03.03-12/15/92-00348

FINAL

SAMPLING AND ANALYSIS PLAN

PART I: FIELD SAMPLING PLAN

PHASE I REMEDIAL INVESTIGATION

INSTALLATION RESTORATION PROGRAM ACTIVITIES

NAVAL STATION ROOSEVELT ROADS PUERTO RICO

CONTRACT TASK ORDER 0007

Prepared For:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under the:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

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1.0 INTRODUCTION

This Sampling and Analysis Plan (SAP) was prepared for the Navy CLEAN Program, Contract Number N62470-89-D-4814, Contract Task Order CTO-0007 for Naval Station Roosevelt Roads (NSRR), Puerto Rico (Figures 1-1 and 1-2).

This Field Sampling Plan (FSP), which is Part I of the Sampling and Analyses Plan (SAP) discusses the field activities, sample collection methods and procedures to be followed throughout the field portion of the investigation. The plan presents procedures conforming to those relevant to CERCLA investigations based on EPA guidance. These procedures are designed to provide high quality data which will be usable in any CERCLA or RCRA programs which may follow at this site.

These descriptions support the implementation of the program presented in the project Work Plan (WP).

1.1 Statement of the Objectives

In response to the provisions for a RCRA Facilities Investigation (RFI) and for negotiation of the content of the RFI, the principal objectives of the Phase I Remedial Investigation (Phase I RI) are:

- Provide usable and defensible data regarding site characterization of suspected contamination areas at the NSRR; and,

- Provide the technical basis for design of an RFI directly addressing the relevant concerns at each site not excluded at the facility.

Supporting the principal objectives are supplementary objectives:

- Establish a technical foundation for the negotiating position with EPA to support the principal objectives; and,

- Establish a justification for consideration during negotiation with the EPA of the analytical information developed by the Confirmation Study (CS).

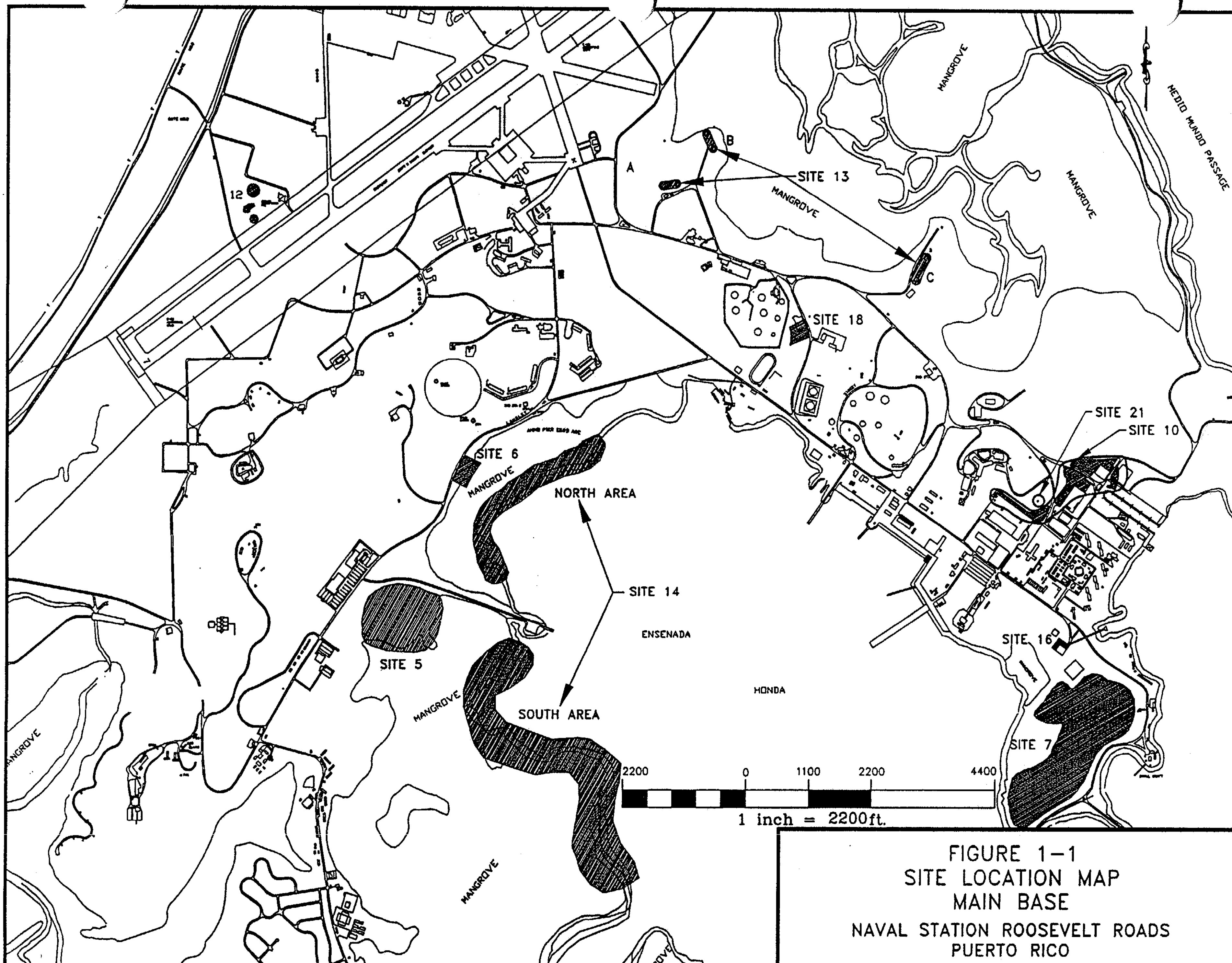


FIGURE 1-1
SITE LOCATION MAP
MAIN BASE
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

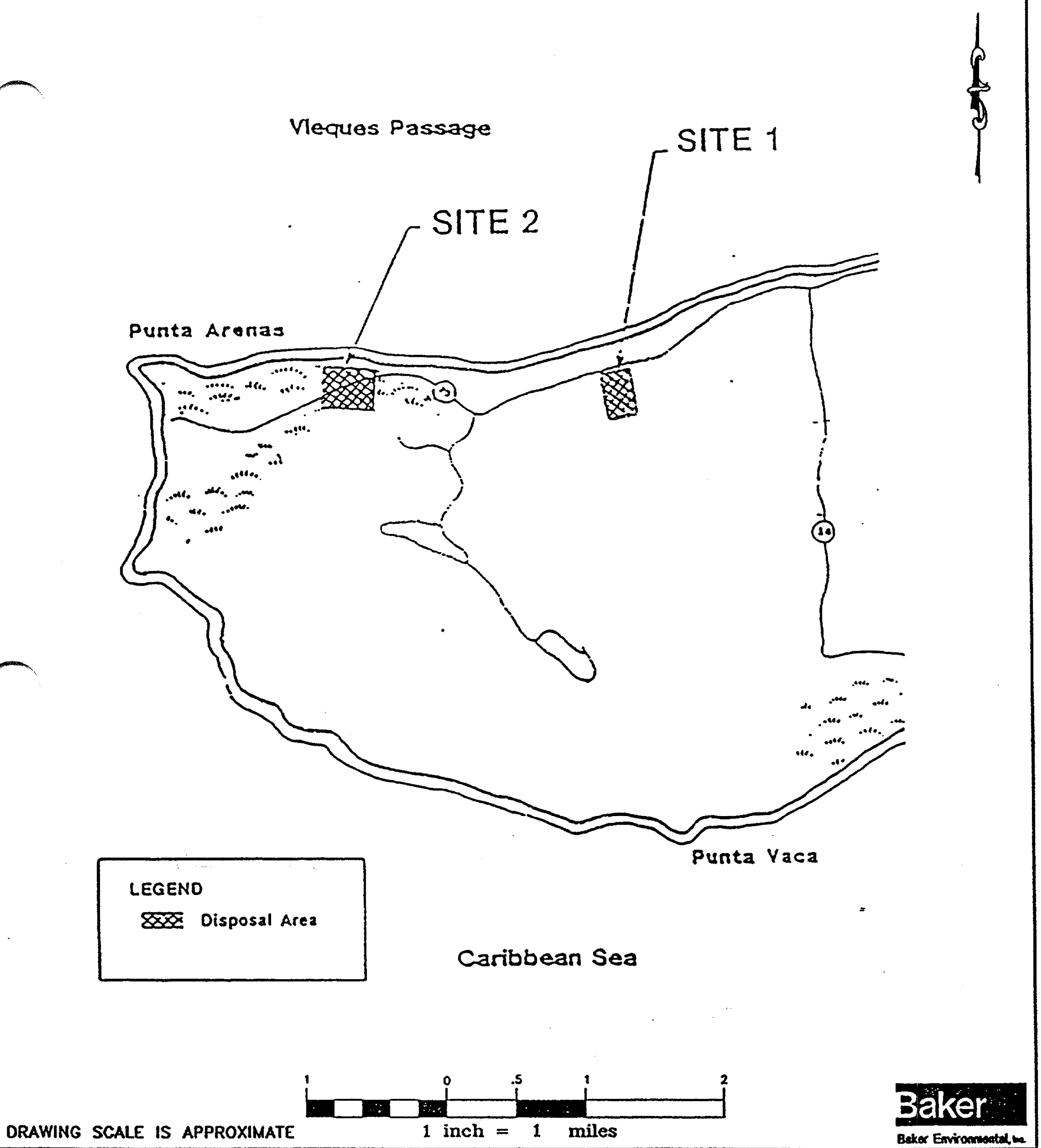


FIGURE 1–2
SITE LOCATION MAP
WESTERN PORTION OF VIEQUES ISLAND

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: NEESA, 1984b; ESE, 1985.

1.2 Project Organization

The project organization consists of several tasks, both technical and administrative:

Task 1	Project Management
Task 2	Project Plans
Task 3	Subcontract Procurement
Task 4	Field Investigation
Task 5	Sample Analysis and Tracking
Task 6	Data Evaluation
Task 7	Reporting
Task 8	Meeting
Task 9	Community Relations Plan
Task 10	Site Information and Photograph Album

The tasks (2, 4, 7 and 8) dealing with the performance of the technical analysis of the Phase I RI are described in Section 2 of this FSP and Section 5 of the WP. The tasks (1, 3, 5 and 6) dealing with the administration of the project are described in Section 6 of the WP. The tasks (9 and 10) dealing with administration and performance of the Community Relations Program for the project are described in Section 7 of the WP.

Section 3 of this FSP deals with the implementation of the activities presented in the Technical Approach.

1.3 Subject Sites

Although all of NSRR is potentially subject to the provisions of RCRA, the following sites (Figures 1-1 and 1-2) have been identified for inclusion under CTO-0007:

Site 1	Quebrada Disposal Site, Vieques Island
Site 2	Mangrove Disposal Site, Vieques Island
Site 5	Army Cremator Disposal Area
Site 6	Langley Drive Disposal Area
Site 7	Station Landfill
Site 10	Building 25 Storage Area
Site 13	Tanks 210-217
Site 14	Ensenada Honda Shoreline and Mangroves
Site 16	Old Power Plant, Building 38 (intake and discharge tunnels)
Site 18	Pest Control Shop and Surrounding Area
Site 21	Old Pesticide Storage Building 121

2.0 TECHNICAL APPROACH

The technical approach to the Phase I RI includes:

Task 2 Project Plans
Task 4 Field Investigation
Task 7 Reporting
Task 8 Meeting

2.1 Task 2 - Project Plans

The project plans consist of the following documents:

- Work Plan (WP)
- Sampling and Analysis Plan (SAP), containing
  - Field Sampling Plan (FSP)
  - Quality Assurance Project Plan (QAPP)
- Health and Safety Plan (HASP)

The WP, HASP, and QAPP appear in separate volumes. Two editions of these plans will be published: The Draft Edition; and the Final Edition.

2.2 Task 4 - Field Investigation

The Phase I RI will include:

- Mobilization/Demobilization
- Land Clearing
- Soil and Structure Sampling and Geophysical Surveying
- Groundwater Sampling
- Sediment Sampling
- Geohydrologic Study

This section describes each category of the field investigation, and presents the technical approach to the objectives. The indicated actions at each site for the Phase I RI directly support the supplementary objectives, either by establishing the justification for the results of the CS or by providing reliable information independent of the CS.

2.2.1 Categories of the Field Investigation

2.2.1.1 Mobilization/Demobilization

Mobilization and demobilization consist of moving personnel and equipment to the study area, and returning those personnel and materials. The majority of the field investigation will be conducted by Baker (BEI) personnel; the participation of the only expected contractor for the field investigation, the land surveyor, is expected to be a minor effort. [Note: It was originally planned to use a local subcontractor for site clearing; however, NSRR will be able to provide this service.] Also included in this category are the various administrative and logistic functions directly related to support of personnel, and to provision and transport of materiel during the field operations.

2.2.1.2 Land Clearing

Review of conditions at Sites 1, 5 and 6 indicates that no valuable data stations could be occupied without clearing some of the densely grown vegetation. Other sites may display this impediment to a lesser extent.

2.2.1.3 Soil and Structure Sampling and Geophysical Surveying

Sampling of soil is available at all sites described below for the Phase I RI, except Sites 7, 13 and 14. An electromagnetic induction geophysical survey at Site 5 will attempt to identify the locations of the disposal trenches, preliminarily indicated in the initial photo-interpretation.

2.2.1.4 Groundwater Sampling

Suitable monitor wells for sampling of groundwater are expected at Sites 1, 5, 6, 7, and 18.

2.2.1.5 Sediment Sampling

Sediment sampling appears appropriate at Sites 2, 14, and 16, and may also be productive at Sites 1 and 18.

2.2.1.6 Geohydrologic Study

A geohydrologic study of the groundwater regime will be made in two components: Well-head tests and representation of groundwater flow.

2.2.1.6.1 Well-Head Tests

Tests for the Phase I RI will consist of slug-tests (rising and falling-head) which will yield information for calculation of the local hydraulic conductivity.

2.2.1.6.2 Representation of Groundwater Flow

Measurements of water levels in the monitor wells of the study sites can be calculated (vertically and horizontally) from the survey data to provide a representation of the shape of the water table underlying a particular site. A minimum of one round of water level measurements will be recorded. This can further indicate the direction of flow of groundwater and possible preferential migration routes for contaminants. The usual result of this analysis is a groundwater contour map, with calculation of gradient from the streamlines represented on the map. Calculation of this gradient can be utilized (along with other information) to assess the rate of groundwater movement.

2.2.2 Investigation Activities

2.2.2.1 General Activities

In the execution of the Phase I RI of this project, the expected activities that will apply to all sites are:

- Interpretation of historical aerial photographs according to Environmental Photo-Interpretation Center (EPIC) standards for RCRA/CERCLA investigations;

- Organization of the data available from the CS;

- Transfer of topographic mapping, land surveying and photo-interpretation information to Computer Assisted Drafting (CAD) files; and,

- Reporting.

Descriptions of these activities are provided in Section 2.2.3.

2.2.2.2 Site Activities

Actions, outlined below, at the specific sites will fall into two categories: technical study and support. The technical studies comprise photo-interpretation, sampling of various environmental matrices, analysis of samples according to the appropriate protocols, reconnaissance of aquifer parameters (well-head tests for hydraulic conductivity), representation of the pattern of groundwater flow and geophysical surveying. Not all of these apply to each site (Section 2.2.1).

In general, sampling stations have been selected in the area at each site most likely to exhibit the greatest adverse effect of disposal. Therefore, analyses of these samples will provide either:

- A reasonable absence of concern for that site (if no significant concentrations of contaminants are found), or

- Identification of the specific compounds to be used in the RFI in indicating the extent and severity of contamination.

Support actions for each site appear according to site-specific requirements. The support activities are directly focussed on facilitating the technical study.

The technical and support activities at each site (Figures 2-1 through 2-9) are outlined in this section.

The following abbreviations are used throughout this document.

GW	groundwater	TCL	Target Compound List
S	soil	TAL	Target Analyte List
SW	surface water	TAR	asphaltic oil
SED	sediment	SVOC	TCL Semivolatile Organic Compounds
BG	background	NA	not applicable to CTO-0007

Site 1 - Quebrada Disposal Site, Vieques Island

Confirmation Study

Scope

Three monitoring wells were installed and sampled during Round 1 of the program. Soil and sediment samples were taken during Round 1. Groundwater only was sampled during Round 2. The CS sampling and analytical program is summarized in Appendix A.

Results

The soil and sediment samples collected during Round 1 showed no detections of constituents of concern. Based on this, no soils or sediments were sampled during Round 2.

Groundwater samples were collected during both rounds of sampling. The data indicated that metals concentrations in the groundwater exceeded drinking water criteria and ambient water criteria in samples from both rounds.

Investigation Program

The investigation for Site 1 includes sampling the groundwater from the existing three wells, sampling soil from four stations within the expected area of disposal, and sampling one sediment station along the ravine carrying storm-water from the site. Final positioning of the stations (other than groundwater) depends on coordinating ground conditions with the results of the limited analysis of aerial photographs. The monitor wells will be assessed for integrity, measured for water level, have reconnaissance well-head tests performed and have an initial representation of the groundwater flow pattern prepared. The wells will be sampled and the sample analyzed in accordance with Level D QA/QC protocols. Sampling Locations are shown on Figure 2-1.

The support activities for the investigations at Site 1 include land-clearing and surveying of the monitor wells. Land-clearing is required at this site due to the impassable overgrowth of groundcover; no suitable stations for soil sampling can be reached at the present time.

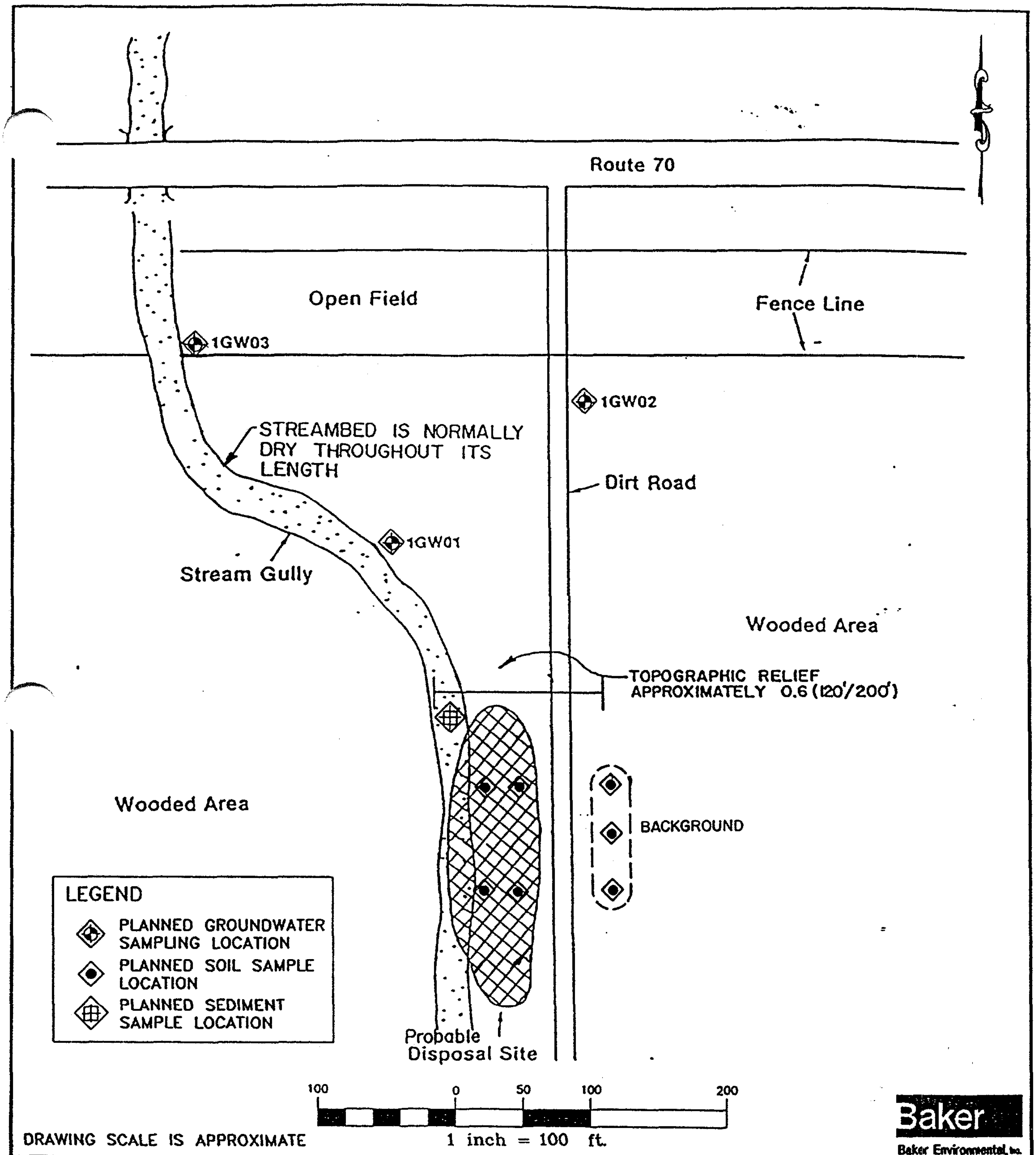


FIGURE 2-1
SAMPLE LOCATION MAP
SITE 1, QUEBRADA DISPOSAL SITE,
VIEQUES ISLAND

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: NEESA, 1984b; ESE, 1985.

