03.05-10/02/94-01533

FINAL

REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN FOR OPERABLE UNIT NO. 8 (SITE 16) OPERABLE UNIT NO. 11 (SITES 7 AND 80) OPERABLE UNIT NO. 12 (SITE 3) MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0233

OCTOBER 2, 1994

Prepared for:

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

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

PREFACE

These Remedial Investigation/Feasibility Study Project Plans consist of a Work Plan, Sampling and Analysis Plan, and Quality Assurance Project Plan. In accordance with discussions between the Navy/Marine Corps, EPA Region IV, and the North Carolina DEHNR, the format of the Project Plans has been condensed to eliminate repetitive information (e.g., discussing site background information in both the Work Plan and Sampling and Analysis Plan, presenting identical site maps in both documents, discussing the objectives in each document, etc.). The Project Plans reflect the necessary information suggested in EPA Guidance (OSWER Directive No. 9355.3-01).

The Work Plan focuses on the scope of work and rationale (i.e., the "what" and "why" aspects of the project). The Field Sampling and Analysis Plan focuses on how the field scope of work will be implemented. The Quality Assurance Project Plan addresses the quality assurance/quality control aspects of the field and analytical programs.

TABLE OF CONTENTS

			Page
PREFACE			**ii**
1.0	**INTRODUCTION**		**1-1**
	1.1	Objective of RI/FS Work Plan	1-1
	1.2	RI/FS Scoping	1-1
	1.3	RI/FS Work Plan Format	1-2
2.0	**BACKGROUND AND SETTING**		**2-1**
	2.1	Marine Corps Base, Camp Lejeune	2-1
		2.1.1 Location and Setting	2-2
		2.1.2 History and Mission	2-3
		2.1.3 Previous Investigations	2-4
		2.1.4 Topography and Surface Drainage	2-4
		2.1.5 Regional Geology	2-5
		2.1.6 Regional Hydrogeology	2-5
		2.1.7 Surface Water Hydrology	2-6
		2.1.8 Climatology	2-7
		2.1.9 Natural Resources and Ecological Features	2-7
		2.1.10 Land Use and Demographics	2-8
		2.1.11 Water Supply	2-10
	2.2	Operable Unit No. 8 (Site 16) - Montford Point Burn Dump	2-11
		2.2.1 Site Location and Setting	2-11
		2.2.2 Site Topography and Drainage	2-11
		2.2.3 Site History	2-11
		2.2.4 Site Geology and Hydrogeology	2-12
		2.2.5 Previous Investigations	2-12
	2.3	Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump	2-12
		2.3.1 Site Location and Setting	2-12
		2.3.2 Site Topography and Drainage	2-12
		2.3.3 Site History	2-13
		2.3.4 Site Geology and Hydrogeology	2-13
		2.3.5 Previous Investigations	2-13
	2.4	Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area	2-14
		2.4.1 Site Location and Setting	2-14
		2.4.2 Site Topography and Drainage	2-14
		2.4.3 Site History	2-15
		2.4.4 Site Geology and Hydrogeology	2-15
		2.4.5 Previous Investigations and Findings	2-15
	2.5	Operable Unit No. 12 (Site 3) - Old Creosote Plant	2-16
		2.5.1 Site Location and Setting	2-16
		2.5.2 Site Topography and Drainage	2-16

TABLE OF CONTENTS
(Continued)

			Page
	2.5.3	Site History	2-17
	2.5.4	Site Geology and Hydrogeology	2-17
	2.5.5	Previous Investigation and Findings	2-17
3.0	**DATA QUALITY AND SAMPLING OBJECTIVES**		**3-1**
	3.1	Data Quality Objectives	3-1
	3.1.1	Stage 1 - Identification of Decision Types	3-1
	3.1.2	Stage 2 - Identification of Data Uses/Needs	3-1
	3.1.3	Stage 3 - Design Data Collection Program	3-5
	3.2	Study Objectives	3-5
4.0	**REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASK**		**4-1**
	4.1	Task 1 - Project Management	4-1
	4.2	Task 2 - Subcontract Procurement	4-1
	4.3	Task 3 - Field Investigations	4-1
	4.3.1	Operable Unit No. 8 (Site 16) - Montford Point Burn Dump	4-1
	4.3.2	Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump	4-3
	4.3.3	Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area	4-6
	4.3.4	Operable Unit No. 12 (Site 3) - Old Creosote Plant	4-7
	4.3.5	Investigative Derived Waste Handling	4-8
	4.4	Task 4 - Sample Analysis and Validation	4-9
	4.5	Task 5 - Data Evaluation	4-9
	4.6	Task 6 - Risk Assessment	4-10
	4.6.1	Human Health Evaluation Process	4-11
	4.6.2	Ecological Risk Assessment	4-17
	4.7	Task 7 - Treatability Study/Pilot Testing	4-20
	4.8	Task 8 - Remedial Investigation Report	4-21
	4.9	Task 9 - Remedial Alternatives Screening	4-21
	4.10	Task 10 - Remedial Alternatives Evaluation	4-21
	4.11	Task 11 - Feasibility Study Report	4-22
	4.12	Task 12 - Post RI/FS Support	4-22
	4.13	Task 13 - Meetings	4-22
5.0	**PROJECT MANAGEMENT AND STAFFING**		**5-1**
6.0	**SCHEDULE**		**6-1**
7.0	**REFERENCES**		**7-1**

LIST OF TABLES

Number

2-1	Generalized Hydrogeologic Cross Section
2-2	Land Utilization: Developed Areas Acres/Land Use (Percent)
2-3	Groundwater Investigation Findings, OU No. 11 (Site 7)
2-4	Soil Investigation Findings, OU No. 11 (Site 7)
2-5	Groundwater Investigation Findings, OU No. 11 (Site 80)
2-6	Soil Investigation Findings, OU No. 11 (Site 80)
2-7	Surface Water Investigation Findings, OU No. 11 (Site 80)
2-8	Groundwater Investigation Findings, OU No. 12 (Site 3)
2-9	Soil Investigation Findings, OU No. 12 (Site 3)
3-1	Remedial Investigation/Feasibility Study Objectives
4-1	Summary of Sampling, Analytical, and Data Quality Objectives
4-2	Preliminary Remediation Goals, OU No. 11 (Site 7) Tarawa Terrace Dump
4-3	Preliminary Remediation Goals, OU No. 11 (Site 80) Paradise Point Golf Course Maintenance Area
4-4	Preliminary Remediation Goals, OU No. 12 (Site 3) Old Creosote Plant

LIST OF FIGURES

Number

2-1 Operable Units and Site Location Map
2-2 Location of Hydrogeologic Cross Sections
2-2A Operable Unit Supply Well Location
2-3 Hydrogeologic Cross Section
2-4 Site Location Map, Site 16 - Montford Point Burn Dump
2-5 Site Location Map, Site 7 - Tarawa Terrace Dump
2-6 Previous Investigation Sampling Locations, Site 7 - Tarawa Terrace Dump
2-7 Site Location Map, Site 80 - Paradise Point Golf Course Maintenance Area
2-8 Previous Investigation Sampling Locations, Site 80 - Paradise Point Golf Course Maintenance Area
2-9 Site Location Map, Site 3 - Old Creosote Plant
2-10 Previous Investigation Sampling Locations, Site 3 - Old Creosote Plant

5-1 Project Organization

6-1 Project Schedule Operable Unit No. 8
6-2 Project Schedule Operable Unit No. 11
6-3 Project Schedule Operable Unit No. 12

LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
bls	below land surface
BOD	biological oxygen demand
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLEJ	Camp Lejeune
CLP	Contract Laboratory Program
COD	chemical oxygen demand
DOD	Department of the Defense
DoN	Department of the Navy
DQO	Data Quality Objective
EMD	Environmental Management Division (Camp Lejeune)
ESE	Environmental Science and Engineering, Inc.
°F	degrees Fahrenheit
FFA	Federal Facilities Agreement
FMF	Fleet Marine Force
FMFLANT	Fleet Marine Force Atlantic
FFSG	Force Service Support Group
ft	feet
ft/ft	foot per foot
gpm	gallons per minute
GSRA	Greater Sandy Run Area
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HPIA	Hadnot Point Industrial Area
HQ	hazard quotient
IAS	Initial Assessment Study
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MAGTF	Marine Air Ground Task Force
MCAS	Marine Corps Air Station
MCB	Marine Corps Base

MCL	maximum contaminant level
mgd	million gallons per day
mg/L	milligram per liter
msl	mean sea level
NACIP	Navy Assessment and Control of Installation Pollutants
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCP	National Contingency Plan
NCWQS	North Carolina Water Quality Standard
NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic Atmosphere Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NREA	Natural Resources and Environmental Affairs
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PRGs	Preliminary Remediation Goals
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SMCL	Secondary Maximum Contaminant Level
SQC	Sediment Quality Criteria
SSV	Sediment Screening Value
TAL	Target Analyte List
TBC	To be Considered
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TDS	total dissolved solids
TSS	total suspended solids
μg/L	micrograms per liter
μg/kg	micrograms per kilogram

USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WOE	weight-of-evidence

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment, Health and Natural Resources (DEHNR), and the United States Department of the Navy (DoN) entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are thoroughly investigated, and that appropriate CERCLA response Resource Conservation Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect the public health and welfare, and the environment (MCB Camp Lejeune FFA, 1989).

