

Advantages of ground penetrating radar systems include:

- Rapid coverage of an area
- GPR is a non-destructive technique
- Portable equipment
- Provides high vertical resolution profiles in the field for immediate interpretation

Ground penetrating radar provides a cost effective way of evaluating a large site in a short amount of time. One day of work coverage completed by GPR may be equivalent to four or five days of work with seismic refraction or electrical resistivity. The GPR method is "non-destructive" in that it does not require any excavation or probing of the overburden materials, although verification of anomalies should be conducted.

Equipment can be easily loaded in the back of a truck as most pieces comprising the radar system weigh under 40 pounds. The 80 MHz antenna weighs about 100 pounds and is less portable as it is approximately 4 feet wide.

Limitations of radar systems include:

- Survey lines must be cleared to ground level
- Multiple receiver antennas are generally required to stack and process radar data
- Penetration is site specific, requiring data corroboration using alternative geophysical methods and/or verification
- Interpretations are subjective

To maximize resolution and minimize scattering losses, survey lines must be as level as possible to prevent the bouncing and jarring of the radar antenna. Survey lines cleared of debris also allow the antenna to be pulled at an even, continuous pace, permitting the easy determination of horizontal scale.

Application of GPR to a site is limited by soil type and presence of high loss materials. In New England, the presence of glacial tills, and lacustrine and marine clays limit the depth of penetration. Delineation of buried drums beneath a conductive plume also may not be possible. The unpredictability of radar effectiveness requires that site investigations be conducted with alternative geophysical methods, such as electromagnetic induction, seismic refraction, magnetometry, and/or electrical resistivity.

## 6.0 QUALITY ASSURANCE RECORDS

All data will be recorded in field log books with the following information: date, location, personnel on site, start and finish times (in military time), and Contract Task Order number.

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**Section 5.4**  
**Geophysics - Magnetometry**  
**Profiling SOP**

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## GEOPHYSICS: MAGNETOMETRY

### 1.0 PURPOSE

This SOP provides general reference information and standard techniques for using magnetometry.

### 2.0 SCOPE

This SOP provides a description of the field procedures, equipment, and interpretation methods necessary to fully utilize this procedure.

### 3.0 DEFINITIONS

Diurnal variations - daily changes in the total magnetic field strength may be as large as 100 gammas or more

Gradient - change in magnetic field strength in a given vertical or horizontal distance

Magnetic storm - sudden and simultaneous variations of up to several hundred gammas throughout the world. Magnetic storms can occur as often as several times a month and can last one to several days.

Total magnetic field intensity - a scalar measurement of the magnitude of the earth's magnetic field vector independent of its direction.

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the borehole technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the borehole logging activities have been briefed and trained to execute these procedures.

## **5.0 PROCEDURES**

### **5.1 Overview**

Magnetic surveying is a passive geophysical technique which measures the strength of the earth's magnetic field. The earth's field is a vector quantity having a unique magnitude and direction at every point on the earth's surface. A magnetometer is the instrument which measures the magnetic field strength in units of gammas or nanoteslas. In order to recognize a magnetic anomaly, it must be several times larger than the background noise level along that profile. Buried ferrous metal objects such as steel drums or tanks cause local variations or anomalies in the earth's magnetic field that can be detected by a magnetometer. Geologic features such as igneous intrusion or iron rich sands can also be mapped using magnetic surveying.

The earth's magnetic field is not completely stable. It undergoes long-term (secular) variations over centuries; small, daily (diurnal) variations (less than 1% of the total field magnitude); and transient fluctuations called magnetic storms resulting from solar flare phenomena. Both naturally-occurring and manmade magnetic materials can modify the earth's magnetic field locally.

Analysis of magnetic data by an experienced geophysicist can provide an estimate of the areal extent and quantity of buried ferrous objects. Depth of burial approximations can be made using graphical methods of interpretation such as slope techniques and half-width rules as described in Nettleton, (1976).

### **5.2 Application and Uses**

Buried ferrous metal objects such as pipelines, barrels, tanks, etc., generally produce a perturbation in the earth's naturally occurring magnetic field. The size (amplitude) of this

perturbation is related to the size of, distance to, susceptibility and remanent magnetization of the buried object. The magnetic survey method, therefore, is a useful tool for site studies to locate and identify buried ferrous metal. Figures 1 and 2 shows magnetic profiles and contour maps over buried metal objects. Non-anomalous magnetic data acquired over EM conductivity anomalies is an indication of the existence buried conductive, non-ferrous metal (copper, aluminum, brass) objects.

Magnetic data also can be helpful in determining the size and geometry of geologic features such as fault zones, mineralized zones, and bedrock valleys and depressions. These features are characterized generally by longer wavelength anomalies and are readily distinguishable from anomalies associated with buried metal. In many areas, such geologic features may control or affect the direction and magnitude of ground water flow.

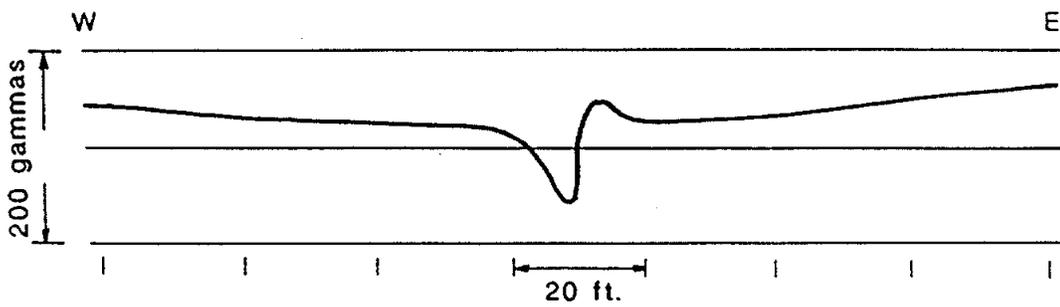
The total field proton precession magnetometer, the fluxgate magnetometer, and the magnetic gradiometer are commonly used magnetometers in environmental site investigations. The total field proton precession magnetometer is the most commonly used magnetometer because they are easy to operate, have no instrumental drift, and can acquire data rapidly. The fluxgate magnetometer can better define the boundaries of buried ferrous objects than the proton precession magnetometer but is subject to instrument drift, and needs to be exactly oriented. Magnetic gradiometer measurements enhance anomalies resulting from shallow magnetic sources.

### 5.3 Equipment

Magnetometers commonly used in hazardous waste site investigations include the total field proton precession magnetometer, the flux gate magnetometer, and the magnetic gradiometer. Text books such as Telford (1976) and Nettleton (1976) discuss in detail the operation and construction of these and other magnetometers.

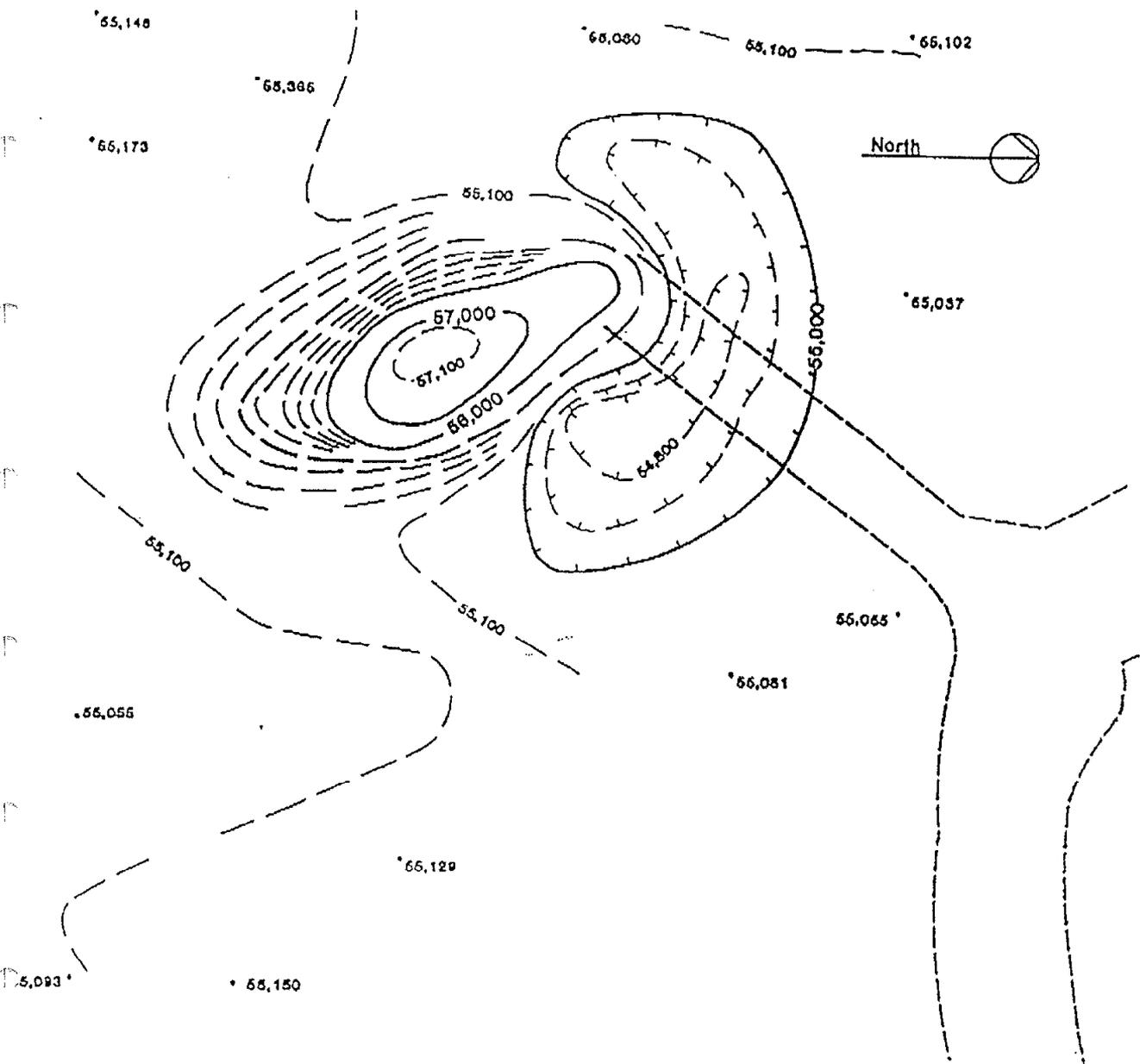
The total field proton precession magnetometer is the most commonly used magnetometer in hazardous waste investigations. This instrument utilizes the precession of spinning protons of hydrogen atoms in a sample fluid (kerosene, alcohol or water) to measure the total magnetic field intensity. Total field proton precession magnetometers are portable and do not require precise orientation and leveling; the sensor must be oriented with one side facing approximately north and the sensor held stationary during the cycling period. Proton

FIGURE 1



MAGNETIC ANOMALY FROM A SINGLE BARREL  
BURIED AT A DEPTH OF 6-7 FT.

8.8-3 6/10/88



65,000 Magnetic contours (gammas)  
• 55,103 Spot magnetic value (gammas)

0 20 40  
Scale in Feet

MAGNETIC ANOMALY CAUSED BY 75 BARRELS  
BURIED 4 TO 10 FEET DEEP

precession magnetometers have no instrument drift, do not require calibrations, are easy to operate, and have an accuracy of 0.1 gamma. Most modern proton precession magnetometers have digital readouts and electronic storage of data.

Vertical magnetic gradiometers are magnetometers that measure vertical differences of the earth's total magnetic field. Gradient measurements enhance magnetic anomalies resulting from near surface magnetic source and discrimination between neighboring magnetic anomalies is also enhanced. These measurements are generally made using an instrument similar to a total field magnetometer that has two or more sensors mounted on a staff. The sensors are vertically separated by a constant distance, usually one to three feet. Gradient readings are adversely affected by ferrous metal surface debris since signals from this surface debris are also amplified. Consequently, removal of surface metal should be considered before conducting a gradiometer survey.

The flux gate magnetometer was developed during World War II as a submarine detector. Text books such as Telford (1976), RAO and Murthy (1978) explain in detail the principals of operation of the flux gate magnetometer. A fluxgate magnetometer can define the boundaries of regions of buried ferrous metal objects more precisely than the proton precession magnetometer. There are several sources of errors in flux gate magnetometers including unbalance in the two coils, thermal and shock noise, circuit drift and temperature sensitivity. The advantages are direct readout, no azimuth orientation, coarse leveling required, light weight and portability (Telford, 1976).

#### 5.4 Field Procedures

Magnetic data are generally acquired at relatively close station spacings (5 to 50 foot intervals) along closely spaced (10 to 50 feet) parallel survey lines.

Magnetic data can be acquired in a rectangular grid pattern or along traverses. Grid data are readings acquired at the nodes of a rectangular grid; traverse data is acquired at fixed intervals along a line. Traverse data is often preferable to grid data because it generally is less expensive to acquire (heavily vegetated sites require time consuming brush cutting to establish a complete grid) and more useful for interpretation than an equal number of grid readings. Traverse lines generally ought to be oriented in a north-south direction so that the

maximum amplitude of an anomaly can be detected. However, line orientations are often more dependent on site obstacles and sources of magnetic noise.

Station and line spacing intervals are determined on the basis of the desired resolution of the survey. If individual drums or clusters of deeply (greater than 25 feet) buried drums are the objective of the survey, then a detailed magnetic survey with relatively close station spacings (approximately 5 to 10 feet) and line spacings (approximately 10 to 25 feet) should be used. If large metal objects such as 10,000 gallon tanks or trenches filled with barrels are the objective of the magnetic survey, then a reconnaissance or screening survey with longer station spacings (25, 50, or 100 feet) and line spacings of (25, 50, or 100 feet) may be appropriate.

In conducting a survey, the field operator must avoid or note any sources of high magnetic gradients and alternating currents, such as power lines, buildings, and any large iron or steel objects. It is also important that the operator be relatively free of magnetic materials on his/her person and the magnetometer sensor be kept clean to avoid possible magnetic-bearing dirt. Periodically during a survey, and particularly when an anomaly is detected, it is important to establish that the magnetometer is providing valid readings and not random, meaningless instrument noise. The simplest means of verifying magnetometer field readings is to take several successive readings at one location. These readings should repeat to within  $\pm 1$  gamma. Readings are taken at predetermined intervals which depend on the nature of the survey and which may have to be modified depending on the gradients encountered. For detailed surveys, a base station or the reoccupation of a set of stations several times a day or a continuous monitoring station (within 100 miles) is established to check for diurnal variations and magnetic storms. At the height of a magnetic storm, magnetic surveying may be impractical due to the large instantaneous changes in the total magnetic field.

## 5.5 Interpretation

### 5.5.1 Data Analysis

Magnetic data can be corrected for diurnal variations; however, diurnal changes are generally very gradual and linear and should not have the extreme fluctuations associated with buried ferrous metal objects. Magnetic data can be plotted in profile form or contoured depending upon the survey coverage. Noise sources (surface ferrous metal objects, fences, power lines, etc.) should be noted on the profiles or contour map so that anomalies due to these known

sources can be accounted for. The amplitudes of similar sized surface metal objects should be compared. If similar sized ferrous metal surface objects have extremely different anomaly amplitudes, it may be an indication that buried ferrous metal objects exist in the vicinity of the higher amplitude anomalies.

### **5.5.2 Presentation of Results**

The results of a magnetic survey should be presented in profile and/or contour map form. The orientation of the traverses should be indicated on profiles and lines of coverage on contour maps. Locations of observed ferrous metal and other cultural fractures (hills, valleys, streams, etc.) should be noted on both the profile and the contour maps.

### **5.5.3 Interpretation**

Magnetic anomalies can be analyzed both qualitatively and quantitatively. The shape and gradient of an anomaly (slope, wave-length, amplitude, etc.) contains enough information to draw qualitative conclusions regarding the location and depth of the causative source.

Quantitative computer modeling interpretations of magnetic data are complicated both by the inherent complexity of dipole magnetic behavior and by the fact that a number of different types and configurations of sources can cause the same anomaly. Where the properties of the earth's field and the local geologic materials (inclination, declination, susceptibility, and remanent magnetization) are well known, reasonable assumptions regarding the nature of the source can be made, and a fairly accurate model of the source generally can be derived.

## **5.6 Advantages and Limitations**

Advantages of the magnetic survey method include:

- Rapid operation
- Low expense
- Identification of buried metal (ferrous)
- Sensitivity to small ferrous objects

Limitations of the magnetic survey method include:

- Susceptible to effects of manmade structures, utilities, buildings, fences, etc.
- Detection is limited to the distance to and quantity of ferrous metal present

## 6.0 QUALITY ASSURANCE RECORDS

All data will be recorded in log books and/or data logging sheets designed for this procedure. All data will be entered with the following basic information: date, start and end times (military time), location, personnel on site, Contract Task Order number, and weather.

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**Section 5.5**  
**Water Quality Testing SOP**

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## ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

### 1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance (Sc)
- Temperature (T)
- Dissolved Oxygen Concentration (DO) (Optional)

The first three are the usual field parameters; dissolved oxygen may be used in particular applications according to project requirements.

### 2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

### 3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Ohm - Standard unit of electrical resistance (R). A siemen or ohm is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law,  $E = IR$ , where E is the potential difference, I is the current, and R is the resistance.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP, or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

## 5.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance, temperature, and dissolved oxygen concentration measurements.

### 5.1 Measurement of pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques are not described here.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required; the pH meter is used when a more accurate measurement is needed. The response of a pH meter can be effected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In most cases, use of a pH meter will be required.

### 5.1.1 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

### 5.1.2 Equipment

The following equipment and reagents are needed for taking pH measurements:

- Portable pH meter, or pH indicator paper, such as Mydrion or Alkacid, to cover the pH range 2 through 12.
- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

### 5.1.3 Measurement Techniques for Field Determination of pH

#### 1. pH Meter

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions. The following procedure is used for measuring pH with a pH meter:

- a. The instrument and batteries shall be checked and calibrated prior to initiation of the field effort.

- b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
- c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- e. Immerse the electrode(s) in a pH-7 buffer solution.
- f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.
- g. Adjust the pH meter to read 7.0.
- h. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
- i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.

- j. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the field logbook.
- k. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
- l. The electrode(s) shall remain immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the field logbook.

## 2. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

## 5.2 Measurement of Specific Conductance

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the

various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

### **5.2.1 Principles of Equipment Operation**

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

### **5.2.2 Equipment**

A portable conductivity meter, probe and thermometer are needed for taking specific conductance measurements.

A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

### 5.2.3 Measurement Techniques for Specific Conductance

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions. The steps involved in taking specific conductance measurements are listed below.

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature (or record the temperature measurement in the field log book).
- Read and record the results in a field logbook.
- If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
- Specific conductivity measurements always shall be reported with the associated temperature measurement. If the conductivity has been corrected, the measurements shall be reported as "corrected to 25°C."

### 5.3 Measurement of Temperature

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field prior to sample collection. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

### 5.3.1 Equipment

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or bimetal thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

### 5.3.2 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field log book to the nearest 0.5 or 0.1°C, depending on the measurement device used.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to the manufacturer's recommendations with an approved thermometer.

### 5.4 Measurement of Dissolved Oxygen Concentration

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms, as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time, if the sample is not adequately preserved.

The method discussed here is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are

suitable for highly polluted waters, because the probe is completely submersible. DO meters also are free from interference caused by color, turbidity, colloidal material or suspended matter.

#### **5.4.1 Principles of Equipment Operation**

Dissolved oxygen probes normally are electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of higher nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations also can cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation normally is provided by the manufacturer.

#### **5.4.2 Equipment**

The following, similar or equivalent, equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor.
- Dissolved oxygen/temperature probe.
- Sufficient cable to allow the probe to contact the sample.

#### **5.4.3 Measurement Techniques for Dissolved Oxygen Determination**

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration.

- Calibrate equipment and check batteries in the laboratory before going to the field.
- The probe shall be conditioned in a water sample for as long as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers which are placed in wells should be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook.
- Recalibrate the probe when the membrane is replaced, or following similar maintenance, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This, however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or whether a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records for on-site water quality management consists principally of observations and measurements recorded in the field logbook. Records of instrument calibration, malfunction, repair, etc., shall be maintained in an equipment logbook as described in the Navy CLEAN Contractor Quality Control Plan.

## 7.0 REFERENCES

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**ATTACHMENT A**

**SPECIFIC CONDUCTANCE TEMPERATURE COMPENSATION**

## ATTACHMENT A

### SPECIFIC CONDUCTANCE TEMPERATURE COMPENSATION

<u>Temperature (°C)</u>	<u>Multiplier*</u>	<u>Temperature (°C)</u>	<u>Multiplier*</u>
5.0	1.571	18.0	1.147
5.5	1.553	18.5	1.133
6.0	1.536	19.0	1.121
6.5	1.518	19.5	1.110
7.0	1.500	20.0	1.100
7.5	1.485	20.5	1.088
8.0	1.470	21.0	1.077
8.5	1.452	21.5	1.067
9.0	1.433	22.0	1.058
9.5	1.415	22.5	1.048
10.0	1.395	23.0	1.038
10.5	1.377	23.5	1.029
11.0	1.357	24.0	1.019
11.5	1.339	24.5	1.010
12.0	1.318	25.0	1.000
12.5	1.302	25.5	0.990
13.0	1.283	26.0	0.980
13.5	1.268	26.5	0.970
14.0	1.252	27.0	0.960
14.5	1.237	27.5	0.950
15.0	1.223	28.0	0.940
15.5	1.210	28.5	0.930
16.0	1.198	29.0	0.920
16.5	1.187	29.5	0.910
17.0	1.171	30.0	0.900
17.5	1.159		

\* The multiplier corrects the specific conductivity reading from a given temperature to 25°C.

**ATTACHMENT B**

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION  
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

## ATTACHMENT B

### VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature °C	Dissolved Oxygen mg/l					
	Chloride Concentration in Water					Difference/ 100 mg chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.106
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

**ATTACHMENT B**  
**(Continued)**  
**VARIATION OF DISSOLVED OXYGEN CONCENTRATION**  
**IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

Temperature °C	Dissolved Oxygen mg/l					
	Chloride Concentration in Water					Difference/ 100 mg chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore used to correct measured D.O. concentration) using Attachment A.

**Section 5.6**  
**Surface Water and Sediment**  
**Sample Acquisition SOP**

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## **SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION**

### **1.0 PURPOSE**

This procedure describes methods and equipment commonly used for collecting environmental samples of surface water and aquatic sediment either for on-site examination and chemical testing or for laboratory analysis.

### **2.0 SCOPE**

The information presented in this SOP is generally applicable to all environmental sampling of surface waters (Section 5.2) and aquatic sediments (Section 5.3), except where the analyte(s) may interact with the sampling equipment.

Specific sampling problems may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented and presented in the Sampling and Analysis Plan.

### **3.0 DEFINITIONS**

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes.

Composite Sample - A sample collected over time that typically consists of a series of discrete samples which are combined or composited.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation for procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific surface water and/or sediment sampling techniques and equipment to be used, and

documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of surface water and sediment samples.

## 5.0 PROCEDURES

Collecting a representative sample from surface water or sediments is difficult due to water movement, stratification or patchiness. To collect representative samples, one must standardize sampling bias related to site selection; sampling frequency; sample collection; sampling devices; and sample handling, preservation, and identification.

Representativeness is a qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important quality not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location, selection, and collection methods are important to ensure that a truly representative sample has been collected. Regardless of scrutiny and quality control applied during laboratory analyses, reported data are only as good as the confidence that can be placed on the representativeness of the samples.

### 5.1 Defining the Sampling Program

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives; accessibility; site topography; flow, mixing and other physical characteristics of the water body; point and diffuse sources of contamination; and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which effect adsorption/desorption). The sampling

plan must therefore reflect not only the mixing characteristics of streams and lakes, but also the role of fluvial-sediment transport, deposition, and chemical sorption.

#### 5.1.1 Sampling Program Objectives

The objective of surface water sampling is to determine the surface water quality entering, leaving or remaining within the site. The scope of the sampling program must consider the sources and potential pathways for transport of contamination to or within a surface water body. Sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., spills). The major pathways for surface water contamination (not including airborne deposition are: (a) overland runoff; (b) leachate influx to the waterbody; (c) direct waste disposal (solid or liquid) into the water body; and (d) groundwater flow influx to the water body. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) which encompass the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (when constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the location of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc., shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly nondetectable concentrations. Such dispersion does not, however, always readily occur throughout the entire body of water; the mixing may be limited to specific flow streams within the water body. For example, obtaining a representative sample of contamination from the center of a channel immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, nonhomogeneous distribution is a particular problem with regard to sediment-associated contaminants which may accumulate

in low-energy environments while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to adsorb on particulate matter. Nitrogen, phosphorus, and the heavy metals also may be transported by particulates. Samples will be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

The first step in selecting sampling locations, therefore, is to review site history, define hydrologic boundaries and features of the site, and identify the sources, pathways and potential distribution of contamination based on these considerations. The numbers, types and general locations of required samples upgradient, on site and downgradient can then be identified.

#### 5.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Wading or sampling from a stream bank often is sufficient for springs, seeps, and small streams. Bridges or piers are the first choice for locating a sampling station on a larger stream or small river; they provide ready access and also permit the sampling technician to sample any point across the stream or river. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs, as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment.

If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample. Use of boats or wading to collect samples requires the use of U. S. Coast Guard approved personal flotation devices (PFDs).

Sampling in marshes or tidal areas may require the use of an all-terrain-vehicle (ATV). The same precautions mentioned above with regard to sediment disturbance will apply.

The availability of stream flow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Stream flow data in association with contaminant concentration data are essential for estimating the total contaminant load carried by the stream. If a gaging station is not conveniently located on a selected stream, obtaining stream flow data by direct or indirect methods shall be explored.

### **5.1.3 Frequency of Sampling**

The sampling frequency and the objectives of the sampling event will be defined by the Sampling and Analysis Plan. For single-event, site- or area-characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of the contaminant between the solid and aqueous phases it may be appropriate to sample only one phase, although this often is not recommended. If samples are collected primarily for monitoring purposes, consisting of repetitive, continuing measurements to define variations and trends at a given location, water samples shall be collected at established and consistent intervals, as specified in the Sampling and Analysis Plan (often monthly or quarterly), and during droughts and floods. Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably during both spring and fall seasons.

The variability in available water quality data shall be evaluated before deciding on the number and collection frequency of samples required to maintain an effective monitoring program.

## **5.2 Surface Water Sample Collection**

This section presents methods for collection of samples from various surface water bodies, as well as a description of types of surface water sampling equipment. The guidance in this section should be used to develop specific sampling procedures based on site conditions and investigation goals. A summary of sampling techniques and procedures is given in Section 5.2.5.

### **5.2.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)**

Methods for sampling streams, rivers, outfalls and drainage features at a single point vary from the simplest of hand sampling procedures to the more sophisticated multi-point sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) method.

Samples from different depths or cross-sectional locations, collected during the same sampling episode, shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be collected depend on the river's width, depth, discharge, and amount of suspended sediment. With a greater number of individual points sampled, it is more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling location can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross-section.

For larger streams, at least one vertical composite at each station shall be taken with equal components from just below the surface, at mid-depth, and just above the bottom. The measurement of dissolved oxygen (DO), pH, temperature, conductivity, etc., shall be made on each aliquot of the vertical composite and on the composite itself. For rivers, several vertical composites shall be collected along a transverse section normal to the stream flow.

### **5.2.2 Lakes, Ponds and Reservoirs**

Lakes, ponds, and reservoirs have a much greater tendency to stratify according to physical or chemical differences than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling locations on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest

point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical grab samples shall be composited to form a single sample. These vertical samples often are collected along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline which is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer which is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite sample consists of several vertical samples collected at various depths.

As it is likely that poor mixing may occur in lakes with irregular shape (with bays and coves that are protected from the wind), separate composite samples may be needed to adequately represent water quality. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements now are made in-situ using sensors and automatic readout or recording devices. Single and multi-parameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen, some cations and anions, and light penetration.

### 5.2.3 Estuaries

Estuarine areas are by definition among those zones where inland freshwaters (both surface and ground) mix with marine saline waters. Estuaries generally are categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations:

- Mixed estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater

sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt wedge estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.
- Oceanic estuary - characterized by salinities approaching full strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas normally is based upon the tidal phases, with samples collected on successive slack tides (i.e., when the tide turns). Estuarine sampling programs shall include vertical salinity measurements coupled with vertical dissolved oxygen and temperature profiles.

#### 5.2.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type required. The most frequently used samplers are:

- Dip sampler
- Weighted bottle
- Kemmerer
- Depth-Integrating Sampler

The dip sampler and the weighted bottle sampler are used most often.

The criteria for selecting a sampler include:

- Disposable and/or easily decontaminated
- Inexpensive (if the item is to be disposed of)
- Ease of operation
- Nonreactive/noncontaminating - Teflon-coating, glass, stainless steel or PVC sample chambers are preferred (in that order)

Each sample (grab or each aliquot collected for compositing) shall be measured for: specific conductance; temperature; pH; and dissolved oxygen (optional) as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

#### 5.2.4.1 Dip Sampling

Water often is sampled by filling a container, either attached to a pole or held directly, from just beneath the surface of the water (a dip or grab sample). Constituents measured in grab samples are only indicative of conditions near the surface of the water and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross section. Therefore, whenever possible it is recommended to augment dip samples with samples that represent both dissolved and suspended constituents, and both vertical and horizontal distributions. Dip sampling often is the most appropriate sampling method for springs, seeps, ditches, and small streams.

#### 5.2.4.2 Weighted Bottle Sampling

A grab sample also can be taken using a weighted holder that allows a sample to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects sample throughout the total depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of a stopped glass or plastic bottle, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The procedure for sampling is as follows:

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).
- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.

- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

#### 5.2.4.3 Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while being lowered in a vertical position to allow free passage of water through the cylinder. A "messenger" is sent down the line when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles.

#### 5.2.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container directly in the body of water. The following suggestions are applicable to sampling springs, seeps, ditches, culverts, small streams and other relatively small bodies of water, and are presented to help ensure that the samples obtained are representative of site conditions:

- The most representative samples will likely be collected from near mid-stream, the center of flow in a culvert, etc.
- Downstream samples shall be collected first, with subsequent samples taken while moving upstream. Care shall be taken to minimize sediment disturbance while collecting surface water samples. If necessary, sediment samples shall be collected after the corresponding surface water sample.
- Samples may be collected either by immersing the approved sample container or a glass or nalgene beaker into the water. Sample bottles (or beakers) which do not contain preservatives shall be rinsed at least once with the water to be sampled prior to sample collection.
- Care shall be taken to avoid excessive agitation of the water which may result in the loss of volatile constituents. Additionally, samples for volatile organic analyses shall be collected first, followed by the samples for other constituents.
- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analyses.

- All samples shall be handled as described in SOP F301.
- The sampling location shall be marked via wooden stake placed at the nearest bank or shore. The sampling location number shall be marked with indelible ink on the stake.
- The following information shall be recorded in the field logbook:
  - ▶ Project location, date and time.
  - ▶ Weather.
  - ▶ Sample location number and sample identification number.
  - ▶ Flow conditions (i.e., high, low, in flood, etc.) and estimate of flow rate.
  - ▶ Visual description of water (i.e., clear, cloudy, muddy, etc.).
  - ▶ On-site water quality measurements.
  - ▶ Sketch of sampling location including boundaries of water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake.
  - ▶ Names of sampling personnel.
  - ▶ Sampling technique, procedure, and equipment used.

General guidelines for collection of samples from larger streams, ponds or other water bodies are as follows:

- The most representative samples are obtained from mid-channel at mid-stream depth in a well-mixed stream.
- For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream. Work may also proceed from zones suspected of low contamination to zones of high contamination.
- It is suggested that sample containers which do not contain preservative be rinsed at least once with the water to be sampled before the sample is taken.
- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one composite sample, or several grids are selected at random.
- Care should be taken to avoid excessive agitation of the water that would result in the loss of volatile constituents.
- When obtaining samples in 40 ml septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces inward. The bottle can be turned upside down to check for air bubbles after the bottle is filled and capped.
- Do not sample at the surface unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream.

- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate shall be collected immediately following sample collection for laboratory analysis.
- All samples shall be handled as described in SOP F301.
- Items to be recorded in the field logbook are the same as those described above for small streams.

### 5.3 Sediment Sampling

Sediment samples usually are collected at the same locations as surface water samples. If only one sediment sample is to be collected, the sample location shall be approximately at the center of the water body. If, however, multiple samples are required, sediment samples should be collected along a cross-section to characterize the bed material. A common procedure for obtaining multiple samples is to sample at quarter points along the cross-section of flow. As with surface water samples, sediment samples should be collected from downstream to upstream.

#### 5.3.1 Sampling Equipment and Techniques

A bottom-material sample may consist of a single scoop or core or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using on-shore or off-shore techniques.

When boats are used for sampling, U. S. Coast Guard approved personal flotation devices must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler
- Dredge samplers

#### 5.3.1.1 Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if it can be waded, the easiest and "cleanest" way to collect a sediment sample is to use a scoop sampler. This reduces the potential for cross-contamination. This method is accomplished by reaching over or wading into the water body and, while facing upstream (into the current), scooping in the sample along the bottom in the upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

#### 5.3.1.2 Dredges

Dredges are generally used to sample sediments which cannot easily be obtained using coring devices (i.e., coarse-grained or partially-cemented materials) or when large quantities of materials are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a messenger. Most dredges are heavy (up to several hundred pounds) and require use of a winch and crane assembly for sample retrieval. There are three major types of dredges: Peterson, Eckman and Ponar dredges.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave" and permits direct access to the secured sample without opening the closed jaws. The Ponar dredge is easily

operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates. Access to the secured sample through the covering screens permits subsampling of the secured material with coring tubes or Teflon scoops, thus minimizing the chance of metal contamination from the frame of the device.

### 5.3.2 Sediment Sampling Procedure

The following general procedure should be used, where applicable, for sampling sediment from springs, seeps, small streams, ditches, or other similar small bodies of water. Procedures sampling larger bodies of water (i.e., rivers, lakes, estuaries, etc.) should be developed on a project-specific basis, as needed.

- Sediment samples shall be collected only after the corresponding surface water sample has been collected, if one is to be collected.
- Sediment samples shall be collected from downstream locations to upstream locations.
- Samples shall be collected by excavating a sufficient amount of bottom material using a scoop or beaker. Samples should be collected with the sampling device facing upstream and the sample collected from downstream to upstream. Care should be taken to minimize the loss of fine-grained materials from the sample.
- The sample shall be transferred to the appropriate sample containers. Sampling personnel shall use judgment in removing large plant fragments to limit bias caused by bio-organic accumulation.
- All samples shall be handled as described in SOP F301.
- The sampling location shall be marked via a wooden stake placed at the nearest bank or shore. The sample location number shall be marked on the stake with indelible ink.
- The following information shall be recorded in the field logbook:
  - ▶ Project location, date and time.
  - ▶ Weather.
  - ▶ Sample location number and sample identification number.
  - ▶ Flow conditions.
  - ▶ Sketch of sampling location including boundaries of water body, sample location, water depth, sample collection depth, relative position with respect to the site, location of wooden identifier stake.
  - ▶ Chemical analyses to be performed.
  - ▶ Description of sediment (refer to SOP F001).

## 6.0 QUALITY ASSURANCE RECORDS

The description of the sampling event in the field logbook shall serve as a quality assurance record. Other records include chain-of-custody and sample analysis request forms as discussed in SOP F302.

## 7.0 REFERENCES

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3. U.S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, USEPA Environmental Services Division, Athens, Georgia.
4. U.S. Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, USGS, Reston, Virginia.

**Section 5.7**  
**Borehole and Sample**  
**Logging SOP**

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## **BOREHOLE AND SAMPLE LOGGING**

### **1.0 PURPOSE**

This SOP provides general reference information and technical guidance on borehole and sample logging. Borehole logs provide information used in the determination of geological conditions and ultimately in the assessment of contaminant distribution and the evaluation of remedial actions.

### **2.0 SCOPE**

This SOP provides descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer may develop adequate classifications through careful, thorough observation and consistent application of the classification procedure.

### **3.0 DEFINITIONS**

Soil classifications and terms are given in Sections 5.2 and 5.3. Rock classification and terms are presented in Section 5.4.

### **4.0 RESPONSIBILITIES**

**Project Manager** - It is the responsibility of the Project Manager to ensure that field personnel responsible for borehole logging are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that all appropriate documents (e.g., test boring logs, field logbooks, etc.) have been correctly and completely filled out by the drilling inspector.

**Field Team Leader** - The Field Team Leader is responsible for the overall supervision of all drilling and boring activities, and for ensuring that each borehole is completely logged by the responsible drilling inspector. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures.

Drilling Inspector - The drilling inspector (site geologist) is responsible for the direct supervision of boring and sampling activities. It is the Drilling Inspector's responsibility to log each boring, document subsurface conditions, complete appropriate forms, and direct the drilling crew (or drilling supervisor).

## 5.0 PROCEDURES

The classification of soil and rock is one of the most important jobs of a drilling inspector or site geologist. It is imperative that the drilling inspector understand and accurately use the field classification system described in this SOP to maintain a consistent flow of information. This identification is based on both visual examination and manual tests. The results of the boring activities, including soil and rock classifications, shall be recorded on a Field Test Boring Record (see Figure 1) or the field notebook.

### 5.1 Test Boring Record

Each boring shall be fully described in a Field Test Boring Record (Figure 1). The drilling inspector shall log the boring, as it is being drilled, by recording relevant data on the Boring Record. It may be more appropriate to record the boring information in a bound field log book in cases where the information will not easily fit on the boring record. Field Test Boring Records may then be transcribed from the field log book, but must be completed at a minimum, on a weekly basis. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record. All Field Test Boring Records must be completely filled out and signed prior to demobilization from the field activity. Field Test Boring Records must also be legible. An example of a completed Test Boring Record is provided in Attachment A.

Data which shall be included on the Boring Records, when applicable are:

1. Project name, location, and Contract Task Order Number.
2. Date(s).
3. Identifying number and location of each boring.

Figure 1



# FIELD TEST BORING RECORD

SOP F101  
 Revision No.:  
 Date: 01/10/92  
 Page 3 of 15

PROJECT: Building P-64  
 S.O. NO.: 19010-ST-5RN  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: \_\_\_\_\_ BORING NO.: B-1  
 TOP OF STEEL CASING: \_\_\_\_\_

RIG: <u>Mobile B-57</u>									
	SPLIT SPOON	CASING	AUGERS	CORE BARREL	DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	<u>1-7/8" ID</u>		<u>6-1/4" ID</u>		<u>5/31/91</u>	<u>14.0</u>	<u>Sunny, 80°-90°</u>	<u>-</u>	<u>-</u>
LENGTH	<u>2.0'</u>		<u>5.0'</u>						
TYPE	<u>STD.</u>		<u>HSA</u>						
HAMMER WT.	<u>140 lb.</u>								
FALL	<u>30"</u>								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; No monitoring well installed - borehole grouted to surface

DRILL RECORD							VISUAL DESCRIPTION					
DEPTH	SOIL ROCK	Sample ID Type No. (N = No Samp.)	Samp. Rec. (Ft. & %)	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL ROCK	ELEVATION
				RQD (Ft. & %)	Pen. Rate	RID (pen)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations		
1		S-1	<u>1.3/2.0</u>	<u>3</u>			<u>TOPSOIL, grass roots;</u>	<u>Tan gray</u>	<u>medium dense</u>	<u>dry</u>		<u>1.0'</u>
2	<u>2.0</u>		<u>65%</u>	<u>5</u>			<u>SAND, fine-grained, trace gravel, trace silt</u>	<u>Tan brown</u>	<u>loose</u>	<u>moist to damp</u>		
3		S-2	<u>1.3/2.0</u>	<u>4</u>			<u>SAND, fine-grained, trace silt, trace grass roots</u>	<u>Tan brown</u>	<u>loose</u>	<u>Moist to damp</u>		
4	<u>4.0</u>		<u>65%</u>	<u>4</u>								<u>4.0'</u>
5		S-3	<u>2.0/2.0</u>	<u>11</u>			<u>SAND, fine to medium-grained, trace silt</u>	<u>Tan brown orange</u>	<u>medium dense</u>	<u>moist to wet; water table noted at 6.0'</u>		
6	<u>6.0</u>		<u>100%</u>	<u>8</u>								
7		S-4	<u>1.8/2.0</u>	<u>3</u>								<u>7.0'</u>
8	<u>8.0</u>		<u>90%</u>	<u>4</u>			<u>SAND, medium to coarse-grained, trace silt</u>	<u>Tan gray orange</u>	<u>loose</u>	<u>wet</u>		
9		S-5	<u>2.0/2.0</u>	<u>10</u>								<u>9.0'</u>
10	<u>10.0</u>		<u>100%</u>	<u>1</u>			<u>SAND, medium-grained, trace silt</u>	<u>Gray orange</u>	<u>loose</u>	<u>wet</u>		

DRILLING CO.: A TEC Associates BAKER REP.: R. Bonelli  
 DRILLER: M. Miller BORING NO.: B-1 SHEET 1 OF 2

# FIELD TEST BORING RECORD

PROJECT: Building P-64  
S.O. NO.: 19010-51-381

BORING NO.: B-1

DRILL RECORD							VISUAL DESCRIPTION				
DEPTH	SOIL	Sample ID	Samp. Rec.	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL
	ROCK	Type-No. (N = No Samp.)	(Ft. & %)	RQD (Ft. & %)	Pen. Rate	PIID (ppm)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations	ROCK
1		S-6	2.0 2.0	1 1		0	SAND, medium-grained, trace silt	Gray	Very Loose	wet	
2	12.0		100%								
3		S-7	2.0 2.0	0 0		0	SAND, medium-grained, trace silt	Gray	Very Loose	wet	
4	14.0		100%	1							14.0
5							End of boring at 14.0 ft.				
6											
7											
8											
9											
0											

DRILLING CO.: ATEC Associates  
DRILLER: M. Miller

BAKER REP.: R. Bowelli  
BORING NO.: B-1

4. If required, soil classifications and associated depths in accordance with the Unified Soil Classification System (see Section 5.2 and Attachment B). These classifications will be noted in the field by the drilling inspector and revised, if necessary, based on laboratory analysis and review. Both field determined USCS soil classification and a soil description shall be included on the log.
5. Depth limits, and the type and number of samples taken.
6. The number of blows required for each six-inch penetration of a split-spoon sampler and for each 12-inch penetration of casing, as well as percentage of sample recovered; hammer weight, fall length, hydraulic pressures to push thin-walled tubes will also be recorded.
7. Depth to water as first encountered during drilling, along with method of determination. Any distinct water bearing zones shall also be delineated.
8. Loss of drilling fluid and the interval over which loss occurred.
9. Identification of equipment used, including type of drilling rig, auger types and sizes, etc.
10. Start date and completion dates for the boring.
11. Name of drilling company and driller.
12. Size and length of casing used in each hole.
13. Observations of visual contamination.
14. Field instrument readings (i.e., PID).

As the boring is drilled, the inspector shall evaluate samples and cuttings to determine the location of each stratigraphic unit. Descriptions should contain color, grain-size, consistency moisture, etc., in addition to the USCS classification category (Section 5.3.7).

Each sample collected for chemical or geotechnical analysis shall be handled as described in SOP #F102.

## 5.2 Soil Classification

All data shall be recorded on a Field Test Boring Record, or in a field logbook, as appropriate. The method of deriving the classification should be described, or reference made to this SOP or other applicable manuals. Both soil classification and soil descriptions must be entered on the Field Test Boring Record. If required, the soil classification shall consist of the two-letter USCS classification; the soil description shall be much more detailed.

Where required, soils will be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Attachment B and identifies soil types on the basis of grain-size and liquid limits, and categorizes them through the use of two letters. Although some laboratory testing is required for full USCS classification, preliminary classifications may be made in the field.

Fine-grained soils are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition; peat is designated by "Pt." Coarse-grained soils shall be divided into sand (S) or gravel (G). The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

The second letter of the two-letter USCS symbol provides information about the grain size distribution of granular soil, or the plasticity characteristics of fine-grained soils. These second letter modifiers are (P) poorly graded/well sorted, (W) well graded/poorly sorted, (C) clayey, (M) silty, (L) low plasticity, or (H) high plasticity.

### 5.3 Soil Descriptions

The Test Boring Records shall contain complete soil descriptions in addition to the two-letter USCS classification, if required. Soil descriptions include the following components: grain size identification with descriptive terms indicating the relative percentage of each grain size, color, consistency or relative density, moisture content, organic content, plasticity, and other pertinent observations such as visual contamination, HNu measurements, etc. A summary of the soil description components is given in Attachment C.

### 5.3.1 Grain Size Identification

In nature, soils are comprised of varying size, shape, and combinations of the various grain types. The following terms are used to indicate soil grain size:

<u>Size</u>	<u>Size Limits</u>
Cobbles	3-inches to 12-inches
Coarse gravel	3/4-inches to 3-inches
Fine gravel	4.76 mm (# 4 sieve size) to 3/4-inches
Coarse sand	2 mm (# 10 sieve size) to 4.76 mm
Medium sand	0.42 mm (# 40 sieve size) to 2 mm
Fine sand	0.074 mm (# 200 sieve size) to 0.42 mm
Silt	0.002 mm to 0.074 mm
Clay	less than 0.002 mm

The proportion of each grain size (by weight percent) is indicated using the descriptive terms:

Trace	0 to 10 percent
Little	10 to 20 percent
Some	20 to 35 percent
And (or an adjective form of the grain size, i.e., sandy, silty, clayey)	35 to 50 percent

Some examples of soil grain size descriptions are:

- Silty fine sand: 50 to 65 percent fine sand and 35 to 50 percent silt.
- Medium to coarse sand, some silt: 65 to 90 percent medium to coarse sand, 20 to 35 percent silt.
- Fine sandy silt, trace clay: 50 to 65 percent silt, 35 to 50 percent fine sand, and 0 to 10 percent clay.

The soil type may be classified as noncohesive, granular soils or as cohesive, fine-grained soils as discussed in Section 5.3.3. The grain shape of a soil usually does not need to be determined unless unusual or unique features are readily apparent.

### 5.3.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light-gray" or "blue-gray". Since color can be utilized in correlating units

between sampling locations, it is important for color descriptions to be consistent between borings.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors because sampling devices tend to smear the sample surface creating color variations between interior and exterior.

The term "mottled" shall be used to indicate soil irregularly marked with spots of different colors. Soil color charts shall not be used unless specified by the Project Manager.

### **5.3.3 Relative Density and Consistency**

To classify the relative density and/or consistency of a soil, the drilling inspector first shall identify the soil type. Granular soils contain predominantly sands and gravels. These types of soil are noncohesive (particles do not adhere well when compressed). Conversely, fine-grained soils which contain predominantly silts and clays are cohesive (particles will adhere when compressed).

The density of noncohesive, granular soils or the consistency of cohesive soils is classified according to standard penetration resistances contained from split barrel sampling performed according to ASTM D-1586. Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a two-inch outside diameter 12-inches into the material using a 140-pound hammer falling freely through 30-inches. In cases where geotechnical information is required, the standard penetration test will be performed by driving the sampler through an 18-inch sample interval, the number of blows will then be recorded for each six-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of the sample interval. It is important to note that if gravel and rock fragments are broken by the sampler, or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the Field Test Boring Record and referenced to the sample number. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels may be used in order to obtain a sufficient quantity of sample for required analysis. Accordingly, the second and third six-inch increments will be used to calculate the relative density.

The relative density designations for noncohesive soils are:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very loose	Less than 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	Greater than 50

The consistency of cohesive soils also is determined by blow counts as shown:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very Soft	Less than 2
Soft	2 to 4
Medium Stiff	4 to 8
Stiff	8 to 15
Very Stiff	15 to 30
Hard	Over 30

#### 5.3.4 Moisture Content

Moisture content is estimated in the field according to four categories: dry, damp, moist, and wet:

<u>Designation</u>	<u>Moisture Content</u>	<u>Descriptive</u>
Dry	0 to 10 percent	Little/no perceptible moisture
Damp	10 to 20 percent	Some perceptible moisture - not compactable
Moist	20 to 35 percent	Compactable
Wet	35 to 50 percent	Above compactable range

Little or no water should appear in dry soil. Wet soils appear to contain all the water they can possibly hold (i.e., saturated). Damp and moist are subjective. Laboratory tests for water content shall be performed if the natural water content is important.

### 5.3.5 Stratification

Stratification can only be determined after the split-barrel sampler is opened. Typically, bedding thicknesses are described as follows:

<u>Designation</u>	<u>Bedding Spacing</u>
Indistinct	No bedding apparent
Laminated	Less than 1/2-inch
Very thin	1/2-inch to 1-inch
Thin	1-inch to 4-inches
Medium	4-inches to 1-foot
Thick	1-foot to 3-feet
Massive	Greater than three feet

### 5.3.6 Texture/Fabric/Bedding

The texture/fabric/bedding of a soil shall be described, where appropriate. Texture is described as the relative angularity of the soil particles: rounded, subrounded, subangular, angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation or orientation. The bedding structure also shall be noted (e.g., stratified, lensatic, nonstratified, heterogeneous varved, etc.).

### 5.3.7 Summary of Soil Descriptions

In summary, soils shall be classified in a similar manner by each drilling inspector. The soil description shall include:

- Soil grain size with appropriate descriptors
- Color
- Relative density and/or consistency
- Moisture content
- Stratification
- Texture/fabric/bedding
- Other distinguishing features

These descriptors are evaluated and the soil classified according the USCS system. All information, measurements and observations shall be legibly recorded on a Field Test Boring Record.

#### 5.4 Sedimentary Rock Classifications

Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. Sedimentary rocks are the most predominant type exposed at the earth's surface. As such, this section will consider only classification of sedimentary rocks. Standard geologic references should be used for the complete classification of sedimentary, igneous and metamorphic rocks.

For the purpose of completing the Field Test Boring Record in the field, sedimentary rocks should be classified using the following hierarchy:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Rock Quality Designation
- Weathering
- Other characteristics

##### 5.4.1 Rock Type

There are numerous names for sedimentary rocks such as sandstone, shale, siltstone, claystone, conglomerate, limestone, dolomite, coal, etc. The drilling inspector should select the most appropriate rock type based on experience. Some of the references listed in Section 7.0 provide a more complete discussion of sedimentary rock types.

In addition to selecting a rock type, the drilling inspector should record the grain size (and composition of grains and cement, if apparent) on the Field Test Boring Record. The following designation should be used to describe grain size in sedimentary rocks:

<u>Designation</u>	<u>Grain Size Diameter</u>
Cobbles	Greater than 64 mm (2.5-inches)
Pebbles	4 mm (0.16-inches) to 64 mm
Granules	2 mm (0.08-inches) to 4mm
Very Coarse Sand	1 mm to 2 mm
Coarse Sand	0.5 mm to 1 mm
Medium Sand	0.25 mm to 0.5 mm
Fine Sand	0.125 mm to 0.25 mm
Very Fine Sand	0.0625 mm to 0.125 mm
Silt	0.0039 mm to 0.0625 mm
Clay	Smaller than 0.0039 mm

For individual boundaries of grain size, a scale can be used for coarse-grained rocks. However, the division between silt and clay likely will not be measurable in the field. This boundary shall be determined by use of a hand lens. If the grains cannot be seen with the unaided eye, but are distinguishable with a handlens (5x magnification) the grain size is silt. If the grains are not distinguishable with a handlens, the grain size is clay.

#### 5.4.2 Color

The color of rock can be determined in a manner similar to that for soil samples. Rock cores or fragments shall be classified while wet, when possible. Rock color charts shall not be used unless specified by the Project Manager.

#### 5.4.3 Bedding Thickness

The bedding thickness designation for soils (Section 5.3.5) shall also be used for rock descriptions.

#### 5.4.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness follows:

- Very Soft - Very soft indicates that the rock is easily gouged by a knife, easily scratched by a fingernail, and/or easily broken by hand
- Soft - Soft indicates that the rock may be gouged by a knife, scratched by a fingernail, difficult to break by hand, and/or powders when hit by a hammer.

- **Medium Hard** - Medium hard indicates that the rock is easily scratched by a knife and/or is easily broken when hit by a hammer.
- **Hard** - Hard indicates that the rock is difficult to scratch with a knife but may be broken with a hammer.
- **Very Hard** - Very hard indicates that the rock is difficult to break with a hammer.

Note the difference in usage between the words "scratch" and "gouge". A scratch shall be considered a slight depression in the rock while a gouge is much deeper.

#### 5.4.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is measured and is described by the following terms:

- **Very Broken** - Less than a two-inch spacing between fractures
- **Broken** - A two-inch to one-foot spacing between fractures
- **Blocky** - A one-foot to three-foot spacing between fractures
- **Massive** - A three-foot to ten-foot spacing between fractures

#### 5.4.6 Rock Quality Designation

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding four inches and dividing by the total length of core run:

$$RQD (\%) = r/l \times 100$$

Where:

r = Total length of all pieces of the lithologic unit being measured, which are greater than four inches, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling) friable zones, etc.

l = Total length of core run.

The results of the RQD calculations shall be recorded on the Field Test Boring Record.

#### 5.4.7 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and also is useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Decomposed - Soft to very soft, bedding and fractures indistinct, no cementation.
- Highly weathered - very soft to soft, with medium hard relic rock fragments, little to moderate cementation. Vugs and openings in bedding and fracture planes, some of which may be filled.
- Weathered - Soft to medium hard. Good cementation, bedding and fractures are pronounced. Uniformly stained.
- Slightly weathered - Medium hard. Fractures pronounced, nonuniform staining, bedding distinct.
- Fresh - Medium hard to hard. No staining. Fractures may be present, bedding may or may not be distinct.

#### 5.4.8 Other characteristics

The following items should be included in rock description, where applicable:

- Description of contacts between rock units (sharp or gradational)
- Stratification
- Description of any filled cavities
- Cementation (calcareous, siliceous, hematitic, etc.)
- Description of joints and open fractures (with strike and dip, if possible)
- Observation of the presence of fossils

#### 5.4.9 Additional Terms

The following terms also are used to further identify rocks:

- Seam - thin (12-inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of an accessory material.
- Few - Indicates insignificant (0 to 15 percent) amounts of an accessory material.
- Interbedded - Indicates thin or very thin alternating seams of material occurring in approximately equal amounts.

- **Interlayered** - Indicates thick alternating seams of material occurring in approximately equal amounts.

## **6.0 QUALITY ASSURANCE RECORDS**

Quality Assurance Records shall consist of completed Field Test Boring Records and Test Boring Records.

## **7.0 REFERENCES**

1. American Society for Testing and Materials, 1990. Standard Methods for Classification of Soils for Engineering Purposes. ASTM Method D2487-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1990. Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). ASTM Method D2488-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

**ATTACHMENT A**

**EXAMPLE TEST BORING RECORD**

# Baker

Baker Environmental, Inc.

# TEST BORING RECORD

PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

COORDINATES: EAST: \_\_\_\_\_

ELEVATION: SURFACE: \_\_\_\_\_

BORING NO.: B-1

NORTH: \_\_\_\_\_

TOP OF PVC CASING: \_\_\_\_\_

RIG: Mobile B-57									
	SPLIT SPOON	CASING	AUGERS	CORE BARREL	DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	1-3/8" ID		6-1/4" ID		5/31/91	14.0	Sunny, 80°-90°F	—	—
LENGTH	2.0'		5.0'						
TYPE	STD.		HSA						
HAMMER WT.	140#								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; no monitoring well installed - borehole grouted to surface.