Sampling Program Summary

Matrix	Number	Sequence
Investigation Samples		
GW	3	TCL/TAL
S	8=[4 stations x 2 samples/station]	TCL/TAL
SW	0	
SED	1	TCL/TAL
Background Samples		
BG-GW	0	
BG-S	3=[3x1]	Pest/PCB/TAL
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

Well-Head tests
Flow Analysis

Investigations Rationale

Aerial Photo Interpretation

Historical air photos will be reviewed in as much detail as the available records allow. This analysis will be utilized in two ways:

1. Air photos taken during the time of suspected waste disposal (if available) may show the extent of disposal and possibly provide some indication of the types of material disposed; and

2. Sampling stations for the Phase I RI will be based upon the results of the air photo review.

Groundwater

The three wells will be inspected before any measurements or samples are obtained to assess their suitability as data stations. In particular, 1GW03 was heavily damaged during a hurricane and may not be usable. Should the wells be usable, slug testing for local hydraulic conductivity and water level measurements will be performed. Depending on the results, a general flow analysis of the site can be performed which may indicate flow direction and rate.

Samples will be obtained from all usable wells. Because of the site's arrangement, none of the wells are located in a good background position; however, well 1GW02 may provide background data depending on groundwater flow directions and analytical results. The purpose of this sampling will be to assess whether groundwater is being affected by historical waste disposal at this site. Level D QA/QC will be used during this program to produce defensible data. This approach will allow the data from this program to be compared to that of the CS to either verify or refute the previous information. This comparison across programs will provide a reasonable indication of whether there is groundwater contamination present that is related to Site 1.

Soils

Soil samples will be taken from areas within the site and from areas of similar geologic terrain that are remote from the site.

Samples taken from within the area of suspected waste disposal will be subjected to Level D QA/QC protocols and used to assess whether the site has been impacted. In addition, using the higher level of QA/QC will allow the CS sampling results to be compared to new results and thus either verify or refute the CS study results.

Background soil samples for metals concentrations will be taken from a location away from that suspected of receiving waste but which has similar underlying geology. This data will be used to establish background metals concentrations for comparison purposes. It is possible that, in addition to background, the metals information may provide an indication of whether the apparently elevated concentrations seen in groundwater are a result of natural conditions.

Surface Water/Sediment

There is no surface water sampling planned since Vieques Island only has ephemeral streams. A single sediment sample will be taken immediately downslope of the waste disposal area in the ravine. No background station is available because of site topography.

The purpose of the sediment sample, which will be subjected to Level D QA/QC protocols, is to assess whether the sediments have been affected by reported waste disposal activities. In addition, the data from the CS will be reviewed and compared to the new results. It is expected that sufficient information will be available to either refute or verify the CS findings.

Site 2 - Mangrove Disposal Site, Vieques Island

Confirmation Study

Scope

Two rounds of sampling were included in the study. During the first round soil , sediment, and surface water were collected and analyzed. Only sediment and surface water were sampled in the second round. The CS sampling and analytical program is summarized in Appendix A.

Results

No elevated levels of the constituents of concern were detected in the soil samples from the first round. Based on this finding, soils were not sampled in the second round.

Chromium and lead were found in the sediment samples from both sampling events. The concentrations seen were deemed insignificant when compared to the background soil concentrations. Lead levels were higher in Round 2 samples which the report attributes to seasonal fluctuations and slightly different sampling locations.

Chromium was detected in surface water during Round 1 but not Round 2. Lead was only detected in a single sample. Chromium and lead concentrations were found to meet the ambient water quality criteria and drinking water criteria.

Investigation Program

Six samples of soil will be obtained from three stations within the area of expected disposal. No surface water samples will be taken. Two sediment samples will be obtained. One sample of an asphaltic oil or tar will be taken (with one duplicate) at a soil station. Sample locations are shown on Figure 2-2.

No special support actions are anticipated at this site. A small boat may be needed at the sediment sampling location. The technical study for Site 2 includes:

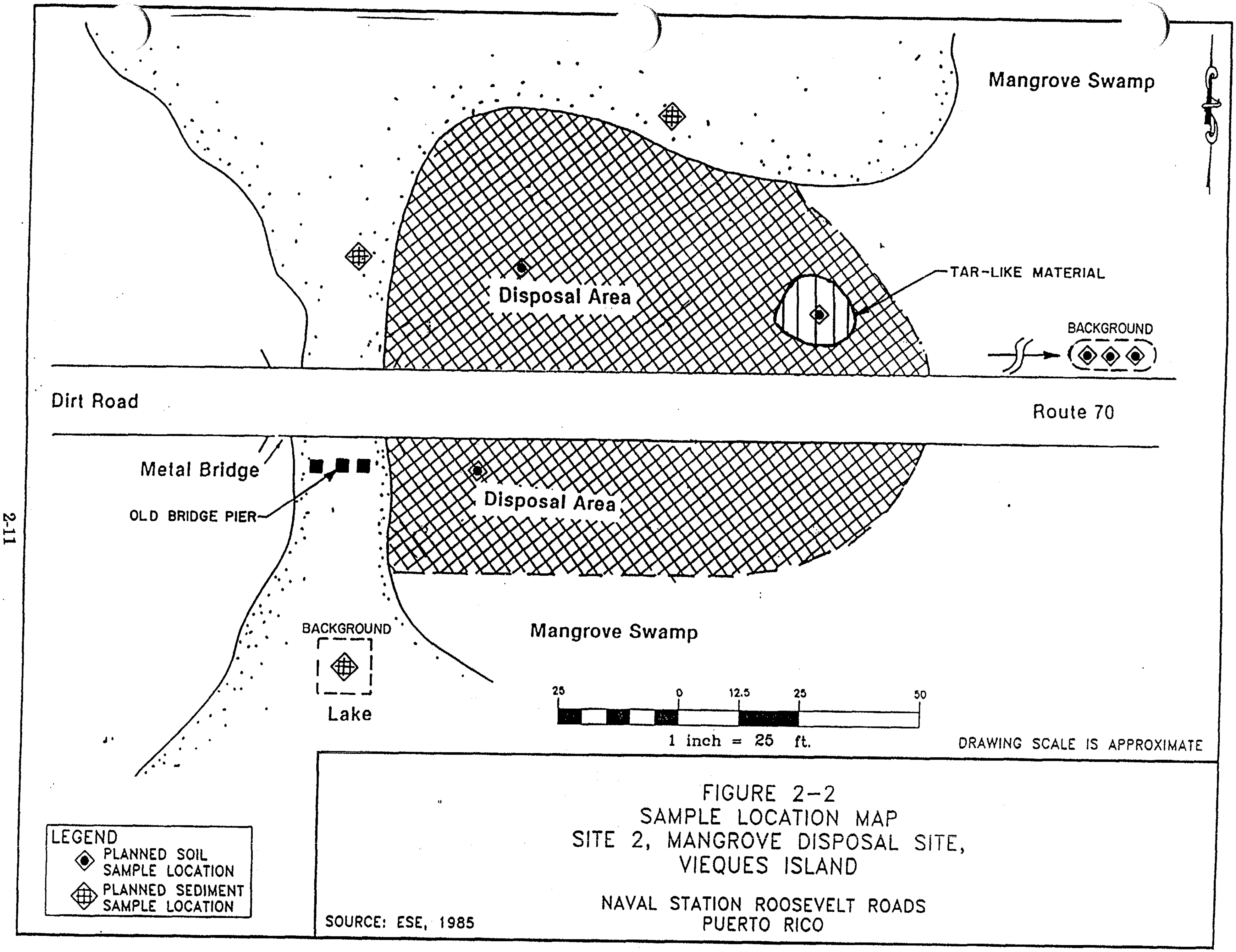


FIGURE 2-2
SAMPLE LOCATION MAP
SITE 2, MANGROVE DISPOSAL SITE,
VIEQUES ISLAND

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: ESE, 1985

Sampling Program Summary

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	6=[3 stations x 2 samples/station]	TCL/TAL
SW	0	
SED	2	TCL/TAL
TAR	1	SVOC
Background Samples		
BG-GW	0	
BG-S	3=[3x1]	Pest/PCB/TAL
BG-SW	0	
BG-SED	1	

Investigations Rationale

Groundwater

Groundwater should not be of concern at this site considering the high water-table and the rapid exchange of water with the adjacent tidal lagoons.

Soils

The soil samples planned for this area will be used to verify or refute the findings of the CS. All data will be developed using Level D QA/QC protocols which will ensure that the data is usable and defensible. One sample of some "asphaltic tar" will be taken. A background soil sample, to be analyzed for metals only, will be taken from a similar parallel sandbar which is unaffected by reported disposal practices.

Surface Water/Sediment

No surface water will be sampled, nor should it be of concern, because of the large volume of frequent exchange due to tidal action in the adjacent tidal lagoons.

Sediments will be sampled from two areas seaward of the site and one area inland. The inland sample will provide background data while the others are located such that they provide information from areas potentially affected by reported disposal practices. The sediment analytical data, which will be subjected to Level D QA/QC protocols, will provide information to verify or refute the findings of the CS.

Site 5 - Army Cremator Disposal Area

Confirmation Study

Scope

Surface water, sediments, and groundwater were sampled during two sampling events which comprised the confirmation study. Samples were taken from the same locations each time. The CS sampling and analytical program is summarized in Appendix A.

Results

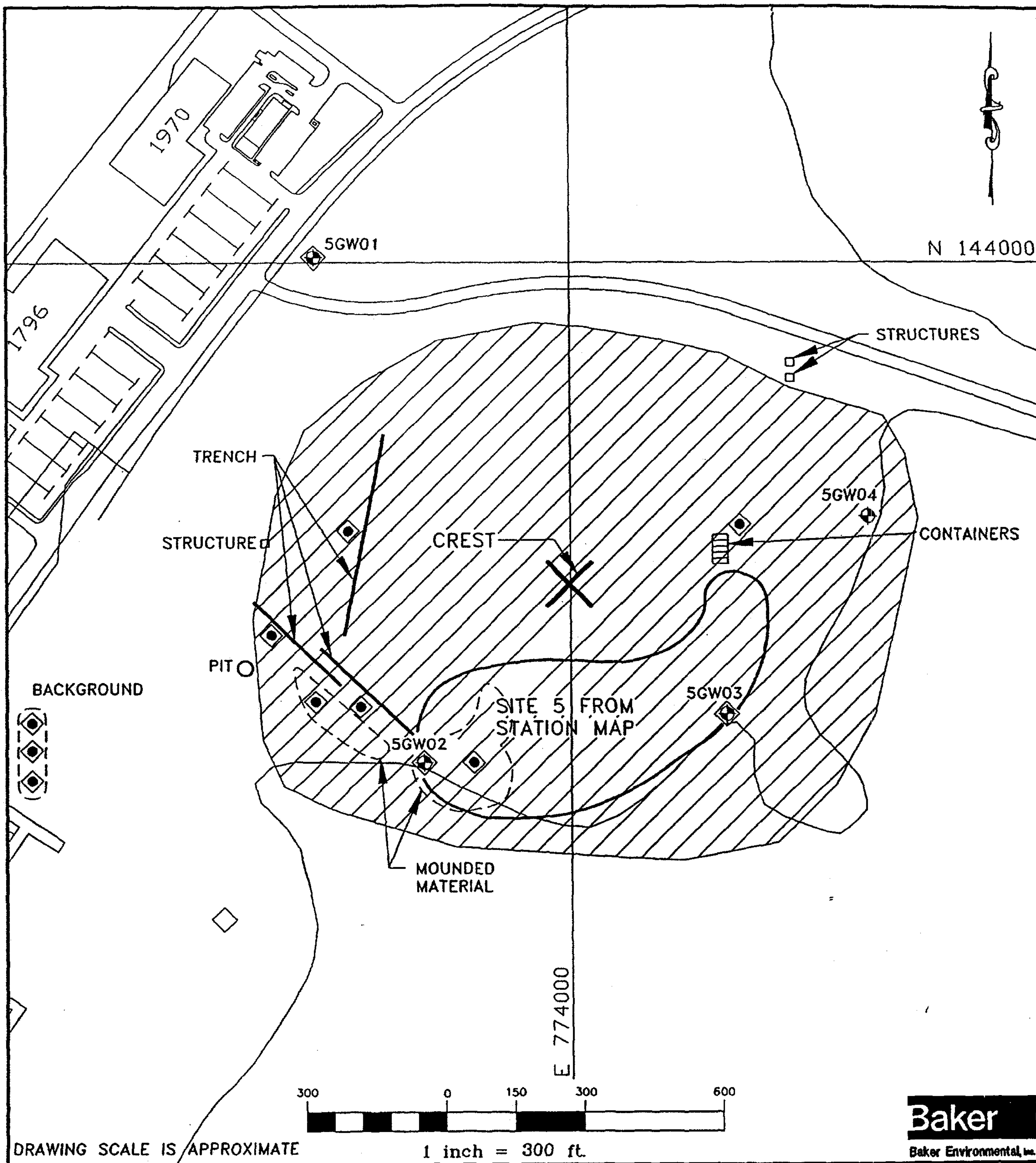
Minor amounts of pesticides were found in the Round 1 samples and only traces in Round 2. Antimony and selenium in some samples exceeded non-site specific published background levels for soils. Phenols were detected in samples from Round 2 but their presence was attributed to naturally occurring phenolic compounds in mangrove environments rather than past waste disposal. Methylene chloride was found in one sample from Round 2.

Surface water samples showed that arsenic, copper, nickel, and selenium were present at levels above the ambient water quality criteria. Low levels of two phthalates were found in both rounds. Round 2 showed the presence of some phenols which were considered to be naturally occurring.

Some metals were found in groundwater samples at levels which exceeded the drinking water criteria. Low levels of organic compounds were also seen. Phenols were present in Round 2 samples but were attributed to naturally occurring phenolic compounds.

Investigation Program

The sampling program will assess groundwater from two of the existing wells, and soil at six stations within the area of disposal indicated by the limited photo-interpretation. No surface water or sediment samples are planned. The monitor wells will be measured for water level, have reconnaissance well-head tests performed and have an initial representation of the groundwater flow pattern prepared. An electromagnetic induction geophysical survey will be conducted to attempt a ground identification of the location of the disposal area. Sampling and investigation locations are shown on Figure 2-3.



LEGEND

- PLANNED SURFACE SOIL SAMPLE LOCATION
- PLANNED GROUNDWATER SAMPLE LOCATION

FIGURE 2-3
SAMPLE LOCATION MAP
SITE 5, ARMY CREMATOR
DISPOSAL SITE

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

The support actions at this site will include extensive land-clearing to provide access to the sampling stations, and surveying of the monitor wells.

The technical study for Site 5 will not be defined until the results of the limited photo-interpretation study are available. At present, there is no firm knowledge of the actual location of the disposal area; however, for interim planning, the technical study can be viewed as:

Sampling Program:

Matrix	Number	Sequence
Investigation Samples		
GW	2	TCL/TAL
S	12=[6 stations x 2 samples/station]	TCL/TAL
SW	0	
SED	0	
Background Samples		
BG-GW	1	Pest/PCB/TAL
BG-S	3=[3x1]	Pest/PCB/TAL
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

Well-Head Tests
Flow Analysis
Geophysical Survey

Investigations Rationale

There is some question regarding where disposal activities were actually conducted in the area. To address this, a program of aerial photo interpretation and ground geophysics will be used prior to finally locating sampling sites.

Aerial Photo Interpretation

Historical air photos were reviewed, preliminarily the results of which are included as Appendix B to the Work Plan. Generally, the photos showed disposal activities as being relatively limited to a series of trenches. A more detailed review will be performed to potentially ascertain the time frame of disposal and to further define the areal extent of activities.

Geophysical Investigation

An electromagnetic induction geophysical survey will be conducted at this site. The purpose of this program will be to establish, in general terms, the area of waste disposal activities. If possible based on soil types and age of excavations, the actual trenches used for waste burial will be identified and possibly roughly quantified.

The results of the geophysical survey will be used to guide the soil sampling program so that samples are obtained in areas of actual waste disposal.

Groundwater

The available monitoring wells will be subjected to testing which will include water level measurements and slug testing to determine local hydraulic conductivity. This information should permit some general flow analysis to be performed which could provide an indication of groundwater flow direction and rate. Information of this type is very important in assessing transport of contamination.

Only two of the wells installed during the CS are thought to lie within areas affected by disposal activities based on the preliminary results of the air photo review. These two wells (5GW02 and 5GW03) along with one background well (5GW01) will be sampled during the program. All new data will be developed using Level D QA/QC protocols. The results will be used to determine whether additional groundwater investigations are needed and to either refute or verify the results of the CS samplings.

Soils

No background soil samples were previously obtained; therefore, a program to obtain background metals concentrations is included in the Phase I RI. An area southwest of Site 5 will be selected for sampling based upon its similarity of geologic terrain.

Soil samples, as described above, will be obtained. The purpose of the soil sampling will be to provide data (at Level D QA/QC) from areas of actual waste disposal activities. This will allow a better assessment of possible site impact to be made. Where sampling locations from this program and the CS overlap, the new data can be used to refute or verify the CS findings.

Surface Water/Sediment

There are no surface water bodies on the site and the adjacent areas are tidal with low water residence time. For these reasons, surface water is not a present concern at the site. Sediments may be of concern but are addressed by the sampling program to be conducted at the adjacent site (Site 14).

Site 6 - Langley Drive Disposal Area

Confirmation Study

Scope

Two rounds of soil, surface water, and sediments were obtained from Site 6. In both rounds the same sampling locations were employed; however, Round 2 contained some additional sampling points. Finally, a shallow groundwater monitoring was installed and sampled upgradient of Site 6 during Round 2 investigations. The CS sampling and analytical program is summarized in Appendix A.

Results

No constituents of concern were detected in any of the sediment samples with the exception of the ubiquitous presence of phenols. The phenols which were detected were attributed to naturally occurring compounds associated with the mangrove environment.

Soils were generally clean in all locations. Elevated levels of lead were detected in two adjacent sampling points during Round 1. As a results, 15 additional samples were collected in the area of this anomalous finding. The results of these samples showed the area of elevated lead concentrations to be limited to the two Round 1 locations.

Surface water findings showed generally lower levels of metals during Round 2 than those found in Round 1. While this is the case, chromium, copper, and selenium concentrations exceeded the ambient water quality criteria. Phenols were also detected in Round 2 but were considered to be the results of naturally occurring compounds.

The groundwater results indicated the presence of low levels of the organics pentachlorophenol and aldrin. Also, the concentration of lead was found to exceed the drinking water standard.

Investigation Program

The sampling program will assess groundwater from the one existing well, and soil at six stations within the area of disposal indicated by the limited photo-interpretation. No surface water or sediment samples are planned. The preliminarily selected sampling locations are shown on Figure 2-4.

The support actions at this site will include extensive land-clearing to provide access to the sampling stations, and surveying of the monitor well.

Sampling Program:

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	12=[6 stations x 2 samples/station]	TCL/TAL
SW	0	
SED	0	
Background Samples		
BG-GW	1	TCL/TAL
BG-S	3=[3x1]	Pest/PCB/TAL
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

Well-Head Tests

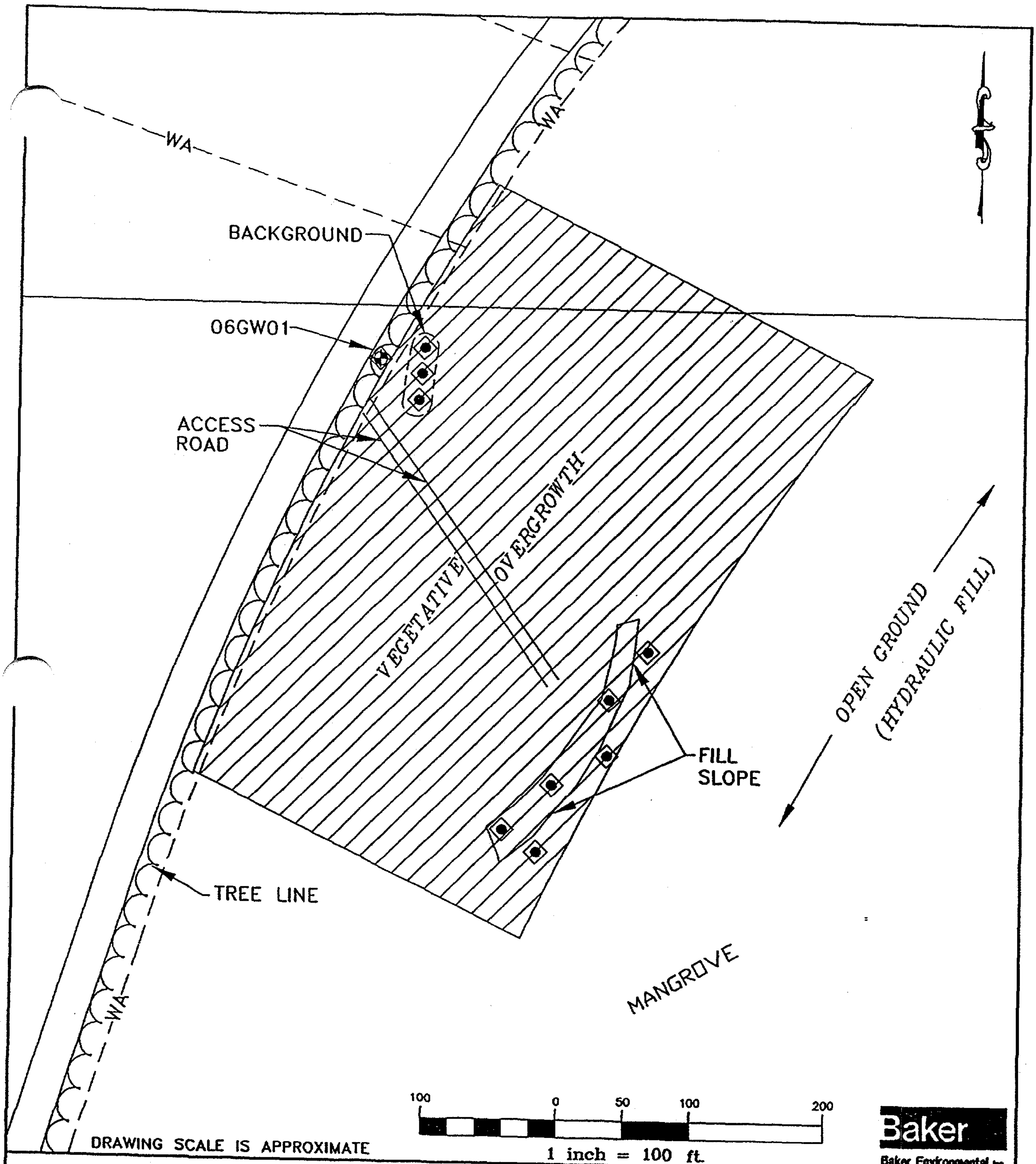
Investigations Rationale

Aerial Photo Interpretation

There is no detailed information available which adequately identifies the area subjected to possible waste disposal. Site 6 was subjected to preliminary review of historic aerial photos to identify suspect areas and to guide the Phase I RI sampling locations. The results of this preliminary review are included as Appendix B to the Work Plan.