The scope of the FFA included the implementation of a remedial investigation/feasibility study (RI/FS) at thirteen Operable Units (OUs) and twenty-seven sites across MCB Camp Lejeune. RIs will be implemented at these OUs to determine fully the nature and extent of the threat to the public health and welfare or to the environment caused by the release and threatened release of hazardous substances, pollutants, contaminants or constituents at the site and to establish requirements for the performance of FSs. Feasibility studies will be conducted to identify, evaluate, and select alternatives for the appropriate CERCLA responses to prevent, mitigate, or abate the release or threatened release of hazardous substances, pollutants, contaminants, or constituents at the site in accordance with CERCLA/Superfund Amendments and Reauthorization Act of 1986 (SARA) and applicable State law (FFA, 1989).

This RI/FS Work Plan addresses three of the OUs: OU No. 8 (Site 16) - Montford Point Burn Dump; OU No. 11 (Site 7) - Tarawa Terrace Dump, and (Site 80) - Paradise Point Golf Course Maintenance Area; and OU No. 12 (Site 3) - Old Creosote Plant. The four sites have been grouped into three OUs for purposes of this RI/FS.

1.1 Objective of RI/FS Work Plan

The objective of this RI/FS Work Plan is to identify the tasks required to implement an RI/FS for Sites 16, 3, 7, and 80 at MCB Camp Lejeune. The various studies or investigations required to collect appropriate data are described in this Work Plan. In addition, the Work Plan documents the scope and objectives of the individual RI/FS activities. It serves as a tool for assigning responsibilities and establishing the project schedule and cost. The preparation and contents of the RI/FS Work Plan are based on the scoping process, which is described below.

1.2 RI/FS Scoping

Scoping is the initial planning stage of the RI/FS and of site remediation. The result or outcome of the scoping process is documented in the RI/FS Work Plan. Scoping begins once the background information is reviewed and evaluated and consists of the following activities:

- Preliminary assessing human health and environmental risks, based on existing information.

- Identifying any potential interim actions which may need to be undertaken early in the program to mitigate potential threats to the public health and environment.
- Identifying potential contaminant migration pathways.
- Identifying contaminants of potential concern.
- Identifying Federal and State Applicable or Relevant and Appropriate Requirements (ARARs).
- Define the optimum sequence of investigation activities.
- Identifying the sampling strategies for the collection of data.
- Determining the type, amount, and data quality objectives (DQOs) to assess human health and environmental risks, and to effectively evaluate feasible technologies/alternatives.
- Identifying potential technologies/alternatives for mitigating site problems.
- Identifying the remedial alternatives suitable to site conditions.

The background information available to this process included a number of existing environmental assessment reports, which are identified in Section 7.0 (References), and information collected during planning visits at each site.

As part of the scoping process, project meetings were conducted with the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), USEPA Region IV, and the North Carolina DEHNR to discuss the proposed RI/FS scope of work for each site, and to obtain technical and administrative input from LANTDIV.

1.3 RI/FS Work Plan Format

The following elements are presented in this RI/FS Work Plan.

- Section 2 - Background and Setting
- Section 3 - RI/FS Data Quality and Sampling Objectives
- Section 4 - RI/FS Tasks
- Section 5 - Project Staffing
- Section 6 - Project Schedule
- Section 7 - References

Section 2 documents the evaluation of background information, along with the location and setting of each site. The purposes of this section is to define the physical and known environmental characteristics of each site. This section focuses on identifying potential and/or confirmed contaminant migration pathways, identifying potential (or known) impacts to public health and environment, listing Federal or State ARARs, and evaluating potential remedial technologies/alternatives for mitigating site problems.

Section 3 defines site-specific RI/FS data quality and sampling objectives. Data or information deemed necessary to identify migration pathways, assess environmental and human health risks, or evaluate feasibility or remedial actions are presented in this section. This data may consist of chemical analyses, hydrogeologic information, or engineering analyses. The collection methods for obtaining this information are also identified and described in general terms [more detailed descriptions of the field investigation activities are documented in the Sampling and Analysis Plan (SAP)].

Section 4 identifies and describes the tasks and field investigation activities that will be implemented to complete the RI/FS at the sites in terms of meeting the site-specific objectives. These tasks generally follow the description of tasks identified in EPA's RI/FS Guidance Document (OSWER Directive 955.3-01).

Section 5 discusses project staffing for implementing the RI/FS. The RI/FS schedule is provided in Section 6. References used in developing the RI/FS Work Plan are provided in Section 7.

2.0 BACKGROUND AND SETTING

The purpose of this section is to summarize and evaluate existing information pertaining to MCB Camp Lejeune, Sites 16, 7, 80, and 3. The analysis of existing information will serve to provide an understanding of the nature and extent of contamination in order to aid in the design of RI tasks. The current understanding of the physical setting of the sites, the history of the sites, and the existing information related to previous environmental investigative activities are described herein.

This section specifically addresses the location and setting of the sites, historical events associated with past usage or disposal activities, topography and surface drainage, regional geology and hydrogeology, site-specific geology and hydrogeology, surface water hydrology, climatology, natural resources and ecological features, and land use.

Additional background information is presented in the following documents:

- Initial Assessment Study (IAS) of Marine Corps Base Camp Lejeune, North Carolina (Water and Air Research, 1983)
- Final Site Summary Report, Marine Corps Base, Camp Lejeune (Environmental Science and Engineering, Inc. 1990)
- Hydrogeology of Aquifers in Cretaceous and Younger Rocks in the Vicinity of Onslow and Southern Jones Counties, North Carolina (U.S. Geological Survey, 1990)
- Continuous Seismic Reflection Profiling of Hydrogeologic Features Beneath New River, Camp Lejeune, North Carolina (U.S. Geological Survey, 1990)
- Assessment of Hydrologic and Hydrogeologic Data at Camp Lejeune Marine Corps Base, North Carolina (U.S. Geological Survey, 1989)
- Preliminary Draft Site Inspection Report IAS Site 3, Old Creosote Plant, Marine Corps Base, Camp Lejeune, North Carolina (Halliburton NUS, 1991)
- Preliminary Draft Site Inspection Report, IAS Site 7, Tarawa Terrace Dump, Marine Corps Base, Camp Lejeune, North Carolina (Halliburton NUS, 1991)
- Preliminary Draft Site Inspection Report, IAS Site 80, Paradise Point Golf Course, Marine Corps Base, Camp Lejeune, North Carolina (Halliburton NUS, 1991)

2.1 MCB Camp Lejeune, North Carolina

This section provides an overview of the physical features associated with MCB Camp Lejeune, North Carolina (which also includes Marine Corps Air Station New River).

2.1.1 Location and Setting

MCB Camp Lejeune is located within the Coastal Plain Physiographic Province. It is located in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington. The facility covers approximately 236 square miles. This includes the recent acquisition of approximately 64 square miles west of the facility within the Greater Sandy Run Area of the county. The military reservation is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean.

The eastern border of MCB Camp Lejeune is the Atlantic shoreline. The western and northwestern boundaries are U.S. Route 17 and State Route 24, respectively. The City of Jacksonville, North Carolina, borders MCB Camp Lejeune to the north. MCB Camp Lejeune is depicted in Figure 2-1.

The Greater Sandy Run Area (GSRA) is located in the southeast portion of Onslow County, North Carolina, near the Pender-Onslow County border. The GSRA is approximately 31 miles northeast of Wilmington, North Carolina; 15 miles south of Jacksonville, North Carolina; and 5 miles northwest of the Atlantic Ocean. The GSRA is located south and west of MCB, Camp Lejeune, sharing a common boundary along Route 17 between Dixon and Verona.