<b>SAMPLE TYPE</b> S = Split Spoon    A = Auger T = Shelby Tube    W = Wash R = Air Rotary    C = Core D = Denison    P = Piston N = No Sample			<b>DEFINITIONS</b> SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis		
---	--	--	---	--	--

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1			3			TOPSOIL, grass roots; tan, gray; medium dense; dry	1.0'
2	S-1	1.3 2.0 65%	7 9 5		0	SAND, fine-grained, trace gravel, trace silt; tan, brown; loose; moist to damp	
3			4				
4	S-2	1.3 2.0 65%	3 4 4		0	SAND, fine-grained, trace silt, trace grass roots; tan, brown; loose; moist to damp	4.0'
5			11				
6	S-3	2.0 2.0 100%	12 10 8		0	SAND, fine to medium-grained, trace silt; tan, brown, orange; medium dense; moist to wet; water table at 6.0'	
7			3				7.0'
8	S-4	1.8 2.0 90%	4 3 4		0	SAND, medium to coarse-grained, trace silt; tan, gray, orange; loose; wet	
9			1				9.0'
10	S-5	2.0 2.0 100%	0 1 1		0	SAND, medium-grained, trace silt; gray, orange; very loose; wet	

Match to Sheet 2

DRILLING CO.: ATEC Associates

DRILLER: M. Miller

BAKER REP.: R. Bonelli

BORING NO.: B-1

SHEET 1 OF 2

# TEST BORING RECORD

PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

BORING NO.: B-1

SAMPLE TYPE						DEFINITIONS																																																																																																																																							
S = Split Spoon	A = Auger					SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5')																																																																																																																																							
T = Shelby Tube	W = Wash					RQD = Rock Quality Designation (%)																																																																																																																																							
R = Air Rotary	C = Core					Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)																																																																																																																																							
D = Denison	P = Piston					Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis																																																																																																																																							
N = No Sample																																																																																																																																													
Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation																																																																																																																																						
11	S-6	2.0 2.0 100%	1		0	SAND, medium-grained, trace silt; gray; very loose; wet																																																																																																																																							
12			1					13	S-7	2.0 2.0 100%	0		0	SAND, medium-grained, trace silt; gray; very loose; wet	14.0'	14	1		15						End of Boring at 14.0'		16								17								18								19								20								21								22								23								24								25								26								27								28								29								30		
13	S-7	2.0 2.0 100%	0		0	SAND, medium-grained, trace silt; gray; very loose; wet	14.0'																																																																																																																																						
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**ATTACHMENT B**

**UNIFIED SOIL CLASSIFICATION SYSTEM**



**ATTACHMENT C**

**SOIL AND ROCK DESCRIPTION SUMMARY**

<u>SOIL DESCRIPTION</u>			<u>ROCK DESCRIPTIONS</u>		
<u>GRAIN SIZE IDENTIFICATION</u>			<u>HARDNESS</u>		
<u>NAME</u>	<u>SIZE LIMITS</u>		Very Soft -	Easily gouged by knife, easily scratched by fingernail, easily broken by hand	
Boulder	12" OR MORE		Soft -	Gouged by knife, scratched by fingernail, difficult to break by hand, powders with hammer	
Cobbles	3" - 12"		Medium Hard -	Easily scratched by knife, easily broken with hammer	
Coarse Gravel	3/4" - 3"		Hard -	Difficult to scratch, breaks with hammer	
Fine Gravel	4.76 mm (#4) - 3/4"		Very Hard -	Difficult to break, rings when struck	
Coarse Sand	2 mm (#10) - 4.76 mm (#4)		<u>WEATHERING</u>		
Medium Sand	0.42 mm (#40) - 2 mm (#10)		Decomposed -	Soft to Very soft, bedding and fractures indistinct, no cementation.	
Fine Sand	0.074 mm (#200)-0.42 mm (#40)		Highly Weathered -	Very soft to soft, with medium hard relict rock fragments; little to moderate cementation. Vugs, openings in bedding and fractures (may be filled).	
Silt	0.002 mm-0.074 mm (#200)		Weathered -	Soft to medium hard. Good cementation, bedding and fractures are pronounced. Uniformly stained.	
Clay	Less than 0.002 mm		Slightly Weathered -	Medium hard. Fractures pronounced, non-uniform staining, bedding distinct.	
<u>RELATIVE DENSITY</u>			Fresh -	Medium hard to hard. No staining. Fractures may be present. Bedding may or may not be indistinct.	
<u>NONCOHESIVE SOIL</u>			<u>BEDDING AND FRACTURES:</u>		
<u>TERM</u>	<u>SPT (Blows/ft)</u>		<u>SPACING</u>	<u>BEDDING</u>	<u>FRACTURES</u>
Very Loose	Below 4		LESS THAN 1/2" (1 cm)	Indistinct	Fissile
Loose	4-10		1/2" to 1" (1cm-3cm)	Laminated	Very Close
Medium Dense	10-30		1" TO 4" (3cm-10cm)	Very Thin	Close
Dense	30-50		4" TO 1' (10cm-30cm)	Thin	Moderate
Very Dense	OVER 50		1' TO 3' (30 cm-1m)	Moderate	Wide
<u>COHESIVE SOILS</u>			3' TO 10' (1m-3m)	Thick	Very Wide
<u>TERM</u>	<u>SPT (Blows/ft)</u>				
Very Soft	BELOW 2				
Soft	2-4				
Medium Stiff	4-8				
Stiff	8-15				
Very Stiff	15-30				
Hard	OVER 30				
<u>MOISTURE</u>	<u>DESCRIPTIVE TERMS</u>				
Dry -	Trace	0-10%			
Damp	Little	10-20%			
Moist	Some	20-35%			
Wet	And	35-50%			
<u>CONTACTS:</u>			<u>SAMPLE TYPE</u>	<u>ABBREVIATIONS</u>	
_____ = DEFINITE			S = Split Spoon	HS = Hollow Stem	
_____ = INDEFINITE			T = Shelby Tube	NP = Non Plastic	
..... = GRADATIONAL			R = Air Rotary	-PL = Below the Plastic Limit	
			D = Denison	PL = At the Plastic Limit	
			A = Auger	+PL = Above the Plastic Limit	
			W = Wash (Roller Bit)	+LL = Above the Liquid Limit	
			C = Core	SPT = Standard Penetration Test	
			P = Piston	RQD = Rock Quality Designation	
			N = No Sample Taken		

ROCK SYMBOLS

	CONGLOMERATE		LIMESTONE
	BRECCIA		DOLOMITE
	SANDSTONE		COAL
	SILTSTONE		VOID
	SHALE		UNDIFFERENTIATED
	CLAYSTONE		

HARDNESS

- V. SOFT - CORE RECOVERY < 50%, EASILY GOUGED BY KNIFE OR SCREWDRIVER, EASILY SCRATCHED BY FINGERNAIL, EASILY BROKEN BY HAND
- SOFT - CORE RECOVERY 50 - 75%, GOUGED BY KNIFE OR SCREWDRIVER, SCRATCHED BY FINGERNAIL, DIFFICULT TO BREAK BY HAND, POWDERS w/HAMMER
- MED. HD. - CORE RECOVERY > 75%, EASILY SCRATCHED BY KNIFE OR SCREWDRIVER, EASILY BROKEN BY HAMMER
- HD. - DIFFICULT TO SCRATCH, BREAKS w/HAMMER
- V. HD. - DIFFICULT TO BREAK, RINGS WHEN STRUCK

SPACING

- LESS THAN 1/4" (1cm)
- 1/4" To 1" (1cm-3cm)
- 1" To 4" (3cm-10cm)
- 4" To 1' (10cm-30cm)
- 1' To 3' (30cm-1m)
- 3' To 10' (1m-3m)

BEDDING

- INDISTINCT
- LAMINATED
- VERY THIN
- THIN
- MODERATE
- THICK
- MASSIVE

FRACTURES

- FISSILE
- VERY CLOSE
- CLOSE
- MODERATE
- WIDE
- VERY WIDE

WEATHERING

- DECOMPOSED - SOFT - V. SOFT, BEDDING AND FRACTURES INDISTINCT, NO CEMENTATION
- HL. WTHR. - V. SOFT - SOFT, w/MED. HD. RELICT ROCK FRAGMENTS; LITTLE TO MOD. CEMENTATION, YUGS, OPENINGS IN BEDDING AND FRACTURES (MAY BE CLAY OR CALC. FILLED)
- WTHR. - SOFT TO MED. HD., GOOD CEMENTATION, BEDDING AND FRACTURES ARE PRONOUNCED, UNIFORMLY STAINED
- SL. WTHR. - MED. HD., FRACTURES PRONOUNCED, NON-UNIFORM STAINING, BEDDING DISTINCT
- FRESH - MED. HD. TO HD., NO STAINING, FRACTURES MAY BE PRESENT, BEDDING MAY OR MAY NOT BE DISTINCT

COMMON LOCAL SEDIMENTARY ROCK CLASSIFICATIONS

MM APP. SIEVE SIZE	% CARBONATE			GRAIN SIZE INCREASES ↑	EASILY VISIBLE - ROUGH
	NO FIZZ	SLIGHT FIZZ	RAPID FIZZ		
2.0	CONGLOMERATE - If particles rounded BRECCIA - If particles angular; classify both particles and matrix as below.				
2.0	VERY COARSE GRAINED				
5	SANDSTONE	CALCAREOUS SANDSTONE	ARENACEOUS LIMESTONE	LIMESTONE	
25					
.125					
.005					
.005	SILTSTONE SHALE (IF LAM OR FIS.)	CALC. SILTSTONE CALC. SHALE (MARL)	SILTY LIMESTONE (AAG)	CRYSTALLINE	SLIGHTLY VISIBLE GRITTY
	CLAYSTONE	CALC. CLAYSTONE	CLAYEY LIMESTONE		NOT VISIBLE SMOOTH

$RQD = \frac{L}{R}$  - N TYPE CORE ONLY

L = TOTAL LENGTH IN A RUN OF CORE PIECES LONGER THAN 4"

R = LENGTH OF THE RUN

— % SILICATE

ROCK DESCRIPTIONS



## Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>1</sup>

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

### 1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

**NOTE 1**—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>

D 1452 Practice for Soil Investigation and Sampling by Auger Borings<sup>2</sup>

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>

D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>  
D 2113 Practice for Diamond Core Drilling for Site Investigation<sup>2</sup>  
D 2487 Test Method for Classification of Soils for Engineering Purposes<sup>2</sup>  
D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)<sup>2</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

**NOTE 2**—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

**Cobbles**—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

**Boulders**—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 **clay**—soil passing a No. 200 (75- $\mu$ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 **gravel**—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

**coarse**—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

**fine**—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 **organic clay**—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 **organic silt**—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 **peat**—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 **sand**—particles of rock that will pass a No. 4

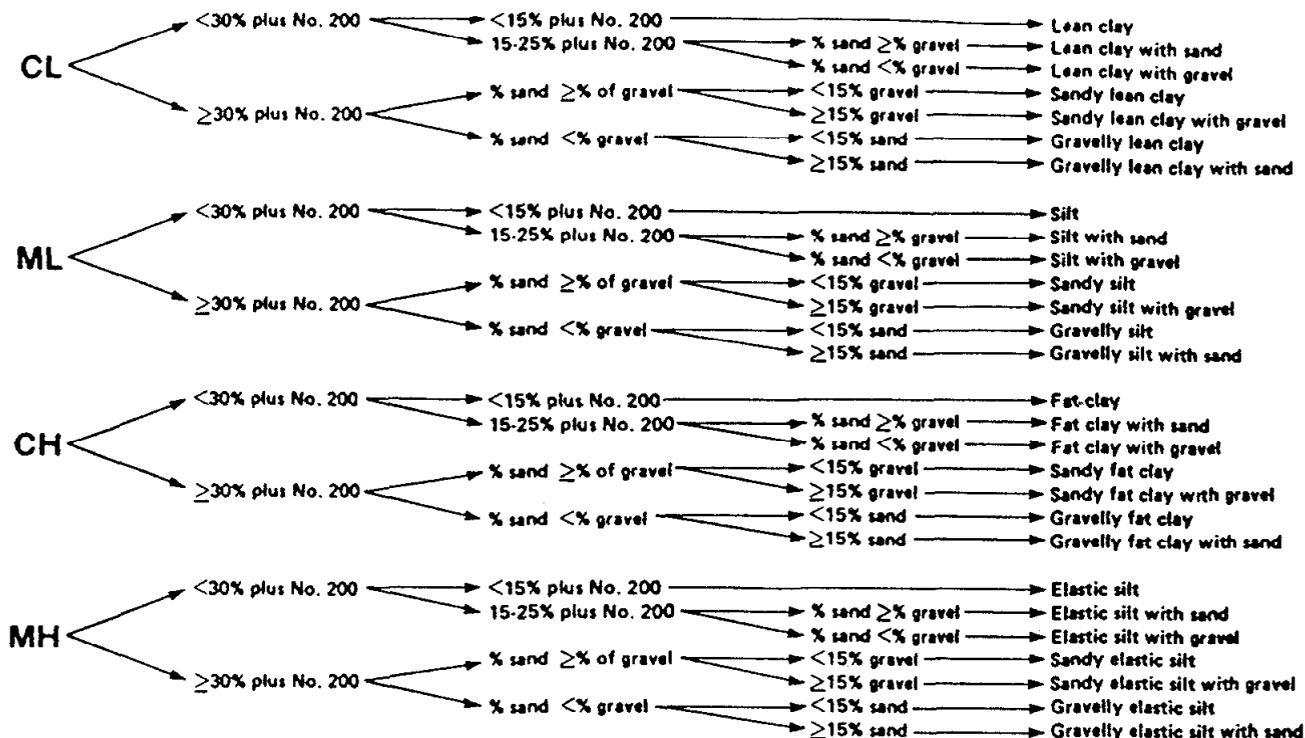
<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved June 29, 1990. Published August 1990. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 84<sup>11</sup>.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

GROUP SYMBOL

GROUP NAME



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

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75- $\mu$ m) sieve with the following subdivisions:

*coarse*—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

*medium*—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425- $\mu$ m) sieve.

*fine*—passes a No. 40 (425- $\mu$ m) sieve and is retained on a No. 200 (75- $\mu$ m) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75- $\mu$ m) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

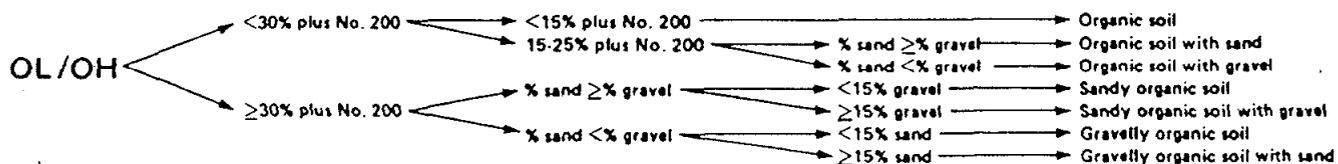
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

*Dual Symbol*—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or

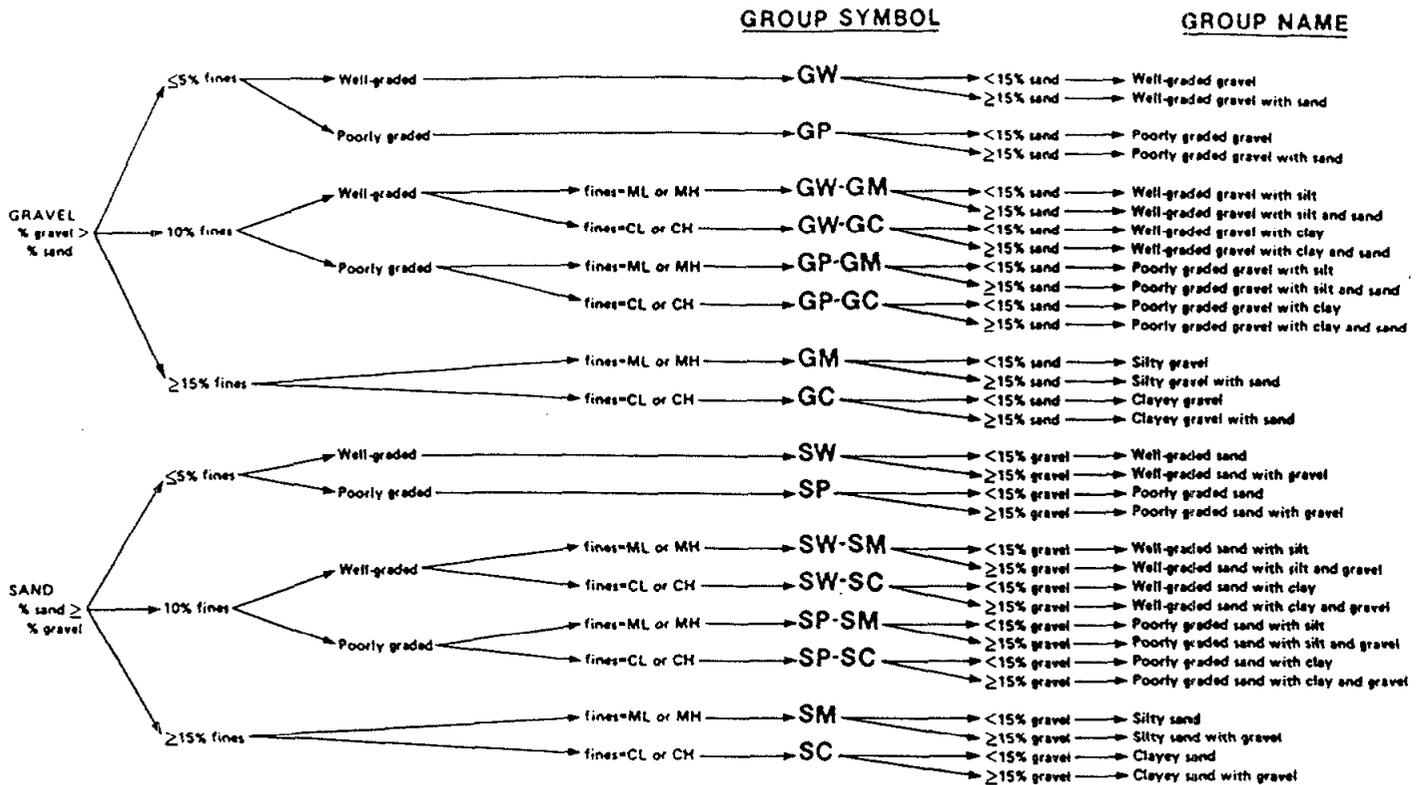
GROUP SYMBOL

GROUP NAME



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

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



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

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

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

**Borderline Symbol**—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together, one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 Required Apparatus:

6.1.1 Pocket Knife or Small Spatula.

6.2 Useful Auxiliary Apparatus:

6.2.1 Small Test Tube and Stopper (or jar with a lid).

6.2.2 Small Hand Lens.

7. Reagents

7.1 Purity of Water—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 Hydrochloric Acid—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

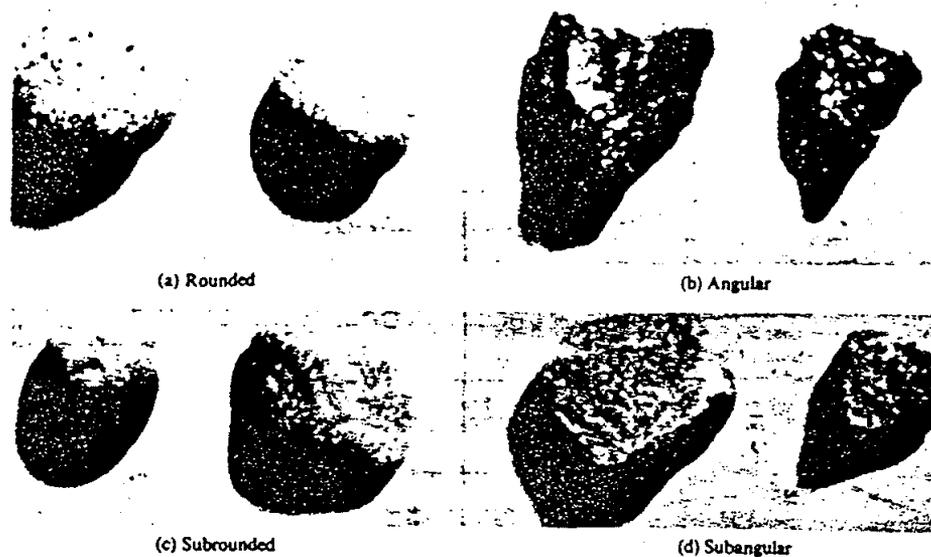


FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If contact comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in

accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.5 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 Angularity—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 Shape—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 Color—Describe the color. Color is an important property in identifying organic soils, and within a given

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

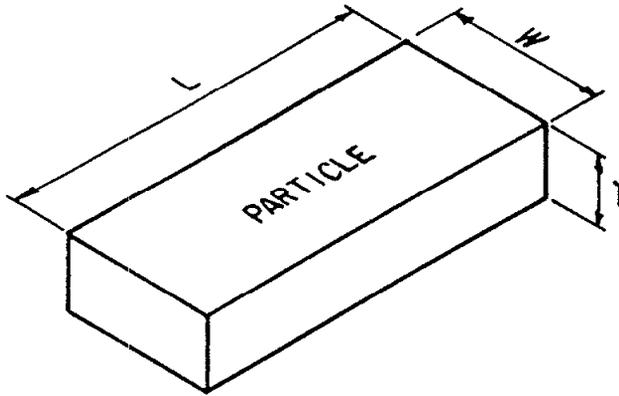
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W = WIDTH  
T = THICKNESS  
L = LENGTH



FLAT:  $W/T > 3$   
ELONGATED:  $L/W > 3$   
FLAT AND ELONGATED:  
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

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

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation.

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.  
 10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

2.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term trace, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

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

the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 Toughness:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and re-roll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 Plasticity—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 Identification of Inorganic Fine-Grained Soils:

TABLE 11 Criteria for Describing Plasticity

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

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 Identification of Organic Fine-Grained Soils:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

## 16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range: Gravel—fine, coarse Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
For intact samples:
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

*Trace*—Particles are present but estimated to be less than 5 %

*Few*—5 to 10 %

*Little*—15 to 25 %

*Some*—30 to 45 %

*Mostly*—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

## 17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

## 18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

XI. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

*In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray;

in-place density 106 lb/ft<sup>3</sup>; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to

100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two

possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay

ML/CL clayey silt

CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

#### X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory terminations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

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## Standard Test Method for Classification of Soils for Engineering Purposes<sup>1</sup>

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This test method has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

### 1. Scope

1.1 This test method describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this system is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this test method is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This test method is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 The system is based on the widely recognized Unified Soil Classification System which was adopted by several U.S. Government agencies in 1952 as an outgrowth of the Airfield Classification System developed by A. Casagrande.<sup>2</sup>

1.6 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- C 117 Test Method for Materials Finer Than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing<sup>3</sup>
- C 136 Method for Sieve Analysis of Fine and Coarse Aggregates<sup>3</sup>
- C 702 Practice for Reducing Field Samples of Aggregate to Testing Size<sup>3</sup>
- D 420 Practice for Investigating and Sampling Soil and Rock for Engineering Purposes<sup>4</sup>
- D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>4</sup>
- D 422 Method for Particle-Size Analysis of Soils<sup>4</sup>
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>4</sup>
- D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75- $\mu$ m) Sieve<sup>4</sup>
- D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures<sup>4</sup>
- D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>4</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>4</sup>
- D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)<sup>4</sup>
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils<sup>4</sup>
- D 4427 Classification of Peat Samples by Laboratory Testing<sup>4</sup>
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>3</sup>

### 3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

*Cobbles*—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and  
*Boulders*—particles of rock that will not pass a 12in. (300-mm) square opening

3.1.1 *gravel*—particles of rock that will pass a 3-in.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved June 29, 1990. Published August 1990. Originally published as D 2487 - 66 T. Last previous edition D 2487 - 85<sup>41</sup>.

<sup>2</sup> Casagrande, A., "Classification and Identification of Soils," *Transactions, ASCE*, 1948, p. 901.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.08.

(75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

*Coarse*—passes 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

*Fine*—passes ¾-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.2 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) U.S. standard sieve with the following subdivisions:

*Coarse*—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

*Medium*—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-µm) sieve, and

*Fine*—passes No. 40 (425-µm) sieve and retained on No. 200 (75-µm) sieve.

3.1.3 *clay*—soil passing a No. 200 (75-µm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line.

3.1.4 *silt*—soil passing a No. 200 (75-µm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the "A" line.

3.1.5 *organic clay*—a clay with sufficient organic content influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.6 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.7 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature, C<sub>c</sub>*—the ratio  $(D_{30})^2 / (D_{10} \times D_{60})$ , where  $D_{60}$ ,  $D_{30}$ , and  $D_{10}$  are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity, C<sub>u</sub>*—the ratio  $D_{60} / D_{10}$ , where  $D_{60}$  and  $D_{10}$  are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary of Test Method

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions further subdivided into a total of 15 basic soil groups.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and

thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

5. Significance and Use

5.1 This test method classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This test method provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This test method may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This test method may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The "U" line shown on Fig. 3 has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Practice D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425-µm) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>a</sup>				Soil Classification	
				Group Symbol	Group Name <sup>g</sup>
Coarse-Grained Soils More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines <sup>c</sup>	$Cu \geq 4$ and $1 \leq Cc \leq 3^e$	GW	Well-graded gravel <sup>f</sup>
			$Cu < 4$ and/or $1 > Cc > 3^e$	GP	Poorly graded gravel <sup>f</sup>
		Gravels with Fines More than 12 % fines <sup>c</sup>	Fines classify as ML or MH Fines classify as CL or CH	GM GC	Silty gravel <sup>f, g, h</sup> Clayey gravel <sup>f, g, h</sup>
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines <sup>c</sup>	$Cu \geq 6$ and $1 \leq Cc \leq 3^e$	SW	Well-graded sand
			$Cu < 6$ and/or $1 > Cc > 3^e$	SP	Poorly graded sand <sup>f</sup>
		Sands with Fines More than 12 % fines <sup>c</sup>	Fines classify as ML or MH Fines classify as CL or CH	SM SC	Silty sand <sup>g, h</sup> Clayey sand <sup>g, h</sup>
Fine-Grained Soils 50 % or more passes the No. 200 sieve	Silt and Clays Liquid limit less than 50	Inorganic	$PI > 7$ and plots on or above "A" line <sup>j</sup> $PI < 4$ or plots below "A" line <sup>j</sup>	CL ML	Lean clay <sup>k, l, m</sup> Silt <sup>k, l, m</sup>
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay <sup>k, l, m, n</sup> Organic silt <sup>k, l, m, o</sup>
	Silt and Clays Liquid limit 50 or more	Inorganic	$PI$ plots on or above "A" line	CH	Fat clay <sup>k, l, m</sup>
			$PI$ plots below "A" line	MH	Elastic silt <sup>k, l, m</sup>
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay <sup>k, l, m, p</sup> Organic silt <sup>k, l, m, o</sup>
			Highly organic soils	Primarily organic matter, dark in color, and organic odor	PT

<sup>a</sup> Based on the material passing the 3-in. (75-mm) sieve.

<sup>b</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>c</sup> Gravels with 5 to 12 % fines require dual symbols:

- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

<sup>d</sup> Sands with 5 to 12 % fines require dual symbols:

- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

$$e \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

<sup>f</sup> If soil contains  $\geq 15$  % sand, add "with sand" to group name.

<sup>g</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>h</sup> If fines are organic, add "with organic fines" to group name.

<sup>i</sup> If soil contains  $\geq 15$  % gravel, add "with gravel" to group name.

<sup>j</sup> If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

<sup>k</sup> If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>l</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly sand, add "sandy" to group name.

<sup>m</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>n</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>o</sup>  $PI < 4$  or plots below "A" line.

<sup>p</sup>  $PI$  plots on or above "A" line.

<sup>q</sup>  $PI$  plots below "A" line.

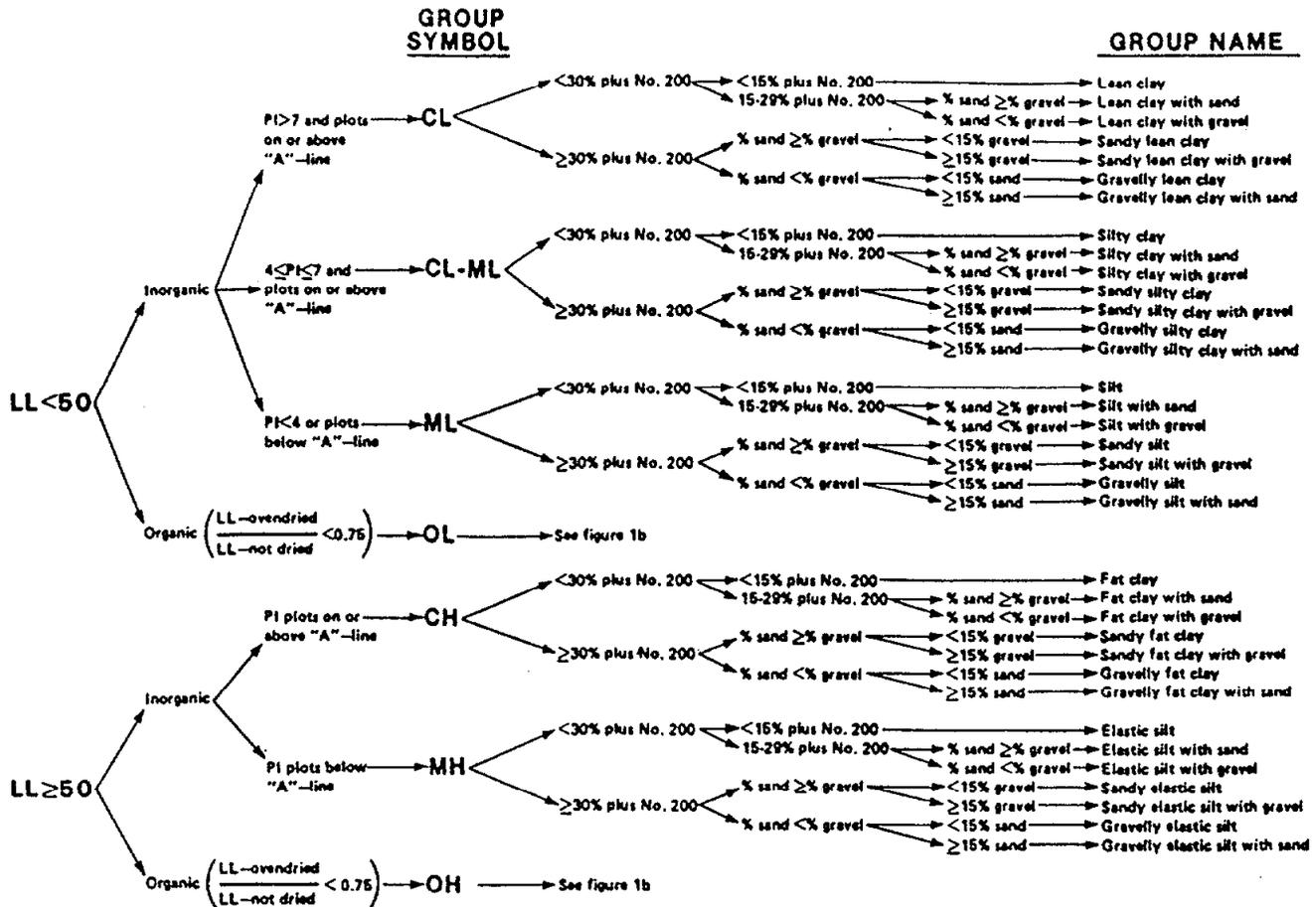


FIG. 1a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

8.2 If desired, classification of type of peat can be performed in accordance with Classification D 4427.

9. Preparation for Classification

9.1 Before a soil can be classified according to this test method, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425-μm) sieve material must be determined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in Appendixes X3 and X4. Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this test method, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

- 3-in. (75-mm)
- ¾-in. (19.0-mm)
- No. 4 (4.75-mm)
- No. 10 (2.00-mm)
- No. 40 (425-μm)
- No. 200 (75-μm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-μm) sieve is required. The cumulative particle-size distribution curve may be plotted on a graph similar to that shown in Fig. 4.