Groundwater

There is only one well which is located upgradient of the site. No groundwater flow parameters can be established with a single well; however, the well will be tested to assess local hydraulic conductivity.



LEGEND

◆ PLANNED SURFACE SOIL SAMPLE LOCATION

◆ PLANNED GROUNDWATER SAMPLING LOCATION

FIGURE 2-4
SAMPLE LOCATION MAP
SITE 6, LANGLEY DRIVE
DISPOSAL SITE

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

The well will be sampled with the sample analyzed in accordance with Level D QA/QC protocols. It is expected that the results can be used to assess local groundwater in terms of metals concentrations and the presence of synthetic organic compounds. In addition, the groundwater results will be compared to those of the CS in an effort to establish the validity of the CS findings.

Soils

Soil samples will be obtained both from within the area suspected of receiving wastes and in a background area near the monitoring well. All samples will be analyzed in accordance with Level D QA/QC protocols. Providing site-specific background data regarding metals will allow a realistic comparison to be made between areas where reported waste disposal took place and those unaffected by past activities. In addition, the results of the soil samples (subjected to a higher level of QA/QC than that employed in the CS) will be compared to the CS findings to test the validity of the earlier results.

Surface Water/Sediment

Surface water does not appear to be of concern at this site since there are no established streams or ponds and the adjacent body of water is tidal with a very low water residence time.

Sediment may be of concern at the site but will be directly addressed in the investigations planned for Site 14.

Site 7 - Station Landfill

No general study is proposed for this site since the landfill is active. This site is being monitored under another program. However, a monitoring round will be included in the Phase I RI, to consist of (1) sampling of each well for TCL/TAL analysis, (2a) conducting well-head tests for calculation of the hydraulic conductivity and (2b) taking water level measurements for construction of a groundwater contour map. This information, developed in as much detail as the site conditions allow, can be very useful in assessing the transport of contamination.

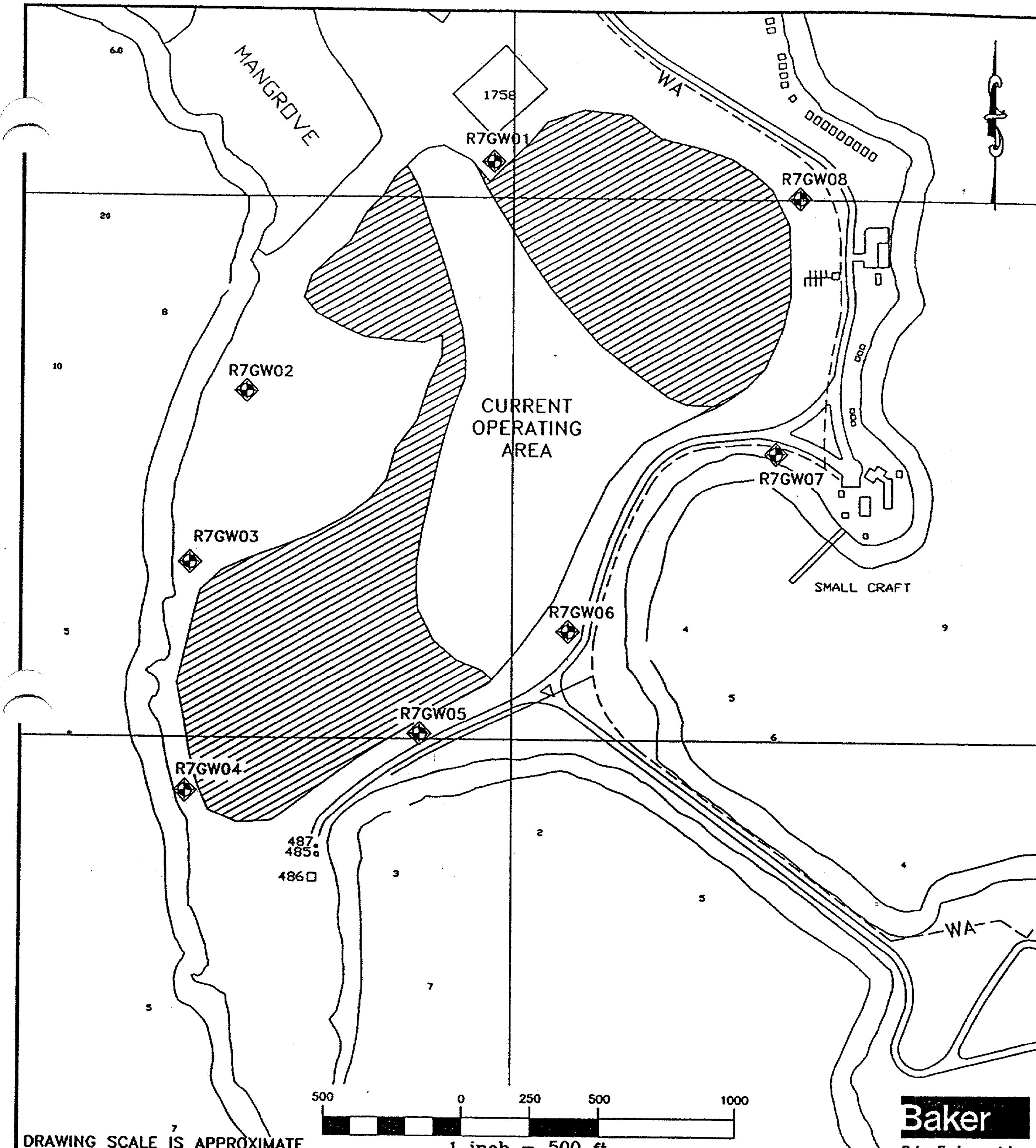
Sampling Program Summary

Matrix	Number	Sequence
Investigation Samples		
GW	7	TCL/TAL
S	0	
SW	0	
SED	0	
Background Samples		
BG-GW	1	TCL/TAL
BG-S	0	
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

Well-Head Tests
Flow Analysis

The support action at this site includes surveying of the measuring points of the monitoring wells.



LEGEND

R7GW03 PROPOSED GROUNDWATER SAMPLE LOCATION

SOURCE: LANTDIV., FEBRUARY 1992

FIGURE 2-5
SAMPLE LOCATION MAP
SITE 7, STATION LANDFILL

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

Site 10 - Building 25 Storage Area

Confirmation Study

Scope

A total of eight groundwater monitoring wells were installed and sampled during Round 1 of the CS, and sampled again during Round 2. No soil, surface water, or sediment samples were collected under the CS. The CS sampling and analytical program is summarized in Appendix A.

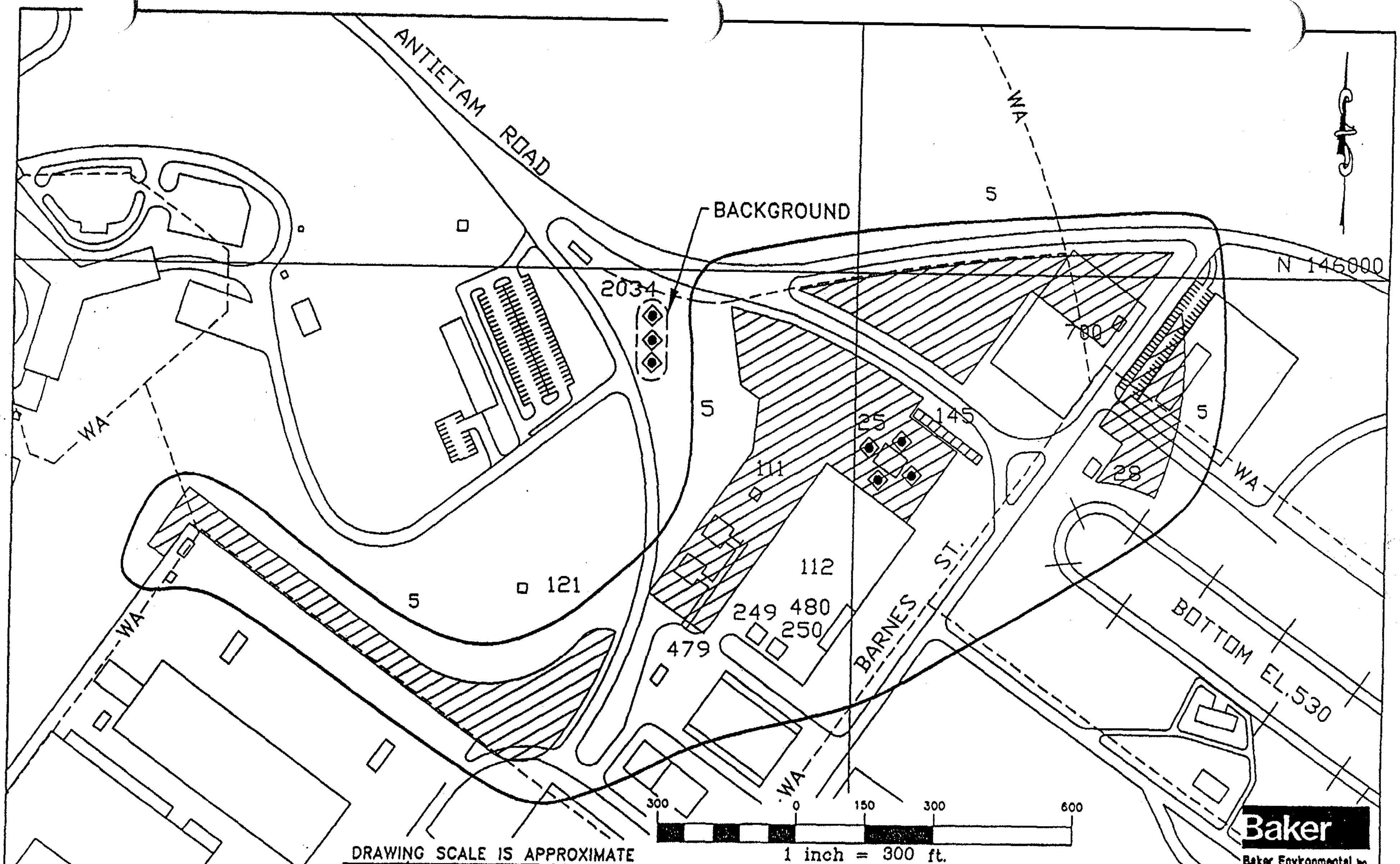
Results

Low to trace levels of a very few (1-3) organic compounds were detected during the two rounds of groundwater sampling. Some metals were detected at levels which exceeded the drinking water and ambient water quality criteria.

Investigation Program

No groundwater sampling at this site is planned. Four soil stations will be sampled around the approximate perimeter of Building 25. There will be no surface water and sediment stations. The locations selected for soil sampling are shown on Figure 2-6.

The support action at this site includes only surveying of the monitor wells.



LEGEND

◈ PLANNED SURFACE SOIL SAMPLE LOCATION

FIGURE 2-6
SAMPLE LOCATION MAP
SITE 10, BUILDING 25
STORAGE AREA

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

Sampling Program Summary

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	8=[4 stations x 2 samples/station]	TCL/TAL
SW	0	
SED	0	
Background Samples		
BG-GW	0	
BG-S	3=[3x1]	Pest/PCB/TAL
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

Well-Head Tests
Flow Analysis

Investigations Rationale

Groundwater

No groundwater sampling is included in the Phase I RI for two reasons:

1. The wells at this site are apparently not in positions capable of reflecting any affect the activities at Building 25 could have had on the groundwater; and,

2. No compounds of concern related to Building 25 were detected during the CS.

The analysis of flow conditions at the site, which will be accomplished through well-head measurements and slug testing, will provide information regarding the relative position of the monitoring wells in relation to the affected area and their continuing potential for future use if needed.

Soils

The locations that have been selected for soil sampling are in areas where the greatest affect from Building 25 activities (if there has been any) should be located. Based on these results, it should be possible to identify whether there is cause for further concern at this site.

A single background soil sample will be obtained from geologically similar terrain upslope from Site 10. The results of metals analysis on this sample will provide comparison data to be used in interpreting the other sampling results.

All soils samples will be analyzed in accordance with Level D QA/QC protocols.

Surface Water/Sediment

Surface water and sediment are not found within this area.

Site 13 - Tanks 210-217

No general study will be made at this site. The tanks in this area should probably be considered part of the UST program and referred to that program for future activity. The potential concerns at the site are the sludge pits reportedly associated with the tanks. The actual locations of these pits are not known. The photo-interpretations performed in preparation for the RFI are designed to indicate the probable presence and locations of the pits. Further consideration of the pits, not associated with the UST program, will be made only after analysis of the aerial photographs.

Site 14 - Ensenada Honda Shoreline and Mangroves

Confirmation Study

Scope

The scope of work for the CS included only the collection of surface water and sediments. The CS sampling and analytical program is summarized in Appendix A.

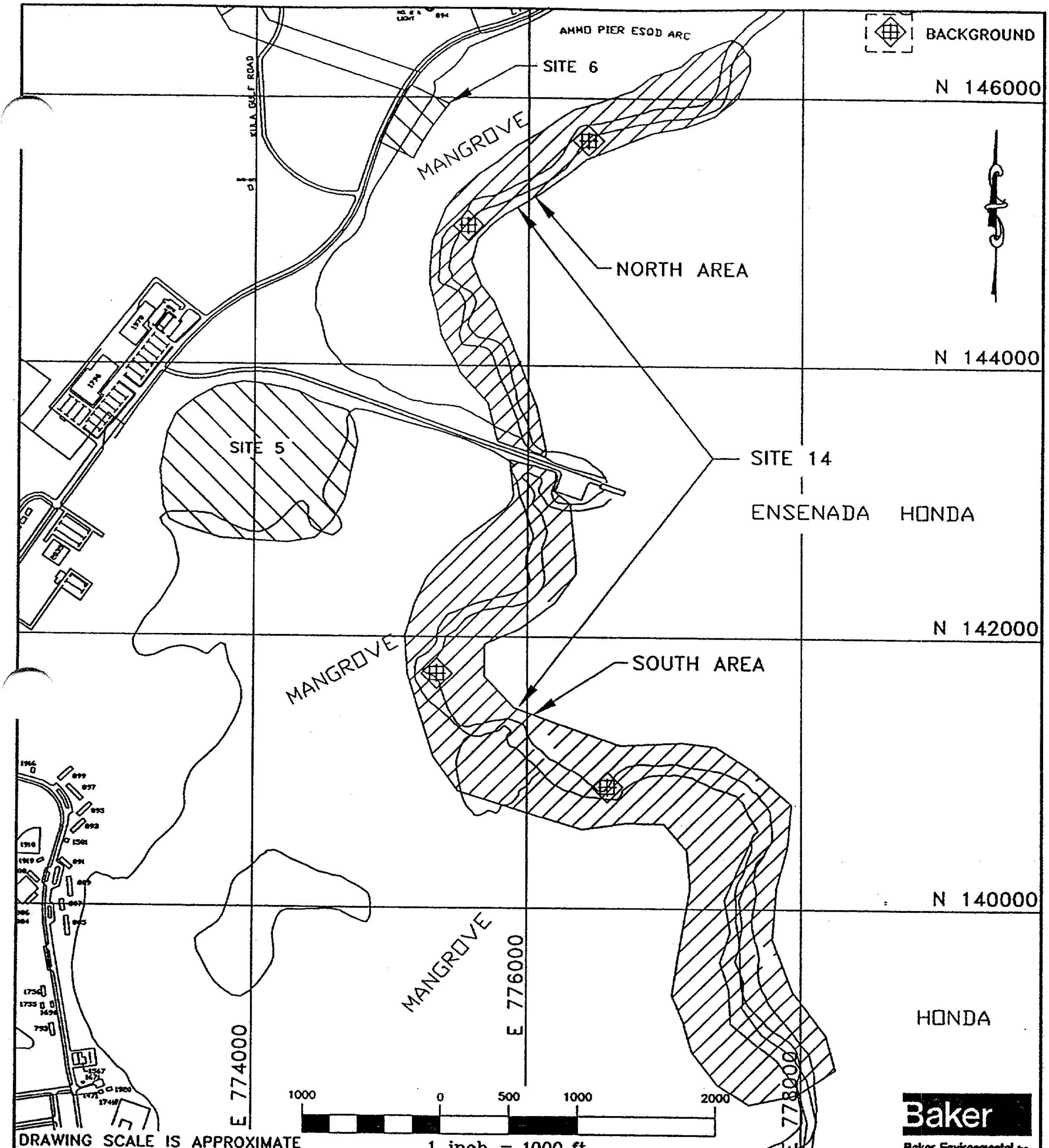
Results

Significant levels of oil and grease were detected in the sediments associated with Site 14. Surface water samples did not indicate significant levels but those more commensurate with levels seen associated with heavy shipping activities.

Damage related to past spillage seen in the mangroves was especially prevalent along the southwestern shore of Ensenada Honda. Signs of recovery in this area were noted during the field work of the CS.

Investigation Program

No groundwater, soil or surface water sampling is planned at this site. Four stations will be used for sampling sediments within the fringe of the mangrove. The general locations of these sampling points are shown on Figure 2-7.



LEGEND

PLANNED SURFACE SEDIMENT SAMPLING LOCATION

FIGURE 2-7
SAMPLE LOCATION MAP
SITE 14, ENSENADA HONDA
SHORELINE AND MANGROVES

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

The mangrove fringe is not accessible by means other than small boat. Accordingly, sea-kayaks supported by a motor-launch will be used in obtaining sediment samples.

Sampling Program:

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	0	
SW	0	
SED	4	TCL/TAL
Background Samples		
BG-GW	0	
BG-S	0	
BG-SW	0	
BG-SED	1	TCL/TAL

Investigation Rationale

The site is inundated by tidal water and therefore, groundwater and soil are not matrices of concern. The exchange of surface water is sufficiently high that a meaningful analysis of surface water quality cannot be made. The sediment of the mangrove swamp accumulates discharge from the adjacent Sites 5 and 6, as well as from other sources; the results of the analyses of sediment at Site 14 can likely be used to indicate the general effects of Sites 5 and 6 on the environment. The sediment samples will be taken from a depth of 0.5 to 1.0 meters with the stations located as far into the mangrove (about 10 meters) as the kayaks can advance, which is where accumulation of contaminants can most likely be found.

Based on careful review of the analytical data (which will be subjected to Level D QA/QC protocols) and consideration of the various "signature" contaminants which may be found at Sites 5 and 6, an assessment of whether these sites are contributing to Site 14 will be conducted. Additionally, the more rigorous QA/QC program of the Phase I RI will allow the CS results to be reassessed regarding their validity.

Site 16 - Old Power Plant, Building 38

Associated with the Old Power Plant is a set of intake and discharge tunnels. It is unclear at this time which tunnel represents the intake and which tunnel represents the outfall. Once the field team has been mobilized, a decision will be made and samples taken accordingly.

These tunnels have been sampled previously (both surface water and sediment) and constituents of concern were detected. This site is presently administered under a different program than that driving the Phase I RI; however, it was determined that confirmation sampling should be performed under this program as an expedient way to obtain data. The results of this sampling will be provided in a separate report which will not be associated with the Phase I RI report.

The technical study for Site 16 includes:

Sampling Program:

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	0	
SW	7	Pest/PCB/SVOC
SED	8	Pest/PCB/SVOC
Background Samples		
BG-GW	0	
BG-S	0	
BG-SW	0	
BG-SED	0	

The support action at this site will most likely require the use of a small boat to reach the sampling stations.

Investigations Rationale

The data from the Phase I RI will be used for comparison purposes and to either verify or refute the previous sampling and analytical work.