The following overview of the Complex was taken from the document "Master Plan, Camp Lejeune Complex, North Carolina." The Complex consists of 12 identifiable developed areas. Of the developed areas, Hadnot Point comprises the most concentrated area of development. This area includes the organizational offices for the Host Activity and for the Headquarters, 26 Marine Amphibious Unit, as well as the Headquarters and regimental areas for the 2nd Marine Division, Marine Expeditionary Force, 6th Marine Expeditionary Brigade, 22nd Marine Expeditionary Unit, 24th Marine Amphibious Unit, the Central Exchange & Commissary and the Naval Dental Clinic Headquarters. Directly north of Hadnot Point are the family housing areas concentrated throughout the wooded areas of the central Complex and along the shores of the New River. Also located in this north central area are major personnel support land uses, including the newly-constructed Naval Hospital, school sites, recreational areas, as well as additional family housing areas (quarters developments, Midway Park and Tarawa Terrace I and II).

The Air Station and Camp Geiger are considered as a single urban area possessing two separate missions and supported by two unrelated groups of personnel. The Marine Corps Air Station (MCAS), New River encompasses 2,772 acres and is located in the northwestern section of the Complex and lies approximately five miles south of Jacksonville. The MCAS includes air support activities, troop housing and personnel support facilities, all of which immediately surround the aircraft operations and maintenance areas.

Camp Geiger, located directly north of MCAS, New River, contains a mixture of troop housing, personnel support and training uses. Currently, the area is utilized by a number of groups which have no direct relationship to one another. The majority of the land surrounding this area is comprised of buffer zones and unbuildable marshland.

The Camp Lejeune Complex contains five other areas of concentrated development, all of which are much smaller in size and population than either Hadnot Point, MCAS New River, or the Camp Geiger area. The oldest of these is the Montford Point area, which is bounded by the New River to the south and west and by Route 24 on the north. New development in Montford Point has been limited, with most of the facilities for troop housing, maintenance, supply and personnel support having been converted from their intended uses. A majority of the MCB training schools requiring classroom instruction are located here and use surrounding undeveloped areas for training operations when required. The French Creek area located directly south of Hadnot Point is occupied by the 2nd Force Service Support Group (2nd FSSG). Its activities are directed toward providing combat service and technical support as required by Headquarters, II Marine Expeditionary Force. Expansion of the French Creek Complex is constrained by the Ordnance Storage Depot explosives safety arc on the south and by the regimental area of Hadnot Point. Onslow Beach, located along the Onslow Bay, east of the New River Inlet, presents assets for amphibious training as well as recreational use. Courthouse Bay is located on one of a series of small bays which are formed by the New River. This area is used for maintenance, storage and training associated with amphibious vehicles and heavy engineering equipment. The Engineering School, also located here, conducts training activities in the large open area located to the southeast of the Courthouse Bay. Another concentrated area of development is the Rifle Range. This area is located on the southwest side of the New River, is singular in purpose and has only a small number of assigned personnel. It was constructed in the early stages of Base development and is used solely for rifle qualification training. The small group of barracks, located at the Rifle Range, are used for two-week periods by troops assigned to range training.

2.1.2 History and Mission

Construction of MCB Camp Lejeune began in 1941 with the objective of developing the "Worlds Most Complete Amphibious Training Base." Construction of the base started at Hadnot Point, where the major functions of the base are centered. Development at the Camp Lejeune Complex is primarily in five geographical locations under the jurisdiction of the Base Command. These areas include Camp Geiger, Montford Point, Courthouse Bay, Mainside, and the Rifle Range Area. Site 16 is located in the Montford Point Area; Sites 7, 80, and 3 are located on the Mainside.

The MCB organization functions as the host command to the two Fleet Marine Force Atlantic (FMFLANT) tenant activities -- Headquarters of the II Marine Expeditionary Division and the 2nd FSSG. The MCB host organization mission is to provide housing, training facilities, logistical support and certain administrative support for tenant units and for other units assigned to MCB Camp Lejeune and to conduct specialized schools and other training maneuvers, as directed.

The mission of the 6th Marine Expeditionary Brigade is to provide the Command element for a brigade-size Marine Air Ground Task Force (MAGTF) with the primary mission of preparing to join up with LantCom MPS equipment and to conduct subsequent combat operations.

The mission of the 2nd Marine Division is to execute amphibious assault operations, and other operations as may be directed, which are supported by Marine aviation and force service support units. With the aircraft wing, the Marine division provides combined arms for service with the Fleet in the seizure or defense of advanced naval bases and for the conduct of land operations essential to the prosecution of a naval campaign.

The mission of the 2nd FSSG is to command, administer and train assigned units in order to provide combat service and technical support as required by Headquarters FMFLANT and its subordinate command in accomplishment of the overall FMFLANT mission.

2.1.3 Previous Investigations

In response to the passage of CERCLA, the DoN initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify, investigate, and clean up past hazardous waste disposal sites at Navy installations. The NACIP investigations were conducted by the Navy Energy and Environmental Support Activity (NEESA) and consisted of Initial Assessment Studies (IAS) and Confirmation Studies. IAS are similar to the USEPA's Preliminary Assessments/Site Investigations (PAs/SIs). Confirmation Studies are similar to USEPA's RI/FS. When the Superfund Amendment and Reauthorization Act (SARA) was passed in 1986, the DoN dissolved the NACIP in favor of the Installation Restoration Program (IRP), which adopted USEPA Superfund terminology and procedures.

The IAS for MCB Camp Lejeune was conducted by Water and Air Research, Inc., (WAR) in 1983. The IAS identified a number of sites at MCB Camp Lejeune as potential sources of contamination, including the sites discussed in this RI/FS Work Plan. Based on historical records, aerial photographs, field inspections, and personnel interviews, the IAS identified 76 sites at MCB Camp Lejeune as potential sources of contamination. Of these 76 sites, 27 sites warranted further investigation to assess potential long-term impacts based on contamination characteristics, migration pathways, and pollutant receptors.

Halliburton NUS Environmental Corporation (Halliburton NUS), under Contract Number 62470-90-R-7629 prepared Site Inspection Reports for the Department of the Navy, Atlantic Division, for MCB, Camp Lejeune, North Carolina. These reports present the results of field investigations conducted at Sites 7 (Tarawa Terrace Dump), 80 (Paradise Point Golf Course), 3 (Old Creosote Plant).

2.1.4 Topography and Surface Drainage

The generally flat topography of MCB Camp Lejeune is typical of the seaward portions of the North Carolina Coastal Plain. Elevations on the base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of MCB Camp Lejeune is between 20 and 40 feet above msl.

Drainage at MCB Camp Lejeune is generally toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of MCB Camp Lejeune is in broad, flat interstream areas. Drainage is poor in these areas (Water and Air Research, 1983).

The U.S. Army Corps of Engineers has mapped the limits of 100-year floodplain at MCB Camp Lejeune at 7.0 feet above msl in the upper reaches of the New River (Water and Air Research, 1983); this increases downstream to 11 feet above msl near the coastal area (Water and Air Research, 1983). Neither Site 16, 7, 80 nor 3 lie within the 100-year floodplain.

2.1.5 Regional Geology

MCB Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments lay in interfingering beds and lenses that gently dip and thicken to the southeast (ESE, 1991). These sediments were deposited in marine or near-marine environments and range in age from early Cretaceous to Quaternary time and overlie igneous and metamorphic basement rocks of pre-Cretaceous age. Table 2-1 presents a generalized stratigraphic column for this area (ESE, 1991).

United States Geological Survey (USGS) studies at MCB Camp Lejeune indicate that the Base is underlain by seven sand and limestone aquifers separated by confining units of silt and clay. These include the water table (i.e., surficial, water-bearing layer), Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear aquifers. The combined thickness of these sediments is approximately 1,500 feet. Less permeable clay and silt beds function as confining units or semiconfining units which separate the aquifers and impede the flow of groundwater between aquifers. A generalized hydrogeologic cross-section illustrating the relationship between the aquifers in this area is presented in Figures 2-2 and 2-3.

2.1.6 Regional Hydrogeology

The following summary of regional hydrogeology was originally presented in Harned et al. (1989).

The surficial water-bearing layer (i.e., surficial aquifer) is a water table aquifer in a series of sediments, primarily sand and clay, which commonly extend to depths of 50 to 100 feet. This unit is not used for water supply on the Base.