GROUP SYMBOL

GROUP NAME

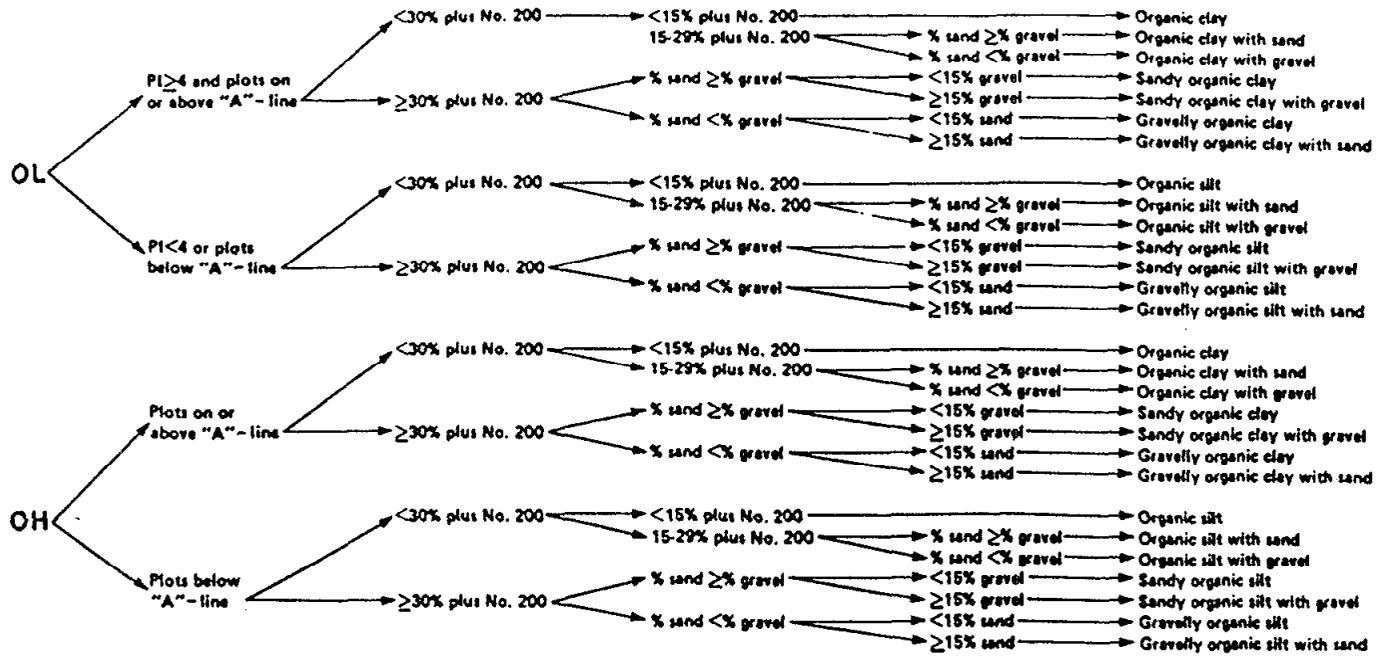


FIG. 1b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

GROUP SYMBOL

GROUP NAME

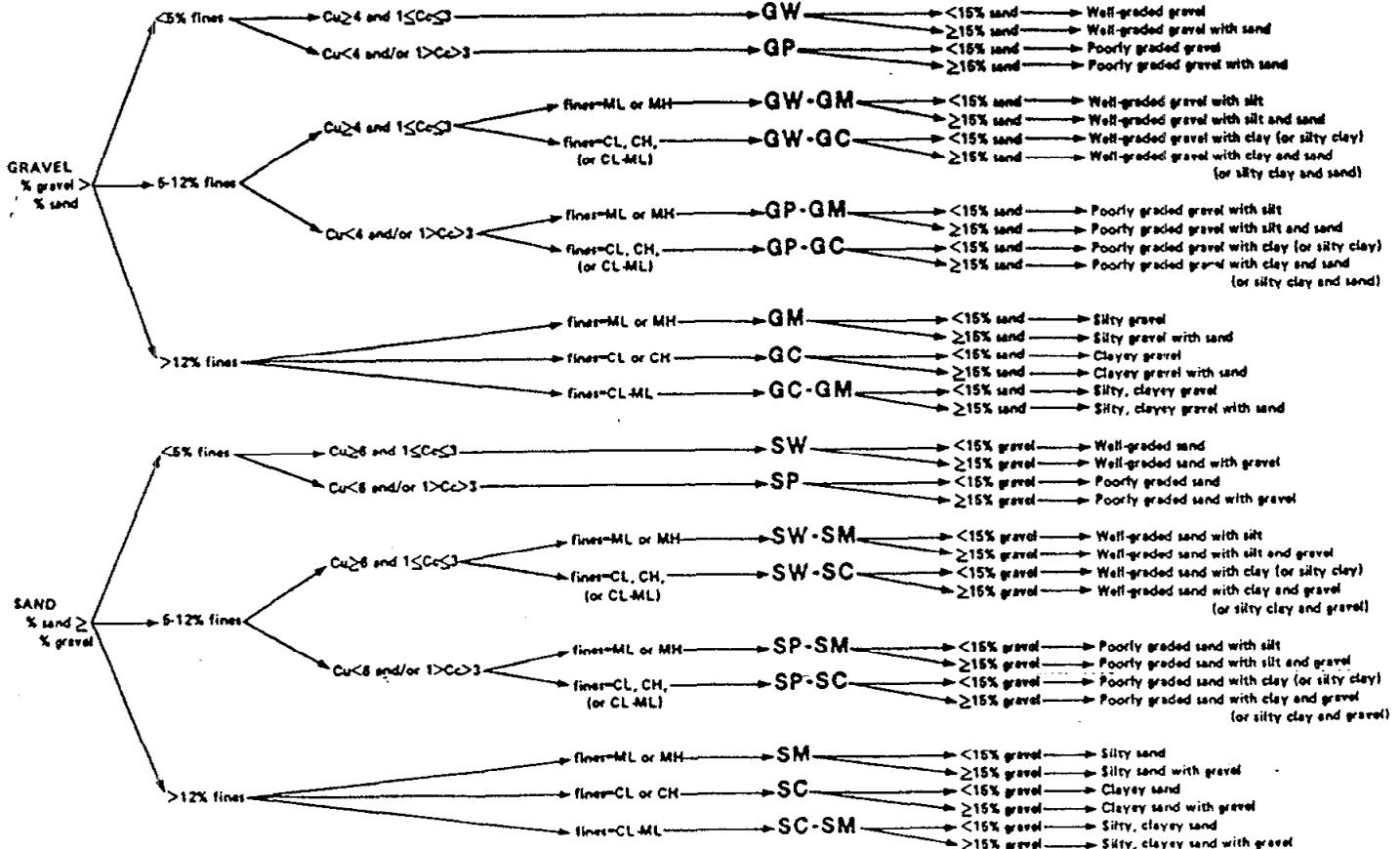


FIG. 2 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

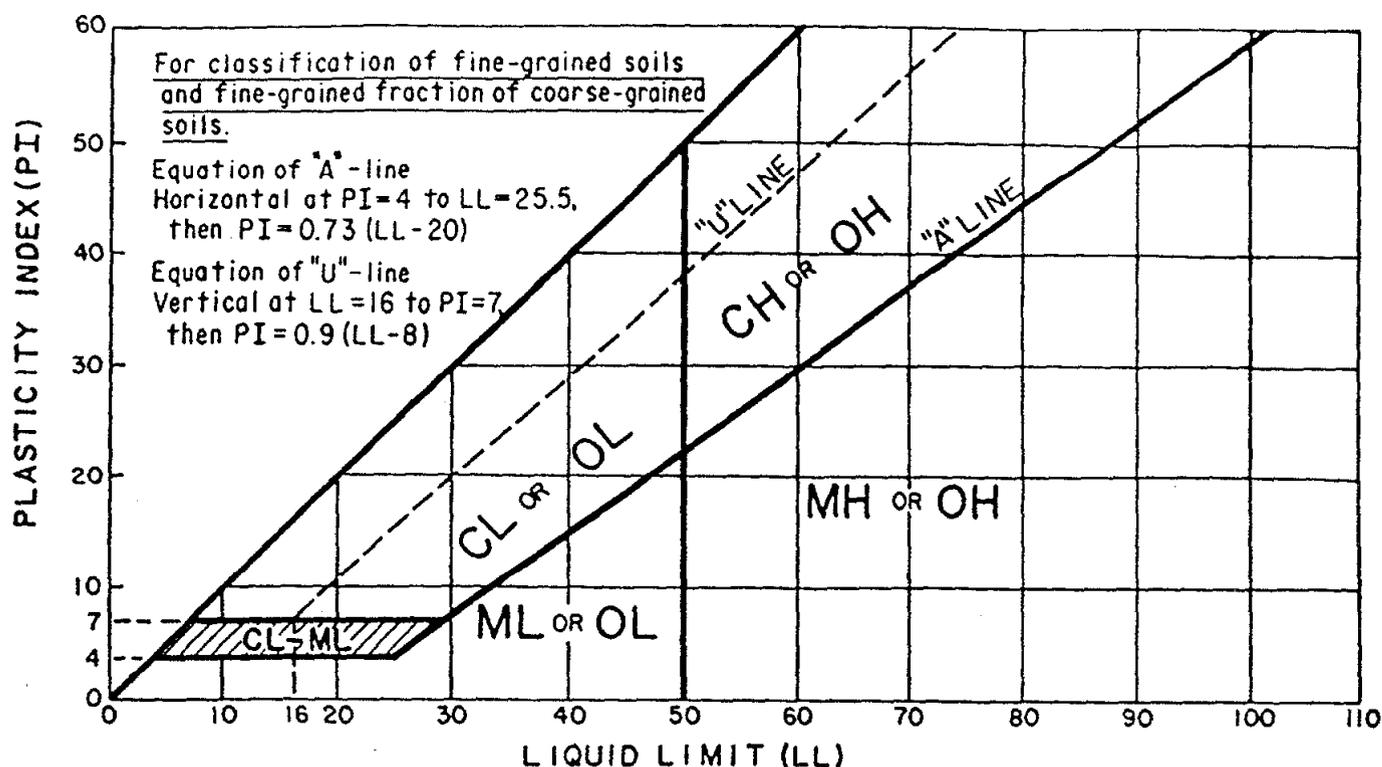


FIG. 3 Plasticity Chart

8.2 For soils estimated to contain 5 to 15 % fines, a relative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75- $\mu$ m) sieve and follow Section 11.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75- $\mu$ m) sieve and follow Section 12.

11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75- $\mu$ m) sieve)

11.1 The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

NOTE 6—The plasticity index and liquid limit are determined on the minus No. 40 (425  $\mu$ m) sieve material.

11.1.1 Classify the soil as a *lean clay*, CL, if the liquid limit is less than 50. See area identified as CL on Fig. 3.

11.1.2 Classify the soil as a *fat clay*, CH, if the liquid limit is 50 or greater. See area identified as CH on Fig. 3.

NOTE 7—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay*, CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 3.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt*, ML, if the liquid limit is less than 50. See area identified as ML on Fig. 3.

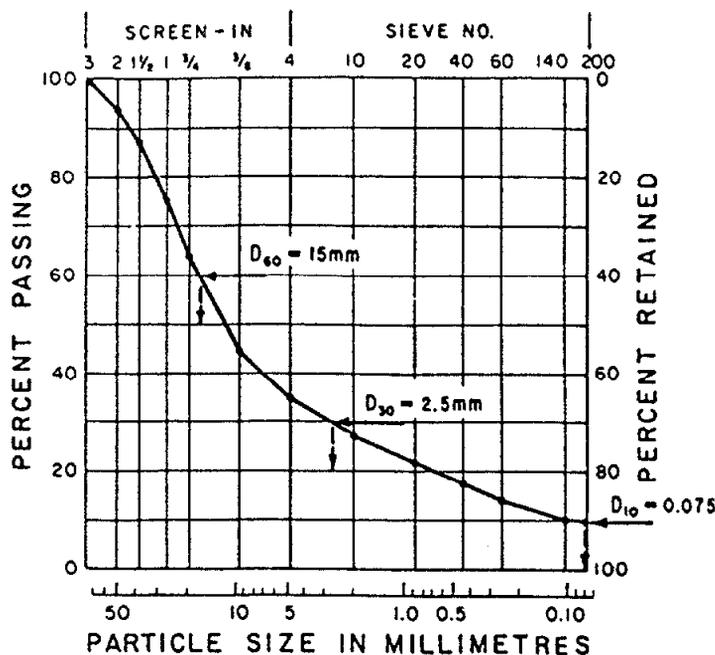
11.2.2 Classify the soil as an *elastic silt*, MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 3.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at  $110 \pm 5^\circ\text{C}$  to a constant weight, typically over night.

11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid

SIEVE ANALYSIS



$$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \quad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 4 Cumulative Particle-Size Plot

limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay*, OL, if the liquid limit (not oven dried) is less than 50 %. Classify the soil as an *organic silt*, OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 3.

11.3.4 Classify the soil as an *organic clay* or *organic silt*, OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt*, OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OH, if the position of the plasticity index versus liquid-limit plot falls on or above the "A" line. See area identified as OH on Fig. 3.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75- $\mu$ m) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75- $\mu$ m) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75- $\mu$ m) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75- $\mu$ m) sieve and the coarse-grained portion is predominantly gravel. For

example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."

12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75- $\mu$ m) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75- $\mu$ m) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75- $\mu$ m) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75- $\mu$ m) sieve, plot the cumulative particle-size distribution, Fig. 4, and compute the coefficient of uniformity,  $C_u$ , and coefficient of curvature,  $C_c$ , as given in Eqs 1 and 2.

$$C_u = D_{60}/D_{10} \quad (1)$$

$$C_c = (D_{30})^2/(D_{10} \times D_{60}) \quad (2)$$

where:

$D_{10}$ ,  $D_{30}$ , and  $D_{60}$  = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 4.

NOTE 8—It may be necessary to extrapolate the curve to obtain the  $D_{10}$  diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75- $\mu$ m) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if  $C_u$  is greater than 4.0 for gravel or greater than 6.0 for sand, and  $C_c$  is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75- $\mu$ m) sieve, classify the soil as *poorly graded gravel*,

GP, or *poorly graded sand*, SP, if either the Cu or the Cc criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75- $\mu$ m) sieve, the soil shall be considered a coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 3. (See 9.8.2.1 if insufficient material available for testing). (See NOTE 6)

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75- $\mu$ m) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM (See 9.8.2.1 if insufficient material available for testing).

NOTE 9—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but

contains 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example, poorly graded gravel with sand, clayey sand with gravel.

12.7 If the field sample contained any cobbles or boulders or both, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name. For example, silty gravel with cobbles, GM.

### 13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 10—*Example: Clayey Gravel with Sand and Cobbles (GC)*—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,  
Geologic Interpretation—alluvial fan.

NOTE 11—Other examples of soil descriptions are given in Appendix X1.

### 14. Precision and Bias

14.1 This test method provides qualitative data only; therefore, a precision and bias statement is nonapplicable.

### 15. Keywords

15.1 Atterberg limits; classification; clay; gradation; gravel; laboratory classification; organic soils; sand; silt; soil classification; soil tests

## APPENDIXES

### (Nonmandatory Information)

#### XI. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

X1.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample

smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist, brown to gray; in-place density = 106 lb/ft<sup>3</sup> and in-place moisture = 9 %.

X1.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded

to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard,

subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

## X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this test method may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this method for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this test method may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as “Sandy Lean Clay (CL)”—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; “Poorly Graded Sand with Silt (SP-SM)”—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—62 % gravel-size broken shells; 31 % sand and sand-size shell pieces; 7 % fines; would be classified as “Poorly Graded Gravel with Sand (GP)”.

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; “Poorly Graded Gravel (GP)”—89 % fine, hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl; Cc = 2.4, Cu = 0.9.

## X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transporting the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this test method assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75- $\mu$ m) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the

fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean, hard surface and select a representative sample by quartering in accordance with Methods C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425- $\mu$ m) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a 3/4-in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Practice C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75- $\mu$ m) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

#### X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75- $\mu$ m) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

#### X5. RATIONALE

X5.1 Significant revisions were made to the standard which appeared as D 2487 - 83 from the previous version of D 2487 - 69 (1975). The changes are documented in the literature.

X5.2 Changes in this version from the last include the

addition of 8.2 on classification of peat, the addition of 4.5 on classification of frozen soils, the addition of NOTE 6 for clarification of materials used to determine the plasticity index and liquid limit, and the addition of Appendix X5 on Rationale.

 D 2487

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.*

**Section 5.8**  
**Soil and Rock Sample**  
**Acquisition SOP**

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## SOIL AND ROCK SAMPLE ACQUISITION

### 1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

### 2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

### 3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length. A stationary piston device is included in the sampler to reduce sample disturbance and increase recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water,

groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite : A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.
- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Drilling Inspector** - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of surface soil samples.

## 5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants from hazardous substance sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at hazardous waste sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

### 5.1 Rock Cores

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock

quality designation (RQD) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate at least 20 linear feet of core in rows of approximately five feet each and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number
- Footage (depths) .....
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible.

## **5.2 Subsurface Soil Samples**

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelly tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelly-tube sampling are provided in Attachments A and B, respectively.

### **5.2.1 Split-Barrel (Split-Spoon) Sampling**

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.
2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
3. The two-inch O.D. split-barrel sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.
4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.

5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance,  $N$ . If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)
6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.
7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to SOP F501.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.
2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.
3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).
4. Pack the samples for shipping (see SOP F300). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F301).
5. Decontaminate the split-spoon sample as described in SOP F501. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. Care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

#### 5.2.2 Thin-Wall (Shelby Tube) Sampling

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.
3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.
5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.

6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.
7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete chain-of-custody and other required forms (see SOP F302). Do not allow tubes to freeze, and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.
8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.
9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

### 5.2.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse

and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

### 5.3 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.

2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.
3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.
4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.
5. Pack and ship as described in SOP F300.
6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.
7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

## 6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F302.

## 7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.
4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D1586-84**

**STANDARD METHOD FOR PENETRATION TEST AND  
SPLIT-BARREL SAMPLING OF SOILS**



## Standard Method for Penetration Test and Split-Barrel Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.*

### 1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For a specific precautionary statement, see 5.4.1.*

1.3 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 2487 Test Method for Classification of Soils for Engineering Purposes<sup>2</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>

### 3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the  $140 \pm 2$  lb ( $63.5 \pm 1$  kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9  $\Delta N$ —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by  $360^\circ$  (see Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

### 4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in

<sup>1</sup> This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 - 58 T. Last previous edition D 1586 - 67 (1974).

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

**ATTACHMENT B**

**ASTM D1587-83**

**STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS**



## Standard Practice for Thin-Walled Tube Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.*

### 1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>

D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>  
D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>

### 3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

### 4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For

hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

### 6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Aug. 17, 1983. Published October 1983. Originally published as D 1587 - 58 T. Last previous edition D 1587 - 74.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

**ATTACHMENT C**

**ASTM D2113-83 (1987)**

**STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR  
SITE INVESTIGATION**



## Standard Practice for Diamond Core Drilling for Site Investigation<sup>1</sup>

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>

D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>

D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>

### 3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

### 4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels*, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for

a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2½ in. (69.85 mm) by 3½ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7¾ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved June 24, 1983. Published August 1983. Originally published as D 2113 - 62 T. Last previous edition D 2113 - 70 (1976).

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

4.5 *Core Bits*—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

4.6 *Reaming Shells*, shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

4.7 *Core Lifters*—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

4.8 *Casings:*

4.8.1 *Drive Pipe or Drive Casing*, shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as re-

quired by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

4.8.2 *Casing*—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

4.8.3 *Casing Liner*—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

4.8.4 *Hollow Stem Auger*—Hollow stem auger may be used as casing for coring.

4.9 *Drill Rods:*

4.9.1 *Drill Rods of Tubular Steel Construction* are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

4.9.2 Large bore drill rods used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 *Composite Drill Rods* are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 *Nonmagnetic Drill Rods* are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 *Auxiliary Equipment*, shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.6
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2 3/4 x 3 7/8	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, ...	3.89	98.8	3.000	76.2
4 x 5 1/2	5.44	138.0	3.97	100.8
6 x 7 3/4	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWT, EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 x 5 1/2
PW	5.50	139.7	5.00	127.0	3	6 x 7 3/4
SW	6.63	168.2	6.00	152.4	3	6 x 7 3/4
UW	7.63	193.6	7.00	177.8	2	...
ZW	8.63	219.0	8.00	203.2	2	...

TABLE 3 Drill Rods

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6 <sup>a</sup>	1.34	34.1	0.63	15.8	3
BW	2.13	53.8	1.75	44.4	0.75	19.0	3
NW	2.83	66.6	2.25	57.1	1.38	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

### 5. Transportation and Storage of Core Containers

5.1 *Core Boxes*, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.<sup>2</sup> Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

### 6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of

drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

#### 6.4 Compatibility of Equipment:

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

## 7. Boring Log

- 7.1 The boring log shall include the following:
- 7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.
  - 7.1.2 Elevation of the ground surface.
  - 7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.
  - 7.1.4 Elevations or depths at which drilling fluid return was lost.
  - 7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.
  - 7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.
  - 7.1.7 Geologist's or engineer's description of the formation recovered in each run.
  - 7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.
  - 7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

## 8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

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**Section 5.9**  
**Monitoring Well Installation SOP**

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## MONITORING WELL INSTALLATION

### 1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at hazardous waste sites.

### 2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities. These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

### 3.0 DEFINITIONS

Monitoring Well - A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer - A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

### 4.0 RESPONSIBILITIES

**Project Manager** - It is the responsibility of the Project Manager to ensure that field personnel installing monitoring wells are familiar with these procedures. The Project Manager also is responsible for ensuring that all appropriate documents (e.g., test boring logs, monitoring well construction logs, etc.) have been correctly and completely filled out by the drilling inspector.

**Field Team Leader** - The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely

and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures.

**Drilling Inspector (Site Geologist)** - The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to log each boring and details of the well installation, document subsurface conditions, complete the appropriate forms, and supervise the drilling crew (or drilling supervisor).

## **5.0 PROCEDURES**

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used.

The objectives for installing monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Performing site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic determination, monitoring wells or cluster wells should be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account

for site conditions. The horizontal and vertical locations of all monitoring wells shall be determined through a site survey upon completion of well installation.

Guidelines for Navy underground storage tank (UST) monitoring well construction are given in Attachment A.

### 5.1 Well Installation

The methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. Typical shallow monitoring well construction details are shown in Figures 1 and 2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon are also available. However, PVC generally is much less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials, or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment B provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually be constructed using either two-inch or four-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from one to 20 feet depending on site-specific conditions. For UST applications, the screen should be installed such that at least two-feet of screen is above the water table and the remainder of the screen extends below the water surface. Should very shallow water table conditions be encountered, the screened interval in both the saturated and

unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A six-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either six inches below the ground surface (for flush-mounted wells) to between one and two feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successfully backfilled with a well graded medium to coarse sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed, preferably via tremie pipe, from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least one-foot thick but no more than three-feet thick, shall be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 20 minutes before further completion of the well.

The annular space above the bentonite seal will be backfilled with a cement grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The grout mixture shall be specified in the project plans.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Monitoring Well Construction Record or in a field logbook.

## 5.2 Surface Completion

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a four or six-inch diameter, five-foot long steel casing with locking cap and lock into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits, with an inverted taper to protect the casing from frost heaving. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

The top of each well will be protected with the installation of three, three-inch diameter, five-foot long steel pipes for UST projects, and four for IR projects, and have a concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5-feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete apron approximately five-feet by five-feet by 0.5-foot thick shall be placed at the same time the pipes are installed. The steel pipes shall be painted with day-glo yellow paint, or equivalent.

The second method considers flush-mounted wells, typically installed in traffic areas. The monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a five-foot by five-foot by 0.5-foot thick apron made of 3,000 psi concrete. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

All wells will have a cap vented to the atmosphere.

All monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing locking cap, and also by labeling on the exterior of the steel casing or manhole cover. For underground storage tank applications, the labeling shall consist of the letters UGW (UST

Groundwater), and a number specific to each well. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron.

### 5.3 Well Development

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501, entitled "Decontamination of Drilling Rigs, Heavy Equipment and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

All wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A maximum time period (typically one hour for shallow wells).
- A maximum well volume (typically three to five well volumes).

- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).
- Clarity based on turbidity measurements (typically less than 50 NTU).

Well development limits shall be specified in project-specific plans. A record of the well development (Figure 3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of two weeks should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval.

#### **5.4 Contaminated Materials Handling**

SOP F503, entitled "Handling of Site Investigation Generated Waste," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the project plans. In general, all site investigation generated wastes shall be containerized unless otherwise specified by LANTDIV. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

#### **5.5 Well Construction Logs**

Field Well Construction Logs shall be completed by the Drilling Inspector for each monitoring well installed. These logs preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook and later transfer it to the construction log. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within five days, or prior to demobilization from the field.

Field Well Construction Logs (in Attachment C), shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Log, or in the field logbook, as appropriate:

- Project name and location.
- CTO number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Log will be used to generate a final Well Construction Log which combines the Field Boring and Well Construction Logs into one package. An example of all three documents is presented in Attachment C.

## 6.0 QUALITY ASSURANCE RECORDS

The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

## 7.0 REFERENCES

1. Driscoll, Fletcher, G. Groundwater and Wells , Johnson division. St. Paul, Minnesota. 2nd ed. 1986.
2. Roscoe Moss Company. Handbook of Ground Water Development. John Wiley & Sons. New York. 1990.
3. USEPA. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (use most recent version).

**ATTACHMENT A**

**UST MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS**

## ATTACHMENT A

### UST MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

#### SPECIFICATIONS

Well permits required by state agencies are the responsibility of the contractor. All monitoring wells will be installed in accordance with Navy UST monitoring well specifications. The wells will be constructed of either a 2-inch or 4-inch inside diameter (I.D.) flush joint threaded PVC well screen and riser casing depending on conditions encountered during borehole completion.

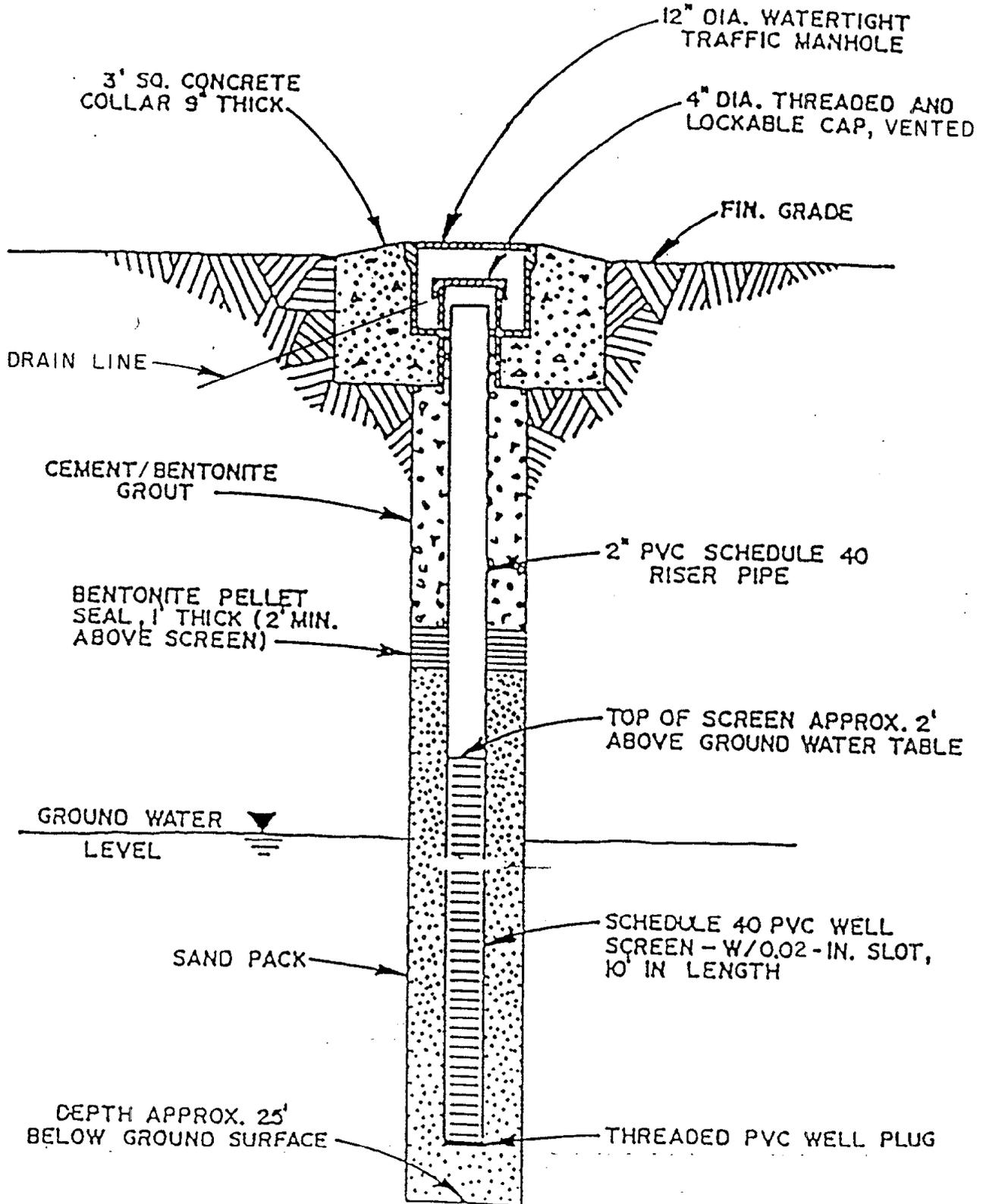
#### DRILLING

During the drilling program, boreholes will be advanced using conventional hollow-stem auger drilling methods. If it is the opinion of the contractor that air or mud rotary drill methods are necessary, approval must be obtained from the EIC. Presentation of justification for a boring method change shall be presented prior to drilling.

Well construction details are shown in Figures A-1 and A-2. A drill mounted on an All-Terrain-Vehicle (ATV) may be required for access to remote areas. Each rig will use necessary tools, supplies and equipment supplied by the contractor to drill each site. Drill crews should consist of an experienced driller and a driller assistant for work on each rig. A geologist, experienced in hazardous waste site investigations, shall be on site to monitor the drillers efforts and for air monitoring/safety control. Additional contractor personnel may be needed to transport water to the rigs, clean tools, assist in the installation of the security and marker pipes, construct the concrete aprons/collars and develop the wells. A potable water source on base will be designated by the Government.