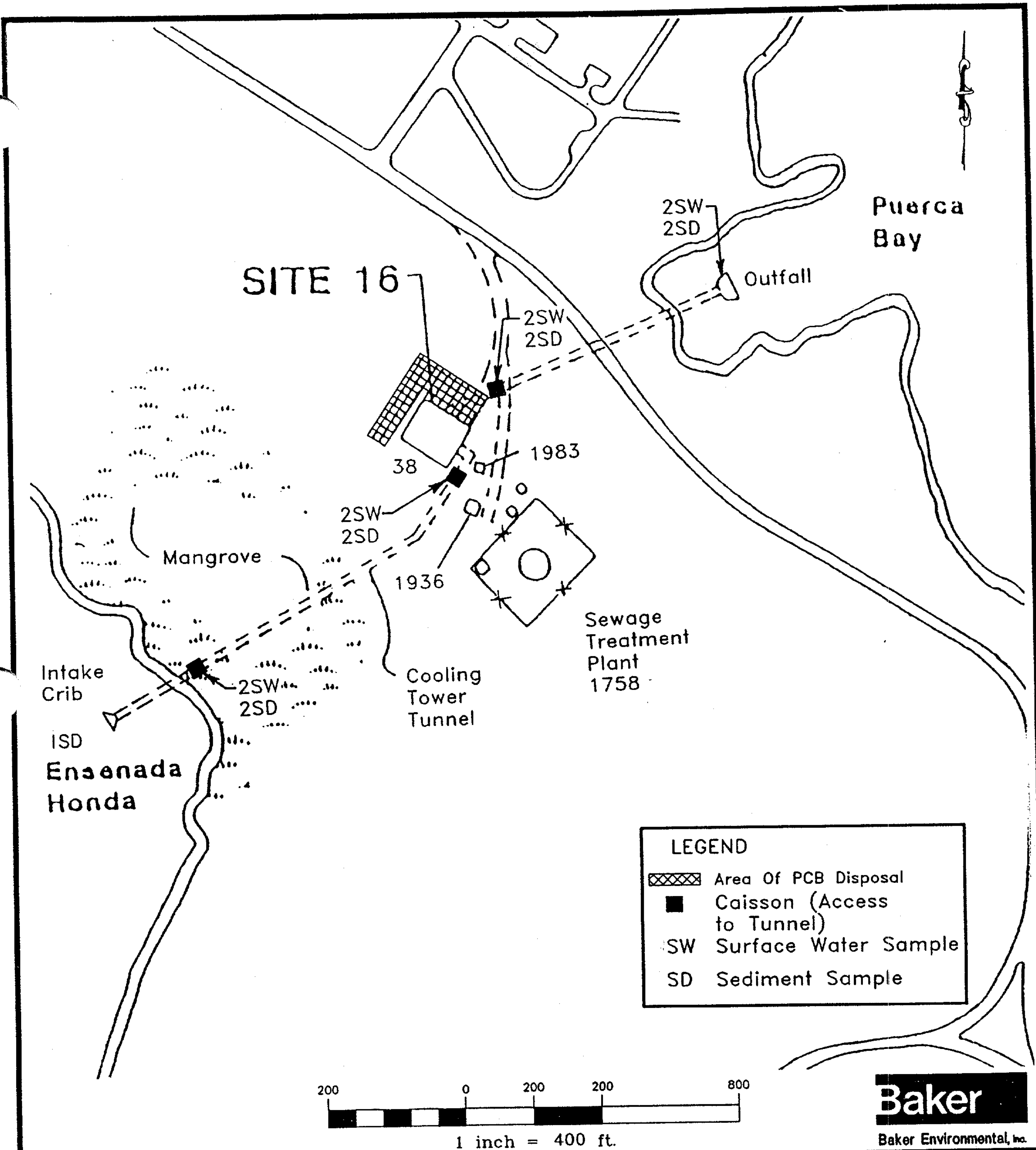


FIGURE 2-8
SAMPLE LOCATION MAP – SITE 16
OLD POWER PLANT, BUILDING 38

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: VERSAR, INC. (1992)

Site 18 - Pest Control Shop and Surrounding Area

Confirmation Study

Scope

The CS included two rounds of sampling and investigative activity. During Round 1, soil samples were taken from the area surrounding the Former Pest Control Shop (Building 258) and from the drainage ditches near the building. Surface water and sediments were also collected from the drainage ditch south of the site. Round activities included:

- Installation and sampling of three groundwater monitoring wells.
- Resampling of the Round 1 surface water/sediment locations; and
- Sampling of an additional four surface water/sediment points further downstream in the drainage ditch leading away from the site.

The CS sampling and analytical program is summarized in Appendix A.

Results

Soil sampling results showed that there were several pesticides present with the highest concentrations found near the entrance, around the eastern corner and on the northwest side of the building.

Sediment samples from both rounds indicated the presence of chlordane and several other pesticides in the areas nearer the building.

Chlordane was found in surface waters at concentrations exceeding the ambient water quality criteria with evidence suggesting downstream migration of contaminants.

Only one well had any detections and that was for a single compound at an extremely low concentration.

Investigation Program

Two groundwater samples will be taken from the (apparently) downgradient wells 18GW2 and 18GW3. Four soil samples will be taken at two stations on the perimeter of the removed

Building 258. One surface water/sediment sample from a drainage ditch will be analyzed. The monitor wells will be measured for water level, have reconnaissance well-head tests performed and have an initial representation of the groundwater flow pattern prepared. The selected sampling locations are shown on Figure 2-9.

The support action at this site includes only surveying of the monitor wells.

Sampling Program:

Matrix	Number	Sequence
Investigation Samples		
GW	2	TCL/TAL
S	8=[4 stations x 2 samples/station]	TCL/TAL
SW	1	TCL/TAL
SED	1	TCL/TAL
Background Samples		
BG-GW	1	TCL/TAL
BG-S	3=[3x1]	TCL/TAL/Pest/PCB
BG-SW	0	
BG-SED	0	

Geohydrologic Program:

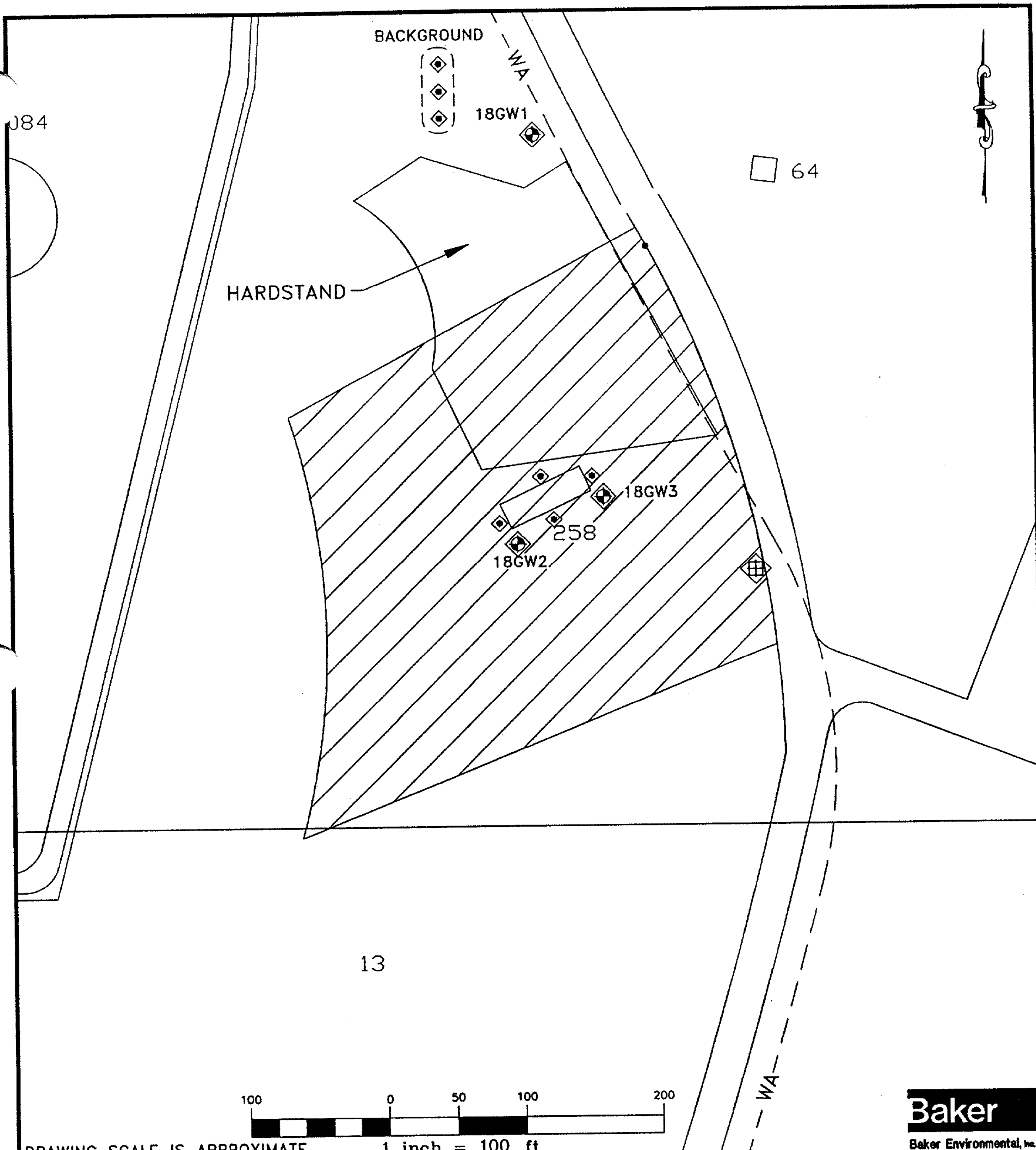
Well-Head Tests
Flow Analysis

Investigation Rationale

Groundwater

Well head analyses, consisting of slug tests and groundwater elevation measurements, will be performed. These tests will provide information regarding the groundwater levels and the local hydraulic conductivity. Based on the results of the head measurements a general analysis of groundwater flow and possibly gradient can be attempted. This information will be valuable in predicting the flow direction and rate should contamination in the aquifer be verified.

The results of the CS indicated minimal impact to groundwater which could potentially be tied to activities at Building 258. The two wells within the suspected impacted area will be



LEGEND

18GW1 PLANNED GROUNDWATER SAMPLE LOCATION WELL

PLANNED SURFACE WATER/SEDIMENT SAMPLE LOCATION

PLANNED SURFACE SOIL SAMPLE LOCATION

SOURCE: LANTDIV., FEBRUARY 1992

FIGURE 2-9
SAMPLE LOCATION MAP
SITE 18, PEST CONTROL SHOP
AND SURROUNDING AREAS
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

sampled during the Phase I RI with the samples subjected to Level D QA/QC protocols. Additionally, the background well will be sampled for comparison purposes. This data will be utilized to confirm or refute the findings of the CS.

Soils

Locations for soil sampling during the Phase I RI have been selected to cover those areas most likely to be affected by site activities. All soil samples will be analyzed in accordance with Level D QA/QC protocols. The data from this program will be compared to that developed during the CS to ascertain the validity of the previous information. In addition, background soil samples will be collected from geologically similar terrain near the site. These samples will be analyzed for TCL and TAL contaminants.

The background data will be utilized for comparison purposes when reviewing the overall data package.

Surface Water/Sediments

Surface water (if available) and sediment will be sampled at a station at the downstream edge of Site 18. These samples will also be subjected to Level D QA/QC protocols. The results of surface water and sediments will be compared to those of the CS to assess the validity of the earlier work.

Site 21 - Old Pesticide Storage Building 121

No general study is planned for this site under this program. A RCRA Closure Permit Application has been made for this area; therefore, further action depends on the disposition of that application. Samples will be collected and analyzed as part of the Phase I RI, although the results of analyses will not be reported under this project. These results will be turned over to another program administered by LANTDIV. The general location of the site is shown on Figure 2-10-1. Sampling locations are indicated on Figure 2-10-2.

Sampling Program Summary

Matrix	Number	Sequence
Investigation Samples		
GW	0	
S	10=[5 stations x 2 samples/station]	NA
SW	0	
SED	0	
CHIP	3	NA
Background Samples		
BG-GW	0	
BG-S	1	NA
BG-SW	0	
BG-SED	0	

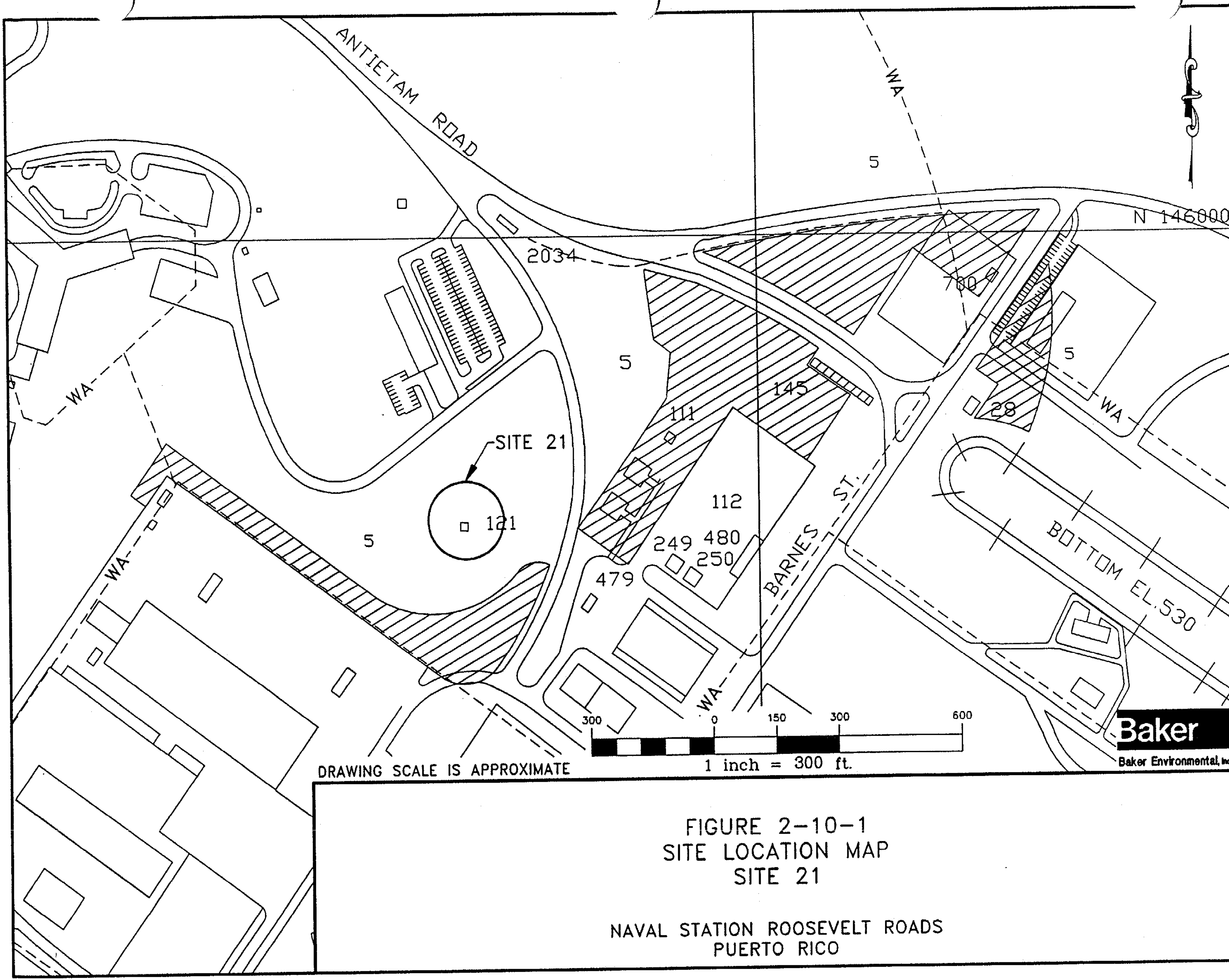
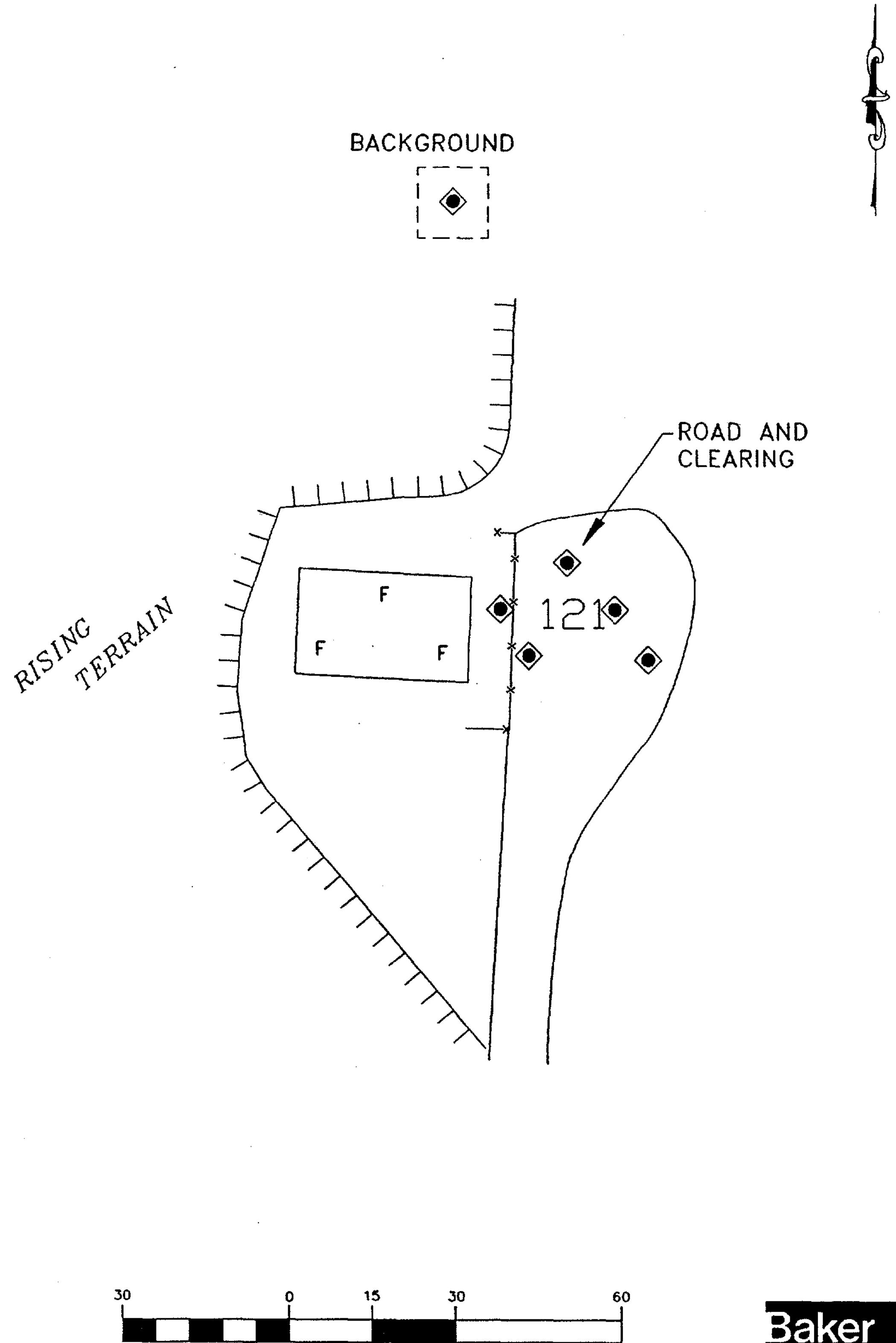


FIGURE 2-10-1
SITE LOCATION MAP
SITE 21

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



DRAWING SCALE IS APPROXIMATE

Baker
Baker Environmental, Inc.

LEGEND

F PLANNED FLOOR CHIP SAMPLE LOCATION

● PLANNED SOIL SAMPLING LOCATION

SOURCE: LANTDIV., FEBRUARY 1992

FIGURE 2-10-2
SAMPLE LOCATION MAP
SITE 21, OLD PESTICIDE
STORAGE BUILDING 121

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

2.2.3 Discussion

2.2.3.1 General

The EPA has indicated that the sites at the Naval Ammunition Facility, Vieques Island (NAF-V) will be considered separately from those on the main base. Accordingly, this FSP has been constructed to allow Sites 1 and 2 to be administered and reported separately from the remainder. The most economical approach, however, to the field studies and to the analysis of data is to combine the efforts into concurrent action; this approach has been utilized in this document.

2.2.3.2 Technical Investigations

The technical investigations for the Phase I RI fall into the following major categories: Photo-interpretation; well-head tests; representation of groundwater flow; sampling and analysis; and geophysical investigation.

2.2.3.2.1 Photo-Interpretation

A detailed interpretation of historical aerial photographs will be performed for each of the sites addressed by this project. This interpretation will be performed by a private contractor in a fashion similar to the EPIC analyses of the EPA for CERCLA/RCRA sites.

The interpretation will extend to the historical limit of coverage, attempting for each site an analysis of relevant physical features, disposal locations and practices, and changes through time. Detailed descriptions of these concerns are highly desirable in providing the rationale for future investigation techniques, and in illustrating the findings and recommendations at the sites. These descriptions are notably absent from the existing reports on the sites.