The principal water-supply aquifer for the Base is found in the series of sand and limestone beds that occur between 50 and 300 feet below land surface. This series of sediments generally is referred to as the Castle Hayne Formation, associated with the Castle Hayne aquifer. This aquifer is about 150 to 350 feet thick in the area and is the most productive aquifer in North Carolina.

Clay layers occur in both of the aquifers. However, the layers are thin and discontinuous in most of the area, and no continuous clay layer separates the surficial aquifer from the Castle Hayne aquifer. The clay layers range from 5 to 30 feet thick and comprise between 15 and 24 percent of the combined thickness of the two aquifers. The clay layers appear to be thicker and more continuous in the northwestern part of the Base, particularly in the area of the MCAS. It is inferred from their generally thin and discontinuous nature that considerable leakage of groundwater occurs across and around the clay layers, particularly in the upper part of the Castle Hayne aquifer.

Onslow County and MCB Camp Lejeune lie in an area where the Castle Hayne aquifer contains freshwater, although the proximity of saltwater in deeper layers just below the aquifer and in the New River estuary is of concern in managing water withdrawals. Overpumping of the deeper parts of the aquifer could cause encroachment of saltwater. The aquifer contains water having less than 250 milligrams per liter (mg/L) chloride throughout the area of the Base.

The aquifers that lie below the Castle Hayne lie in a thick sequence of sand and clay. Although some of these aquifers are used for water supply elsewhere in the Coastal Plain, they contain saltwater in the MCB Camp Lejeune area and are not used.

Rainfall in the MCB Camp Lejeune area enters the ground in recharge areas, infiltrates the soil, and moves downward until it reaches the water table, which is the top of the saturated zone. In the saturated zone, groundwater flows in the direction of lower hydraulic head, moving through the system to discharge areas like the New River and its tributaries, or the ocean.

The water table varies seasonally. The water table receives more recharge in the winter than in the summer when much of the water evaporates or is transpired by plants before it can reach the water table. Therefore, the water table generally is highest in the winter months and lowest in summer or early fall.

In confined aquifers, water is under excess hydraulic (i.e., head) pressure and the level to which it rises in a tightly cased well is called the potentiometric surface. The hydraulic head in a confined or semiconfined aquifer, such as the Castle Hayne, shows a different pattern of variation over time than that in an unconfined aquifer. Some seasonal variation also is common in the water levels of the Castle Hayne aquifer, but the changes tend to be slower and over a smaller range than for water table wells.

2.1.7 Surface Water Hydrology

The following summary of surface water hydrology was originally presented in the IAS report (WAR, 1983).

The dominant surface water feature at MCB Camp Lejeune is the New River. It receives drainage from most of the base. The New River is short, with a course of approximately 50 miles on the central Coastal Plain of North Carolina. Over most of its course, the New River is confined to a relatively narrow channel entrenched in Eocene and Oligocene limestones. South of Jacksonville, the river widens dramatically as it flows across less resistant sands, clays, and marls. At MCB Camp Lejeune, the New River flows in a southerly direction into the Atlantic Ocean through the New River Inlet. Several small coastal creeks drain the area of MCB Camp Lejeune not associated with the New River and its tributaries. These creeks flow into the Intracoastal Waterway, which is connected to the Atlantic Ocean by Bear Inlet, Brown's Inlet, and the New River Inlet (WAR, 1983). The New River, the Intracoastal Waterway, and the Atlantic Ocean meet the New River Inlet.

Water quality criteria for surface waters in North Carolina have been published under Title 15 of the North Carolina Administrative Code. At MCB Camp Lejeune, the New River falls into two classifications: SC (estuarine waters not suited for body-contact sports or commercial shellfishing) and SA (estuarine waters suited for commercial shellfishing). The SC classification applies to three areas of the New River at MCB Camp Lejeune, including the Rifle Range area; the rest of the New River at MCB Camp Lejeune falls into the SA classification (ESE, 1991).

2.1.8 Climatology

MCB Camp Lejeune experiences mild winters and hot and humid summers. The average yearly rainfall is greater than 50 inches, and the potential evapotranspiration in the region varies from 34 to 36 inches of rainfall equivalent per year. The winter and summer seasons usually receive the most precipitation. Temperature ranges are reported to be 33 to 53 degrees Fahrenheit (°F) in the winter (i.e., January) and 71 to 88°F in the summer (i.e., July). Winds are generally south-southwesterly in the summer, and north-northwesterly in the winter (Water and Air Research, 1983).

2.1.9 Natural Resources and Ecological Features

The following summary of natural resources and ecological features was obtained from the IAS Report (Water and Air Research, 1983).

The Camp Lejeune Complex is predominantly tree-covered with large amounts of softwood including shortleaf, longleaf, pond, and pines (primarily loblolly), and substantial stands of hardwood species. Approximately 60,000 of the 112,000 acres of MCB Camp Lejeune are under forestry management. Timber producing areas are under even-aged management with the exception of those areas along streams and swamps. These areas are managed to provide both wildlife habitat and erosion control. Forest management provides wood production, increased wildlife populations, enhancement of natural beauty, soil protection, prevention of stream pollution, and protection of endangered species.

Upland game species including black bear, whitetail deer, gray squirrel, fox squirrel, quail, turkey, and migratory waterfowl are abundant and are considered in the wildlife management programs.

Aquatic ecosystems on MCB Camp Lejeune consist of small lakes, the New River estuary, numerous tributaries, creeks, and part of the Intracoastal Waterway. A wide variety of freshwater and saltwater fish species exist here. Freshwater ponds are under management to produce optimum yields and ensure continued harvest of desirable fish species (Water and Air Research, 1983). Freshwater fish in the streams and ponds include largemouth bass, redbreast sunfish, bluegill, chain pickerel, yellow perch, and catfish. Reptiles include alligators, turtles, and snakes, including venomous. Both recreational and commercial fishing are practiced in the waterways of the New River and its tributaries.

Wetland ecosystems at MCB Camp Lejeune can be categorized into five habitat types: (1) pond pine or pocosin; (2) sweet gum, water oak, cypress, and tupelo; (3) sweet bay, swamp black gum, and red maple; (4) tidal marshes; and, (5) coastal beaches. Pocosins provide excellent habitat for bear and deer because these areas are seldom disturbed by humans. The presence of pocosin-type habitat at MCB Camp Lejeune is primarily responsible for the continued existence of black bear in the area. Many of the pocosins are overgrown with brush and pine species that would not be profitable to harvest. Sweet gum, water oak, cypress, and tupelo habitat is found in the rich, moist bottomlands along streams and rivers. This habitat extends to the marine shorelines. Deer, bear, turkey, and waterfowl are commonly found in this type of habitat. Sweet bay, swamp black gum, and red maple habitat exist in the floodplain areas of MCB Camp Lejeune. Fauna including waterfowl, mink, otter, raccoon, deer, bear, and gray squirrel frequent this habitat. The tidal marsh at the mouth of the New River is one of the few remaining North Carolina coastal areas relatively free from filling or other manmade changes. This habitat, which consists of marsh and aquatic plants such as algae, cattails, saltgrass, cordgrass, bulrush, and spikerush, provides wildlife with food and cover. Migratory waterfowl, alligators, raccoons, and river otter exist in this habitat. Coastal beaches along the Intracoastal Waterway and along the outer banks of MCB Camp Lejeune are used for recreation and to house a small military command unit. Basic assault training maneuvers are also conducted along these beaches. Training regulations presently restrict activities that would impact ecologically sensitive coastal barrier dunes. The coastal beaches provides habitat for many shorebirds (Water and Air Research, 1983).

The Natural Resources and Environmental Affairs (NREA) Division of MCB Camp Lejeune, the U.S. Fish and Wildlife Service, and the North Carolina Wildlife Resource Commission have entered into an agreement for the protection of endangered and threatened species that might inhabit MCB Camp Lejeune. Habitats are maintained at MCB Camp Lejeune for the preservation and protection of rare and endangered species through the Base's forest and wildlife management programs. Full protection is provided to such species, and critical habitat is designated in management plans to prevent or mitigate adverse effects of Base activities. Special emphasis is placed on habitat and sightings of alligators, osprey, bald eagles, cougars, dusky seaside sparrows, and red-cockaded woodpeckers (Water and Air Research, 1983).

None of the four sites under investigation are within or in close proximity (i.e., one-half mile) to either a natural area or a protected area. Protected areas have only been established for the red-cockaded woodpecker.