Standard Penetration Tests (SPTs) will be performed in accordance with ASTM D-1586. Standard penetration tests will be performed at the following depths: 0.0-1.5 feet; 1.5-3.0 feet; 3.0-4.5 feet; and 5-foot centers thereafter. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels may be used in the SPT to obtain a sufficient amount of sample for required analysis. A boring log of the soil type, stratification, consistency, and groundwater level will be prepared.

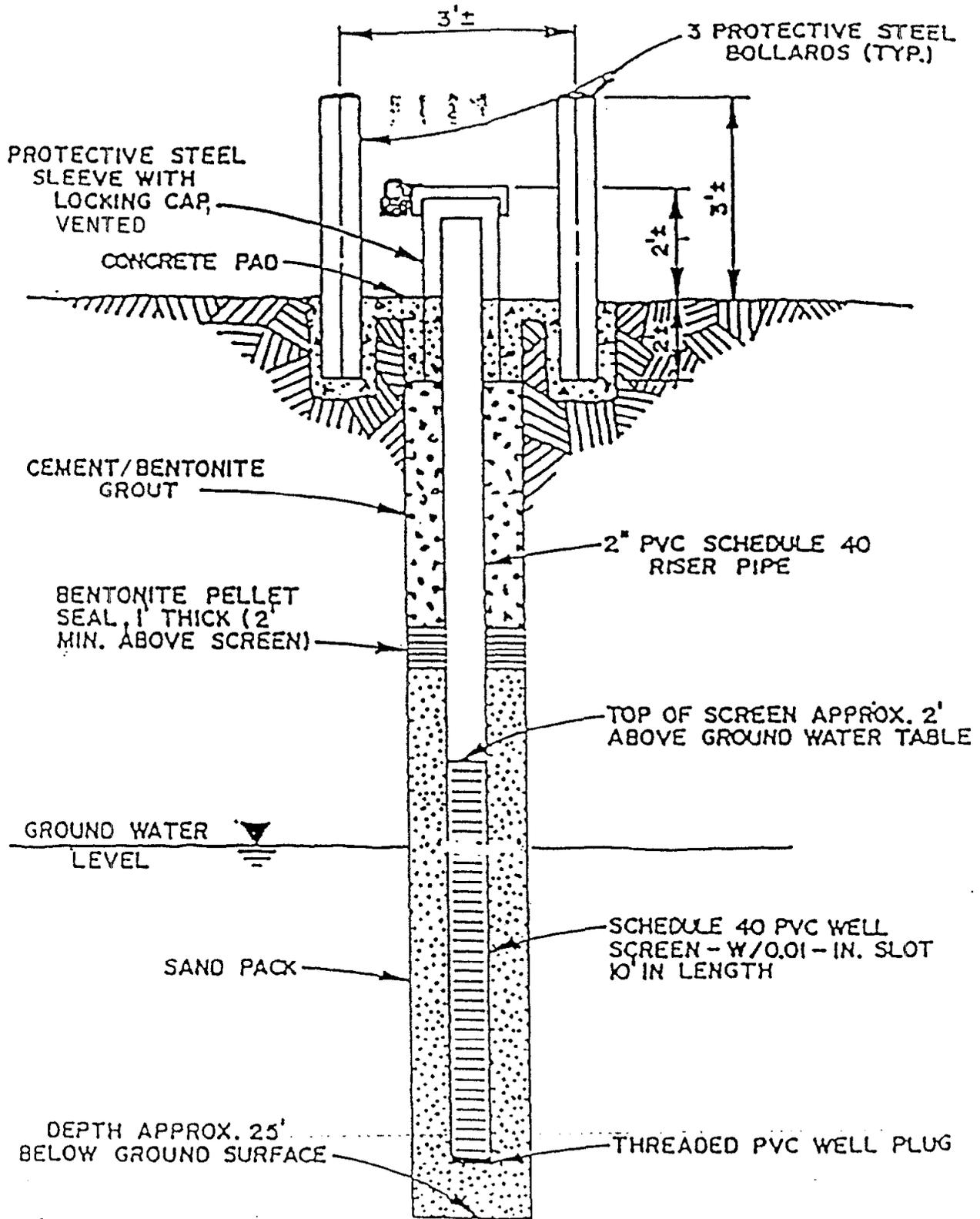
FIGURE A-1



MONITORING WELL CONSTRUCTION DETAIL  
(TRAFFIC AREA)

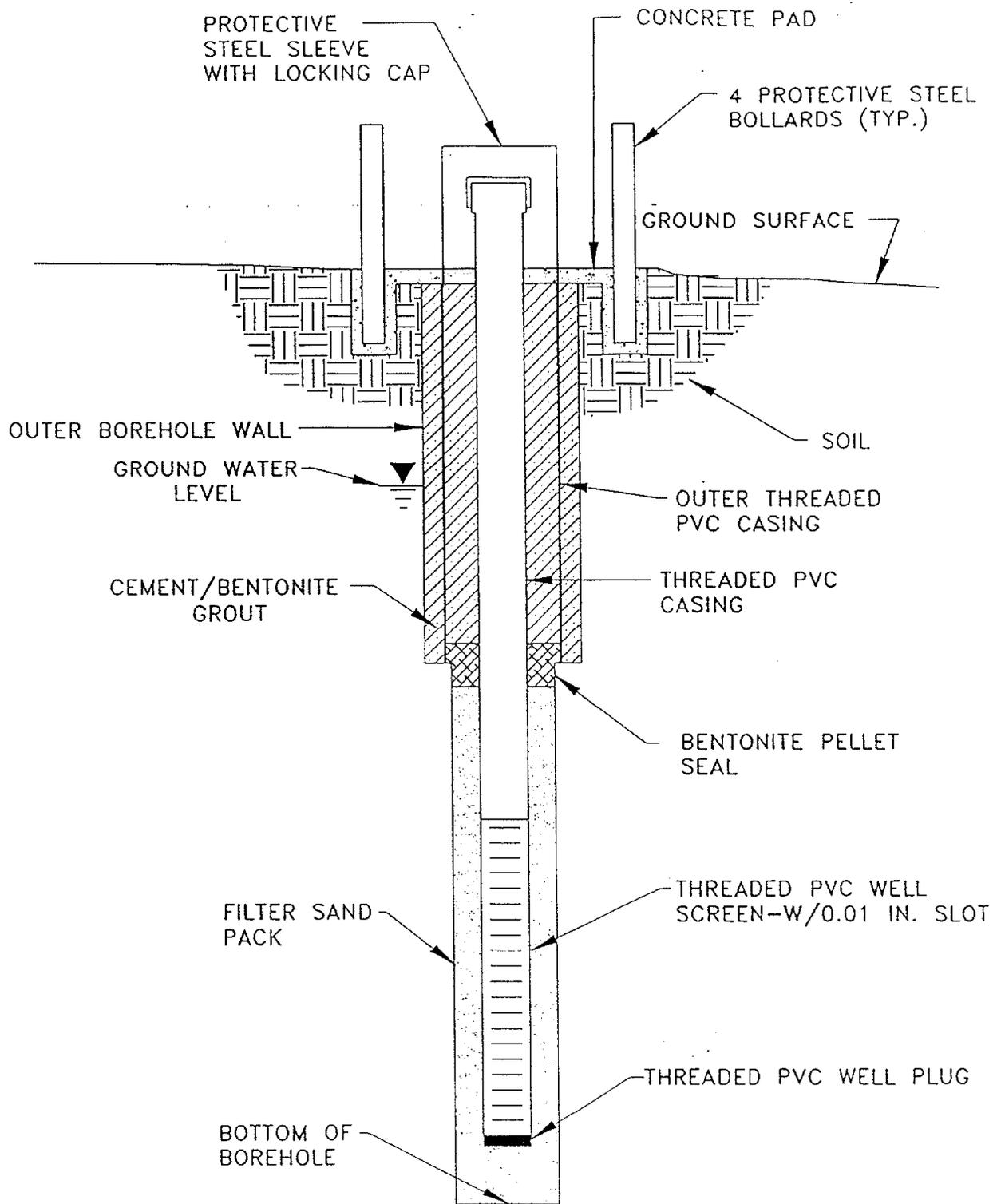
NOT TO SCALE

FIGURE A-2



MONITORING WELL CONSTRUCTION DETAIL  
(NON TRAFFIC AREA)

NOT TO SCALE



N.T.S.



TYPE III WELL

## **SAMPLING**

Soil samples of the subsurface materials will be collected every five feet or change in formation throughout the borehole in accordance with ASTM Method D-1586. Each soil sample will be screened in the field using an HNu photoionizer, organic vapor detector or similar type direct readout instrument to identify the presence of petroleum product within the soils. This field screening will provide a preliminary indication of the vertical and horizontal extent of contamination in order to select the optimum locations of other monitoring wells during the drilling program. Based on the field screening, two-inch or four-inch diameter monitoring wells will be installed at the locations where the most significant accumulation of fuel is encountered.

## **WELL DEVELOPMENT**

After completion of soil sampling and drilling to the specified depth, two-inch and/or four-inch (as required by the EIC) inside-diameter, flush-threaded Schedule 40 PVC (Schedule 80 in traffic areas) monitoring wells with slotted screens and well casings will be installed in the borehole. A 5- to 15-foot section of 0.01-inch slotted PVC well screen shall be used in each well. A sand pack will be placed around the slotted well screen extending to 2 feet above the top of the screen. A bentonite seal (minimum thickness of 1 foot) will be placed on top of the sand pack. Finally, a grout mixture of two parts sand and one part cement, thoroughly mixed with the specified amount of potable water, will be placed in the borehole to insure a proper seal.

All wells will be developed not less than 24 hours following their installation to remove fine ground materials that may have entered the well during construction. Figure A-3 presents the Field Well Development Log used to document development data. This will be accomplished by either bailing or continuous, low-yield pumping. Equipment used for well installation that may have come in contact with potentially contaminated material will be decontaminated with a high pressure steam wash followed by a potable water rinse. It is assumed that all fluid generated from well development and equipment decontamination can be disposed of on the ground at each respective well site, unless otherwise specified.

The soil removed from the borehole will be piled beneath the drill rig while drilling. The drill equipment and tools will be cleaned prior to drilling each well using a portable decontamination system supplied by the contractor. Washwater at the sites will not be contained, unless otherwise directed by the Government, and may seep into the ground locally.



Supplies and equipment will be transported to the lay-down area designated on the station by the Government. Any office space, trailers, etc., required for drilling, subsequent sampling and shipping shall be arranged and provided by the contractor.

## **WELLHEAD COMPLETION**

A four-inch diameter security pipe with a hinged locking cap will be installed over the well casing top and will be embedded approximately 2.5 feet into the grout.

There are two acceptable methods of completing the wellheads.

In traffic areas (and non-traffic areas where required), a "flush" manhole type cover shall be built into a concrete pad as shown in Figure A-1. If the well is installed through a paved or concrete surface, the annular space between the casing and the borehole shall be grouted to a depth of at least 2.5 feet and finished with a concrete collar. If the well is not installed through a concrete or paved medium and still finished as a high traffic area well, a concrete apron measuring 5-foot by 5-foot by 0.5 foot will be constructed around each well. This apron/collar will be constructed of 3,000 psi ready-mixed concrete. The concrete will be crowned to provide and to meet the finished grade of surrounding pavement as required. The concrete pads can be constructed within five days after all of the wells have been installed.

In non-traffic areas the acceptable method of finishing a wellhead is shown in Figure A-2. Each well will be marked with three, Schedule 40 steel pipes, three-inch I.D., embedded in a minimum of 2.5-foot of 3,000 psi concrete. (The concrete used to secure the three pipes will be poured at the same time and be an integral part of the 5-foot by 5-foot by 0.5-foot concrete apron described above.) The security pipes will extend a minimum of 2.5 feet and maximum of 4.0 feet above the ground surface. The steel marker pipes will be filled with concrete and painted day-glo yellow or an equivalent. Attachment C presents Sample Field Test Boring Records and Field Well Construction Record Forms.

In all finishing methods, the well covers will be properly labeled by metal stamping on the exterior of the security pipe locking cap and by labeling vertically on the exterior of the security pipe or manhole cover, as appropriate. The labeling shall consist of the letters UGW (UST Groundwater) (to describe the medium and the reason for the well) and a number specific to each well.

A sign reading "NOT FOR POTABLE USE OR DISPOSAL" shall be firmly attached to each well.

- \* The contractor or project team may supplement these requirements, but may not modify or delete them, in total or in part, without prior approval of the EIC.

If any part of the above specifications is in conflict with the regulations set forth by the State, the State regulations take precedent.

**ATTACHMENT B**

**ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

## ATTACHMENT B

### ALTERNATE WELL CASING MATERIAL JUSTIFICATION

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."
2. The anticipated compounds and their concentration ranges.
3. The anticipated residence time of the sample in the well and the aquifer's productivity.
4. The reasons for not using other casing materials.
5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.
6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.
7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

**ATTACHMENT C**

**FIELD TEST BORING RECORD AND  
FIELD WELL CONSTRUCTION RECORD FORMS**

## FIELD TEST BORING RECORD

PROJECT: Building P-64  
 S.O. NO.: 19010-51-58N BORING NO.: B-1  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: \_\_\_\_\_ TOP OF STEEL CASING: \_\_\_\_\_

RIG: <u>Mobile B-57</u>					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	<u>1-7/8" ID</u>	CASING	<u>6-1/4" ID</u>	CORE BARREL	<u>5/31/91</u>	<u>14.0</u>	<u>Sunny, 80°-90°F</u>	<u>-</u>	<u>-</u>
LENGTH	<u>2.0'</u>		<u>5.0'</u>						
TYPE	<u>STD.</u>		<u>HSA</u>						
HAMMER WT.	<u>140 lb.</u>								
FALL	<u>30"</u>								
STICK UP									

REMARKS: Advanced boring to 14ft taking continuous 2-foot split-spoon samples; No monitoring well installed - borehole grouted to surface

DRILL RECORD							VISUAL DESCRIPTION				
DEPTH	SOIL	Sample ID	SPT Blows Per 0.5'	Lab Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL ELEVATION	
	ROCK	Type No. (N = No Samp.)	(Ft. & %)	RQD (Ft. & %)	Pen. Rate	RID (ppm)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness		Weathering, Bedding, Fracturing, and Other Observations
1		S-1	1.3 20	3		TOPSOIL, grass roots;	Tan Gray	medium dense	Dry	1.0'	
2	2.0		65%	5		SAND, fine-grained, trace gravel, trace silt	Tan brown	Loose	Moist to damp		
3		S-2	1.3 20	4		SAND, fine-grained, trace silt, trace grass roots	Tan brown	Loose	Moist to damp		
4	4.0		65%	4						4.0'	
5		S-3	2.0 20	11		SAND, fine to medium-grained, trace silt	Tan brown orange	Medium dense	Moist to wet; water table noted at 6.0'		
6	6.0		100%	8							
7		S-4	1.8 20	3						7.0'	
8	8.0		90%	4		SAND, medium to coarse-grained; trace silt	Tan Gray orange	Loose	Wet		
9		S-5	2.0 20	1						9.0'	
10	10.0		100%	1		SAND, medium-grained, trace silt	Gray orange	Loose	Wet		

DRILLING CO.: ATEC Associates  
 DRILLER: M. Miller

BAKER REP.: R. Bonelli  
 BORING NO.: B-1 SHEET 1 OF 2

# Baker

Baker Environmental, Inc.

# TEST BORING RECORD

PROJECT: Building P-64  
 S.O. NO.: 19010-51-SRN BORING NO.: B-1  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: \_\_\_\_\_ TOP OF PVC CASING: \_\_\_\_\_

RIG: Mobile B-57					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
1-3/8" ID			6-1/4" ID		5/31/91	14.0	Sunny, 80°-90°F	----	----
LENGTH	2.0'		5.0'						
TYPE	STD.		HSA						
HAMMER WT.	140#								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; no monitoring well installed - borehole grouted to surface.

<b>SAMPLE TYPE</b> S = Split Spoon    A = Auger T = Shelby Tube    W = Wash R = Air Rotary    C = Core D = Denison        P = Piston N = No Sample	<b>DEFINITIONS</b> SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis
---	---

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1			3			TOPSOIL, grass roots; tan, gray; medium dense; dry	1.0'
2	S-1	1.3 2.0 65%	7 9 5			SAND, fine-grained, trace gravel, trace silt; tan, brown; loose; moist to damp	
3			4				
4	S-2	1.3 2.0 65%	3 4 4			SAND, fine-grained, trace silt, trace grass roots; tan, brown; loose; moist to damp	4.0'
5			11				
6	S-3	2.0 2.0 100%	12 10 8			SAND, fine to medium-grained, trace silt; tan, brown, orange; medium dense; moist to wet; water table at 6.0'	
7			3				7.0'
8	S-4	1.8 2.0 90%	4 3 4			SAND, medium to coarse-grained, trace silt; tan, gray, orange; loose; wet	
9			1				9.0'
10	S-5	2.0 2.0 100%	0 1 1			SAND, medium-grained, trace silt; gray, orange; very loose; wet	

Match to Sheet 2

## FIELD TEST BORING RECORD

PROJECT: Building P-64  
 S.O. NO.: 19010-51-5RN

BORING NO.: B-1

DRILL RECORD							VISUAL DESCRIPTION					
DEPTH	SOIL	Sample ID	Samp. Rec.	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL	ELEVATION
	ROCK	Type-No. (N = No Samp.)	(Ft. & %)	RQD (FL & %)	Pen. Rate	PSD (ppm)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations	ROCK	
1		S-6	2.0 2.0	1 0		0	SAND, medium-grained, trace silt	Gray	Very Loose	wet		
2	12.0		100%	1								
3		S-7	2.0 2.0	0 1		0	SAND, medium-grained, trace silt	Gray	Very Loose	wet		
4	14.0		100%	1								14.0
5							End of boring at 14.0 ft.					
6												
7												
8												
9												
0												
1												
2												
3												
4												
5												
6												
7												
8												
9												
0												

DRILLING CO.: ATFC Associates  
 DRILLER: M. Miller

BAKER REP.: R. Bonelli  
 BORING NO.: B-1

# Baker

Baker Environmental, Inc.

# TEST BORING RECORD

PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

BORING NO.: B-1

COORDINATES: EAST: \_\_\_\_\_

NORTH: \_\_\_\_\_

ELEVATION: SURFACE: \_\_\_\_\_

TOP OF PVC CASING: \_\_\_\_\_

RIG: Mobile B-57									
	SPLIT SPOON	CASING	AUGERS	CORE BARREL	DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	1-3/8" ID		6-1/4" ID		5/31/91	14.0	Sunny, 80°-90°F	----	----
LENGTH	2.0'		5.0'						
TYPE	STD.		HSA						
HAMMER WT.	140#								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; no monitoring well installed - borehole grouted to surface.

<b>SAMPLE TYPE</b> S = Split Spoon    A = Auger T = Shelby Tube    W = Wash R = Air Rotary    C = Core D = Denison    P = Piston N = No Sample						<b>DEFINITIONS</b> SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis			
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Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1	S-1	1.3	3			TOPSOIL, grass roots; tan, gray; medium dense; dry	1.0'
2		2.0	7				0 SAND, fine-grained, trace gravel, trace silt; tan, brown; loose; moist to damp
3	S-2	1.3	4			SAND, fine-grained, trace silt, trace grass roots; tan, brown; loose; moist to damp	4.0'
4		2.0	3				
5	S-3	2.0	11			SAND, fine to medium-grained, trace silt; tan, brown, orange; medium dense; moist to wet; water table at 6.0'	7.0'
6		2.0	12				
7	S-4	1.8	3			SAND, medium to coarse-grained, trace silt; tan, gray, orange; loose; wet	9.0'
8		2.0	4				
9	S-5	2.0	1			SAND, medium-grained, trace silt; gray, orange; very loose; wet	Match to Sheet 2
10		2.0	0				

DRILLING CO.: ATEC Associates

DRILLER: M. Miller

BAKER REP.: R. Bonelli

BORING NO.: B-1

SHEET 1 OF 2



# FIELD TEST BORING RECORD

PROJECT: Building P-64  
 S.O. NO.: 19010-51-SRN BORING NO.: B-1

DRILL RECORD							VISUAL DESCRIPTION					
DEPTH	SOIL	Sample ID	Samp. Rec.	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL	ELEVATION
	ROCK	Type-No. (N = No Samp.)	(Ft. & %)	RQD (Ft & %)	Pen. Rate	PIED (ppm)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations	ROCK	
1		S-6	2.0 2.0	1 1		0	SAND, medium-grained, trace silt	Gray	very loose	wet		
2	12.0		100%	1								
3		S-7	2.0 2.0	0 1		0	SAND, medium-grained, trace silt	Gray	very loose	wet		
4	14.0		100%	1								14.0
5							End of boring at 14.0 ft.					
6												
7												
8												
9												
0												

DRILLING CO.: ATFC Associates BAKER REP.: R. Bowelli  
 DRILLER: M. Miller BORING NO.: B-1 SHEET 2 OF 2

# TEST BORING RECORD

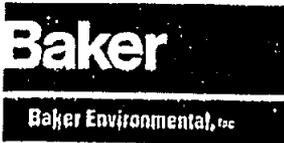
PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

BORING NO.: B-1

SAMPLE TYPE						DEFINITIONS	
S = Split Spoon	A = Auger					SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5')	
T = Shelby Tube	W = Wash					RQD = Rock Quality Designation (%)	
R = Air Rotary	C = Core					Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)	
D = Denison	P = Piston					Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis	
N = No Sample							
Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
11	S-6	2.0 2.0 100%	1		0	SAND, medium-grained, trace silt; gray; very loose; wet	14.0'
12			1				
13			0				
14	S-7	2.0 2.0 100%	1		0	SAND, medium-grained, trace silt; gray; very loose; wet	14.0'
14	End of Boring at 14.0'						
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

# FIELD TEST BORING RECORD



PROJECT: Building P-64  
 CTO NO.: 19010-51 SRN  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: 13.94 TOP OF STEEL CASING: 13.66

RIG: <u>Mobile B-57</u>					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
LENGTH	2'		5'		5/29/91	14.0	SUNNY, 70-80°F	--	--
TYPE	STD		HSA		5/30/91	--	SUNNY, 80-90°F	6.64	24 hrs
HAMMER WT.	140 lb.								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14ft taking continuous 2-foot split spoon samples;  
Monitoring well installed at 14.35 ft

DRILL RECORD							VISUAL DESCRIPTION					
DEPTH	SOIL ROCK	Sample ID	Samp. Rec. (Ft. & %)	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL ROCK	ELEVATION
				RQD (FL & %)	Pen. Rate	PID (ppm)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations		
1		S-1	1.2 / 2.0	16 / 6		0	SAND, fill material, trace gravel	brown-gray	medium dense	dry		
2	2.0		60%	5			SAND, fill material, trace carbon frags	brown-gray-black	loose	dry		
3		S-2	1.4 / 2.0	4		0	SAND, fine-grained, trace gravel, trace silt	gray-brown	very loose	damp to moist	30'	10.9
4	4.0		70%	3			SAND, fine to medium-grained, trace silt, trace clay	gray-brown	very loose	damp to moist; water-table noted at 5.5-6.0'	40'	9.94
5		S-3	1.8 / 2.0	1		0	SAND, fine to medium-grained, trace silt	gray-white	loose	wet; petroleum odor noted in spoon sample		
6	6.0		90%	1			SAND, medium to coarse-grained, trace silt;	gray-white-brown	loose	wet; petroleum odor noted in spoon sample	70'	7.2
7		S-4	2.0 / 2.0	2		1-3						
8	8.0		100%	5								
9		S-5	0.95 / 2.0	3		0.5						
10	10.0		48%	1								

DRILLING CO.: ATEC Associates BAKER REP.: R. Bowelli  
 DRILLER: M. Miller BORING NO.: NW-1 SHEET 1 OF 2

# FIELD TEST BORING RECORD

**Baker**

Baker Environmental, Inc.

PROJECT: Building RG4  
CTO NO.: 19010-SI-SRN

BORING NO.: MW-1

DRILL RECORD							VISUAL DESCRIPTION					
DEPTH	SOIL	Sample ID	Samp. Rec.	SPT Blows Per 0.5'	Lab. Class	Lab. M.C. %	Classification (Grain Size, Principal Constituents, Etc.)	Color	Consist. or Density	Moisture Content, Organic Content, Plasticity, and Other Observations	SOIL	ELEVATION
	ROCK	Type-No. (N = No Samp.)	(Ft. & %)	RQD (Ft. & %)	Pen. Rate	MWD (PPM)	Classification (Name, Grain Size, Principal Constituents, Etc.)	Color	Hardness	Weathering, Bedding, Fracturing, and Other Observations	ROCK	
1			20 20	2 1		0	SAND, fine to medium-grained, trace silt	Dark gray	Very loose	Wet; petroleum odor noted in spoon sample		
2	12.0	S-6	100%	1			SAND, fine to medium-grained, trace silt	Dark gray	Very loose	Wet; petroleum odor noted in spoon sample		
3			20 20	1 1		0		Dark gray gray-brown				
4	14.0	S-7	100%	1			End of boring at 14.0'					14.0' :0.
5												
6												
7												
8												
9												
0												
1												
2												
3												
4												
5												
6												
7												
8												
9												
0												

DRILLING CO.: ATEC Associates  
DRILLER: M. Miller

BAKER REP.: R. Bonelli  
BORING NO.: MW-1

# FIELD WELL CONSTRUCTION LOG

**Baker**

Baker Environmental, Inc.

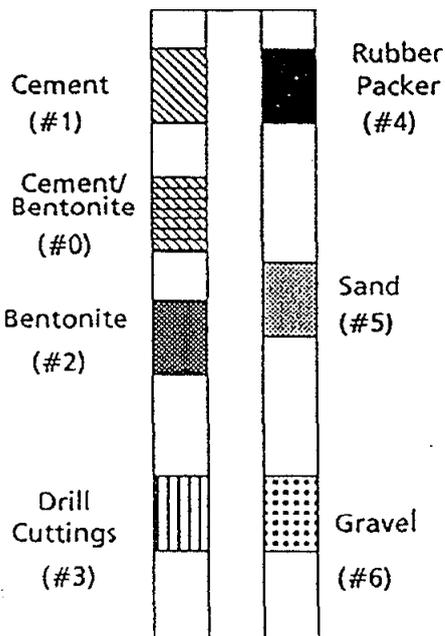
PROJECT: Building P-64 DATE: 5/29/91  
 CTO NO.: 19010-SF-SRW BORING NO.: MW-1  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: 13.94 TOP OF STEEL CASING: 13.66  
PVC

## Pay Items

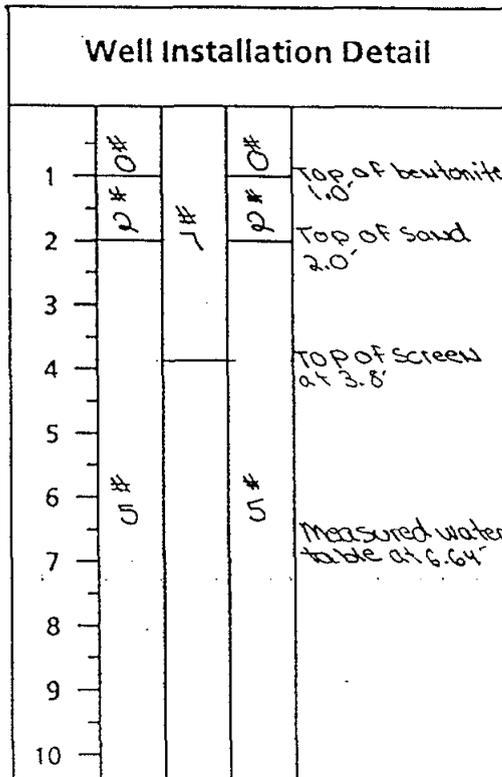
Item	Quantity	Unit	Remarks
SAND - Industrial #2	3 1/2	bags	
Bentonite - Pellets	1/2	bucket	
Screen - #20 Slot, 2-inch PVC	10	LF	
Casing - 2 in PVC	4	LF	
Mouthhole Cover	1	ea	
Locking Cap + lock (#2006)	1	ea	
Cement/bentonite	1	LF	

WELL INFORMATION	DIAM. (INCHES)	TYPE	TOP DEPTH (FT.)	BOTTOM DEPTH (FT.)
Well Casing	2.0	Sch 40 PVC	0.3	3.8
Well Screen	2.0	Sch 40 PVC	3.8	13.9

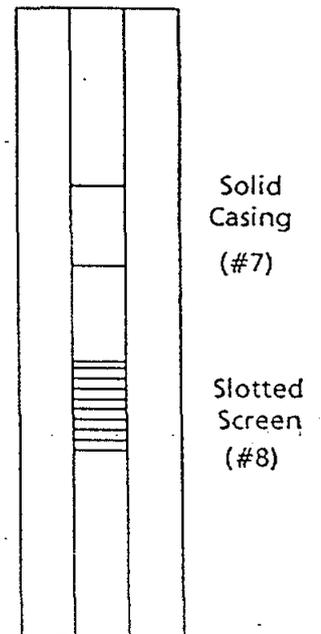
### Backfill Key



### Well Installation Detail



### Well Key



DRILLING CO.: ATFC Associates  
 DRILLER: M. Miller

BAKER REP.: R. Boxelli  
 BORING NO.: MW-1 SHEET 1 OF 2

**Baker**

Baker Environmental, Inc.

**TEST BORING AND WELL CONSTRUCTION RECORD**PROJECT: Building P-64S.O. NO.: 19010-51-SRNBORING NO.: MW-1

COORDINATES: EAST: \_\_\_\_\_

NORTH: \_\_\_\_\_

ELEVATION: SURFACE: 13.94TOP OF PVC CASING: 13.66

<b>RIG: Mobile B-57</b>									
	SPLIT SPOON	CASING	AUGERS	CORE BARREL	DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	1-3/8" ID		6-1/4" ID		5/29/91	14.0	sunny, 70°-80° F	---	---
LENGTH	2.0'		5.0'		5/30/91	---	sunny, 80°-90° F	6.64	24 hrs.
TYPE	STD		HSA						
HAMMER WT.	140 lb.								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; monitoring well installed at 14.35 ft.