Analysis by photo-interpretation is especially useful at Sites 1, 5 and 6, for which there are no reliable indications in the site reports of the locations of disposal at these sites. Field reconnaissance on the ground and from aircraft has similarly been unable to find the disposal areas. A limited investigation by photo-interpretation has been made prior to development of this FSP, specifically for the purpose of identifying the specific ground relevant to the project.

2.2.3.2.2 Well-Head Tests

Geohydrologic tests for this project will consist of slug-tests (rising or falling-head) for calculation of the local hydraulic conductivity. This technique is well represented in environmental investigations as a general or reconnaissance characterization of the aquifer across the area of a study site. Calculation of the hydraulic conductivity provides a basis for estimation of the rate of flow of groundwater, and, to a lesser extent, on the probable rate of transport and area of distribution of contaminants in the groundwater. A standard operating procedure for slug testing (SOP F402) is included in Appendix B.

2.2.3.2.3 Representation of Groundwater Flow

Measurements of water levels in the monitor wells at the study sites can be calculated (vertically and horizontally) from the survey data to provide a representation of the shape of the water table underlying a particular site. This can further indicate the direction of flow of groundwater and the possible areal distribution of contaminants in the groundwater. A minimum of one round of water level measurements will be recorded.

The usual result of this analysis is a groundwater contour map, with calculation of gradient from the streamlines represented on the map. Calculation of this gradient contributes to the representation of the rate of groundwater movement and likely contaminant transport directions.

2.2.3.2.4 Sampling and Analysis

Groundwater, soil and sediment are the environmental matrices generally relevant to the Phase I RI of this project and to the preparation for the RFI. These matrices will be sampled variously at different sites, depending on site conditions. Additionally, at particular sites, other matrices will be added (specifically, tar from the asphaltic layer at Site 2 and structural samples from the interior of Building 121 at Site 21, although the data from Site 21 will be reported by others). Analyses will be made as described in Section 3.3.

2.2.3.2.5 Geophysical Survey

Geophysical surveying applies specifically to Site 5. There are indications that the burial trenches at the site would not be recognized at the surface, even after land clearing. An electromagnetic induction geophysical survey will attempt to identify the trench locations, coordinated with the locations indicated by the limited photo-interpretation. Selection of geophysical transect line spacing will be determined by field conditions. Some difficulty in the interpretation of the geophysical survey is expected, however, from the rock underlying the knoll (iron-rich diorite) and from the native soil (natural oxides of metals and other iron-bearing minerals). A standard operating procedure for electromagnetic geophysical survey (SOP F702) is included in Appendix B.

2.2.3.3 Support of Investigations

The main support for the technical investigations comprises: Land navigation; surveying; land clearing; high-angle climbing; small boat operations; computer mapping; and correlation of analytical data.

2.2.3.3.1 Land Navigation

The land navigation planned for the Phase I RI will be conducted using GPS (Global Positioning System) receivers, as a base-station and a remote station. Due to the modulation of this system by the Department of Defense, the horizontal resolution of paired receivers is about one meter, the resolution of a single receiver being about 100 meters. The one-meter resolution is sufficient for surveying the horizontal position of the data stations in this project.

Review of the existing reports and inquiry at NSRR have found no indication of coordination, either horizontal or vertical, of any of the data stations, including the monitor wells. This absence makes reference of the data stations to physical features of the site difficult or impossible (essentially making some of the existing data irrelevant until horizontal coordination can be made); it also makes interpretation of the groundwater regime virtually impossible.

At least some of the data stations are improperly represented on the maps of the available reports: Wells at Sites 7 and 10 are not at the positions indicated on those maps. The available maps actually represent unscaled sketches from which no detailed planning or calculation can be made. Accurate maps are required for the purposes of this project and for an RFI.

Mapping control can be established by a line survey or by GPS mapping. While horizontal control can be established most accurately by a line survey, the accuracy acceptable to this project and to an RFI can be achieved by GPS mapping. Given the terrain and conditions of the sites addressed by CTO-0007 (numerous stations and stations on steep slopes, in heavy vegetation or on open water), the level of effort of a line survey would be prohibitive in complexity, cost and schedule. The GPS mapping is expected to represent a considerable increase in efficiency and decrease in cost over a line survey.

Lastly, the navigation receiver makes possible guided movement to specific coordinates on the ground. This is particularly important at Sites 1, 5 and 6, where only the calculated locations from the photo-interpretation can be used to find the actual disposal areas.

2.2.3.3.2 Surveying

While the GPS receiver is suitable for horizontal control of the positions of the data stations, and can be used where land surveying would be difficult or impossible (the slope at Site 1 and the offshore stations at Site 14), GPS does not provide the accuracy and precision of vertical control require for interpretation of groundwater flow. To meet this need, a licensed surveyor will record the elevation of each well used in this project to 0.01 feet accuracy against a standard Station, Commonwealth or Federal datum.

2.2.3.3.3 Land Clearing

Review of conditions at Sites 1, 5 and 6 indicates that no valuable data stations could be occupied without clearing the densely grown vegetation. Other sites may display this impediment to a lesser extent.

At Site 1, the vegetation on the steep slope (where disposal apparently occurred and sampling is, therefore, necessary) must be cut. Normally, heavy machinery could be used. However, since the disposal of materials at Site 1 was apparently across, rather than beneath the land surface, scarification by heavy equipment is undesirable at this site.

The preliminary indications of the photo-interpretation seem to be that the disposal area of Site 5 is remote from the two remaining hardstands, on the reverse side of the knoll. Access to this area will be possible only after clearing of the area. The distance involved is much greater than that at Site 1, indicating that clearing by hand is infeasible. However, use of heavy equipment is acceptable, since the apparent practice of disposal by burial, rather than by surface scattering at Site 5, makes preservation of the land surface during sampling relatively unimportant.

Site 6 may require similar preparation as Site 5.

2.2.3.3.4 High-Angle Climbing

The difficulties at Site 1 are compounded by the steepness of the slope, with approximately 120 feet of drop over about 200 feet of horizontal distance. This inclination makes it difficult to attempt normal "walking access", sampling operations. Accordingly, provisions have been made for descent and ascent of the high-angle slope using belaying gear. Proper use by trained individuals of this system of ropes, anchors and harnesses makes execution of the sampling possible.

2.2.3.3.5 Small-Boat Operations

Access to the sampling stations at Site 14 is possible by small boats having easy handling and a shallow draft. These boats will be used in the fringe of the mangrove, no more than about 10 meters from open water. In particular, sea-kayaks will be used for sampling, while a motor-launch will be used for support and transit. A small dinghy may also be used for the sediment sampling at Site 2.

2.2.3.3.6 Computer Mapping

The maps of the study sites available from the existing reports are unscaled sketches, having value for illustration only. Detailed planning or analysis cannot be made from these representations.

The general areas of the relevant sites have been extracted from the Station's surveyed base map and placed into a computer mapping file. The locations of data stations from the GPS records and the land surveyor's report will be superposed on these maps. The computer maps will then be used to represent information relevant to each site, including characterizations of the chemical environment and of the groundwater regime.

2.2.3.3.7 Correlation of Analytical Data

There is a considerable amount of data available from the chemical analyses of the previous studies. The most economical means of providing this coordination is the correlation of the data for each site by computer file. This requires loading of the data from the CS and from this project into a single program.

2.3 Task 7 - Reporting

The final document for the Phase I RI will comprise:

1. A report of activities;

2. A discussion of findings for the facility and the sites; and,

3. A presentation of the recommended technical approach to the negotiation for the RFI and to the Statement of Work for the RFI.

The report format will generally conform to the guidance presented in "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA," Interim Final, October 1988 (EPA/540/G-89/004).

2.3.1 Report of Activities

The report of activities will indicate the technical investigations engaged during this project, and the significant actions supporting those studies. The technical investigations:

1. Detailed photo-interpretation for Sites 1, 2, 5, 6, 7, 10, 13, 14, 18 and 21;

2. Sampling of representative environmental media at certain sites;

3. Analysis of samples for representative sequences of organic and inorganic species; and,

4. Measurements leading to analysis of the geohydrologic regime (particularly: well-head tests for hydraulic conductivity and calculation of the groundwater elevation) at sites with accessible monitor wells.

The significant support activities, in addition to normal administrative and logistic functions, are expected to be:

1. Horizontal control of data stations by land navigation receiver;
2. Vertical control of the measuring points for geohydrologic data by land surveying;
3. Limited or extensive land-clearing at certain sites; and,
4. Small-boat operations for sampling at Site 14.

2.3.2 Findings

The findings of this project will probably contain, depending on the derived information:

1. Summarized and full documentation of the chemical analyses for this project;

2. Summarization, in the same format as the data of this project, of the relevant chemical data from the CS;

3. Identification of the presence or absence of significant, adverse effects on human health or the environment at each site studied;

4. Selection of a limited list of indicator compounds for use in further investigation at those sites showing significant adverse effects from contamination;

5. Details of the relevant aerial photographs and overlays from the photo-interpretation indicating past locations of disposal, disposal practices and probable paths of influence from the disposal areas;

6. Mapping by CAD (Computer-Aided Drafting) of the sites, including surveyor's data and coordination from the land navigation receiver;

7. Analyses of the geohydrologic regime, including gradient, flow-path and probable rate of flow; and,

8. Analysis of the usefulness of and on the disposition of wells at particular sites, or on additions to the monitoring plan.

2.3.3 Technical Approach to the RFI

The findings of this project will indicate the options available for:

1. Negotiation of the RFI; and,

2. Finalization of an efficient and economical RFI addressing

   a. Only particular sites showing some concern of adverse effects from past disposal; and,

   b. Only the contaminants reliably indicating the presence and extent of those effects.

2.4 Task 8 - Meeting

One conference between LANTDIV and NSRR personnel should be held at the offices of BEI. The expected duration of this meeting should be three work days. The entire technical performance of this project will be reviewed, and preparations made for the negotiation of the RFI.

3.0 SAMPLING PROCEDURES

The sampling and field activity procedures employed during this investigation are based on Navy CLEAN Standard Operating Procedures (SOPs). SOPs for this investigation, included in Appendix B, are listed below:

- Rock and Sample Acquisition (F102)
- Groundwater Sample Acquisition (F104)
- Surface Water and Sediment Sample Acquisition (F105)
- Water Level, Water-Product Level, and Well Depth Measurements (F202)
- Sample Preservation and Handling (F301)
- Chain-of-Custody (F302)
- Field Logbook (F303)
- QA/QC Samples (F304)
- Slug Testing (F402)
- Decontamination of Chemical Sampling and Field Analytical Equipment (F502)
- Handling of Site Investigation Wastes (F504)
- Geophysics - Electromagnetic Induction (F702)

Activities not having a specific SOP available will have an SOP prepared for the final edition of the FSP, as appropriate and depending on continued discussions with LANTDIV and the Station.

3.1 Sampling Approach

This sampling program is designed to obtain data to meet the Data Quality Objectives (DQOs) and to fulfill the goals of the Phase I RI. Due to the variability of sampling media encountered at these sites, sampling techniques have been separated into four types:

- Soil
- Groundwater
- Surface water/sediment
- Concrete

A brief explanation of each type is presented below.

3.1.1 Soil

Surface and shallow subsurface soil samples will be collected. Sample collection procedures are discussed below.

Surface and shallow subsurface soil samples will be collected from several sites. The samples will be collected using a trowel or spoon, or a hand auger (Section 3.2). Sample collection procedures will conform to the following SOPs (Appendix B):

- Rock and Sample Acquisition (F102)
- Sample Preservation and Handling (F301)
- Chain-of-Custody (F302)
- Field Logbook (F303)
- QA/QC Samples (F304)
- Decontamination of Chemical Sampling and Field Analytical Equipment (F502)
- Handling of Site Investigation Wastes (F504)

3.1.2 Groundwater

Groundwater samples will be collected from monitoring wells at several sites. Groundwater will be collected in bailers (Section 3.2). Temperature, pH, and specific conductivity of the groundwater will be measured in the field, with the water level at the time of sampling. When water levels are measured, without sampling, temperature and specific conductance will also be measured. Sample collection procedures will conform to the following SOPs (Appendix B):

- Groundwater Sample Acquisition (F104)
- Water Level, Water-Product Level, and Well Depth Measurements (F202)
- Sample Preservation and Handling (F301)
- Chain-of-Custody (F302)
- Field Logbook (F303)
- QA/QC Samples (F304)
- Slug Testing (F402)
- Decontamination of Chemical Sampling and Field Analytical Equipment (F502)
- Handling of Site Investigation Wastes (F504)

Hydraulic conductivity tests (also commonly referred to as slug tests) will be conducted in selected monitoring wells. The tests will be performed by rapidly inserting an object of known volume (slug) within a monitoring well and allowing the groundwater level in the well to re-equilibrate to its former static level prior to removing the submersed slug. The slug displaces a volume of groundwater within the monitoring well resulting in a rise and fall of the groundwater level that is measured with respect to time. The slug insertion portion of the test is also referred to as a falling-head conductivity test; slug removal is referred to as a rising-head conductivity test.

3.1.3 Surface Water/Sediment

Surface water/sediment samples will be collected from several sites. Surface water samples will be collected using a pond sampler. Surface sediment samples will be collected using a trowel, spoon, pond sampler or auger (Section 3.2). Sample collection procedures will conform to the following SOPs (Appendix B):

- Surface Water and Sediment Sample Acquisition (F105)
- Sample Preservation and Handling (F301)
- Chain-of-Custody (F302)
- Field Logbook (F303)
- QA/QC Samples (F304)
- Decontamination of Chemical Sampling and Field Analytical Equipment (F502)
- Handling of Site Investigation Wastes (F504)

3.1.4 Concrete

Concrete chip samples will be collected from the floor of the building at Site 21. A hammer and chisel will be used to collect the samples. Sample collection procedures will conform to the following SOPs (Appendix B):

- Sample Preservation and Handling (F301)
- Chain-of-Custody (F302)
- Field Logbook (F303)
- QA/QC Samples (F304)
- Decontamination of Chemical Sampling and Field Analytical Equipment (F502)
- Handling of Site Investigation Wastes (F504)

3.2 Sampling Equipment

Scoop or Spoon

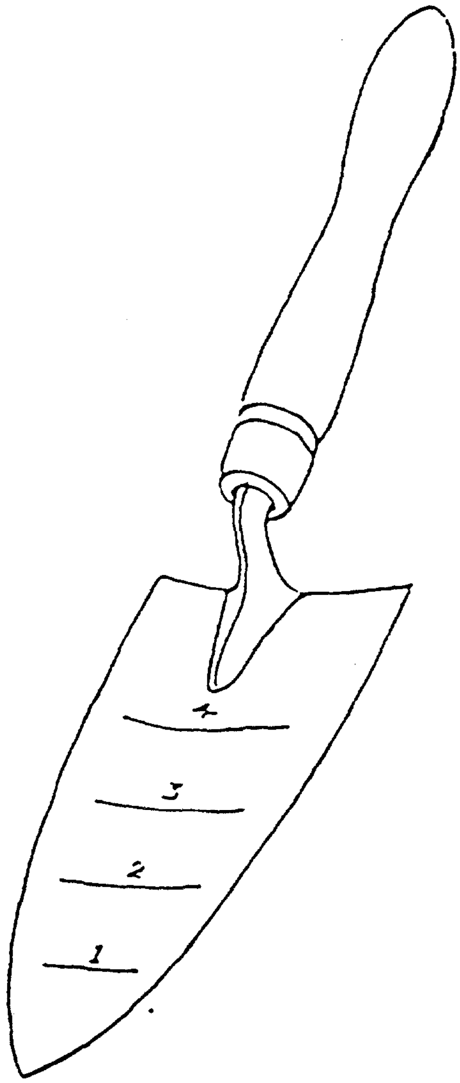
A scoop or spoon is used in collecting surface soil samples (Figure 3-1). Both items should be constructed of stainless steel to minimize the potential for contamination. Scoops or spoons can be purchased in a variety of sizes from laboratory supply houses and restaurant supply stores. The items are relatively inexpensive and can be discarded after sample collection. Procedures for the use of this equipment are listed below:

- Collect small, equal portions of sample at the required depth.
- Transfer the sample into the appropriate sample container and follow the SOPs for sample preservation and transportation.

Bailer

Bailing is considered one of the simplest and best methods of collecting samples from a monitoring well. A bailer consists of a length of relatively inert material (Teflon or stainless steel) with a check valve at the bottom (Figure 3-2). It is normally lowered into the well with a cable made of inert material. Bailers are available in various sizes to accommodate a variety of wells. Procedures for the use of this equipment are listed below:

- Unwrap the decontaminated bailer and attach it to a length of cable.
- Lower the bailer slowly until it comes in contact with the water.
- Allow the bailer to sink and fill with a minimum of surface disturbance.
- Slowly raise the bailer to the surface; avoid contact of the cable to either the ground or well casing.
- Tip the bailer and allow for a slow discharge of the water into a precleaned sample container.



Baker
Baker Environmental, Inc.

FIGURE 3-1
SCOOP/TROWEL

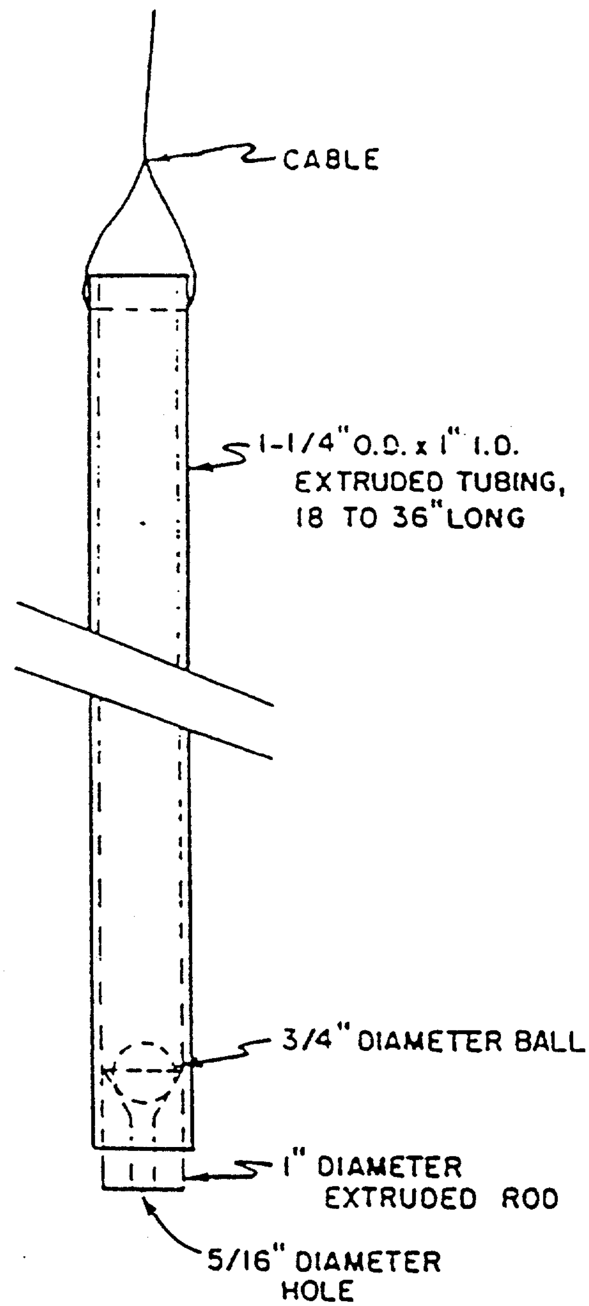


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FIGURE 3-2
BOTTOM FILL BAILER

- Continue the collection of water until all of the sample containers have been filled.

- Follow the SOPs for preservation and transportation of the samples.

Pond Sampler

A pond sampler consists of an adjustable clamp attached to the end of a two- or three-piece telescoping aluminum tube that serves as a handle (Figure 3-3). The clamp is used to secure a sampling beaker. The pond sampler is used to collect sediment or liquid samples from ponds, pits, lagoons, or similar reservoirs. It is not commercially available but can easily be fabricated. Procedures for the use of this equipment are listed below:

- Assemble the sampler, ensuring that all parts are securely tightened.

- Submerge the beaker with minimal surface disturbance.

- Collect sediment samples by scraping the bottom; collect liquid samples by allowing the beaker to fill.

- Transfer the sample into the appropriate container.

- Follow the SOPs for preservation and transportation of the samples.

Hand Auger

Augering is considered one of the simplest methods for collecting shallow subsurface soil or sediment samples. Depending on soil conditions, an auger can be advanced 1.5 to 2.0 meters. The auger (Figure 3-4) consists of a stainless steel, 2-inch diameter cylinder that cuts its way through the soil. The cylinder holds the soil for sample retrieval. Extension rods, in one meter lengths, are attached to the auger until the desired depth is reached. Decontamination of the auger and attachments is simple. Disconnect the extension rods from the auger and decontaminate each part separately according to the standard operating procedures for the sampling event.