Within 15 miles of MCB Camp Lejeune are three publicly owned forests: Croatan National Forest; Hofmann Forest; and Camp Davis Forest. The remaining land surrounding MCB Camp Lejeune is primarily used for agriculture. Typical crops include soybeans, small grains, and tobacco (Water and Air Research, 1983).

2.1.10 Land Use and Demographics

MCB Camp Lejeune presently covers an area of approximately 236 square miles. Military and civilian population is approximately 60,000. During World War II, MCB Camp Lejeune was used as a training area to prepare Marines for combat. This has been a continuing function of the facility during the Korean and Vietnam conflicts, and the recent Gulf War (i.e., Desert Storm). Toward the end of World War II, the camp was designated as a home base for the Second Marine Division. Since that time, Fleet Marine Force (FMF) units also have been stationed here as tenant commands.

The following information was extracted from the document "Master Plan, Camp Lejeune Complex, North Carolina." The existing land use patterns in the various geographic areas within the Marine Corps Base are described in this section and listed, per geographic area, on Table 2-2. The areas described below are depicted on Figure 2-1. In addition, the number of acres comprising each land use category has been estimated and provided on the table. The following is a summary of the land use area for Sites 16, 3, 7, and 80.

2.1.10.1 Paradise Point

North of Hadnot Point are low-density family housing and recreational area. These two uses make up about 94 percent (i.e., 343 acres and 610 acres, respectively) of all the developed areas on Paradise Point. The golf course, also located in this area, comprises the single largest land use. In the center of the Paradise Point shoreline, is the Bachelor Officers' Housing Area and associated community facilities which are accessible from both troop and family housing areas.

Additional recreational uses, including the only riding stable at MCB Camp Lejeune, are situated between Paradise Point and Berkeley Manor. Site 80 (Paradise Point Golf Course Maintenance Area) is located within the boundaries of the golf course.

2.1.10.2 Supply and Storage Uses

Approximately 10.5 percent of all developed land in the Complex is comprised of supply and storage uses, most of which are concentrated in the area east of Paradise Field at Hadnot Point or east of Holcomb Boulevard in an open storage area. The location area of Site 3 (Old Creosote Plant) is located east of Holcomb Boulevard approximately 3/4 of a mile from the intersection of Brewster and Holcomb. This area is currently not being used for open storage but is located in the general area of Open Storage Lots 203 and 201.

2.1.10.3 Tarawa Terrace I and II

The largest amount of family housing, roughly 428 acres, exists at Tarawa Terrace. Land use arrangements are logical and compatible. These duplexes are arranged around a central area of community uses and the residences are buffered from North Carolina (NC) Route 24 by open recreational and natural wooded areas. All 70 one-bedroom housing units are located at Tarawa Terrace. Site 7 (Tarawa Terrace Dump) is located south, southwest of the family housing areas.

2.1.10.4 Montford Point

Montford Point is one of the Marine Corps Bases' oldest areas and has seen little planning over the decades. Most of the 233 acres of development are congregated on the eastern side of Montford Landing Road. Of the 233 acres of development, 35 percent (i.e., 32 acres) consist of troop housing. Community facilities are located near the troop housing in the northeast section of the area. The troop housing facilities located at the southern tip of Montford Point have very limited community facilities nearby.

Classroom training facilities are scattered throughout the developed areas of Montford Point. This use constitutes nearly 21 percent (i.e., 48 acres) of the developed area and, therefore, is the second largest land use category existing at Montford Point. Site 16 (Montford Point Burn Dump) is located within this area.

2.1.10.5 Base-Wide

Present military population of Camp Lejeune is approximately 40,928 active duty personnel. The military dependent community is in excess of 32,081. About 36,086 of these personnel and dependents reside in base housing units. The remaining personnel and dependents live off base and have had dramatic effects on the surrounding area. An additional 4,412 civilian employees perform facilities management and support functions. The population of Onslow County has grown from 17,739 in 1940, prior to the formation of the base, to its present population of 121,350.

2.1.11 Water Supply

MCB Camp Lejeune water is supplied entirely from groundwater. Groundwater is obtained from approximately 90 water supply wells and treated. There are eight water treatment plants with a total capacity of 15,821 million gallons per day (mgd). Groundwater usage is estimated at over 7 mgd (Harned, et al., 1989).

The water supply wells are all located within the boundaries of the Base. The average water supply well at the base has a depth of 162 feet, a casing diameter of eight inches, and yields 174 gpm (Harned, et al., 1989).

All of the water supply wells utilize the Castle Hayne aquifer. The Castle Hayne aquifer is a highly permeable, semiconfined aquifer that is capable of yielding several hundred to 1,000 gpm in municipal and industrial wells in the MCB Camp Lejeune Area. The water retrieved is typically a hard, calcium bicarbonate type.

The following is a summary of the supply wells within a one-half mile radius of Sites 16, 7, 80, and 3:

Site 16 - Montford Point Burn Dump

M-142
M-243
M-267
T-12
M-629

Site 7 - Tarawa Terrace Dump

TT-23
TT-67
TT-52
TT-31
TT-54

Site 80 - Paradise Point Golf Course Maintenance Area

No supply wells are located within a one-half mile radius of this site.

Site 3 - Old Creosote Plant

HP-654
HP-613
HP-616
OW-3

Supply well locations for all Operable Units are shown on Figure 2-2A.

2.2 Operable Unit No. 8 (Site 16) - Montford Point Burn Dump

This section addresses the setting, site topography and drainage features, site history, site geology and hydrology for Site 16 - Montford Point Burn Dump.

2.2.1 Site Location and Setting

The former Montford Point burn dump area is located southwest of the intersection of Montford Landing Road and Wilson Drive in the Montford Point area of Camp Lejeune (see Figure 2-4). The study area is approximately 4 acres in size. The Northeast Creek is approximately 400 feet southeast from the boundary of the burn dump. The remainder of the study area is bordered by wooded areas.

Most of the site is currently a cleared area; the other areas are comprised of pine trees. There is an opening in the wooded area in the southeast corner of the study area which leads to Northeast Creek. An apparent storm sewer line, located to the southeast of the burn dump, runs in a northeast-southwest direction. There is also a storm sewer line that runs from the intersection with Coolidge Road and Harding Road, and connects to the storm line southeast of the site. Currently, the study area is being used for staging vehicles and for vehicle training exercises. In the center of the study area is a mock-up jet aircraft. This aircraft is used to train in refueling exercises by tank truck operators. During these exercises, however, no fuel is used. A four-foot wide ditch, believed to be a fire break, was noticed advancing from the storm sewer line to the southwest of the study area and extending around the western side of the former burn dump. There are no permanent structures at this site.

2.2.2 Site Topography and Drainage

Most of the study area is relatively flat, with a slight slope to the southeast. Overland drainage is in the southeast direction. During the March 1994 site reconnaissance, the southeast portion of the site exhibited eroded soils, which could indicate heavy overland drainage in this area. Surface runoff in the far southeastern portion of the site apparently drains to Northeast Creek. The remaining areas are relatively flat and heavily wooded which could inhibit overland surface runoff at great distances.

2.2.3 Site History

Limited information is available concerning the operational history of the burn dump. Practices at other burn dumps at MCB Camp Lejeune indicate that the Montford Point burn dump may have accepted municipal waste/trash from the surrounding area housing and activity buildings. Records indicate that liquids (waste oils) were also disposed of at this site. Typically, the debris was burned, then graded to the perimeter of the disposal area so that more debris could be dumped and burned.

2.2.4 Site Geology and Hydrogeology

Site-specific geologic information is not available since there has not been any previous investigations conducted at this site. A general description of the soils underlying the site, however, can be inferred from the cross section map of Camp Lejeune as shown on Figure 2-3. In general the site is underlain by undifferentiated deposits of sand, silt, and/or clay. Due to the proximity of the site to Northeast Creek, shallow groundwater is believed to be in a southeast direction.

2.2.5 Previous Investigations

No previous investigations to determine the presence or absence of contamination have been conducted at this site. Visual observations recorded during a site reconnaissance and review of historical photographs are the only information obtained.

2.3 Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump

This section addresses the background and setting of Site 7. A summary of previous investigations is also presented in Section 2.3.5.