SAMPLE TYPE		WELL INFORMATION	DIAM	TYPE	TOP DEPTH (FT)	BOTTOM DEPTH (FT)
S = Split Spoon	A = Auger	Well Casing	2"	Sch. 40 PVC, flush-jointed	0.28	3.8
T = Shelby Tube	W = Wash	Well Screen	2"	Sch. 40 PVC, flush-jointed	3.8	13.9
R = Air Rotary	C = Core					
D = Denison	P = Piston					
N = No Sample						

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevation Ft. MSL
1		1.2	16			SAND, fill material, trace gravel; brown-gray; medium dense; dry	Top of bentonite at 1.0'	
2	S-1	2.0 60%	12 6 5		0			
3		1.4	4			SAND, fill material, trace carbon frags; brown-gray-black; loose; dry	Top of sand at 2.0'	10.94'
4	S-2	2.0 70%	4 4 3		0			
5		1.8	1			SAND, fine-grained, trace gravel, trace silt; gray-brown; very loose; damp to moist	Top of screen at 3.8'	9.94'
6	S-3	2.0 90%	1 1 1		0			
7		2.0	1			SAND, fine to medium - grained, trace silt; gray-white; loose; wet; petroleum odor noted in spoon sample	Measured water table at 6.64'	7.30'
8	S-4	2.0 100%	2 3 5		1-3			
9		.95	3			SAND, medium to coarse-grained, trace silt; gray-white-brown; loose; wet; petroleum odor noted in spoon sample		6.94'
10	S-5	2.0 48%	1 1 1		0.5			

Match to Sheet 2

DRILLING CO.: ATEC AssociatesBAKER REP.: R. BonelliDRILLER: M. MillerBORING NO.: MW-1SHEET 1 OF 2

**Section 5.10**  
**Photoionization Detector (PID) SOP**

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**PHOTOIONIZATION DETECTOR (PID)  
HNu MODEL PI 101**

**1.0 PURPOSE**

The purpose of this SOP is to provide general reference information for using the HNu Model PI 101 photoionization detector (PID), or an equivalent or similar instrument, in the field. Calibration and operation, along with field maintenance will be included in this SOP.

**2.0 SCOPE**

This procedure provides information on the field operation and general maintenance of the HNu (PID). Application of the information contained herein will ensure that this type of field monitoring equipment will be used properly. Review of the manufacturer's instruction manual is a necessity for more complete information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

**3.0 DEFINITIONS**

PID - Photoionization Detector

Ionization Potential - In this case, a numeric equivalent that expresses the amount of energy needed to replace an electron with a photon. This energy is further defined in terms of electron volts (eV).

**4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the air monitoring techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing air monitoring activities, have been briefed and trained to execute these procedures.

**Field Investigation Personnel** - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project procedures as directed by the Field Team Leader and the Project Manager. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the field log book and the air monitoring result sheets that accompany each piece of air monitoring equipment.

## **5.0 PROCEDURES**

The HNu utilizes the principle of photoionization whereby contaminant molecules enter the ion chamber and electrons are displaced by ultraviolet photons producing positive ions. These displaced positive ions are in turn collected on a special electrode. As the positive ions collect on the electrode, they create an electrical current which is amplified and displayed on the meter as a concentration in parts per million (ppm).

The HNu is only effective for contaminants that have ionization potentials (IP) of less than or equal to the electron volt (eV) capacity of the lamp (i.e., methane, having an IP of 12.98 eV, will not be detected at a lamp potential of 11.7 eV). The standard lamp is 10.2 eV with optional lamps of 9.5 eV and 11.7 eV, respectively. Also, the HNu is capable of detecting some inorganic compounds.

The following subsections will discuss HNu calibration, operation, and maintenance. These sections, however, should not be used as a substitute for the manufacturer's instruction manual.

### **5.1 Calibration**

For calibration purposes, the following items will be needed:

- \*Gas cylinder containing 100 parts per million of isobutylene/balance in air.

- A 0.25 or 0.30 liters per minute regulator.
- Connector tubing.
- Screwdriver set.

\*Note: Do not rely on accuracy of rated concentration when cylinder content drops to <30 psi.

Prior to each use, make sure that the battery is fully charged, the ultraviolet lamp is working, and that the fan is operating and drawing air into the probe (fan operates at approximately 100 cc/minute). Procedures for completing these preliminary activities are given in the manufacturer's instruction manual.

To calibrate the HNu, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 3-5 in the manufacturer's instruction manual.

- Turn the function control switch to the standby position and zero the instrument by turning the zero adjustment knob to align the indicator needle with zero on the readout meter.
- Set the range on the HNu. Choices for range are 0-20, 0-200, and 0-2,000 ppm, respectively. Range choice must take into account the concentration of the calibration gas. If you have to zero the instrument in the desired range, record background if present.
- Attach tubing to the regulator.
- Attach the free end of the tubing to the probe and turn on the calibration gas.
- If the reading on the meter is not  $\pm 5$  percent of the concentration of the calibration gas, adjust the span setting knob until the meter reads accordingly. If after adjusting the span setting knob the readout meter is still not responding, refer to the manufacturer's instruction manual. Also, when the HNu is calibrated it should respond to a minimum of 90 percent of the concentration of the contaminant within three seconds after introduction of that contaminant.
- Record the calibration on the calibration log sheet which accompanies the HNu.

## 5.2 Operation

Note: **IMPORTANT** - The HNu must be "zeroed" in a fresh air environment. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the HNu, check that the battery is fully charged, and that the ultraviolet lamp and the fan are working properly.

- Select your desired range. HNu ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range.

Note: When using an HNu make sure that you do not stick the probe in water or soil during sampling. This will cause erroneous readings and will possibly damage the HNu.

### 5.3 Maintenance

The best way to keep an HNu operating properly is to keep it as clean as possible. HNu's should be decontaminated and wiped down after each use.

#### **Corrective Maintenance**

- The ultraviolet lamp should be periodically cleaned. This is done by a special compound supplied by HNu Systems, Inc.; please consult the manufacturer's instruction manual for specific cleaning instructions.
- The ionization chamber can be periodically cleaned with methyl alcohol and a swab.
- Documenting the HNu's observed symptoms and then referring to the manufacturer's instruction manual section on troubleshooting also can be employed. If this does not work, the Field Team Leader should be consulted for an appropriate course of action.

Repair and Warranty Repair - HNu's have different warranties for different parts, so documenting the problem and sending it into the manufacturer assists in expediting repair time and obtaining appropriate warranty service.

### 6.0 **QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the field log book and the air monitoring result sheets that accompany the HNu.

- Identification - Site name, location, CTO number, weather (humidity), media sampled (air, soil, water, etc.), HNu's serial number, time and date, resultant concentration, and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the HNu meter had wide range fluctuations during air monitoring activities).

**7.0 REFERENCES**

HNu Systems, Inc. Instruction Manual. Model PI 101, 1986.

**Section 5.11**  
**Flame Ionization Detector (FID) SOP**

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**FLAME IONIZING DETECTOR (FID)  
FOXBORO OVA 128**

**1.0 PURPOSE**

The purpose of this procedure is to provide general reference information for using the Foxboro OVA 128, Flame Ionization Detector (FID) or an equivalent or substitute device, in the field. Calibration, operation, and field maintenance will be included in this SOP.

**2.0 SCOPE**

This procedure provides information on the field operation and general maintenance of the Foxboro OVA 128 (FID). Application of the information contained herein will ensure that this type of field monitoring equipment will be properly operated. Review of the manufacturer's operating manual is a necessity for more detailed descriptions and operating information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

**3.0 DEFINITIONS**

FID - Flame Ionization Detector

**4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the air monitoring techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing air monitoring activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project procedures as directed by the Field Team Leader and the Project Manager. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the field log book and the air monitoring result sheets that accompany each piece of air monitoring equipment.

## 5.0 PROCEDURES

The OVA 128 utilizes the principle of flame ionization whereby contaminant molecules enter the detector chamber and are exposed to a hydrogen flame which ionizes the organic vapors. As the vapors are burned they leave positively-charged carbon-containing ions. These positive ions are driven by an electric field to a collecting electrode. As the positive ions collect on the electrode, a current is created. This current corresponds to the collection rate of the positive ions. The current is then measured with a linear electrometer preamplifier which produces a signal proportional to the ionization current. This signal is then amplified by a signal conditioning amplifier and sent to the readout assembly and/or the strip chart recorder in parts per million (ppm).

The OVA 128 is an intrinsically safe organic vapor monitor, but it cannot be used in atmospheres that are oxygen deficient and it is unable to detect inorganic compounds, including poisonous atmospheres. Caution must be used when filling the hydrogen tank to maintain safe operating pressures and temperatures. Only prepurified or zero grade hydrogen will be used.

The following subsections will discuss calibration, operation and maintenance of the OVA 128. These sections, however, should not be used as a substitute for the manufacturer's operating manual.

### 5.1 Calibration

Primary calibration involves internal adjustments and should only be done by the manufacturer or an authorized equipment technician.

The following items will be needed for secondary calibration of the OVA 128:

- Calibration gas (usually methane but can be contaminant specific).
- Gas regulator.
- Tedlar bag (usually two to three liter capacity).
- Tubing.
- Screw driver set.

Prior to each use, make sure that the battery is fully charged (a minimum of 7.5 on the 1x scale), the pump is working, there is a sufficient supply of hydrogen gas in the tank, and the ignitor is working (refer to operating manual).

#### Points to follow for "Single Sample Calibration:"

- For methane calibration in the 90 to 100 ppm range, set to 10x scale with gas select control to 300.
- Use calibration adjustment knob to "zero" the meter.
- Introduce methane sample of known concentration from Tedlar Bag and adjust gas select knob so that meter reading equals sample concentration. Withdraw methane sample, allow meter reading to stabilize and repeat. Discontinue calibration when meter reaction to sample introduction is consistent.
- If there is a problem with calibration, consult the manufacturer's operating manual or an experienced technician.
- Refer to manufacturer's operating manual for additional information.

Since the Foxboro OVA 128 uses flame ionization, it has a broad application in terms of which organic contaminants it can ionize. Care must be taken to document background readings before zeroing the instruments. Note: the OVA 128 hydrogen flame ionization detector is more sensitive to hydrocarbons than any other class of organic compounds.

#### 5.2 Operation

Review of the Startup Procedure (given on page 7 of the manufacturer's operating manual) is critical prior to actual field operation.

#### Points to follow for startup of the OVA 128:

- After the OVA is assembled check that the battery level is sufficient for operation. At a minimum, a reading of 7.5 on the 1x scale should provide four hours of operation.

- Turn instrument switch on and allow a minimum of a five minute warmup before turning pump on.
- Use calibrate adjust knob to set meter to predetermined level for activating audible alarm (if desired).
- Set to 1x scale and adjust meter reading to zero.
- Open hydrogen tank valve to be certain that there is enough hydrogen in the tank for operation. The OVA will use approximately 150 psi/hour. Then open the hydrogen supply valve noting that the reading should be within the range of 8 to 12 psi.
- After approximately one minute depress the ignitor button until the hydrogen has been ignited. **DO NOT HOLD THE IGNITOR BUTTON IN FOR MORE THAN FIVE SECONDS.** If hydrogen does not light, wait five minutes and try again. If it still does not light, consult manufacturer's operating manual.
- The instrument is now ready for calibration, if required.

Once the Foxboro OVA 128 has been running and stabilized for 15 minutes, it is ready for "Survey Mode" procedures. Set the calibrate switch to the desired range and the Foxboro OVA 128 is now ready for field operation.

Note: Care must be taken when operating the Foxboro OVA 128. Special areas of concern are the probe assembly and the analyzer. Do not stick the probe in water or soil; this will give erroneous readings and could possibly damage the pump. The analyzer unit must be kept clean and away from physical hazards, and the exhaust free from obstructions.

For shutdown and refueling, follow manufacturer's recommend procedures.

### 5.3 Maintenance

Preventive maintenance consists of keeping the Foxboro OVA 128 as clean as possible. The Foxboro OVA 128 must be decontaminated and wiped down after each use.

The other type of maintenance is the manufacturer's scheduled maintenance which consists of the following:

- Check particle filters on a monthly basis.
- Check quad rings on a monthly basis or as needed.

- Clean burner chamber on a quarterly basis or as needed.
- Primary calibration and factory check on an annual basis or when non-operational.
- Secondary calibration on a daily or weekly basis depending on usage.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the field log book and the air monitoring result sheets that accompany the Foxboro OVA 128.

- Identification - Site name, location, CTO number, media sampled (air, soil, water, etc.), Foxboro OVA 128 serial number, time and date, resultant concentration, and identification of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Foxboro OVA 128 meter had wide range fluctuations during air monitoring activities).

## 7.0 REFERENCES

Foxboro Model OVA 128 Century Organic Vapor Analyzer Instruction Manual, 1985.

**Section 5.12**  
**Water Level, Water-Product Level,**  
**and Well Depth Measurements SOP**

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## **WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS**

### **1.0 PURPOSE**

The purpose of this procedure is to describe the method of determining groundwater levels and product levels, if present, in groundwater monitoring wells. This procedure also describes determining the depth of a well.

### **2.0 SCOPE**

The methods described in this SOP generally are applicable to the measurement of water levels, product levels, and well depths in monitoring wells and piezometers.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

**Field Team Leader** - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of water level, water product level, and well depth measurements.

## 5.0 PROCEDURES

Calculations on water level and water-product level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient (i.e., the direction of groundwater flow and the potential rate of movement [magnitude] in the horizontal plane).
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow and the potential rate of movement in the vertical plane).
- Product thicknesses (either floating or sinking product).

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring water levels, product levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the steel protective casing, and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum.

### 5.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the top of the protective steel casing, unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The location on the electric cord against the measuring point surveyes on the top of the steel casing is marked. The water level is recorded to the nearest foot (rounding down) using the graduated markings on the water level indicator cord. The water level then is measured off the cord to the nearest 0.01 foot using an engineers scale. The

measurements are combined (feet plus hundredths of a foot) to yield a measurement of the depth to water below the top of the steel casing. This measurement, when subtracted from the measuring point elevation, yields the water level elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

## 5.2 Groundwater-Product Level Measurements

The procedure for groundwater product level measurement is nearly identical to that for water level measurements. The only differences are the use of an interface probe that detects both product and water, and the indication signal given by the measurement device. Typically, encountering product in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the product layer in a well and the water/product interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

- WTE<sub>c</sub> = Corrected water table elevation
- WTE<sub>a</sub> = Apparent water table elevation
- 0.80 = Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

## 5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape

is taut. The well depth measurement is read directly off of the measuring tape, at the top of the steel casing, to the nearest 0.01-foot and recorded in the field logbook.

#### **5.4 Decontamination of Measuring Devices**

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with:
  - ▶ Methanol or acetone (EPA Region I)
  - ▶ Methanol or acetone (EPA Region II)
  - ▶ Methanol (EPA Region III)
  - ▶ Isopropanol (EPA Region IV)
- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

#### **6.0 QUALITY ASSURANCE RECORDS**

The field logbook shall serve as the quality assurance record for water, product level or well depth measurements.

#### **7.0 REFERENCE**

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**Section 5.13**  
**Groundwater Sample**  
**Acquisition SOP**

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## **GROUNDWATER SAMPLE ACQUISITION**

### **1.0 PURPOSE**

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

### **2.0 SCOPE**

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team

Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

## 5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. For wells that can be pumped or bailed to dryness with the sampling equipment being used, the well shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from

separation of flow streams by physical division (for example, around clay leases) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Pumping rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site specific and must be addressed in the Sampling and Analysis Plan.

#### **5.1 Sampling, Monitoring, and Evacuation Equipment**

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.
2. Field tools and instrumentation - Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; water-level indicator; and, where applicable, flow meter.
3. Pumps
  - a. Shallow-well pumps - Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
  - b. Deep-well pumps - Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing - Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment - Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with

tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails - Plastic, graduated.
7. Decontamination solutions - Decontamination materials are discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

## 5.2 Calculations of Well Volume

Calculation of gallons/linear feet from a well:

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Where:

7.48 = the conversion factor of cubic feet to gallons

A =

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To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).

2. Determine well or casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (if not known from past records) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure.
5. Calculate number of linear feet of static water (total depth or length of well pipe or casing minus the depth to static water level).
6. Calculate the volume of water in the casing:

$$V_W = (\pi/4) D^2 (TD - DW)$$

$$V_{gal} = V_W \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = V_{gal} (\# \text{ Well Vol})$$

Where:

$V_W$	= Volume of water in well in cubic feet (i.e., one well volume)
$\pi$	= pi, 3.14
$D$	= Well diameter in feet (use (D/12) if D is in inches)
$TD$	= Total depth of well in feet (below ground surface or top of casing)
$DW$	= Depth to water in feet (below ground surface or top of casing)
$V_{gal}$	= Volume of water in well in gallons
$V_{purge}$	= Volume of water to be purged from well in gallons
$\# \text{ Well Vol.}$	= Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note:  $V_{purge}$  should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

### 5.3 Evacuation of Static Water (Purging)

The amount of flushing a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove

the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly developed when the values have stabilized.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

### 5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- Potentially excessively time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samplers - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

#### 5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

##### 5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).

4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
7. Record measurements of specific conductance, temperature, and pH during purging to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.
8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.
11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).
12. Purgeable organics vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which 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 capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure.
13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.

14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

#### **5.4.2 Sample Containers**

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2-047B.

#### **5.4.3 Preservation of Samples and Sample Volume Requirements**

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

#### **5.4.4 Field Filtration**

In general, preparation and preservation of water samples involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be collected and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of monitoring wells is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

#### **5.4.5 Handling and Transporting Samples**

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

#### **5.4.6 Sample Holding Times**

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

### **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

## 7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D4448-85A**

**STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS**



## Standard Guide for Sampling Groundwater Monitoring Wells<sup>1</sup>

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).<sup>2</sup> The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for  $\mu\text{g/L}$  (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

### 3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

Current edition approved Aug. 23 and Oct. 25, 1985. Published May 1986.

<sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of this guide.

**TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program**

Sample and Measurement	Volume Required (mL)	Container P— Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H <sub>2</sub> SO <sub>4</sub> to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluoro- carbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluoro- carbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocar- bon-lined sep- tum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

#### 4. Well Flushing (Purging)

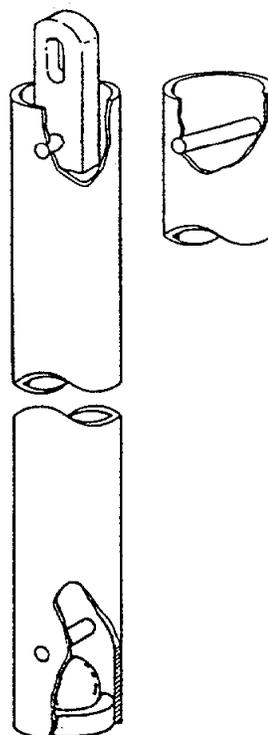
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Baller

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

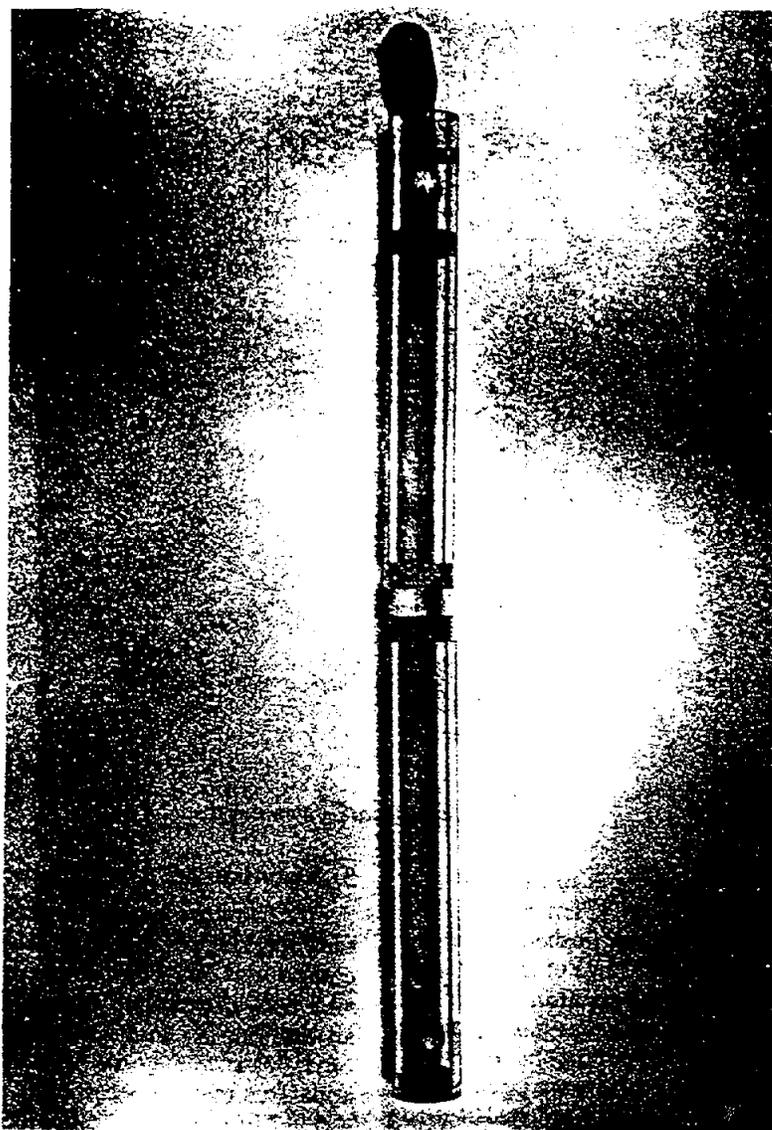
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

## 5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ( $\mu\text{g/L}$  levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

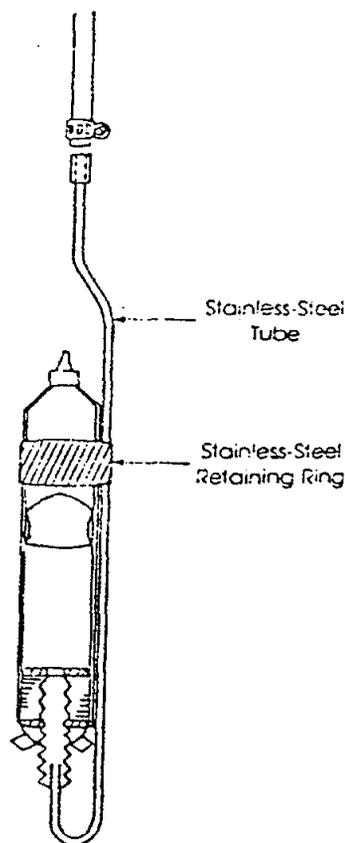
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

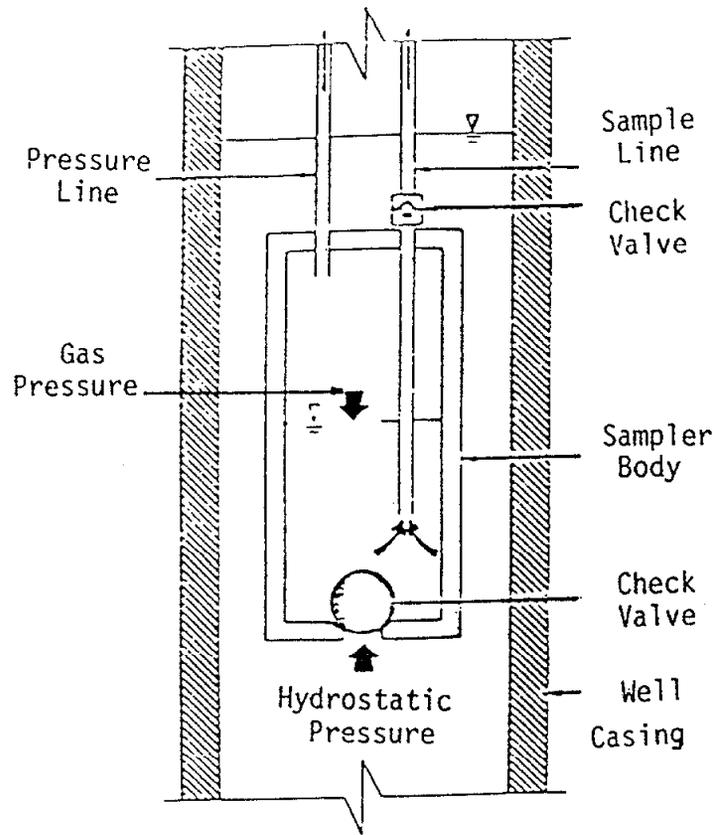
## 6. Sampling Equipment

6.1 There is a fairly large choice of equipment present available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categorized into the following eight basic types.

### 6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposure surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in de-



NOTE—Taken from Ref (5).

FIG. 4 The Principal of Gas Displacement Pumping

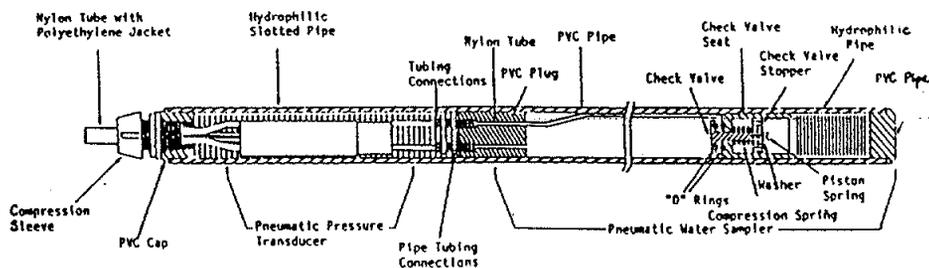
wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check

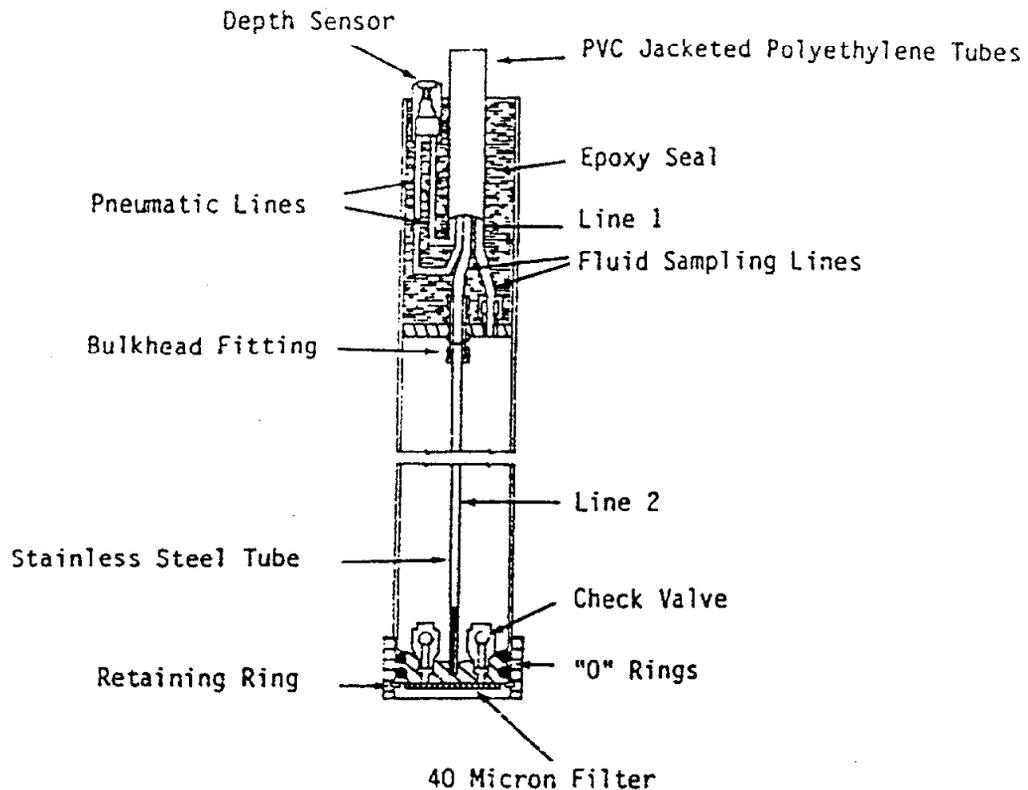
valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve-bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

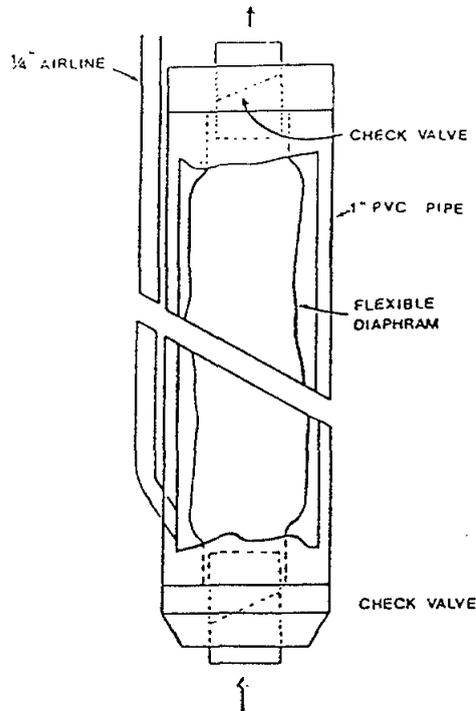
of thief or messenger devices are available in various materials and shapes.