BASIC PARTS OF A POND SAMPLER

QUANTITY	ITEM	SUPPLIER
1	Clamp, adjustable, 6.4 to 8.9 cm (2 1/2 to 3 1/2 in.) for 250 to 600 ml (1/2 to 1 1/4 pt.) beakers	Laboratory supply houses
1	Tube, aluminum, heavy duty, telescoping extends 2.5 to 4.5 m (8 to 15 ft.) with joint cam locking mechanism. Pole diameters 2.54 cm (1 in.) in diameter and 3.18 cm (1 1/4 in.) in diameter	Olympic Swimming Pool Co., 807 Buena Vista St., Almadea, CA 94501 or other general swimming pool supply houses
1	Beaker, tetrafluoropolyethylene or stainless steel, 250 ml (1/2 pt.)	Laboratory supply houses
1	Bolts 6.35 by 0.64 cm (2 1/4 by 1/4 in.) NC	Hardware Stores
1	Nuts, 0.64 cm (1/4 in.) NC	Hardware Stores

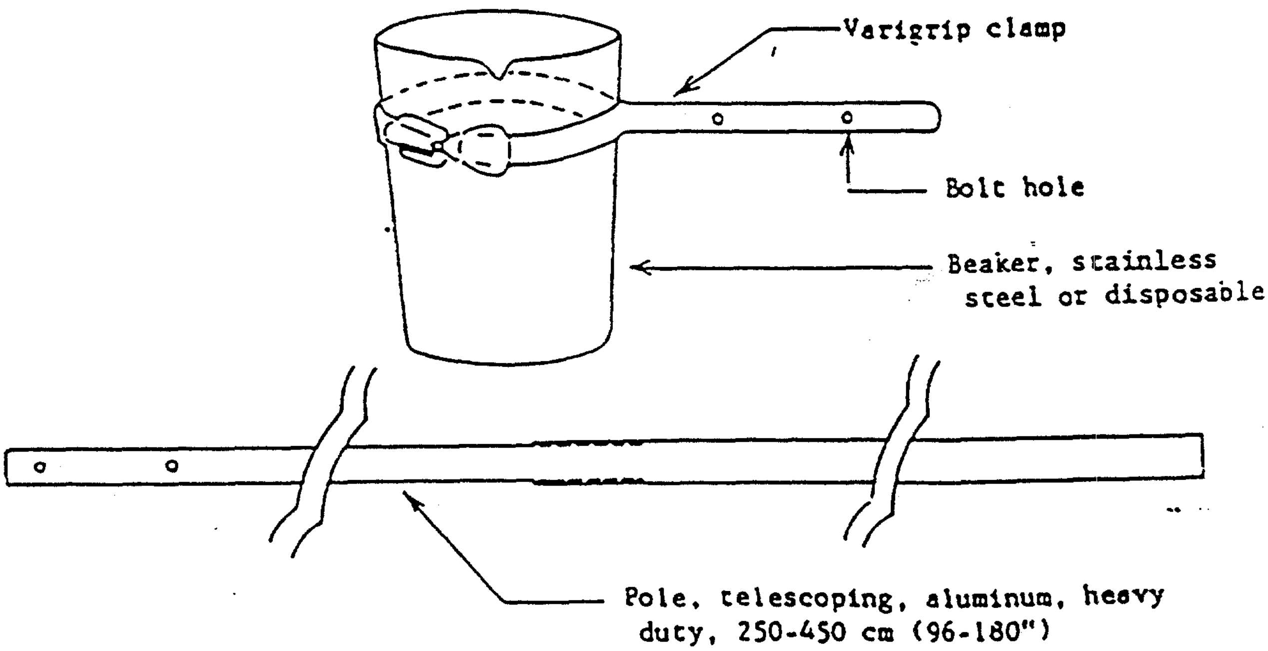

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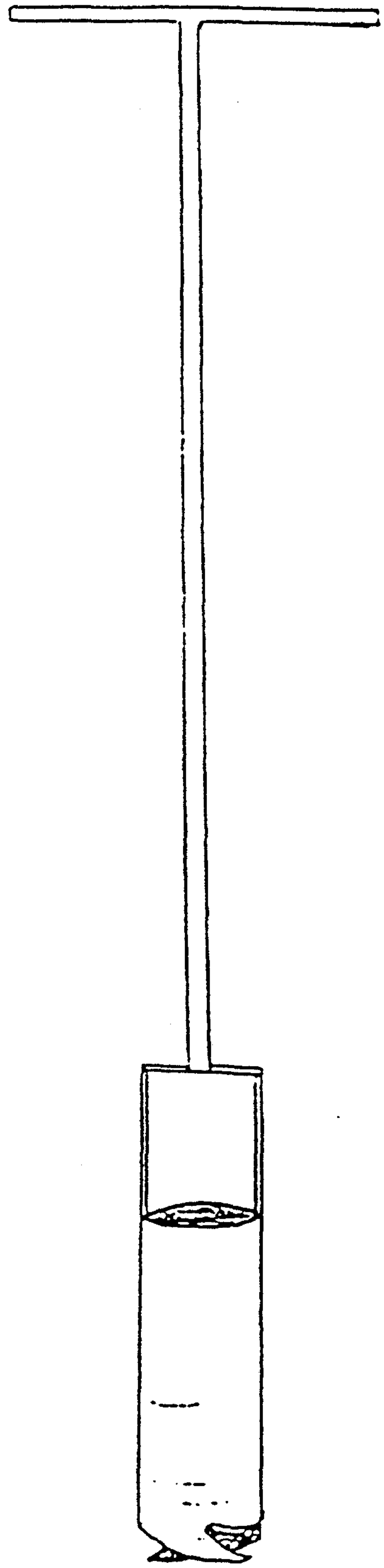
FIGURE 3-3
POND SAMPLER



Baker
Baker Environmental, Inc.

FIGURE 3-4
BUCKET AUGER

3.3 Task 5 - Sample Analysis and Tracking

Sample analysis will be performed by a chemical laboratory approved by NEESA. In general, Quality Control Level D, equivalent to Contract Laboratory Program (CLP) procedures, will be employed and reported where possible; otherwise, applicable techniques and control procedures will be used.

- Soil and Sediment (except Site 21)
  - CLP Volatile Organic Compounds (VOC)
  - CLP Semivolatile Organic Compounds (SVOC)
  - CLP Pesticides and Polychlorinated Biphenyl Compounds (P/PCB)
  - CLP Metals (TAL)
  - CLP Percent Moisture
  - Total Organic Compounds (TOC)(sediment only)

- Soil and Structural Chip (Site 21) (SW846 analytical methods)
  - TCLP-P (Toxic Compound Leaching Procedure - Pesticides)
  - TCLP-H (Toxic Compound Leaching Procedure - Herbicides)
  - As (total Arsenic)
  - CN (total Cyanide)
  - Ethylene Bromide
  - Zn (total Zinc)

- Water
  - CLP Volatile Organic Compounds (VOC)
  - CLP Semivolatile Organic Compounds (SVOC)
  - CLP Pesticides and Polychlorinated Biphenyl Compounds (P/PCB)
  - CLP Metals (TAL)

All aqueous samples indicated for analysis of metals will have both the total and dissolved fractions run.

Field parameters of groundwater quality will be taken:

1. During measurement of water levels:
   - Water level
   - Temperature - T
   - Specific conductance - SC

2. During sampling:
   - Water level
   - Temperature - T
   - Specific conductance - SC
   - Hydrogen ion activity - pH

Soil samples will be taken by hand auger, unless otherwise required by site conditions. Soil stations will each, unless otherwise required by site conditions, have two samples taken: One from a depth of 0.25 to 0.5 meters and one from 0.5 to 1.0 meters. Background soil samples will be taken from three stations having one sample each (from a depth of 0.5 to 1.0 meters); multiple analyses are required to establish the statistical range for variation across the soil and rock types of the Station and NAF-V. The variations of soils, either from the differing parent rocks or from the differing depositional environments, require separate stations at each site for background samples.

Duplicate samples will be taken according to the distribution of original samples across the facility rather than at each station.

3.4 Quality Assurance and Quality Control

Quality Assurance/Quality Control procedures will include both duplicate samples, and blank, trip and rinsate samples. Field duplicate samples will be collected at a minimum of 10 percent of total samples collected from each matrix. An equipment rinsate sample will be collected daily during each sampling event and a field blank will be collected for each sampling event. Trip blanks will accompany each cooler containing volatile organic samples.

Used sampling equipment that is to be decontaminated will be thoroughly flushed with copious amounts of water, then further decontaminated with a rinsate, and held in a clean container until the next application. The preference is to use devices that hold a container to obtain the sample; the container would be disposed after each sample and a new container would be attached to the sampling device. This minimizes the possibility of cross-contamination and eliminates the need for rinsate field blanks. A detailed explanation of QA/QC procedures and sample requirements is discussed in the Quality Assurance Project Plan (QAPP).

3.5 Sample Containers and Preservation Requirements

Precleaned sample bottles will be obtained from the contracted laboratory. The samples will be preserved as required by the analysis. A summary of the parameters, the preservation and holding times are presented below.

Parameter	Holding Time	Preservative
Volatile Organic Compounds		
Water	10 days	HCl, Cool, 4°C (no headspace)
Soil and Sediment	10 days	Cool, 4°C
Semivolatile Organic Compounds		
Soil and Sediment	Extraction 10 days 40 days after extraction	Cool, 4°C
Metals		
Water	6 months (Hg 26 days)	Cool, 4°C HNO_3, pH<2 *NaOH, Cool, 4°C
Soil and Sediment	6 months (Hg 26 days)	Cool, 4°C

*Cyanide only.

3.6 Sampling Program Operations

Field activities will be conducted according to the guidance of Section 3.0 of the USEPA. (OSWER) Guidance Directive 9355.0-14 for implementing field activities. This will include Sections 3.2 (Control of Fieldwork Generated Contaminated Material), 3.3 (Organization of the Field Team), 3.4 (Decontamination), and 3.5 (General Health and Safety Considerations).

3.7 Sample Control

The purpose of sample control is to maintain the quality of samples during collection, transportation, and storage for analysis. Sample control in the field will be according to OSWER Directive 9355.0-14 Sections 3.0 and 6.2. Information detailed in these sections includes:

- Records
- Procedures for sample identification tags, sample traffic reports, chain-of-custody records, receipt-for-samples forms, custody seals, and field notebooks
- Packaging, labeling, and shipping

3.8 Sample Designation

All samples collected during this investigation, including QA/QC samples, will be designated a unique number. The number will serve to identify the site, media, and location from which the sample was collected. For example, the sample number 07GW101 refers to the following:

07GW101	-	Site 7 (Station Landfill)
07GW101	-	Groundwater
07GW101	-	100 series serves to distinguish these samples from those collected during previous investigations
07GW101	-	Monitoring Well 1

The following are used to identify sample media:

GW	-	Groundwater
SS	-	Site Soils
SED	-	Sediment
CC	-	Concrete Chip
SW	-	Surface Water

QA/QC samples will be numbered, without distribution, in sequence following the collection of the field samples. For example, at Site 7 (Station Landfill) groundwater samples will be collected from the eight existing monitoring wells (07GW101 through 07GW108). The first QA/QC groundwater sample (e.g., field duplicate) will be designated 07GW109.

All pertinent sample information (location, date, time, etc.) will be recorded in the field log book.

3.9 Chain-of-Custody

Chain-of-custody procedures will be followed to ensure a documented, traceable link between measurement results and the sample/parameter that they represent. These procedures are intended to provide a legally acceptable record of sample preparation, storage and analysis.

To track sample custody transfers before ultimate disposition, sample custody will be documented using a chain-of-custody form, similar to the one shown in Figure 3-5. A chain-of-custody seal is shown in Figure 3-6. A sample label is shown in Figure 3-7. In addition, a master logbook will be used as a centralized mechanism for documenting project activities.

A chain-of-custody form will be completed for each container in which the samples are shipped. The shipping containers will usually be coolers. After the samples are properly packaged, the coolers will be sealed and prepared for shipment. Custody seals will be placed on the outside of the coolers to ensure that the samples are not disturbed prior to reaching the laboratory.

A field notebook, containing a master sample log, will be maintained for the site.

3.10 Logbooks

Field notebooks and a master sample log will be used to record sampling activities and information. Field notebooks will be bound, field survey books. Notebooks will be copied and submitted to the field sampling task leader, for filing upon completion of the assignment. The cover of each logbook will contain:

- The name of the person to whom the book is assigned
- The book number
- The project name

FIGURE 3-5

CHAIN-OF-CUSTODY RECORD

Name: ______________________________
S.[illegible] Number: ______________________________

Sampler: ____________________
(Print)

Signature: ____________________

Sheet _____ of _____

BAKER ENVIRONMENTAL, INC.
Airport Office Park - Bldg No. 3
420 Rouser Road
Coraopolis, PA 15108
(412) 269-6000

Baker Sample I.D. No.	Sample Type	Sampled		Sample Storage and Preservation Details*									
				Cooling		HNO_3		H_2SO_4 Cooling		Other		Other	
		Date	Time	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.

General Remarks:

*NOTES: Record type of container used with abbreviation P (plastic) or G (glass)
Record volume of containers in leters

Relinguished By (Sign):
Date: Time:
Remarks:

Received By (Sign):
Date: Time:
Remarks:

Shipment/Transportation Details:

Relinguished By (Sign):
Date: Time:
Remarks:

Received By (Sign):
Date: Time:
Remarks:

Shipment/Transportation Details:

Relinguished 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

FIGURE 3-6

EXAMPLE CUSTODY SEAL

Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**	Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**

FIGURE 3-7

EXAMPLE SAMPLE LABEL

Baker

Baker Environmental Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108

Project: ________________ **CTO No.:** __________

Sample Description: ________________________

Date: ____/____/____ **Sampler:** ______________

Time: ___________

Analysis: ____________ **Preservation:** __________

Project Sample No.: ________________________

- Entry start date
- Entry completion date

Entries will include general sampling information so that site activities may be reconstructed. The beginning of each entry will include the date, sampling site, start time, weather conditions, field personnel present and level of personal protection. Other possible entries would be names and purpose of any visitors to the vicinity during sampling, unusual conditions which might impact the interpretation of the subsequent sampling data, or problems with the sampling equipment. All entries will be in ink with no erasures. Incorrect entries will be crossed out with a single strike and initialed.

A master sample log will be maintained on site for all samples taken. A full description of the sample, its origin and its condition will be included in the master log entry.

3.11 Contaminated Materials Handling

Contaminated materials handling will be coordinated before site operations. Decontamination equipment and solutions will be ready to use before site entry. Removing possible sources of off-site contamination from equipment before the start of work will minimize the off-site transportation of waste upon completion of work and will minimize cross-contamination while working on site. Equipment must be decontaminated after each sample to avoid cross-contamination. Decontamination solutions and purged well water will be collected into containers and discarded in a designated disposal area. Disposal areas will be identified for each site during mobilization activities. These areas will be selected in coordination with LANTDIV and Station personnel. Excess soil materials resulting from subsurface soil sampling activities will be backfilled into the auger borehole. If these disposal options are not sufficient, alternative methods will be arranged before work begins.

APPENDIX A
CONFIRMATION STUDY ANALYTICAL SUMMARY TABLE

Table 1-1. Summary Table of Rounds One and Two Verification Sampling and Analysis, NAVSTA Roosevelt Roads and NAF Vieques Confirmation Study

SITE NO. / SAMPLING ROUND NO.	WELLS INSTALLED	GROUND WATER SAMPLES	SURFACE WATER SAMPLES	SEDIMENT SAMPLES	SOIL SAMPLES	ANALYTICAL CONSTITUENTS a
NAF Vieques						
1/1	3	3	0	3	6	pH, oil and grease, VOA, MEK, MIBK, EDB, Cr (total and hexavalent), xylene, Pb
1/2	0	3	0	0	0	pH, Priority Pollutant scan, MEK, MIBK, EDB, Cr hexavalent, xylene
2/1	0	0	5	5	8	pH, Cr (total and hexavalent), Pb, VOA, xylene, MEK, MIBK
2/2	0	0	5	5	0	pH, Cr (total and hexavalent), Pb, VOA, xylene, MEK, MIBK
3/1	0	0	0	0	0	
3/2	0	1	0	0	0	pH, Priority Pollutant scan
NAVSTA Roosevelt Roads						
5/1	5	5	5	5	0	pH, Priority Pollutant scan, Cr hexavalent, xylene, MEK, MIBK, EDB
5/2	0	5	5	5	0	pH, Priority Pollutant scan, Cr hexavalent, xylene, MEK, MIBK, EDB
6/1	0	0	3	3	15	pH, Priority Pollutant scan, Cr hexavalent xylene, MEK, MIBK, EDB
6/2	1	1	3	3	---	pH, Priority Pollutant scan, xylene, MEK, MIBK, EDB
	---	---	---	---	15	Pb
	---	---	---	---	2	EP Toxicity Test-Pb only
7/1	8	8	0	0	0	pH, Priority Pollutant scan, Cr hexavalent
	---	---	---	---	2	oil and grease, VOA, xylene, MEK, MIBK,EDB
7/2	2b	8	0	0	0	pH, Priority Pollutant scan, Cr hexavalent
8/1	0	0	3	3	1	Oil and grease, Pb, VOA, xylene, MEK, MIBK, EDB
8/2	0	0	5	3	0	Oil and grease, Pb, VOA, xylene, MEK, MIBK, EDB
9/1	0	0	4	30	0	PCBs
10/1	8	8	0	0	0	pH, Priority Pollutant scan, Cr hexavalent xylene, MEK, MIBK, EDB
10/2	0	8	0	0	0	pH, Priority Pollutant scan, Cr hexavalent xylene, MEK, MIBK, EDB

--- = not applicable
a = Key to Constituent Abbreviations.
EDB = ethylene dibromide
MIBK = methyl isobutyl ketone
Cr = chromium
PCBs = polychlorinated biphenyls
Pb = lead
VOA = volatile organic analysis
MEK = methyl ethyl ketone
GC = gas chromatograph
EPA Toxicity Test = Extraction procedure (EP) toxicity test as described in 40 CFR Part 261.25, Appendix II.
Priority Pollutant Scan = EPA Priority Pollutant list of 129 pollutants, excluding asbestos, cyanide, and dioxin.
b = Two replacement wells for wells which were installed during Round I but were damaged by landfill activities prior to Round 2.

Source: ESE, 1988.

Table 1-1 (Continued)

12/1	6	6	1	1	---	pH, VOA, EDB, xylene, oil and grease, Pb,
	---	---	---	---	2	EP Toxicity Test metals
	---	---	---	---	20	No analyses. Visual inspection for oil and measurement of thickness of oil layer.
12/2	0	6	1	---	---	pH, VOA, EDB, xylene, oil and grease, Pb, GC fingerprint
	---	---	---	1	---	pH, VOA, EDB, xylene, oil and grease, Pb
	---	---	---	---	52	No analyses. Visual inspection for oil and measurement of thickness of oil layer.
13/1	11	11	6	6	0	pH, VOA, Pb, oil and grease, EDB, xylene
13/2	0	11	6	6	0	pH, VOA, Pb, oil and grease, EDB, xylene MEK, MIBK
14/1	0	0	12	12	0	pH, VOA, Pb, oil and grease, EDB, xylene MEK, MIBK
18/1	0	0	2	2	15	Pesticides
18/2	3	3	0	0	0	Pesticides, VOA
	---	---	6	6	---	Pesticides

--- = not applicable
a = Key to Constituent Abbreviations.
EDB = ethylene dibromide
MIBK = methyl isobutyl ketone
Cr = chromium
PCBs = polychlorinated biphenyls
Pb = lead
VOA = volatile organic analysis
MEK = methyl ethyl ketone
GC = gas chromatograph
EPA Toxicity Test = Extraction procedure (EP) toxicity test as described in 40 CFR Part 261.25, Appendix II.
Priority Pollutant Scan = EPA Priority Pollutant list of 129 pollutants, excluding asbestos, cyanide, and dioxin.

Source: ESE, 1988.

APPENDIX B
STANDARD OPERATING PROCEDURES

SOP F102
Soil and Rock Sample Acquisition

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, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, 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 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 contaminants from various 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 various 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 rock coring has been completed and the core recovered, the rock core must 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) shelby 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 shelby-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

Designation: D 1586 – 84

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103
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Standard Method for Penetration Test and Split-Barrel Sampling of Soils[1]

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 (ε) 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[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

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 ± 2 lb (63.5 ± 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 ΔN—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° (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 conjuction 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

[1] 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.

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[2] *Annual Book of ASTM Standards,* Vol 04.08.

ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS

Designation: D 1587 – 83

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103
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If not listed in the current combined index, will appear in the next edition.

Standard Practice for Thin-Walled Tube Sampling of Soils[1]

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 (ε) 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)[2]
D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]
D 4220 Practices for Preserving and Transporting Soil Samples[2]

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

[1] 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.
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[2] *Annual Book of ASTM Standards,* Vol 04.08.

ATTACHMENT C

ASTM D2113-83 (1987)
STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR SITE INVESTIGATION

Designation: D 2113 – 83 (Reapproved 1987)

Standard Practice for Diamond Core Drilling for Site Investigation[1]

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 (ε) 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[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

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: 2¾ in. (69.85 mm) by 3⅞ 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.

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[1] 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.

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[2] *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 required 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	44.5
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
2¾ × 3⅞	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 × 5½	5.44	138.0	3.97	100.8
6 × 7¾	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 × 5½
PW	5.50	139.7	5.00	127.0	3	6 × 7¾
SW	6.63	168.2	6.00	152.4	3	6 × 7¾
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	1.34	34.1	0.63	15.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	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 additionally, must be permanently marked internally to ...ate the upper-left corner of the bottom with the letters ...L or a splotch of red paint not less than 1 in.[2] 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 ...nt 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.

SOP F104
Groundwater Sample Acquisition

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

$$V = \pi r^2 h$$

Where: V = volume of standing water in well
r = well radius
h = feet of standing water in well

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameter.