2.3.1 Site Location and Setting

Site 7, the Tarawa Terrace Dump, is located northeast of the water treatment plant and south of the community center between Tarawa Boulevard and Northeast Creek. The general location of the site is shown on Figure 2-5. The study area is approximately 5 acres in size, and public access is not restricted. A marsh area is encountered in the southern portion of the study area in the vicinity of Northeast Creek. The entire study area is dense with wooded areas and ground cover. Northeast Creek flows to the west in the direction of the New River. Two unnamed surface water bodies, within the site boundaries, flow southerly in the direction of Northeast Creek. Northeast Creek and the surface water bodies are influenced by tides. During high tide much of the marsh area is covered with ponded water.

During a March 1994 site reconnaissance, four areas of concern were apparent (Figure 2-5). Aerial photos from 1973 and 1978 indicated a potential dump area east of the utility right-of-way. Additionally, a smaller cleared area was shown on the western side of the utility right-of-way. The area south of the community center is a concern based on elevated levels of pesticides/PCBs reported in a previous investigation. Visual debris (i.e., paint cans, motor oil cans, and other rusted cans) were observed in the wooded area east of the water treatment plant. What appeared to be a cleared area, where past dumping may have occurred was observed due east of the water treatment plant adjacent to the smaller surface water body.

2.3.2 Site Topography and Drainage

The site topography is variable with elevations ranging from 20 feet msl to the north to 5 feet msl to the south. The slope of the site is to the south toward Northeast Creek. Several surface water bodies and drainage areas within the vicinity of the Tarawa Terrace Dump site are considered significant. Surface waters and runoff from the site flow in a southerly direction into Northeast Creek. Northeast Creek flows in a southwesterly direction long the southern edge of the site and flows into the New River approximately 3 miles downstream. Northeast Creek and the surface water bodies are influenced by the tides. During high tides much of the southern portion of the site is covered with ponded water.

2.3.3 Site History

Site 7, the Tarawa Terrace Dump is a former dump that was used during the construction of the base housing located in Tarawa Terrace. Precise years of operation are unknown, but is has been reported that the dump was closed in 1972. Historical records do not indicate that hazardous materials were disposed of at this facility, only construction debris, water treatment plant filter media, and household trash are known to have been disposed. Aerial photos from the 1970s indicate a cleared area east of the right-of-way, and a smaller cleared area west of the right-of-way.

2.3.4 Site Geology and Hydrogeology

The shallow subsurface geology of the study area consists of a surficial layer of unconsolidated fine grained sand loam with varying amounts of sand and clay. This surficial layer is underlain by fine grained clayey sand with thin, discontinuous silty sand and clay lenses. Soil densities range from very loose to medium dense (Halliburton NUS, 1991). A general description of the soils underlying the site can be inferred from the cross section map of Camp Lejeune as shown on Figure 2-3.

The water table at this site is located in the near surface sands at approximately 3 to 4 feet during low tide. The water table fluctuates approximately 1 to 2 feet with tidal advances to rise to near ground surface during high tide. Groundwater flow direction across the site is to the south toward Northeast Creek.

2.3.5 Previous Investigations and Findings

The following summarizes the findings of the Site Inspection investigation conducted by Halliburton NUS (1991).

2.3.5.1 Groundwater Investigation

Three shallow monitoring wells (7MW01, 7MW02, 7MW03) were installed in June of 1991. These wells were installed to a depth of 7 feet bgs to 15 ft bgs. One round of groundwater samples were collected and analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) total metals and cyanide. Groundwater analytical results are summarized on Table 2-3.

Two pesticides, dieldrin and endrin ketone, were reported at low levels in monitoring well MW02. Manganese, chromium, lead, and iron were the only metals which exceeded either the North Carolina Water Quality Standard (NCWQS) or the Federal Maximum Contaminant Level (MCL).

Groundwater sampling locations are shown on Figure 2-6.

2.3.5.2 Soil Investigation

Eight surface soil samples (0 to 2 feet) and five subsurface soil samples (3 to 12 feet) were collected in June of 1991. All samples were analyzed for TCL organics and TAL metals and cyanide. Analytical findings are summarized on Table 2-4.

Soil sample location MW02 exhibited pesticides and PCBs. Pesticides and PCBs were also reported in soils samples SB01 and SB02. The maximum concentration of dieldrin (2,500 µg/kg) and endrin (1,300 µg/kg) were reported at location MW02 (7.5 to 9.5 feet) and the maximum concentration of endosulfan II (2,000 µg/kg) was found in the 7 to 9 foot deep sample from location SB02. PCB-1260 was detected in seven surface and subsurface soil samples at concentrations ranging from 108 µg/kg at location SB05 to 25,000 µg/kg at location MW02 (7.5 to 9.5 feet).

Soil sampling locations are shown on Figure 2-6.

2.3.5.3 Surface Water/Sediment Investigation

A surface water/sediment investigation has not been performed under any previous investigation.

2.4 Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area

This section addresses the setting, site topography and drainage features, site history, site geology, and hydrogeology for Site 80 - Paradise Point Golf Course Maintenance Area. A summary of previous investigation findings is also discussed in Section 2.4.5.

2.4.1 Site Location and Setting

The study area is northwest of Brewster Boulevard within the Paradise Point Golf Course, as shown on Figure 2-7. Site 80 consists of a 1-acre area located in the rear of the machine shop (Building 1916) and a maintenance wash area consisting of a concrete wash pad and sump. The sump is used to collect water and oil runoff generated from spraying of the maintenance equipment. A drainage ditch is located to the southeast of the wash area. The drainage ditch enters the site form the machine shop road to the south of the site, curves around the back of the site, and leaves the site to the north. There are several large soil mounds in the northeast portion of the site, behind the machine shop. The soil mounds are overgrown with small pines. There is an open area in front of the mounds where vegetation debris is deposited. There is old maintenance equipment placed in the lawn and wooded areas around the maintenance shop. An oil collection system is located in the maintenance building (Building 600). Two drums, which have been removed from the site by Activity personnel, were located northeast of Building 600 just across the dirt access road.

2.4.2 Site Topography and Drainage

The study area is relatively flat, with a slight slope to the northeast. During the March 1994 site reconnaissance, surface water runoff was observed flowing in a southeast direction in the direction of the ditch. Surface water continues in a north-northeast direction away from the site. Site elevations vary from 3 to approximately 26 feet above msl.

2.4.3 Site History

Site 80, Paradise Point Golf Course Maintenance Area, is used for maintenance and cleaning of equipment used at the golf course. The area is used to house and mix pesticides and herbicides used in the golf course maintenance. Prior to construction of the existing concrete wash pad, chemical mixing was conducted on a concrete pad with no containment controls. The soil mounds, located in the northeast portion of the site, were generated during the construction of ponds along the golf fairways in 1987 or 1988. It was reported that wastes were disposed of in this area. Employees of the maintenance garage were instructed not to use the soil from this area for fill material. It has not been documented whether wastes were disposed on the mounds, or whether the area beneath the piles was used to dispose wastes.

2.4.4 Site Geology and Hydrogeology

The soil characterization at this site is limited to the top 22 feet of the subsurface (Halliburton NUS, 1991). The shallow subsurface geology of the study area consists of an approximately 2-foot thick surficial layer of unconsolidated fine grained silt sand with varying amounts of clay and rock fragments. This surficial layer is underlain by fine grained clayey sand with this, discontinuous silt and silty sand lenses. Soil density ranges from loose to medium dense. At a depth of approximately 10 feet, soils grade into a dense, fine medium grained with silty sand lenses. A general description of the soils underlying the site can be inferred from the cross section map of Camp Lejeune as shown on Figure 2-3.

The water table at the Paradise Point Golf Course is located in the dense sands at depths ranging from approximately 5 to 14 feet below the ground surface. Groundwater flow direction across the site is to the northwest and discharges into Northeast Creek and its confluence with the New River.

2.4.5 Previous Investigations and Findings

The following summarizes the findings of the Site Inspection investigation conducted by Halliburton NUS (1991).

2.4.5.1 <u>Groundwater Investigation</u>

Three shallow monitoring wells (80MW01, 80MW02, and 80MW03) were installed at the Paradise Point Golf Course as part of the site inspection. The location of the monitoring wells are shown on Figure 2-8. One sample was collected from each well and analyzed for full TCL organics and chlorinated herbicides. Analytical results are summarized on Table 2-5.

Four volatile organic chemicals, toluene (180 µg/L), ethylbenzene (5 µg/L), xylenes (21 µg/L), and carbon disulfide (25 µg/L) were detected in the groundwater sample collected from monitoring well 80MW03. This well is located near the mixing pad and sump area.