#### 6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton<sup>3</sup> for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

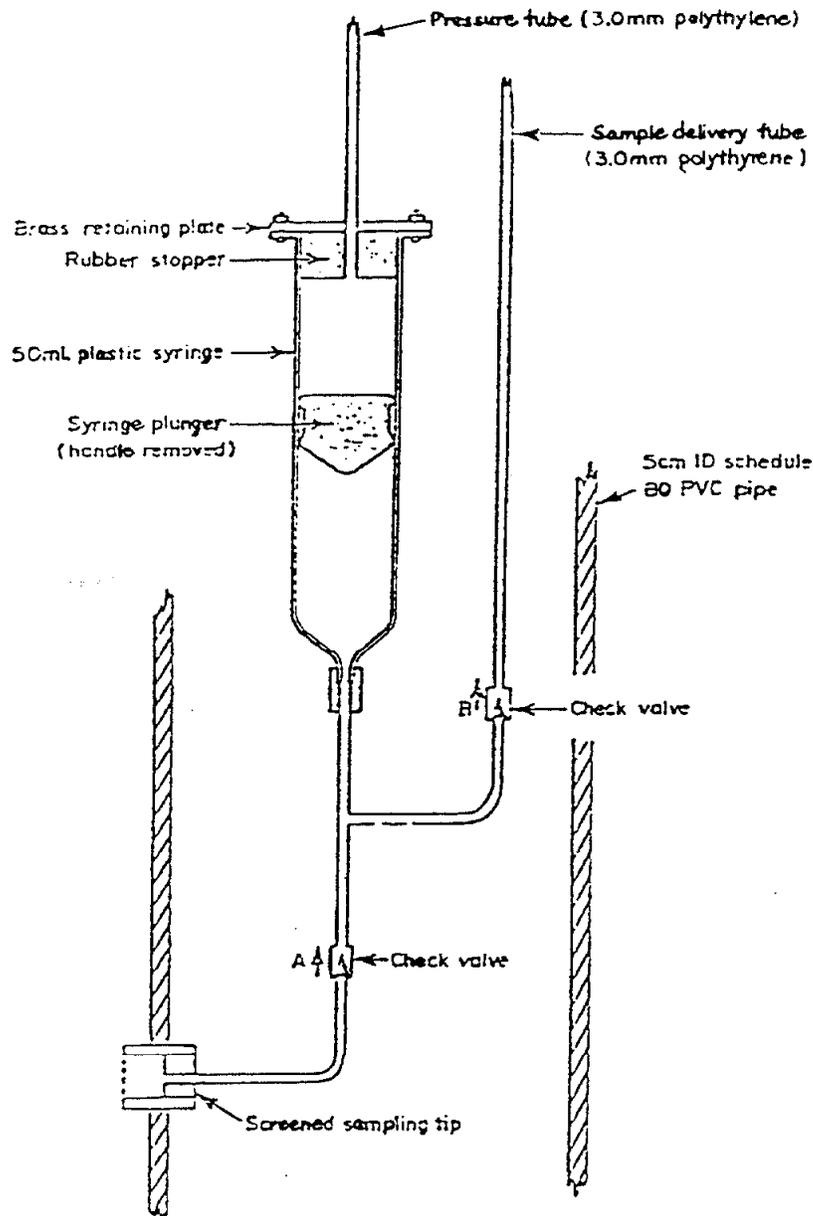
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

#### 6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

<sup>3</sup> Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

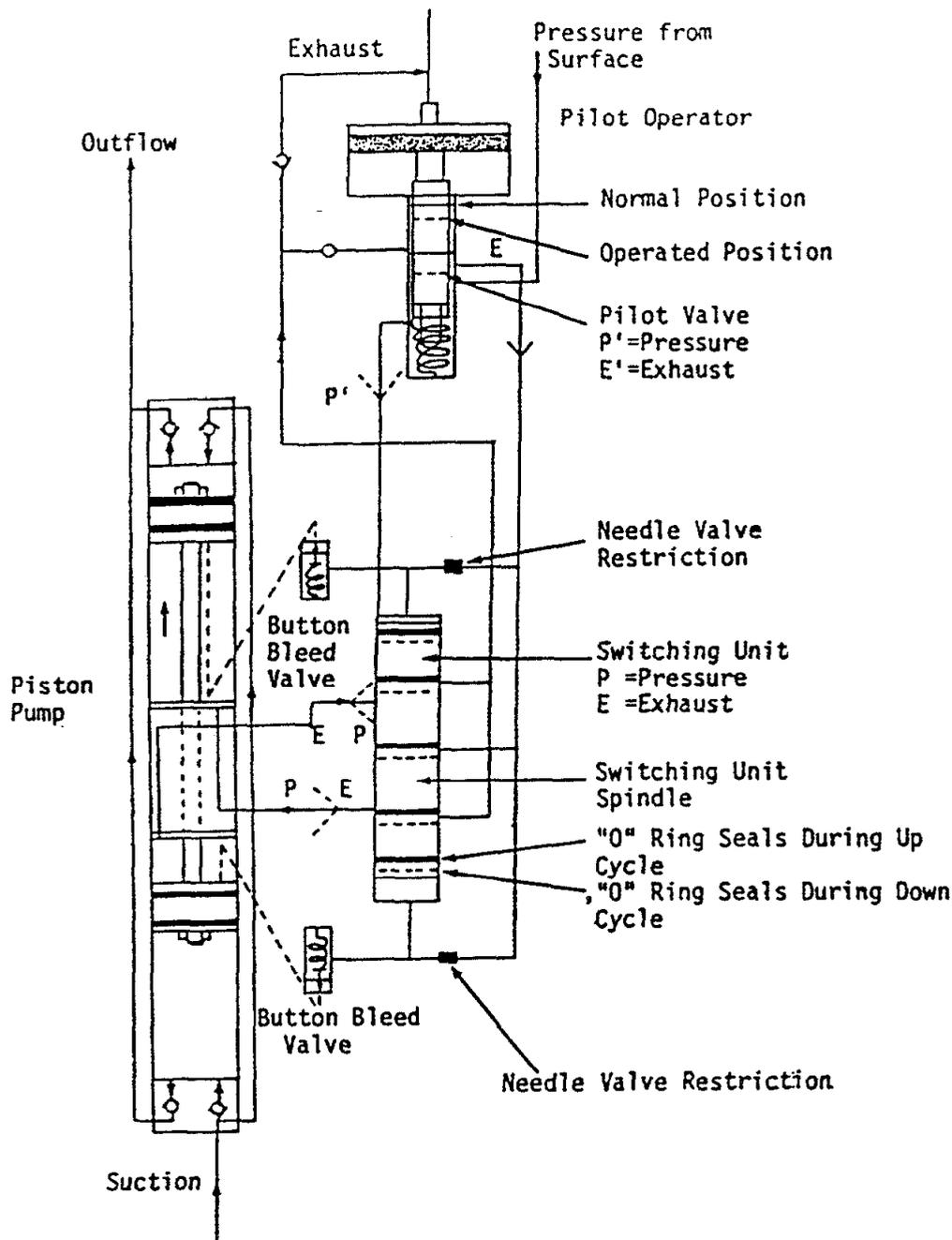
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

#### 6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

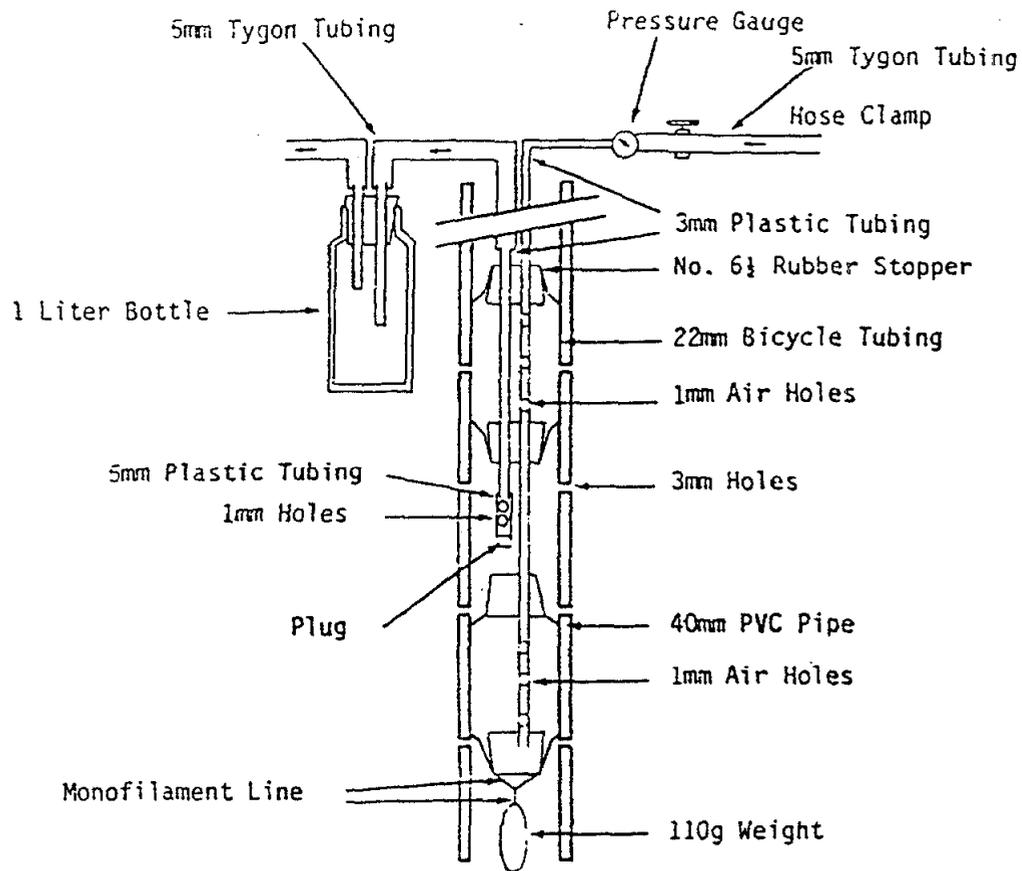
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sampler in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sampler with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

#### 6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.<sup>3</sup> A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

#### 6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

#### 6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

## 7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

**Section 5.14**  
**In-Situ Hydraulic Conductivity**  
**Testing SOP**

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## WELL-HEAD TESTING (SLUG-TESTS)

### 1.0 PURPOSE

This SOP provides a general description of the technical methods and field procedures of a representative suite of well-head testing (slug tests) to approximate part of the aquifer parameters. The well-head tests are to be considered at all times as a reconnaissance of the aquifer parameters across an area (the site under investigation); they are never reliable as definitive calculations of those parameters either at a point (an individual well) or across an area (the well-field). Aquifer testing (pump-tests) to calculate these parameters is discussed in SOP F401. The descriptions herein are general in nature and do not apply to a specific well, well-field or project. Prior to designing well-head tests as part of a site investigation and during execution of the tests, the Project Manager, Site Manager and Program Geohydrologist must consult on the appropriate procedures; these procedures must then be recorded in the project documents.

### 2.0 SCOPE

The procedures described here apply to tests for evaluation of the aquifer parameters at sites being investigated under both the Underground Storage Tank (UST) Program and the Installation Restoration (IR) Program of Navy CLEAN. The well-head tests apply both to consolidated and unconsolidated strata; and to confined, semiconfined and phreatic conditions. The aquifer parameters subject to evaluation and approximate calculation are the Coefficient of Transmissivity or the Hydraulic Conductivity.

### 3.0 DEFINITIONS

The following definitions are extracted or abstracted from standard references (Section 7); further discussions are available in those references.

Hydraulic Conductivity (K) - A medium has a hydraulic conductivity (K) of unit length per unit time (for example, feet per day [ft/d]) if it will transmit in unit time a unit volume of groundwater at the prevailing viscosity through a cross-section of unit area, measured at right

angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman 1979).

Coefficient of Transmissivity (T) - The transmissivity (T) is the rate (for example, in gallons per day per foot of drawdown [gpd/ft]) at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman 1979). The transmissivity is mathematically equivalent to the hydraulic conductivity multiplied by the saturated thickness:  $T = Kb$ .

Saturated Thickness (b) - The saturated thickness (b) is the distance (for example, in feet [ft]) from the elevation of the upper groundwater surface in either a phreatic system (the water table) or a confined or semiconfined system (the lower boundary of the upper confining or semiconfining layer, but not the potentiometric surface in a well) to the elevation of the upper boundary of the lower confining or semiconfining layer for the aquifer or water-bearing layer.

Drawdown (s) - The drawdown (s) in any well affected by a well-head test is the differential distance, usually in feet (ft), between the static (unstressed) water level in the well measured immediately prior to the test, and the (stressed) water level at the specified time during the test. (Due to the expectably short duration available for examination of trends in the water-bearing layer preceding and following individual tests, trends in static levels are ignored for the purposes of Navy CLEAN.)

Falling-Head Test - The falling-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically upward at the initiation of the test; the decay of this artificially impressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Rising-Head Test - The rising-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically downward at the initiation of the test; the decay of this artificially depressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Confined Conditions - Confined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are impermeable to water, and where the total head of the system at the upper surface of the groundwater is

greater than atmospheric pressure. For a confined system, when a well is drilled below the bottom of the upper confining layer, the water level in the well rises to an elevation (at least) within or (possibly) above the upper confining layer.

Unconfined (Phreatic) Conditions - Unconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically only by a single surface or layer at the bottom of the water-bearing layer that is impermeable or semipermeable to water, and where the total head of the system at the upper surface of the groundwater is equal to atmospheric pressure. For an unconfined or phreatic or water-table system, when a well is drilled below the upper surface of the groundwater, the water level in the well does not rise to a significantly higher elevation.

Semiconfined Conditions - Semiconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are less permeable to water than the water-bearing layer itself, and where the total head of the system is greater than atmospheric pressure. For a semiconfined system, when a well is drilled below the bottom of the upper semiconfining layer, the water level in the well rises to an elevation within or above the upper semiconfining layer. However, one or both of the semiconfining layers will be, in some fashion, in hydraulic and hydrologic communication with the water-bearing layer, and may contribute water to or receive water from that layer.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation procedures which deviate from those presented herein.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that the procedures herein are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Site Geologist - Responsible for determining the need for hydrogeologic testing and has overall responsibility for the planning and implementation of the test. Evaluation and interpretation of the data is also the responsibility of the Site Geologist.

Program Geologist - Responsible for QA/QC oversight of the planning and implementation of the test, along with the evaluation of data generated by the test.

## 5.0 PROCEDURES

The procedures presented in this section concern the administration and execution of well-head tests; the technical content of a given test will be established by the project and program management for each instance according to experience and best professional practice.

### 5.1 Overview

The well-head test will conform to the objectives of the investigation and to standards of good practice common in geohydrologic investigations. Sufficient personnel, and sufficient standard and special equipment will be available for the intentions of the test. Data collection will conform to the practice described in SOP F202 (Water Level, Water/Product Level Measurements and Well Depth Measurements); additionally, time will be measured and recorded no less precisely than the nearest minute or half-minute, as appropriate, while conforming to the intent of the test. Containment and disposal of discharged liquids will conform to the general status of the site being investigated.

### 5.2 Applications

The well-head test will usually be divided into three stages:

1. Static measurement
2. Falling-head test
3. Rising-head test

Each stage will normally be run for no more than 30 minutes. The water level in the test well should recover to between 90 and 100 percent of static conditions before beginning the next stage. Should the recovery be less than acceptable after 30 minutes from the start of the first stage, or should other field conditions conspire adversely, the second stage will not be run. Measurements of recovery during the first stage may then be extended to 60 minutes.

### 5.2.1 Static Measurement

This stage of the well-head test provides the data on static conditions to be used in subsequent approximation of the aquifer parameters. The static water levels are to be measured no later than immediately prior to the first stage of the test, whether falling-head or rising-head. The levels should also have been measured once daily, if possible, for two or more days preceding the test; the optimal measurement program would provide continuous measurement and recording of levels in all wells to be used for a period of several weeks preceding well-head testing.

### 5.2.2 Falling-Head Test

The falling-head stage of the well-head test is usually conducted before the rising-head. This stage imposes a stress on the water-bearing layer by nearly instantaneously injecting water or introducing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters. The test should be planned to use between 50 and 75 percent of the available displacement in the well, but may use between 1 and 100 percent, at the discretion of the Site Manager. The use of a solid slug is favored by the program. The impressed head developed by this test must rise above the top of the well screen.

### 5.2.3 Rising-Head Test

The rising-head stage of the well-head test imposes a stress on the water-bearing layer by nearly instantaneously extracting water or removing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters. The test should be planned to use between 50 and 75 percent of the available displacement in the well, but may use between 1 and 100 percent, at the discretion of the Site Manager. The use of a solid slug is favored by the program.

### 5.3 Measurements and Measurement Intervals

The measurement intervals for water levels in the test well during each stage will be modified from the following suggestions:

<u>Time Since Start of Test (min)</u>	<u>Measurement Frequency (min)</u>
0-5	0.5
5-10	1
10-20	2
20-60	5

The actual time and the test time for each reading will be recorded, with the water level measured to a precision of 0.01 ft.

The sequence of stations tested and the frequency of readings will be established by project and program management prior to the tests, and will be adjusted according to site conditions during the tests.

### 5.4 Calculation Methods

Calculation of the approximate values of the aquifer parameters will follow standard practice, with particular reference to the resources of Section 7, or as otherwise noted in the calculation sequence. A computer program, AQTESOLV (Duffield and Rambaugh) or similar or equivalent, may also be used; if the computer program is used, an example that has previously been verified by traditional calculation will be run as part of the data from the subject site.

## 6.0 QUALITY ASSURANCE RECORDS

The readings made during the well-head test may be recorded in field books or on separate forms, according to management decisions. The field books will be stored according to SOP F303, with photocopies of the specific pages with test data included in the file for each test. The file for each test will include the field data, the calculations and graphs, and summaries with references for calculations by computer program.

## 7.0 REFERENCES

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**Section 5.15**  
**Aquifer Testing SOP**

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## AQUIFER TESTING (PUMP-TESTS)

### 1.0 PURPOSE

This SOP provides a general description of the technical methods and field procedures of a representative suite of aquifer testing (pump-tests) to calculate the aquifer parameters. Well-head testing (slug tests) to approximate part of these parameters is discussed in SOP F402. The descriptions herein are general in nature and do not apply to a specific well, well-field or project. Prior to designing pump-tests as part of a site investigation and during execution of the tests, the Project Manager, Site Manager and Program Geohydrologist must consult on the appropriate procedures; these procedures must then be recorded in the project documents.

### 2.0 SCOPE

The procedures described here apply to tests for evaluation of the aquifer parameters at sites being investigated under both the Underground Storage Tank (UST) Program and the Installation Restoration (IR) Program of Navy CLEAN. The aquifer tests apply both to consolidated and unconsolidated strata; and to confined, semiconfined and phreatic conditions. The aquifer parameters subject to evaluation are:

- (Primary) Aquifer Parameters
  - ▶ The Coefficient of Transmissivity
  - ▶ The Coefficient of Storage
- (Secondary) Aquifer Characteristics
  - ▶ The Hydraulic Conductivity
  - ▶ The saturated thickness of the aquifer

### 3.0 DEFINITIONS

The following definitions are extracted or abstracted from standard references (Section 7); further discussions are available in those references:

Darcian Conditions - Darcian conditions are found where a saturated groundwater system has established an actual or potential flow regime under a head developed within that

groundwater system, according to the provisions of Darcy's Law and within the boundary conditions for that law.

Gravity Flow - Gravity flow (vadose conditions) is found where a saturated or unsaturated groundwater system lies within a regime where movement by gravity drainage and capillarity dominate.

Coefficient of Transmissivity (T) - The transmissivity (T) is the rate (for example, in gallons per day per foot of drawdown (gpd/ft)) at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman 1979). The transmissivity is mathematically equivalent to the hydraulic conductivity multiplied by the saturated thickness:  $T = Kb$ .

Coefficient of Storage (S) - The storage coefficient (S) is the (dimensionless) volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Lohman 1979).

Hydraulic Conductivity (K) - A medium has a hydraulic conductivity (K) of unit length per unit time (for example, feet per day (ft/d)) if it will transmit in unit time a unit volume of groundwater at the prevailing viscosity through a cross-section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman 1979).

Saturated Thickness (b) - The saturated thickness (b) is the distance (for example, in feet (ft)) from the elevation of the upper groundwater surface in either a phreatic system (the water table) or a confined or semiconfined system (the lower boundary of the upper confining or semiconfining layer, but not the potentiometric surface in a well) to the elevation of the upper boundary of the lower confining or semiconfining layer for the aquifer or water-bearing layer.

Production (Discharge/Injection) Well - The production or discharge/injection well in a pump-test is the well from which water is extracted or into which water is injected for the test.

Observation Well - An observation well is sited near the production well, with an interception interval within, or (at least potentially) in hydrologic or hydraulic communication with, the water-bearing layer intercepted by the production well.

Radial Distance (r) - The radial distance (r) used in pump-test calculations is the horizontal distance, usually in feet (ft), between the production well and the specified observation well.

Drawdown (s) - The drawdown (s) in any well affected by a pump-test is the differential distance, usually in feet (ft), between the static (unstressed) water level in the production or observation well measured immediately prior to the test, and the (stressed) water level at the specified time during the test. (Due to the expectably short duration available for examination of trends in the water-bearing layer preceding and following individual pump-tests, trends in static levels are ignored for the purposes of Navy CLEAN.)

Discharge/Injection Test - The discharge/injection test stage is the part of the pump-test during which water is withdrawn from or injected into the water-bearing layer. The rate of discharge/injection (Q) is typically reported in gallons per minute (gpm) and is usually constant across this part of the pump-test; a stepped test may also be conducted, where Q is varied in a controlled manner.

Recovery Test - The recovery test stage follows cessation of discharge/injection during the pump-test, and, for calculation, uses the Q value of the constant discharge/injection test stage or a weighted value of Q of the stepped test. For the purposes of Navy CLEAN, the recovery test will be conducted for a minimum of 200 minutes, and usually for eight hours, following cessation of discharge/injection.

Confined Conditions - Confined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are impermeable to water, and where the total head of the system at the upper surface of the groundwater is greater than atmospheric pressure. For a confined system, when a well is drilled below the bottom of the upper confining layer, the water level in the well rises to an elevation (at least) within or (possibly) above the upper confining layer.

Unconfined (Phreatic) Conditions - Unconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically only by a single surface or layer at the bottom of the water-bearing layer that is impermeable or semipermeable to water, and where the total head of the system at the upper surface of the groundwater is equal to atmospheric pressure. For an unconfined or phreatic or water-table system, when a well is drilled below the upper

surface of the groundwater, the water level in the well does not rise to a significantly higher elevation.

Semiconfined Conditions - Semiconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are less permeable to water than the water-bearing layer itself, and where the total head of the system is greater than atmospheric pressure. For a semiconfined system, when a well is drilled below the bottom of the upper semiconfining layer, the water level in the well rises to an elevation within or above the upper semiconfining layer. However, one or both of the semiconfining layers will be, in some fashion, in hydraulic and hydrologic communication with the water-bearing layer, and may contribute water to or receive water from that layer.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation procedures which deviate from those presented herein.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that the procedures herein are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Site Geologist - Responsible for determining the need for hydrogeologic testing and has overall responsibility for the planning and implementation of the test. Evaluation and interpretation of the data is also the responsibility of the Site Geologist.

Program Geologist - Responsible for QA/QC oversight of the planning and implementation of the test, along with the evaluation of data generated by the test.

#### 5.0 PROCEDURES

The procedures presented in this section concern the administration and execution of pump-tests; the technical content of a given test will be established by the project and program management for each instance according to experience and best professional practice.

## 5.1 Overview

The pump-test will conform to the objectives of the investigation and to standards of good practice common in geohydrologic investigations. Sufficient personnel, and sufficient standard and special equipment will be available for the intentions of the test. Data collection will conform to the practice described in SOP F202 (Water Level, Water/Product Level Measurements and Well Depth Measurements); additionally, time will be measured and recorded no less precisely than the nearest minute or half-minute, as appropriate, and pumpage rates will be measured to the limits of accuracy of the meter while conforming to the intent of the test. Containment and disposal of discharged liquids will conform to the general status of the site being investigated.

## 5.2 Applications

The pump-test will usually be divided into five stages:

1. Static measurement
2. Preliminary test
3. Equilibration
4. Discharge/injection test
5. Recovery test

The second and third stages may be deleted or expanded.

### 5.2.1 Static Measurement

This stage of the pump-test provides the data on static conditions to be used in subsequent calculation of the aquifer parameters. The static water levels are to be measured no later than immediately prior to the preliminary tests or to the first discharge/injection stage of testing in all wells available for the test. The levels also should have been measured once daily, if possible, for two or more days preceding the test; the optimal measurement program would provide continuous measurement and recording of levels in all wells to be used for a period of several weeks preceding pumpage/injection.

### **5.2.2 Preliminary Test**

Preliminary tests will consist of short periods of pumpage or injection at one or a number of rates of discharge/injection. The objectives will be to:

- Predict a probable rate or successive rates of discharge/injection that can maintain a total variation of drawdown or impression within 50 to 75 percent of the available range (the discharge/injection test stage itself can accommodate up to 100 percent of this range);
- Discover observation wells responding especially rapidly or in an exaggerated fashion to the stress induced by discharge/injection; and,
- Provide a general trial of the test system (in particular, that all piping is secure, that all devices perform properly and that the discharge from the pumping well does not provide recharge to the water-bearing layer).

### **5.2.3 Equilibration**

The equilibration stage follows the preliminary test to allow return to similar conditions of static levels as those measured before the preliminary test. Calculation of the main test while the water-bearing layer is recovering from the effects of the preliminary test is unnecessarily tedious and subject to error.

### **5.2.4 Discharge/Injection Test**

The discharge/injection stage of the pump-test imposes a stress on the water-bearing layer by withdrawing or injecting water at one or more points (the production well or well-field). The measurements of the rates of discharge/injection and of the drawdown in the observation wells provide data used in calculation of the aquifer parameters. The test should be planned to use between 50 and 75 percent of the available drawdown in the production well, but may use up to 100 percent, at the discretion of the Site Geologist and Field Team Leader.

The rate of discharge/injection may be constant or systematically varied. The duration of this stage of the test will be a marginally acceptable minimum of eight hours, with a preferred

minimum of 24 hours for tests under confined conditions and a preferred minimum of 72 hours for tests of unconfined conditions. (This stage can be extended to three or more weeks, according to the intentions of the site investigation.)

### 5.2.5 Recovery Test

The recovery stage will last a minimum of 200 minutes after cessation of discharge/injection, and usually eight hours. This stage monitors the return to equilibrium of the stressed water-bearing layer. Calculations on this stage of the test are used to corroborate or replace the calculations on data from the discharge/injection test; under certain conditions, this stage provides more reliable information than the discharge/injection stage.

## 5.3 Measurements and Measurement Intervals

### 5.3.1 Water Levels

The measurement intervals for water levels in responding observation wells during the discharge/injection stage and in both the production well and the responding observation wells during recovery will be modified from the following suggestions:

<u>Time Since Start of Discharge/Injection or Recovery (min)</u>	<u>Measurement Frequency (min)</u>
0-5	0.5
5-10	1
10-20	2
20-50	5
50-100	10
100-200	20
200-500	50
500-1000	100
1000-2000	200
2000-5000	500
5000-10000	1000
10000-20000	2000
20000-50000	5000

Since the crew for the test must monitor conditions in addition to the water levels, a reading interval of not more than 100 minutes is usually reasonable. The actual time and the test time for each reading will be recorded, with the water level measured to a precision of 0.01 ft.

The sequence of stations read and the frequency of readings will be established by project and program management prior to the test, and will be adjusted according to site conditions during the test.

### **5.3.2 Flow Rates**

Flow rates for the discharge/injection stage of the test will be measured by a suitable device. Readings will usually be made at intervals of not more than 100 minutes, possibly following an initial period of more frequent readings while the pump stabilizes.

### **5.3.3 Field Parameters**

The field parameters of temperature, specific conductance and pH (SOP F201) for the discharge/injection stage of the test will be measured by suitable devices. Readings will usually be made at intervals of not more than 1000 minutes, possibly following an initial period of more frequent readings while the pump stabilizes.

### **5.3.4 Surveying**

The radial distance between the production well and an observation well will be measured to a precision of not less than one percent, either by chaining or inspection, or by land survey. The measuring points for water levels need not be surveyed to an accuracy of 0.01 feet, although this is highly desirable for other reasons related to the site investigation.

## **5.4 Calculation Methods**

Calculation of the aquifer parameters will follow standard practice, with particular reference to the resources of Section 7, or as otherwise noted in the calculation sequence. A computer program, AQTESOLV (Duffield and Rambaugh) or similar or equivalent program, may also be used, provided that not less than 10 percent of the stations monitored also are calculated by traditional methods.

The calculations will particularly note if the test performance or the resultant calculations indicate a departure from Darcian conditions into vadose flow. Should this be decided, a statement will be made that, although calculations can be made, the calculations are invalid and the values are only roughly approximate; in such case, no valid calculation can be made and no similar pump-tests should be planned for the particular site or area of a site.

## 6.0 QUALITY ASSURANCE RECORDS

The readings made during the pump-test may be recorded in field books or on separate forms, according to management decisions. The field books will be stored according to SOP F303, with photocopies of the specific pages with pump-test data included in the file for each test. The file for each test will include the field data, the calculations and graphs, and summaries with references for calculations by computer program.

## 7.0 REFERENCES

Chow, V.T.; 1964; Handbook of Applied Hydrology; McGraw-Hill; New York.