TABLE 5-1
WELL VOLUMES

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

Notes:
1. Gallons per foot of depth will be multiplied by amount of standing water to obtain well volume quantity.
2. 1 gallon = 3.785 liters
1 meter = 3.281 feet
1 gallon water weighs 8.33 pounds = 3.785 kilograms
1 liter water weighs 1 kilogram = 2.205 pounds
1 gallon per foot of depth = 12.419 liters per foot of depth
1 gallon per meter of depth = 12.419 x 10^{-3} cubic meters per meter of depth

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:

$$VW = \pi D^2 (TD - DW)$$

$$V_{gal} = VW \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = Vgal \, (\# \text{ Well Vol})$$

   Where:

V_W	= Volume of water in well in cubic feet (i.e., one well volume)
π	= 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
# 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 Samples - 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

Designation: D 4448 – 85a

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Guide for Sampling Groundwater Monitoring Wells[1]

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 (ε) 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**).[2] 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 μg/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

[1] 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.

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[2] 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 % $K_2Cr_2O_7$	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_2SO_4 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_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	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.

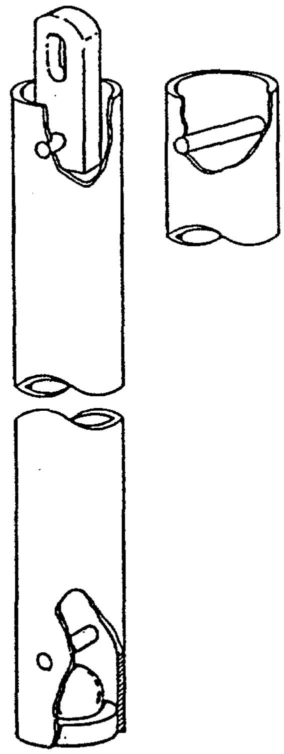
4. Well Flushing (Purging)

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 Bailer

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.

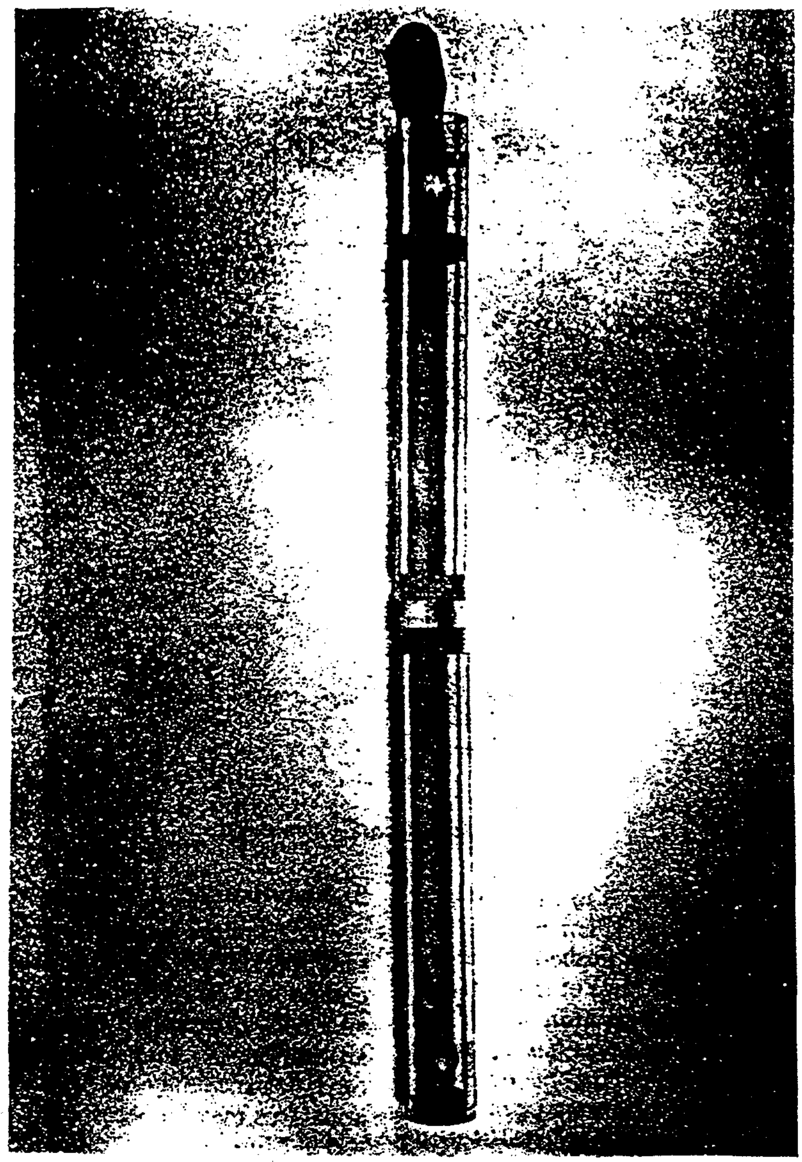
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

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 (μg/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

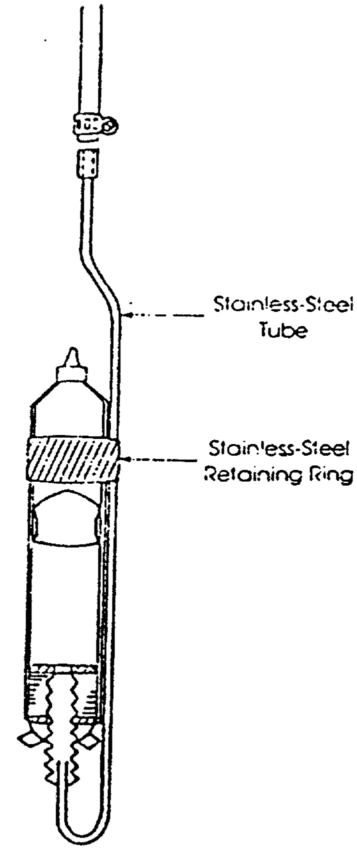
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (**8, 10**) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, 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 nonplastic (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 Chemical Society's committee on environmental improvement h published guidelines for data acquisition and data evaluati which should be useful in such environmental evaluatio (10, 12).

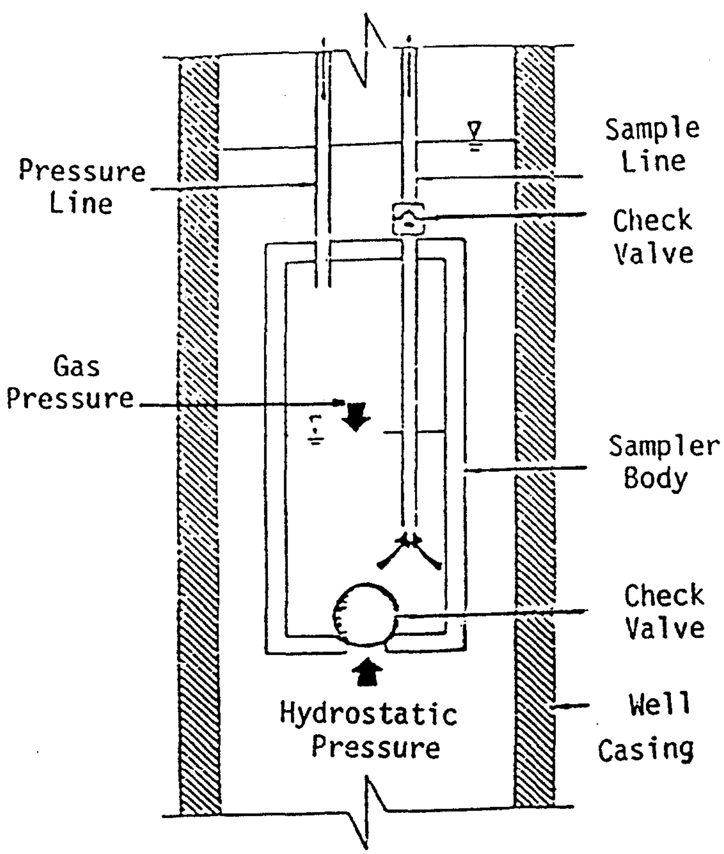
6. Sampling Equipment

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 categ rized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samplers (1 14) are examples of down-hole devices that probably provi valid samples once the well has been flushed. They are n practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from variety of materials. They do not subject the sample t pressure extremes.

6.1.1.2 Bailers do expose part of the sample to t atmosphere during withdrawal. Bailers used for sampling volatile organic compounds should have a sample cock draft valve in or near the bottom of the sampler allowi withdrawal of a sample from the well below the expose surface of the water or the first few inches of the samp should be discarded. Suspension lines for bailers and oth samplers should be kept off the ground and free of oth contaminating materials that could be carried into the we Down-hole devices are not very practical for use in de



NOTE—Taken from Ref **(5)**.

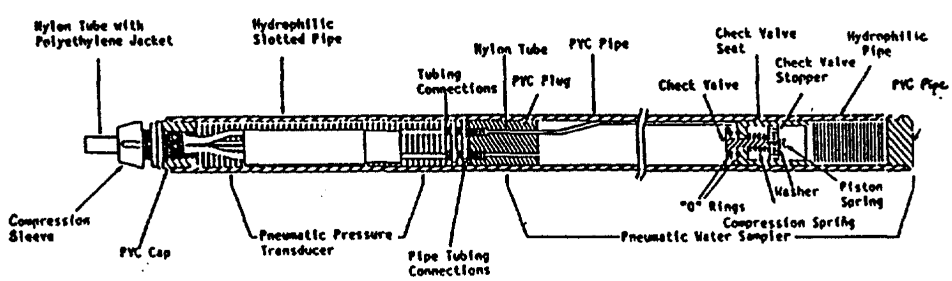
FIG. 4 The Principal of Gas Displacement Pumping

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)**.

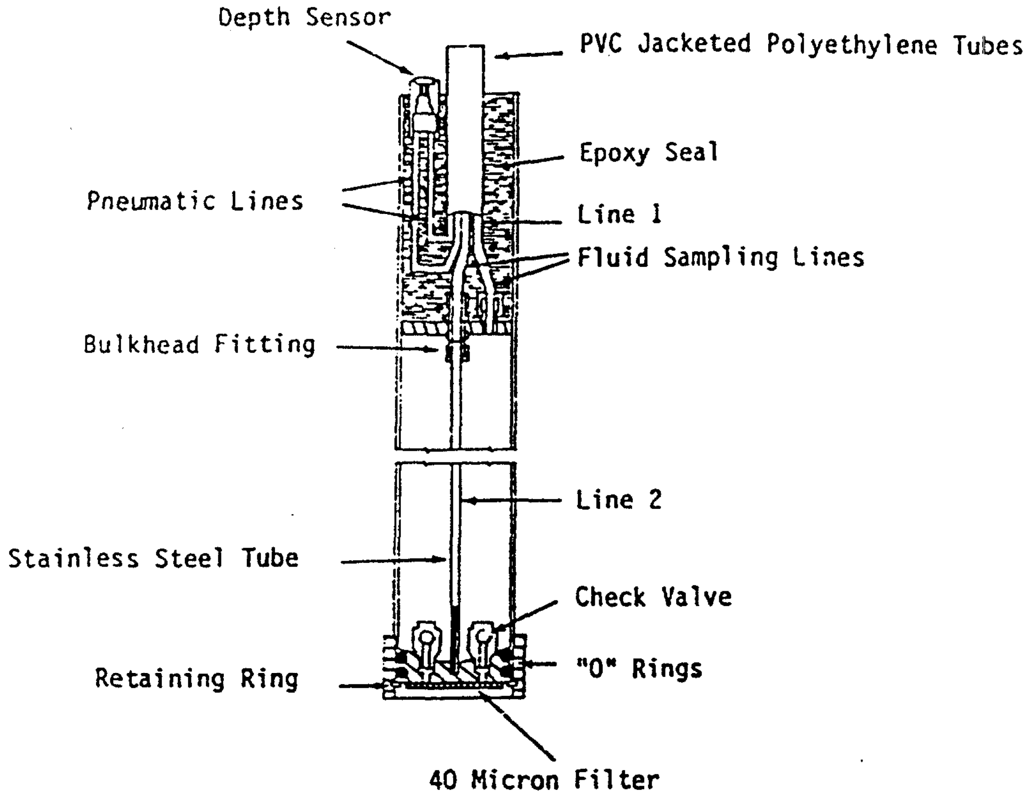
6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check 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.

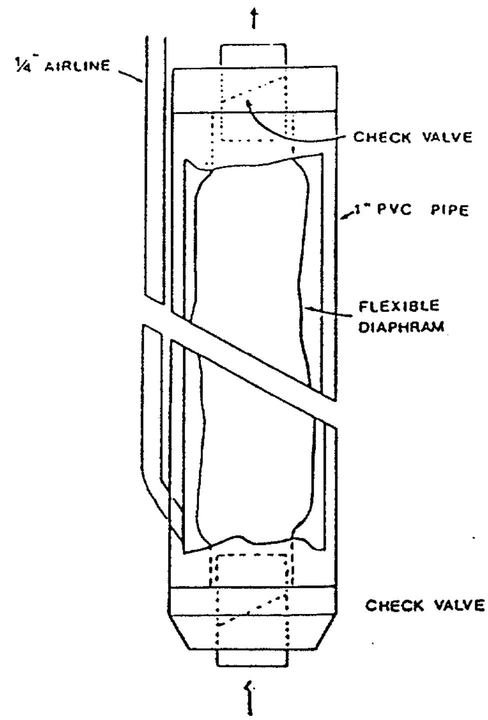
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber **(18)**. Foerst, Kemmerer, and Bacon samplers are of this variety **(14, 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[3] 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.

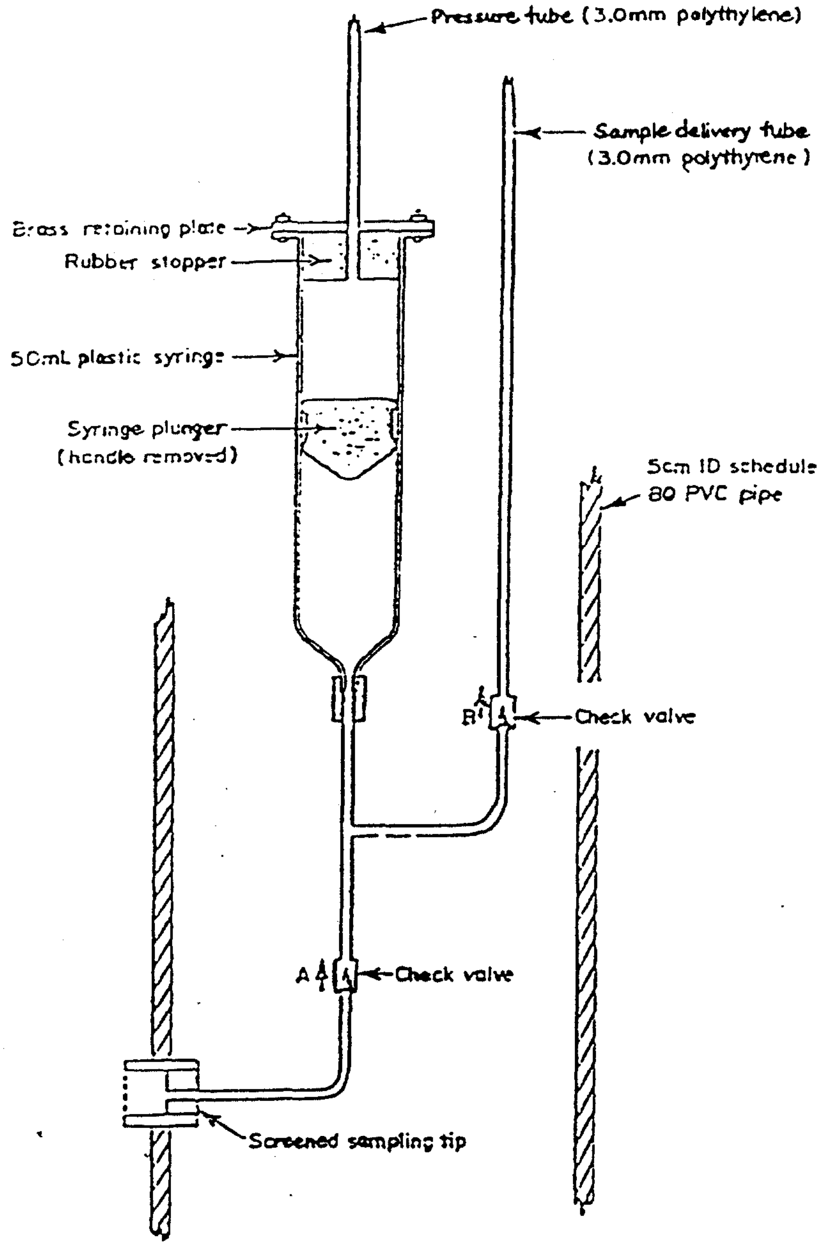
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

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

[3] 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

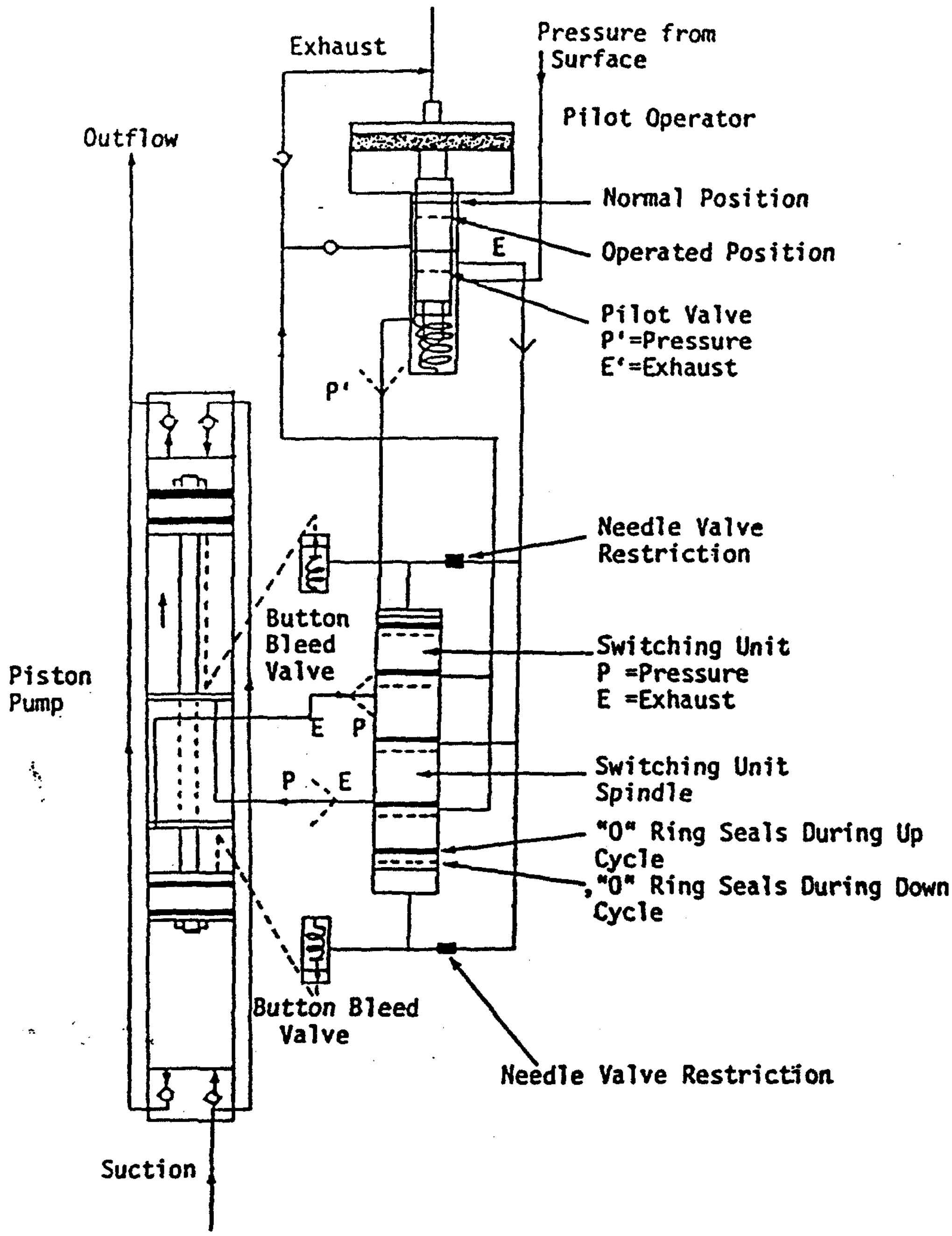
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) 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).