2.4.5.2 <u>Soil Investigation</u>

Three surface soils (0 to 6 inches), seven near surface soil samples (0 to 2 feet), and seven subsurface soil samples (3 to 17 feet) were collected (Halliburton NUS, 1991). All samples were analyzed for full TCL organics and chlorinated herbicides. Analytical findings are presented on Table 2-6.

Several pesticides were detected in these samples, such as aldrin, chlordane, 4,4'-DDT and its metabolites, and dieldrin. 4,4'-DDD was the pesticide that was reported at the greatest concentration (700 µg/kg in sample SB02-0002). No herbicides were detected in any of the samples.

PCB-1254 was detected in two discrete surface soil locations (SB02 and MW03) at concentrations of 830 µg/kg and 1,500 µg/kg, respectively.

Soil sample locations are shown on Figure 2-8.

2.4.5.3 Surface Water/Sediment Investigation

Three surface water samples and five sediment samples were collected from the drainage ditch and analyzed for full TCL organics, chlorinated herbicides, and total petroleum hydrocarbons. All of the surface water samples contained acetone, at concentrations ranging from 11 to 190 µg/L. Surface water samples from locations SW04 and SW05 also exhibited toluene at concentrations of 30 µg/L and 140 µg/L, respectively, and petroleum hydrocarbons (1.39 mg/L and 1.66 mg/L). Analytical findings are summarized on Table 2-7. Surface water/sediment sampling locations are shown on Figure 2-8.

2.5 Operable Unit No. 12 (Site 3) - Old Creosote Plant

This section addressees the setting, site topography and drainage features, site history, site geology and hydrogeology for Site 80 - Old Creosote Plant. Section 2.5.5 discusses previous investigation findings.

2.5.1 Site Location and Setting

The Old Creosote Plant area is located on the mainside portion of MCB Camp Lejeune, approximately one quarter mile east of Holcomb Boulevard and one mile north of Wallace Creek. The general site location is shown on Figure 2-9. Remnants of the former creosote plant including a chimney, concrete pads, and train rails are present in the southern portion of the site. The cleared area in the northern portion of the site was reported to be the location of the former sawmill.

The site area encompasses approximately 5 acres, is generally flat and unpaved, and is intersected by a dirt access road. Access to the site is unrestricted. The study area can be directly accessed from Holcomb Boulevard. The Camp Lejeune Railroad lies approximately 200 feet to the west of the study area. The remainder of the area is surrounded by woods.

2.5.2 Site Topography and Drainage

The study area is relatively flat, mostly cleared parcel of land. During periods of heavy rain the western area of the site exhibited several areas of standing water. Surface water runoff from the site flows in both an easterly and westerly direction since runoff ditches flank both the eastern and western edges of the site. To the east is a small drainageway in which ponded water is evident during periods of heavy rain. To the west of the site are drainage areas which parallel the Camp Lejeune Railroad and Holcomb Boulevard. None of these potential drainage areas were under flow conditions during the March 1994 reconnaissance.

2.5.3 Site History

The old creosote plant reportedly operated from 1951 to 1952 to supply treated lumber during construction of the base railroad. Logs were cut into railroad ties at an on-site sawmill, then pressure treated with hot creosote stored in a railroad tank car. There is no indication of creosote disposal on site, and records show that creosote remaining in the pressure chamber at the end of the treatment cycle was stored for future use. Historical information indicates that the on-site sawmill was located the north of the current dirt access road.

2.5.4 Site Geology and Hydrogeology

Based on the drilling program employed during previous investigations, the soil investigation was confined to the top 25 feet of the subsurface. As a result, the geologic conditions at the site have been defined only to a depth of 25 feet.

The shallow subsurface geology of the study area consist of a surficial layer of unconsolidated fine grained sand with varying amounts of silt and limestone fragments. This surficial layer is underlain by fine grained sand with thin, discontinuous silty sand lenses. Soil density ranges from very loose to medium dense.

The water table is located near the surface sands at depths ranging from approximately 8 to 25 feet below the ground surface. The large range in the groundwater levels is believed to be caused by a rapid and pronounced change in surface topography across a relatively small area (Halliburton NUS, 1991); however, this will be verified during the RI. Along the western edge of the site is a 10- to 15-foot drop in elevation to the Camp Lejeune Railroad bed. The close proximity of well 3MW01 to this drop off, results in a low water level in the wells. Based on the general topography of the site it is likely that local groundwater flows to the west in the direction of Holcomb Boulevard. Based on regional topography, however, and the sites close proximity to Wallace Creek, it is believed that at some distance away from the railroad groundwater may flow south in the direction of Wallace Creek.

2.5.5 Previous Investigation and Findings

The following summarizes the findings of the Site Inspection investigations conducted by Halliburton NUS in 1991.

2.5.5.1 <u>Groundwater Investigation</u>

Three shallow monitoring wells (3MW01, 3MW02, 3MW03) were installed in June of 1991. One sample was collected from each well and analyzed for TCL semivolatile organic compounds. Analytical results are summarized on Table 2-8.

Of the three monitoring wells, only well 3MW02 was found to contain any semivolatile compounds. Several polynuclear aromatic hydrocarbons (PAHs) were detected in this well at concentrations greater than 1,000 µg/L (acenaphthene, 2-methylnaphthalene, naphthalene, and phenanthrene). Other PAHs detected included anthracene (260 µg/L), chrysene (96 µg/L), fluoranthene (640 µg/L), fluorene (890 µg/L), and pyrene (460 µg/L). Dibenzofuran was also detected in this sample at a concentration of 1,100 µg/L.

Groundwater sampling locations are shown on Figure 2-10.

2.5.5.2 Soil Investigation

Eight surface soil samples (0 to 2 feet) and 8 subsurface soil samples (3 to 17 feet) were collected. All samples were analyzed for TCL semivolatile compounds. Analytical findings are summarized on Table 2-9.

The surficial soil samples from locations SB04 and MW02 (0 to 2 feet) exhibited PAH contamination at concentrations ranging from 260 µg/kg for benzo(g,h,i)perylene to 2,200 µg/kg for benzo(b)fluoranthene. Other PAHs detected at concentrations greater than 1,000 µg/kg include chrysene, benzo(k)fluoranthene, benzo(a)pyrene, fluoranthene, pyrene, and indeno(1,2,3-cd)pyrene.

PAHs were not detected in the shallow subsurface soil samples (3 to 5 feet) collected at the site. However, in the deep subsurface soil sample collected from MW02 boring (15 to 17 feet), PAHs were detected at elevated concentrations. Several contaminants were detected at concentrations greater than 35,000 µg/kg, such as acenaphthene, fluoranthene, fluorene, naphthalene, and phenanthrene. In addition, dibenzofuran was detected at a concentration of 35,000 µg/kg.

The soil sampling locations are presented on Figure 2-10.

2.5.5.3 Sediment Investigation

Two sediment samples were collected from the low lying areas of the site that collect runoff water. Both samples were analyzed for TCL semivolatile compounds. Only bis(2-ethylhexyl)phthalate was detected, at a concentration of 750 µg/kg in sample SD01, which was collected in the far eastern side of the study area. Sediment sampling locations are shown on Figure 2-10.

3.0 DATA QUALITY AND SAMPLING OBJECTIVES

The purpose of this section is to define the site-specific RI/FS data quality and sampling objectives in order to fulfill the overall goals of characterizing the problems at each site, assessing potential impacts to the public health and environment, and identifying feasible remedial alternatives for remediating the sites, if necessary. The site-specific RI/FS objectives presented in this section have been identified based on review and evaluation of existing background information.

3.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements that ensure data of known and appropriate quality are obtained during the RI/FS. The DQOs associated with each field sampling and analysis program are discussed and presented in this section. The DQOs were developed using the following three stages:

- Stage 1 - Identify decision types
- Stage 2 - Identify data uses/needs
- Stage 3 - Design data collection program

Stage 1 of the DQO process takes place during the scoping of the RI/FS. This stage involves the evaluation of existing information and the development of objectives for field data collection efforts.

Stage 2 of the DQO process involves definition of the quality and quantity of data that will be required to meet the objectives established in Stage 1.

Stage 3 involves the design of a data collection program to meet the requirements identified in Stage 2.

3.1.1 Stage 1 - Identification of Decision Types

As part of the Stage 1 DQO process, available information from previous site investigations and other sources (e.g., USGS) were reviewed in order to describe current site conditions, evaluate existing data, and assess the adequacy of the data. This was documented in Section 2.0 of this Work Plan. From this review and evaluation, RI/FS objectives have been developed to (1) assess the nature of the threat posed by the release or potential release of hazardous substances; (2) characterize the site with respect to the environmental setting; and (3) evaluating potential remedial alternatives. These objectives are presented in Section 3.2.