Lohman, S.W.; 1979; Ground-Water Hydraulics; Geological Survey Professional Paper 708; U.S. Government. Printing Office.

Freeze, R.A. and Cherry, J.A.; 1979; Groundwater; Prentice-Hall; Englewood Cliffs.

Driscoll, F.G., ed.; 1986; Groundwater and Wells, 2nd Ed.; Johnson Filtration Systems, St.Paul.

Duffield, G.M., Rambaugh, J. O.; 1989; AQTESOLV; Aquifer Test Solvent; Version 1.00 Documentation.

**Section 5.16**  
**Sample Preservation SOP**

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## SAMPLE PRESERVATION AND HANDLING

### 1.0 PURPOSE

This SOP describes the appropriate containers for samples of particular matrices, and the steps necessary to preserve those samples when shipped off site for chemical analysis.

### 2.0 SCOPE

Some chemicals react with sample containers made of certain materials; for example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the integrity of the sample prior to analysis.

Many water and soil samples are unstable and may change in chemical character during shipment. Therefore, preservation of the sample may be necessary when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s). While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that may occur after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing. Their purposes are to (1) retard biological activity, (2) retard hydrolysis of chemical compounds/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

Sample container and preservation requirements for the CLEAN Program are referenced in NEESA 20.2-047B and are provided in Attachment A of this SOP.

### 3.0 DEFINITIONS

HCl - Hydrochloric Acid

H<sub>2</sub>SO<sub>4</sub> - Sulfuric Acid

HNO<sub>3</sub> - Nitric Acid

NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalents per liter, where an equivalent is the amount of a substance containing one mole of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one mole of H, is "one-normal," while a one molar solution of H<sub>2</sub>SO<sub>4</sub> containing two moles of H, is "two-normal."

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that proper preservation and handling procedures are implemented.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to initiate sample preservation and handling.

#### 5.0 PROCEDURES

The following procedures discuss sample containerization and preservation techniques that are to be followed when collecting environmental samples for laboratory analysis.

##### 5.1 Sample Containers

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be measured is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then the container shall be plastic. Containers shall be kept out of direct sunlight (to minimize biological or photo-oxidation/photolysis of constituents) until they reach the analytical laboratory. The sample container shall have

approximately five to ten percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (one liter of water at 4°C expands by 15 milliliters if heated to 130°F/55°C); however, head space for volatile organic analyses shall be omitted.

The analytical laboratory shall provide containers that have been cleaned according to USEPA procedures. Shipping containers for samples, consisting of sturdy ice chests, are to be provided by the laboratory.

Once opened, the container must be used at once for storage of a particular sample. Unused, but opened, containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing liners (if required for the container) shall be discarded.

General sample container, preservative, and holding time requirements are listed in Attachment A.

## 5.2 Preservation Techniques

The preservation techniques to be used for various analytes are listed in Attachment A. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or added in the field. In general, aqueous samples of low concentration organics (or soil samples of low or medium concentration organics) are cooled to 4°C. Medium concentration aqueous samples and high hazard organics samples are not preserved. Low concentration aqueous samples for metals are acidified with HNO<sub>3</sub>, while medium concentration and high hazard aqueous metal samples are not preserved. Low or medium concentration soil samples for metals are cooled to 4°C, while high hazard samples are not preserved. Unless documented otherwise in the project plans, all samples shall be considered low concentration. All samples preserved with chemicals shall be clearly identified by indicating on the sample label that the sample is preserved.

### 5.3 Sample Holding Times

The elapsed time between sample collection and initiation of laboratory analyses must be within a prescribed time frame for each individual analysis to be performed. Sample holding times for routine sample collection are provided in Attachment A.

### 6.0 SAMPLE HANDLING AND TRANSPORTATION

After collection, all sample handling should be minimized. Personnel should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, personnel should ensure that melted ice cannot cause sample containers to become submerged, as this may result in sample cross-contamination. Sealable plastic bags, such as Zip-Lock® bags, should be used when small sample containers (e.g., VOAs or bacterial samples) are placed in ice chests to prevent cross-contamination.

Samples may be hand delivered to the laboratory or they may be shipped by common carrier. Relevant regulations for the storage and shipping of samples are contained in 40 CFR 261.4(d). Parallel state regulations may also be relevant. Shipment of dangerous goods by air cargo is also regulated by the United Nations/International Civil Aviation Organization (UN/ICAO). The Dangerous Goods Regulations promulgated by the International Air Transport Association (IATA) meet or exceed DOT and UN/ICAO requirements and should be used for shipment of dangerous goods via air cargo. Standard procedure for shipping environmental samples are given in Attachment B.

### 7.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA, Washington, D.C.

USEPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

USEPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. USEPA EMSL, Cincinnati, Ohio.

USEPA, Region IV, 1991. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. Athens, Georgia.

**ATTACHMENT A**

**REQUIRED CONTAINER, PRESERVATION TECHNIQUES  
AND  
HOLDING TIMES**

**ATTACHMENT A**

**REQUIRED CONTAINERS, PRESERVATIVE TECHNIQUES AND HOLDING TIMES**

Parameter	EPA Document SW-846 (3rd Ed.)				Contract Laboratory Protocol			
	Container	Preservative	Holding Time		Container	Preservative	Holding Time	
			Soil	Water			Soil	Water
Volatiles by GC/MS and GC	Water - 40 mL glass vial with Teflon-lined septa  Soil-glass with Teflon-lined septa	Cool to 4°C	14 days	14 days	Water - 40 mL glass vial with Teflon-lined septa  Soil-glass with Teflon-lined septa	Cool to 4°C	10 days	10 days
PCB/Pesticides	G, Teflon-lined lid	Cool to 4°C	Extract within 7 days, analyze 40 days	Extract within 7 days, analyze 40 days	G, Teflon-lined lid	Cool to 4°C	Extract within 10 days, analyze 40 days	Extract within 10 days, analyze 40 days
Extractable Organics	G, Teflon-lined lid	Cool to 4°C	Extract within 7 days, analyze 40 days	Extract within 7 days, analyze 40 days	G, Teflon-lined lid	Cool to 4°C	Extract within 10 days, analyze 40 days	Extract within 10 days, analyze 40 days
Metals	P, G	HNO <sub>3</sub> to pH <2	6 months	6 months	P, G	HNO <sub>3</sub> to pH <2	180 days	180 days
Mercury	P, G	HNO <sub>3</sub> to pH <2	28 days	28 days	P, G	HNO <sub>3</sub> to pH <2	26 days	26 days
Cyanide	P, G	NaOH to pH >12 Cool to 4°C Add 0.6 g ascorbic acid if residual chlorine present	14 days	14 days	P, G	NaOH to pH >12 Cool to 4°C Add 0.6 g ascorbic acid if residual chlorine present	14 days	14 days
Chromium	P, G	HNO <sub>3</sub> to pH <2	24 hrs.	24 hrs.	P, G	HNO <sub>3</sub> to pH <2	24 hrs.	24 hrs.

**ATTACHMENT B**

**SAMPLE SHIPPING PROCEDURES**

**ATTACHMENT B**  
**SAMPLE SHIPPING PROCEDURES**

**Introduction**

Samples collected during field investigations or in response to a hazardous materials incident must be classified by the project leader, prior to shipping by air, as either environmental or hazardous materials samples. The guidance for complying with U.S. DOT regulations in shipping environmental laboratory samples is given in the "National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Pertinent regulations for the shipping of samples is given in 40 CFR 261.4(d). Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods. Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by the United Nations International Civil Aviation Organization (UN/ICAO), which is equivalent to IATA.

Environmental samples shall be packed prior to shipment by commercial air carrier using the following procedures:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug with fiber or duct tape. Line the cooler with a large heavy duty plastic bag.
2. Allow sufficient headspace (ullage) in all bottles (except VOAs) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).
3. Be sure the lids on all bottles are tight (will not leak).
4. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape). Up to three VOA bottles may be packed in one Zip-Lock® container.
5. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.

6. Place two to four inches of vermiculite in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
7. Put "blue ice" (or ice that has been placed in heavy duty polyethylene bags and properly sealed) on top of or between the samples. Fill all remaining space between the bottles or cans with packing material. Securely fasten the top of the large garbage bag with tape (preferably plastic electrical tape).
8. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
9. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill.

**Section 5.17**  
**Chain-of-Custody SOP**

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## CHAIN-OF-CUSTODY

### 1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used under the CLEAN Program.

### 2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters, SOP F101). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

### 3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

**Field Team Leader** - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

#### 5.0 PROCEDURES

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

## 5.1 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s);
- CTO Number;
- Project Sample Number;
- Sample location or sampling station number;
- Date and time of sample collection and/or measurement;
- Field observations;
- Equipment used to collect samples and measurements; and,
- Calibration data for equipment used.

Measurements and observations shall be recorded using waterproof ink.

### 5.1.1 Sample Label

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling Plan and Analysis. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project - Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.

- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

## 5.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

### 5.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

### 5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form is shown in Attachment B. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).
- Enter sample specific information (sample number, media, grab or composite, number and type of sample containers, and date/time sample was collected).
- Sign, date, and enter the time under "Relinquished by" entry.
- Have the person receiving the sample sign the "Received by" entry.
- If a carrier is used, enter the bill-of-lading or airbill number under "Remarks," in the bottom right corner, if appropriate;
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in the appropriate sample shipping package. Retain the copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.
- Complete other carrier-required shipping papers.

The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the sample container (enclosed with other documentation in a plastic zip-lock bag). As long as custody forms are sealed inside the sample container and the custody seals are intact, commercial carriers are not required to sign off on the custody form.

If sent by common carrier or air freight, proper documentation of sample transfer must be maintained.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

## **6.0 QUALITY ASSURANCE RECORDS**

## **7.0 REFERENCES**

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

**ATTACHMENT A**

**EXAMPLE SAMPLE LABEL**

ATTACHMENT A

EXAMPLE SAMPLE LABEL

<b>Baker Environmental Inc.</b>	
<b>Airport Office Park, Bldg. 3</b>	
<b>420 Rouser Road</b>	
<b>Coraopolis, PA 15108</b>	
<b>Project:</b> _____	<b>CTO No.:</b> _____
<b>Sample Description:</b> _____	
<b>Date:</b> ___/___/___	<b>Sampler:</b> _____
<b>Time:</b> _____	
<b>Analysis:</b> _____	<b>Preservation:</b> _____
<b>Project Sample No.:</b> _____	

**ATTACHMENT B**

**EXAMPLE CHAIN-OF-CUSTODY RECORD**

# CHAIN-OF-CUSTODY RECORD

Sampler: \_\_\_\_\_  
(Print)

Sheet \_\_\_\_\_ of \_\_\_\_\_

Signature: \_\_\_\_\_

**BAKER ENVIRONMENTAL, INC.**  
Airport Office Park - Bldg No. 3  
420 Rouser Road  
Coraopolis, PA 15108  
(412) 269-6000

Project Name: \_\_\_\_\_

P.O. Number: \_\_\_\_\_

Baker Sample I.D. No.	Sample Type	Sampled		Sample Storage and Preservation Details*									
				Cooling		HNO <sub>3</sub>		H <sub>2</sub> SO <sub>4</sub> Cooling		Other		Other	
				No. of Contr.	Type/Volume Contr.	No. of Contr.	Type/Volume Contr.	No. of Contr.	Type/Volume Contr.	No. of Contr.	Type/Volume Contr.	No. of Contr.	Type/Volume Contr.
Date	Time												

General Remarks: \_\_\_\_\_

\*NOTES: Record type of container used with abbreviation P (plastic) or G (glass)  
Record volume of containers in liters

Relinquished By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Received By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Shipment/Transportation Details: \_\_\_\_\_

Relinquished By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Received By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Shipment/Transportation Details: \_\_\_\_\_

Relinquished By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Received By (Sign): \_\_\_\_\_  
Date: \_\_\_\_\_ Time: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Shipment/Transportation Details: \_\_\_\_\_

Distribution:  
Original - Sent with samples to lab (return with lab results to Project Manager for filing)  
Copy - Retained by sampling personnel for filing

**ATTACHMENT C**

**EXAMPLE CUSTODY SEAL**

**ATTACHMENT C**

**EXAMPLE CUSTODY SEAL**

<p>____/____/____ Date</p> <p>_____ Signature</p> <p><b>CUSTODY SEAL</b></p>	<p>____/____/____ Date</p> <p>_____ Signature</p> <p><b>CUSTODY SEAL</b></p>
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**Section 5.18**  
**Chemical Sampling and**  
**Field Analytical Equipment**  
**Decontamination SOP**

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## DECONTAMINATION OF CHEMICAL SAMPLING AND FIELD ANALYTICAL EQUIPMENT

### 1.0 PURPOSE

The purpose of this SOP is to provide a general methodology and protocol, and to reference information for the proper decontamination of field chemical sampling and analytical equipment.

### 2.0 SCOPE

This procedure applies to all field sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), bailers, beakers, trowels, filtering apparatus, and pumps. This procedure should be consulted when decontamination procedures are being developed as part of project-specific plans. Additionally, current USEPA regional procedures and decontamination guidance as well as state guidance should be reviewed.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

**Project Manager** - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring field personnel performing decontamination activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader.

## 5.0 PROCEDURES

In order to ensure that chemical analysis results reflect actual concentrations present at sampling locations, sampling equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling locations) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Preferably, sampling equipment should be dedicated to a given sampling location. If this is not possible, equipment must be decontaminated between sampling locations. Sampling personnel also must use disposable gloves and change them between sampling locations.

### 5.1 Sampling Equipment Decontamination Procedures

Soil, sediment and water sampling equipment including, but not limited to split-barrel samplers (split-spoon samplers), bailers, bailing line, pumps and pump tubing, filtering equipment, trowels, beakers, etc., shall be decontaminated using the following USEPA regional procedures. Decontamination procedures for USEPA Region IV are given in "Standard Operating Procedures and Quality Assurance Manual," USEPA 1991.

The following sections summarize decontamination procedures for USEPA Regions I through IV. Each region should be contacted prior to initiation of sampling activities to assure that the most recent, accepted decontamination procedures are used.

#### USEPA Region I

Prior to use, all sampling equipment should be carefully cleaned using the following procedure:

1. A dilute hydrochloric acid rinse
2. Deionized water rinse

3. Methanol or acetone rinse; and,
4. Distilled, organic-free water rinse.

For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure. Additionally, a hexane rinse also may be needed, prior to the final distilled water rinse, when sampling for low-level organic pollutants.

#### USEPA Region II

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Low-phosphate detergent wash (i.e., Alconox or Liquinox)
2. Tap water rinse
3. 10 percent nitric acid solution rinse
4. Tap water rinse
5. Methanol followed by a hexane or an acetone rinse
6. Analyte-free deionized water rinse
7. Air dry
8. Wrap in aluminum foil, shiny side out, for storage or transport

If the samples will not be analyzed for metals, then steps 3 and 4 may be omitted; if samples will not be analyzed for organics, then step 5 may be omitted. All solvents must be pesticide-grade.

#### USEPA Region III

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Potable water rinse
2. Alconox or Liquinox detergent wash
3. Scrubbing, as necessary
4. Potable water rinse
5. 10 percent nitric acid rinse
6. Distilled-deionized water rinse
7. Methanol or hexane rinse
8. Distilled-deionized water rinse
9. Air dry

## USEPA Region IV

The general decontamination procedure for Region IV is similar to that for Regions II and III. However, there may be some specialized procedures applicable to certain types of field equipment such as equipment used for the collection of samples for analysis of trace organic compounds, automatic wastewater sampling equipment, sampling tubing, and miscellaneous equipment (i.e., pumps, hand augers, etc.). The most current version is "Standard Operating Procedures and Quality Assurance Manual," USEPA Region IV, Environmental Services Division, Environmental Compliance Branch (see Appendix B in February 1, 1991 version).

### **5.2 Field Analytical Equipment Decontamination**

Field analytical equipment which may come in direct contact with the sample or sample media, including, but not limited to water level meters, water/product level meters, pH or specific ion probes, specific conductivity probes, thermometers, and/or borehole geophysical probes must be decontaminated before and after use, according to the procedures outlined in Section 5.1, unless manufacturers instructions indicate otherwise. Probes that contact water samples not used for laboratory analyses may be rinsed with distilled water. Probes which make no direct contact (e.g. HNu or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth.

### **6.0 QUALITY ASSURANCE RECORDS**

Decontamination procedures are monitored through the collection of equipment rinsate samples and field blanks. Collection of these samples shall be specified in the project-specific Sampling and Analysis and Quality Assurance Plans following the requirements of NEESA 20.2-047B. Documentation recorded in the field logbook also shall serve as a quality assurance record.

### **7.0 REFERENCES**

NEESA 20.2-047B. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. Naval Energy and Environmental Support Activity. Port Hueneme, CA. June 1988.

U. S. EPA Office of Waste Program Enforcement. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1. 1986.

U. S. EPA. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA Environmental Services Division, Athens, Georgia. 1991.

Micham, J. T., R. Bellandi, E. C. Tift, Jr. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review. Spring 1989.

**Section 5.19**  
**Decontamination of Drilling Rig and**  
**Monitoring Well Materials SOP**

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## DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

### 1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

### 2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

**Project Manager** - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

Drilling Inspector (Site Geologist, Rig Geologist etc.) - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

## **5.0 PROCEDURE**

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site.

### **5.1 Equipment**

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502.

### **5.2 Decontamination Procedures**

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush and alconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding tank. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

For a given project, the location of the steam cleaning area will be identified in the Sampling and Analysis Plan.

Decontamination wastes will be collected and contained unless otherwise directed by LANTDIV. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

## **6.0 QUALITY ASSURANCE RECORDS**

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate. Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

## **7.0 REFERENCES**

None.

**Section 5.20**  
**Field Logbook SOP**

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## FIELD LOGBOOK

### 1.0 PURPOSE

This SOP describes the process for maintaining a field logbook.

### 2.0 SCOPE

The field logbook is a document which records all major on-site activities conducted during a field investigation. At a minimum, the following activities/events shall be recorded in the field logbook:

- Arrival/departure of site workers and visitors
- Arrival/departure of equipment
- Sample pickup (sample numbers, carrier, time)
- Sampling activities
- Start or completion of boreholes, monitoring wells, or sampling activities
- Health and safety issues

The field logbook is initiated upon arrival at the site for the start of the first on-site activity. Entries are made every day that on-site activities take place. At least one field logbook shall be maintained per site.

The field logbook becomes part of the permanent site file. Because information contained in the field logbook may be admitted as evidence in legal proceedings, it is critical that this document is properly maintained.

### 3.0 DEFINITIONS

Field logbook - The field logbook is a bound notebook with consecutively numbered pages. Upon entry of data, the logbook requires the signature of the responsible data/information recorder.

### 4.0 RESPONSIBILITIES

The Field Team Leader is responsible for maintaining the field logbook for the duration of on-site activities.

## 5.0 PROCEDURES

The following sections discuss some of the information which must be recorded in the field logbook. In general, a record of all events and activities, as well as other potentially important information shall be recorded.

### 5.1 Cover

The inside cover or title page of each field logbook shall contain the following information:

- Contract Task Order Number
- Project name and location
- Name of Field Team Leader
- Baker's address and telephone number
- Start date
- If several logbooks are required, a sequential field logbook number

### 5.2 Daily Entries

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded:

- Date
- Start time
- Weather
- All field personnel present
- All visitors present
- Other pertinent information (i.e., planned activities, schedule changes, expected visitors, and equipment changes)

During the day, a summary of all site activities should be recorded in the logbook. The information need not duplicate that recorded in other field logbooks, but should summarize the information in other books and, where appropriate, reference the page numbers of other logbooks where detailed information pertaining to a subject may be found.

Some specific information which must be recorded in the logbook includes:

- Equipment used, equipment numbers, calibration, field servicing
- Field measurements

- Sample numbers, media, bottle size, preservatives, collection methods, and time
- Test boring and monitoring well construction information, including boring/well number and location
- Sketches for each sample location
- Photograph log
- Drum log
- Other pertinent information

All entries should be made in indelible ink; all pages numbered consecutively; and all pages must be signed and dated by the responsible field personnel completing the log. No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single line, initialed, and dated.

### 5.3 Photographs

If photographs are permitted at a site, the record shall be maintained in the field logbook. When movies, slides or photographs are taken of any site location, they are numbered or cross-referenced to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions are entered in the logbook as the photographs are taken. Special lenses, film, or other image-enhancement techniques also must be noted in the field logbook. Once processed, photographs shall be serially numbered and labeled corresponding to the field logbook entries. Note that it may not be permitted to take photographs at all Activities; permission must be obtained from the LANTDIV EIC and the Activity responsible individual.

### 6.0 QUALITY ASSURANCE RECORDS

Once on-site activities have been completed, the field logbook shall be considered a quality assurance record.

### 7.0 REFERENCES

None.

**Section 5.21**  
**Handling of Site Investigation**  
**Wastes SOP**

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## HANDLING OF SITE INVESTIGATION GENERATED WASTES

### 1.0 PURPOSE

The objective of this SOP is to provide general reference information on the control and responsibilities of wastes typically generated during field investigations. The descriptions herein are general in nature and do not apply to a specific handling scheme. Prior to designing a handling scheme as part of a site investigation and during actual management of materials, the Project Manager, Site Manager and a disposal specialist must consult on the appropriate procedures; these procedures must then be recorded in the project documents.

### 2.0 SCOPE

The procedures described here apply to sites being investigated under both the Underground Storage Tank (UST) Program and the Installation Restoration (IR) Program of Navy CLEAN.

This SOP generally is applicable to all of the usual wastes generated during site investigations. Proper segregation and on-site storage of wastes are necessary until the identification and final disposition of those wastes is completed. The field investigation team will containerize or secure the waste appropriately during the site studies. After the laboratory analyses have been received (usually some weeks later), Baker will identify which wastes will require special disposal and assist LANTDIV in arranging and managing that disposal.

Since the final disposition of materials will usually not be known until after the field teams have been released from the site, the division of responsibilities for that disposition will be established by negotiation of the contingencies with LANTDIV. LANTDIV may expect, however, that facility personnel should be responsible for additional handling procedures such as labeling, storing, and transferring materials into proper containers, if necessary.

Time constraints and the final disposition (on site or off site) will be determined based upon the identification of the waste. Project and site conditions may require development of a Contaminated Materials Handling Plan that delineates the potential disposition of site investigation wastes, in the event off-site disposal is required.

### 3.0 DEFINITIONS

Health and Safety (HAS) Waste - HAS waste material is generated during a site investigation from discarded personal protective gear potentially contaminated during site activities. Typically, this includes protective suits, gloves, boots, spent respirator cartridges, and similar items.

By-products - Substances (for example, pumped water or excavated soil) generated during a sampling event or some other site activity in excess of analytical requirements. This includes soil cuttings, development and decontamination water, carcasses of field parameter samples, and so forth.

### 4.0 RESPONSIBILITIES

LANTDIV - LANTDIV or the facility must ultimately be responsible for the final disposition of site wastes. As such, a LANTDIV representative will usually prepare and sign waste disposal manifests as the generator of the material, in the event off-site disposal is required. However, it may be the responsibility of Baker, depending on the contingency discussions during execution of the investigation to provide assistance to LANTDIV in arranging for final disposition and preparing the manifests.

Project Manager - It is the responsibility of the Project Manager to work with the LANTDIV-EIC in determining the final disposition of site investigation wastes. The Project Manager will relay the results and implications of the chemical analysis of the waste or associated material, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Project Manager also is responsible for ensuring that field personnel involved in site investigation waste handling are familiar with the procedures to be implemented in the field, and that all required field documentation has been completed.

Field Team Leader - The Field Team Leader is responsible for the on-site supervision of the waste handling procedures during the site investigations. The Field Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

## 5.0 PROCEDURES

Field investigation activities often result in the production or movement of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. For the purpose of this SOP, contaminated materials are any by-products or HAS materials from a field investigation that are known or suspected to be contaminated with hazardous substances.

The Sampling and Analysis Plan (SAP) shall, in most cases, include a description of control measures for contaminated materials. This portion of the SAP may consider types of contamination, estimates of the amount of waste materials generated by site activities, storage and, possibly, disposal methods. As a general rule, it is preferable to select investigation methods that minimize the generation of waste materials. All site investigation waste materials shall be containerized or secured in a manner appropriate to site conditions until sample analyses have been received.

### 5.1 Sources of Waste Materials

The sources of waste material depend on the site activities planned for a project. The following types of activities (or sources), typical of site investigations, may result in the generation of waste material which must be properly handled:

- Drilling and monitoring well construction
- Monitoring well development
- Groundwater sampling
- Aquifer pump tests
- Heavy equipment decontamination
- Sampling equipment decontamination
- Personal protective equipment

Prior to initiation of site activities, the expected sources, media, quantities and potential contaminants from the investigation should be estimated, as well as the probable method of containerizing or staging of these materials.

## 5.2 Initial Handling of Waste Materials

The initial handling of waste materials generated by on-site activities will include containerization, labeling and storage. Specific procedures for materials handling will be developed for each project and discussed in the Project Work Plan.

### 5.2.1 Containerization

Waste solids (for example, equipment and soil), liquids (for example, decontamination fluids, and development and purge water) and personal protective clothing may be placed in 55-gallon steel drums meeting U.S. Department of Transportation standards, or other approved containers. Waste materials should be segregated to minimize disposal quantities of hazardous materials. To this end, soils from a particular boring will be placed in a single set of containers for that boring. Development and purge water from a given well may be placed in the same set of containers; however, water from different wells should be placed in different containers.

Polyethylene or other suitably compatible liners will be used in containers for liquids, and may be used in containers for solids. The containers are to remain closed except when filling, emptying or sampling. The container lid shall be securely attached at the end of each work day and when the container is completely filled.

### 5.2.2 Labeling

Containers will be consecutively numbered and labeled by the field team during the site investigations. Container labels shall be legible and of an indelible medium (waterproof marker, paint stick, or similar means). Information shall be recorded both on the container lid and its side. Container labels shall include, as a minimum:

- LANTDIV CTO (number)
- Project name
- Drum number
- Date
- Source
- Contents

If samples representative of the containerized materials have been collected during the site investigation (for example, a groundwater collected for laboratory analysis upon completion of purging), the appropriate sample number shall be recorded on the Container Log (Section 5.2.3) to facilitate determination of the disposition of each container.

If laboratory analyses reveals that containerized materials are hazardous or contain PCBs, additional labeling of containers may be required. The project management will assist LANTDIV in additional labeling procedures if necessary after departure of the field team from the facility. These additional labeling procedures will be based upon the identification of material present; EPA regulations applicable to labeling hazardous and PCB wastes are contained in 40 CFR Parts 261, 262, and 761.

### 5.2.3 Container Log

A container log shall be maintained in the site logbook. The container log shall contain the same information as the container label, as discussed in Section 5.2.2, plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample.

### 5.3 Container Storage

Containers of site investigation wastes shall be stored in a specially designated, secure area (usually, a small, fenced area on-site with a locking gate), or an area specified by LANTDIV or the facility, until disposition is determined. All containers shall be covered with plastic sheeting to provide protection from weather.

If the laboratory analyses reveal that the containers hold hazardous or PCB waste, additionally required storage security may be implemented; in the absence of the investigation team, these will be the responsibility of LANTDIV or the facility, as confirmed by the contingency discussions.

Baker will assist LANTDIV in devising the storage requirements, which may include the drums being staged on wooden pallets or other structures to prevent contact with the ground and being staged to provide easy access. Weekly inspections by facility personnel of the

temporary storage area may also be required. These inspections may assess the structural integrity of the containers and proper container labeling. Also, precipitation that may accumulate in the storage area may need to be removed. These weekly inspections and whatever precipitation removal shall be recorded in the site logbook.

#### 5.4 Container Disposition

The disposition of containers of site investigation generated wastes shall be determined by LANTDIV, with the assistance of Baker, as necessary. Container disposition shall be based on quantity of materials, types of materials, and analytical results. If necessary, specific samples of contained materials may be collected to identify further characteristics which may affect disposition. Typically, container disposition will not be addressed until after receipt of applicable analytical results; these results are usually not available until long after completion of the field investigation at the facility.

#### 5.5 Disposal of Contaminated Materials

Actual disposal methods for contaminated materials disturbed during a site investigation are the same as for other PCB or hazardous substances: incineration, landfilling, treatment, and so forth. The responsibility for disposal must be determined and agreed upon by all involved parties during negotiations addressing this contingency.

The usual course will be a contractor specialist retained to conduct the disposal. However, regardless of the mechanism used, all applicable Federal, state and local regulations shall be observed. EPA regulations applicable to generating, storing and transporting PCB or hazardous wastes are contained in 40 CFR Parts 262, 263, and 761.

Another consideration in selecting the method of disposal of contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable on-site disposal or treatment structure is expected, contaminated materials generated during the site investigation may be stored at the site for treatment/disposal with other site materials. In this case, the initial containment (drums or other containers) shall be evaluated for use as long-term storage. Also, other site conditions, such as drainage control, security and soil types must be considered, in order to provide proper storage.

A timely process for disposing of investigation wastes may be:

1. LANTDIV would assist the team management in obtaining the necessary EPA generator numbers.
2. Team personnel would not sign the required manifests as generators of site investigation wastes; this remains the responsibility of LANTDIV or the facility.
3. The team management and LANTDIV would jointly identify authorized, permitted facilities for proper treatment, storage and/or disposal of wastes. However, LANTDIV would make the final determination on disposition.

## 6.0 QUALITY ASSURANCE RECORDS

Quality Assurance Records shall consist of, at a minimum:

- Container logs recorded during the site investigation
- Weekly storage inspection reports, if applicable
- Analytical results from applicable environmental samples
- Manifests and similarly regulated documents

## 7.0 REFERENCES

Federal Register. 40 CFR Parts 261, 263, and 761.