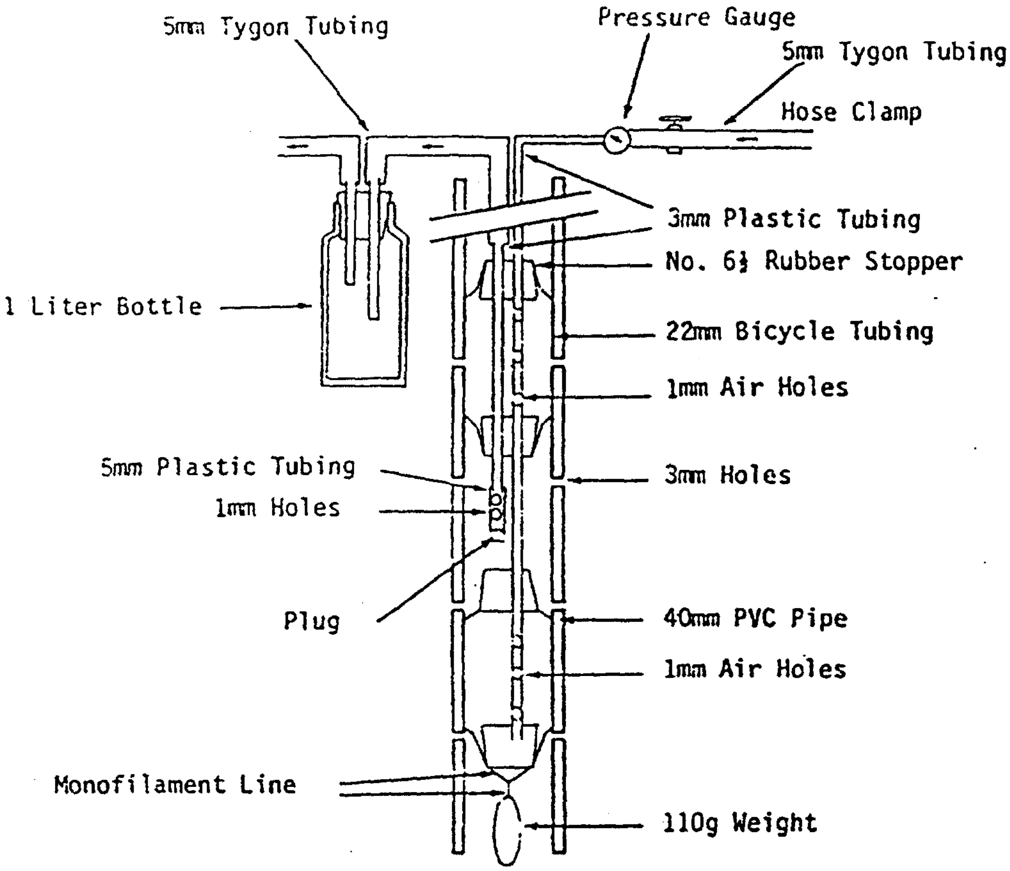
FIG. 9 Gas Driven Piston Pump

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 sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample 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.[3] 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 forrmost 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-flourocarbon 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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SOP F105
Surface Water and Sediment Sample Acquisition

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

1. Feltz, H. R., 1980. Significance of Bottom Material Data in Evaluating Water Quality in Contaminants and Sediments. Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., V. 1, p. 271-287.

2. Kittrell, F. W., 1969. A Practical Guide to Water Quality Studies of Streams. U.S. Federal Water Pollution Control Administration, Washington, D.C., 135p.

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.

SOP F202
Water Level, Water-Product Level, and Well Depth Measurements

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 hundreths 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_c	=	Corrected water table elevation
WTE_a	=	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.

SOP F301
Sample Preservation and Handling

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_2SO_4- Sulfuric Acid
HNO_3 - 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_2SO_4 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 sample 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 sample 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 using laboratory supplied preservatives. 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_3, 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 containers will be wiped clean with a damp paper towel; however 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, (zipper-type 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_3 to pH <2	6 months	6 months	P, G	HNO_3 to pH <2	180 days	180 days
Mercury	P, G	HNO_3 to pH <2	28 days	28 days	P, G	HNO_3 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_3 to pH <2	24 hrs.	24 hrs.	P, G	HNO_3 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. This practice keeps the inside of the cooler clean and minimizes cleanup at the laboratory after samples are removed.

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). In many regions custody seals are also applied to sample container lids. The reason for this practice is two-fold: maintain integrity of sample and keep lid on the container should the lid loosen during shipment. Check with the appropriate regional procedures prior to field work. In many cases, the laboratory manager of the analytical lot to be used on a particular project can also provide this information.

4. It is good practice to wrap all glass containers in bubblewrap prior to placing in plastic bags.

5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.

6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.

7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) 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.

8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large garbage bag with tape (preferably electrical or duct).

9. 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. Wrap the tape three to four times around each side 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.

10. 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. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. 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, which is secured to the top of the shipping container. Please note-several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler 2 of 3, etc.", prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).

SOP F302
Chain-of-Custody

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 and Analysis Plan. 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. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.
- 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, sample analysis required and analytical method 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 shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).
- If a carrier is used, enter the bill-of-lading or airbill number under "Remarks," in the bottom right corner;
- 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 zipper-type 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

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

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

EXAMPLE SAMPLE LABEL

Baker	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108

Project: 19026-SRN CTO No.: 0026

Sample Description: groundwater

Date: 09/17/92 Sampler: ABC

Time: 0944

Analysis: TAL Metals (CAP) Preservation: HNO_3

Project Sample No.: CAX-GW-04

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

ATTACHMENT B

EXAMPLE CHAIN-OF-CUSTODY RECORD

CHAIN-OF-CUSTODY RECORD

Name: ______

S. O. Number: ______

Sampler: ______
(Print)

Signature: ______

Sheet ____ of ____

BAKER ENVIRONMENTAL, INC.
Airport Office Park - Bldg No. 3
420 Rouser Road
Coraopolis, PA 15108
(412) 269-6000

Baker Sample I.D. No.	Sample Type	Sampled		Sample Storage and Preservation Details*									
				Cooling		HNO_3		H_2SO_4 Cooling		Other		Other	
		Date	Time	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.	No. of Contnr.	Type/ Volume Contnr.

General Remarks:

*NOTES: Record type of container used with abbreviation P (plastic) or G (glass)
Record volume of containers in leters

Relinguished By (Sign):
Date: **Time:**
Remarks:

Received By (Sign):
Date: **Time:**
Remarks:

Shipment/Transportation Details:

Relinguished By (Sign):
Date: **Time:**
Remarks:

Received By (Sign):
Date: **Time:**
Remarks:

Shipment/Transportation Details:

Relinguished By (Sign):
Date: **Time:**
Remarks:

Received By (Sign):
Date: **Time:**
Remarks:

pment/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

EXAMPLE CUSTODY SEAL

Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**	Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**

SOP F303
Field Logbook

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 by each member of the field crew.

- 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 a master field logbook for the duration of on-site activities. Each member of the Sampling crew is responsible for maintaining a complete and accurate record of site activities for the duration of the project.

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 by each member of the field team.

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

It is good practice to list important phone numbers and points of contact here.

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 by each team member.

- 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 master logbook kept by the field team leader 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 including appropriate measurements if required.
- 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 or initiated 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, direction of view 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.

SOP F304
QA/QC Samples

RESERVED

SOP F402
Slug Testing

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.

<u>Hydraulic Conductivity (K)</u> - 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:

Time Since Start of Test (min)	Measurement Frequency (min)
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

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.

SOP F502
Decontamination of Chemical Sampling and Field Analytical Equipment

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 and sediment sampling equipment including, but not limited to trowels, beakers, dredges, etc., shall be decontaminated using the following USEPA Region III procedures.

The following sections summarize decontamination procedures for USEPA Regions I through IV for overall comparison. 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.

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Micham, J. T., R. Bellandi, E. C. Tifft, Jr. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review. Spring 1989.

SOP F504
Handling of Site Investigation Generated Waste

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
- Mainfests and similarly regulated documents

7.0 REFERENCES

Federal Register. 40 CFR Parts 261, 263, and 761.

SOP F702
Geophysics - Electromagnetic Induction

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 - Ability of a material to transmit an electrical current. 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 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 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

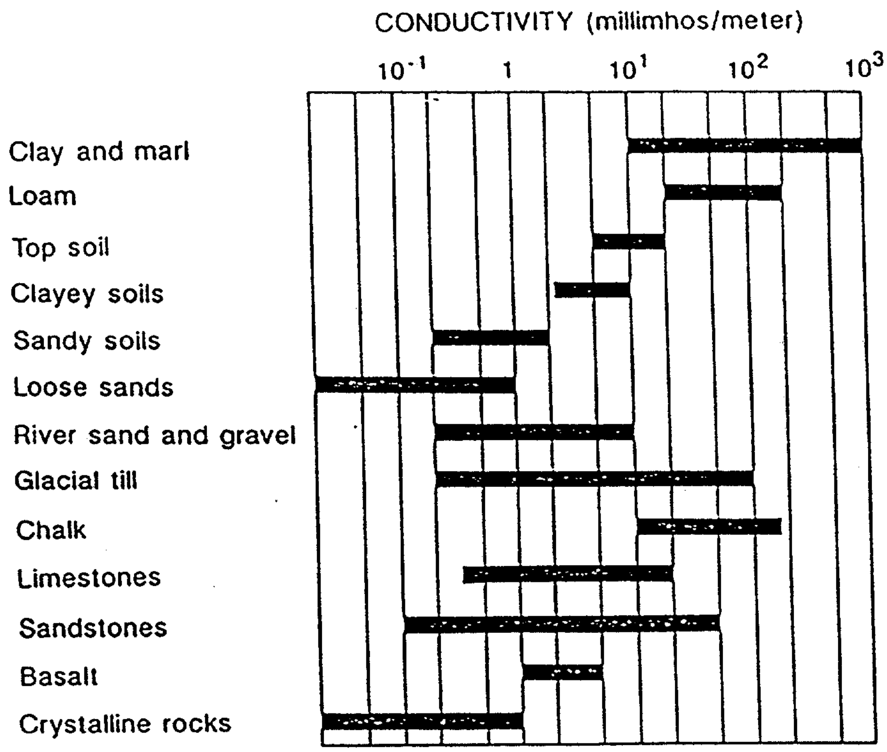
5.1 Overview

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:

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

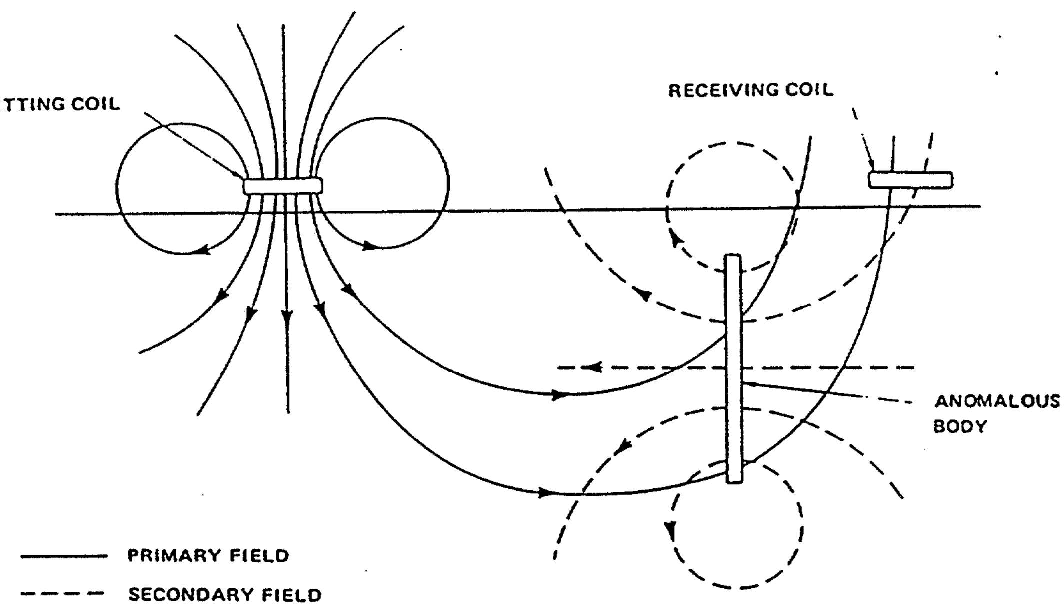
Figure 1



(after Culley et al.)

CONDUCTIVITY RANGES FOR COMMON EARTH MATERIALS

Figure 2



Source: Griffith and King, 1981

TWO-COIL ELECTROMAGNETIC INDUCTION APPARATUS

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

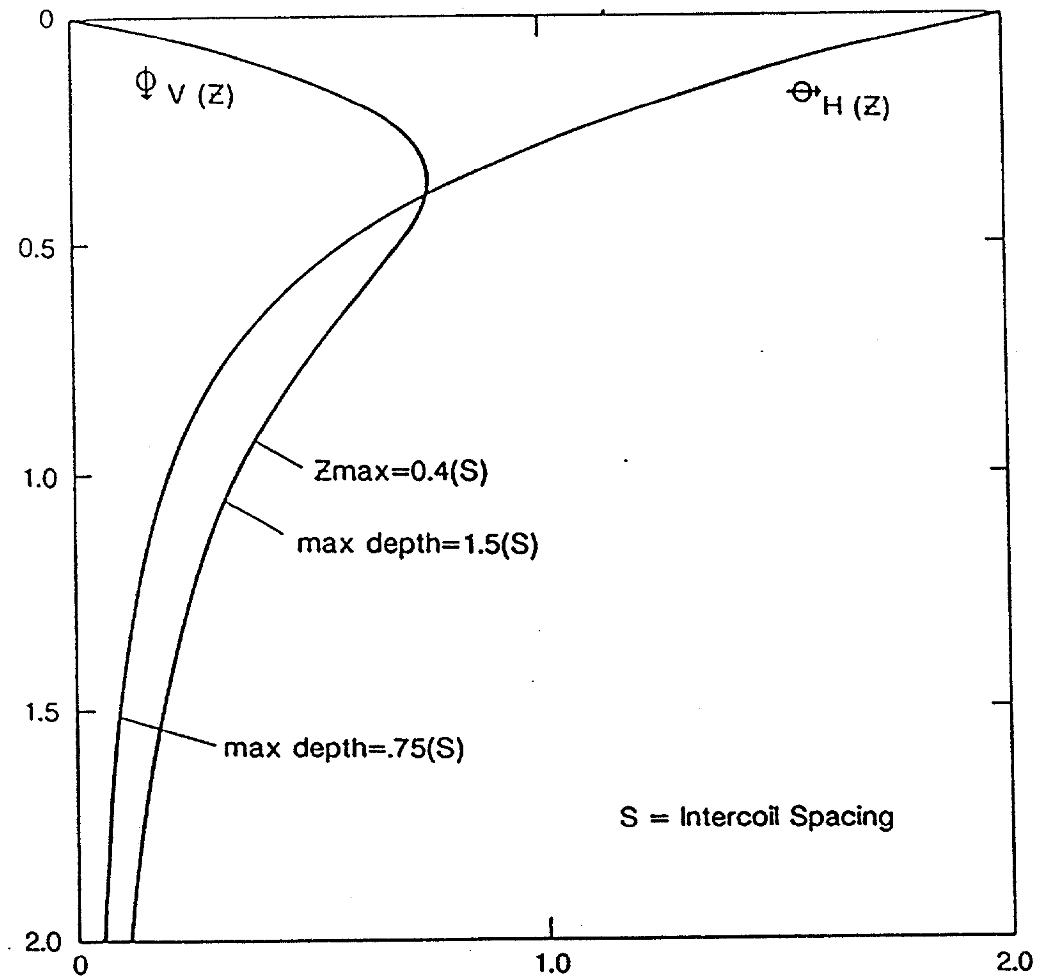
The sampling depth or depth of investigation is related to the coil spacing and coil mode. The two coil modes used are the vertical dipole mode (coils horizontal) and the horizontal dipole mode (coils vertical). Figure 3 shows the relationship of the coil spacings, mode and relative responses.

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 weathĕred 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).

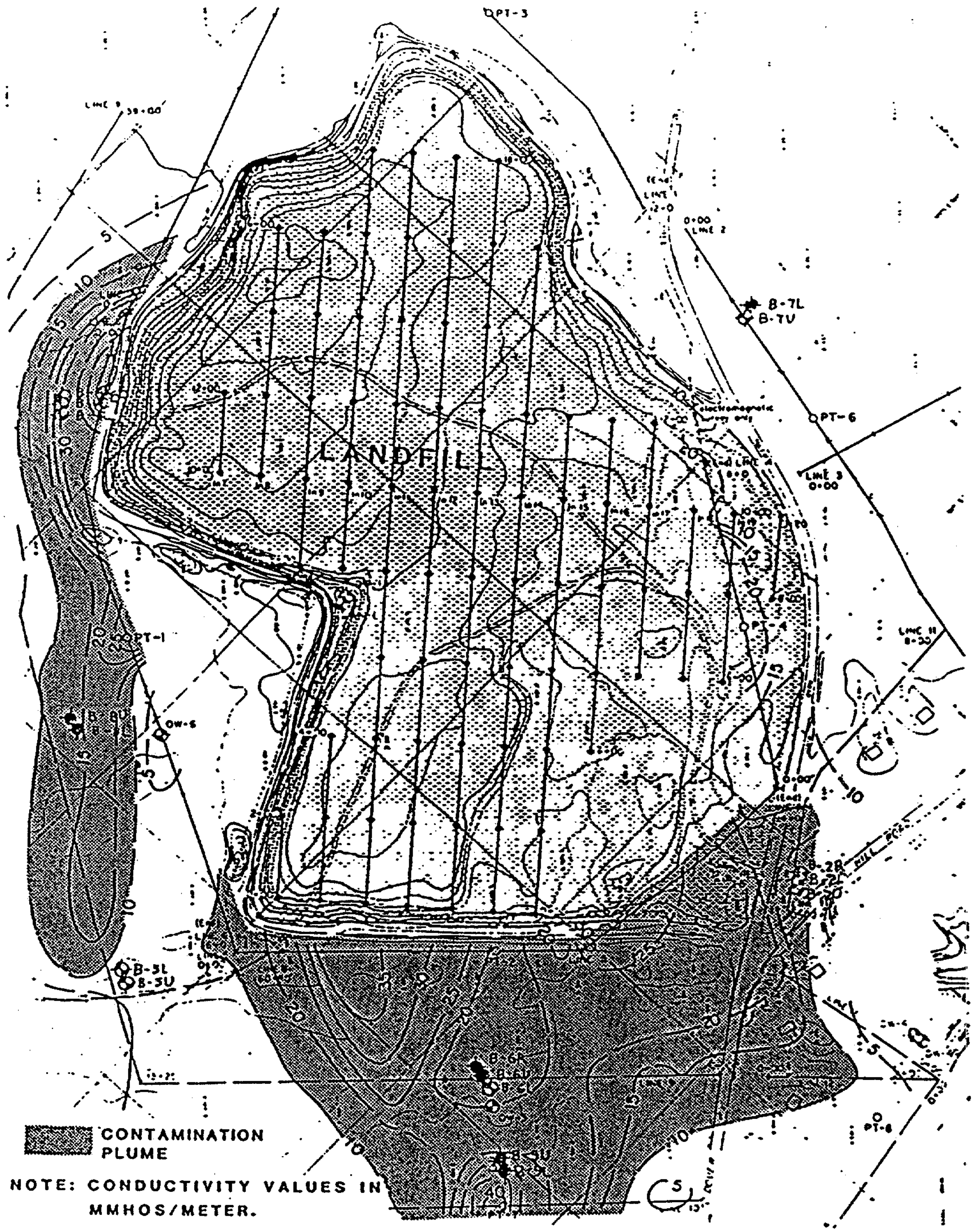
5.3 Equipment

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.

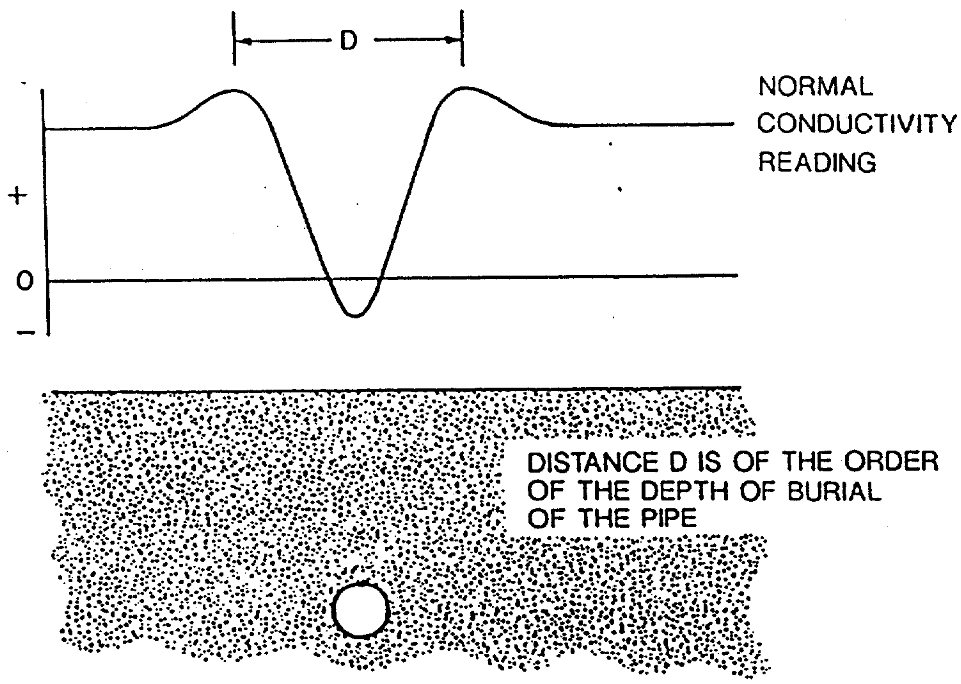
The VLF Instrumentation is a small, lightweight hand-held instrument which can be operated by one person. Principal components of the instrument are a pair of mutually perpendicular coils and a receiving crystal with a frequency specific to a transmitting antenna. The two receiving coils are used to 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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