3.1.2 Stage 2 - Identification of Data Uses/Needs

In Stage 2 of the DQO process. the data quality and quantity required to support the RI/FS objectives developed during Stage 1 are identified. With respect to the RI/FS objectives, data will be required to address specific environmental media at each site. Data uses for each environmental media are presented in Section 3.1.2.1. Site-specific data needs are discussed in Section 3.1.2.2.

3.1.2.1 Data Uses for Environmental Media

RI/FS data uses can be described in general purpose categories. These categories include the following:

- Site Characterization - Data are used to determine the nature and extent of contamination at a site. Site characterization data are generated through the sampling and analysis of waste sources and environmental media.

- Health and Safety - Data are typically used to establish the level of protection needed for investigators or workers at a site, and if there should be an immediate concern for the population living within the site vicinity.

- Risk Assessment - Data are used to evaluate the threat posed by a site to public health and the environment. Risk assessment data are generated through the sampling and analysis of environmental and biological media, particularly where the potential for human or ecological exposure is great (e.g., sediments, surface soil, potable groundwater supplies).

- Evaluation of Alternatives - Data are used to evaluate various remedial technologies. Engineering data are collected in support of remedial alternative evaluation and to develop cost estimates for remediating the site. This may involve conducting bench or pilot-scale studies to determine the effectiveness or implementability of the technology.

- Engineering Design of Alternatives - Data collected during the RI/FS can be used for engineering purposes to develop a preliminary data base in reference to the performance of various remedial technologies. Data types collected during the RI/FS which are applicable to the RD process include waste characterization and preliminary volume estimates (these estimates can be further defined during the remedial design/remedial action via additional field verification sampling).

The above discussion of data uses was extracted from the document entitled Data Quality Objectives for Remedial Response Activities: Development Process (OSWER Directive 9355.0-7B). It has been presented in this Work Plan to provide the user with an understanding of the rationale for determining the site-specific RI/FS objectives as well as the rationale for the proposed sampling and analytical program for each site investigation.

With respect to the above data uses, an understanding of the site background, site history, and contaminant migration and exposure pathways are required in order to define the data needs (or data limitations). This "background" information was presented in Section 2.0 for each site. The site-specific data needs are presented in Section 3.1.2.2. RI/FS objectives, which have been formed to meet the data needs, are presented in Section 3.2.

3.1.2.2 Site-Specific Data Needs

Operable Unit No. 8 (Site 16) - Montford Point Burn Dump

- The potential impact of the reported burn area to human health and the environment based on soil, groundwater, and surface water/sediment data.
- The hazardous or nonhazardous nature of potential buried burn material.
- The presence or absence of site-related contaminants in the surface and subsurface soil in order to conduct a human health risk assessment.
- The hydrogeologic parameters of the shallow aquifer.
- The reliable information to support assessment of risks to human health presented by future potential exposure to shallow groundwater.
- The effects of natural discharge from the shallow groundwater on local surface water.
- The risks to human health and the environment associated with the surface water use or exposure.
- The distribution of contaminant compounds to sediments of Northeast Creek from runoff and groundwater discharge.
- The risk to human health and the environment associated with exposure to sediments in local water bodies.

Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump

- The nature of soil, shallow groundwater, surface water, and sediment contamination at the dump area.
- The vertical and horizontal extent of contamination in the soil along the northern boundary of the site.
- The presence or absence of surface and subsurface soil contamination in the southeast corner of the site.
- The presence or absence of contamination in the marsh area in the southern direction of the site.
- The presence or absence of buried material or waste.
- The hazardous or nonhazardous nature of potential buried material.

- The presence or absence of site-related contaminants in the surface and subsurface soil in order to conduct a human health risk assessment.

- The hydrogeologic parameters of the shallow aquifer.

- The information to support the assessment of risks to human health presented by potential exposure to the shallow groundwater.

- The effects of natural discharge from the shallow aquifer on local surface water.

- The risks to human health and the environment associated with current or future surface water use or exposure.

- Determine the distribution of contaminant compounds to sediments of local tributaries and Northeast Creek from runoff and groundwater discharge.

- The risk to human health and the environment associated with exposure to sediments in local water bodies.

Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area

- The vertical and horizontal extent of contamination distribution in the lawn area and soil mounded area through sampling and analysis.

- The effects on the soil mounds from reported disposal activities.

- The presence or absence of site-related contaminants in the surface and subsurface soil in order to conduct a human health risk assessment.

- The hydrogeologic parameters of the shallow and intermediate groundwater.

- The reliable information to support assessment of risks to human health presented by current patterns of exposures to groundwater.

Operable Unit No. 12 (Site 3) - Old Creosote Plant

- The nature of surface soil contamination in the former sawmill area in the northern portion of the site.

- The nature of surface soil contamination at the former creosote treatment area and the concrete pads in the southern portion of the site.

- The impact of the former creosote operation on soil and groundwater.

- The presence or absence of site-related contaminants in the surface and subsurface soil in order to conduct a human health risk assessment.

- The hydrogeologic parameters of the shallow and intermediate aquifer.
- The information to support the assessment of risks to human health posed by future potential exposure to the groundwater.

The type and quality of data required to meet the criteria listed above are presented in Section 4.0. The data quality levels differ with respect to the end use of the data. Level IV data quality are generally required in risk assessments, characterizing the nature and extent of contamination, and to support subsequent investigations. Level III data quality is appropriate for risk assessments, site characterization, and evaluating treatment alternatives. Level II data quality is appropriate for field screening (i.e., ENSYS Screening). Level I data is appropriate for field measurements such as static water level, specific conductance, and pH. The analytical methods also differ with respect to the end use of the data. For this RI/FS, USEPA methods and Contract Laboratory Program (CLP) methods will be used when applicable.

This field investigation will employ the use of Level III data. Although Level III data allows for the use of analytical methods other than CLP, the samples collected during this field investigation will be analyzed in accordance with CLP. However, the CLP requirements for documentation will not be required. Like Level IV data, Level III data is conformational and used for determining the presence or absence of contaminants.

3.1.3 Stage 3 - Design Data Collection Program

The data collection programs for Sites 16, 7, 80, and 3 have been designed to meet the objectives outlined in the following sections. Section 4.0 of the RI/FS Work Plan provides a general description of the various sampling programs for the four sites. Sections 3.0 through 5.0 of this FSAP provide the specific details of these sampling programs.

3.2 Study Objectives

For each site-specific study objectives, the criteria necessary to meet each objective along with a general description of the study or investigation required to obtain the information in Table 3-1.

4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

This section identifies the tasks and field investigations required to complete RI/FS activities at all sites.

4.1 Task 1 - Project Management

Project Management activities involve such activities as daily technical support and guidance, budget and schedule review and tracking, preparation and review of invoices, personnel resources planning and allocation, preparation of monthly progress reports, and communication with LANTDIV and the Activity.

4.2 Task 2 - Subcontract Procurement

Task 2 involves the procurement of services such as drilling, test pit excavations, surveying, laboratory analysis, and data validation. Procurement of these services will be performed in accordance with the Navy Clean Contract Procurement Manual.

4.3 Task 3 - Field Investigations

The field investigations will be conducted under Task 3. An overview of the field investigations to be conducted at each of the seven sites is presented in the following subsections. Specific details with respect to the sampling procedures, locations and number of samples, and analytical methods are provided in the Field Sampling and Analysis Plan (FSAP) and the Quality Assurance Project Plan (QAPP). The field investigations described below will provide data to meet the overall RI/FS objectives presented in Section 3.0 of this RI/FS Work Plan. Table 4-1 summarizes the sampling and analytical requirements, as well as the data quality levels.

4.3.1 Operable Unit No. 8 (Site 16) - Montford Point Burn Dump

The following investigations and support activities will be conducted at Site 16.

Surveying

- The site survey will involve the surveying of the current site features, soil grid sampling locations, test pit locations, monitoring well locations, and surface water and sediment sampling locations.

Soil Investigation

- A 150-foot x 100-foot sampling grid will be established within the former dump. A total of 22 soil borings will be drilled and one surface soil (0 to 12 inches) and one subsurface soil sample from just above the water table will be collected from each boring. All samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

- Soil borings will be performed at the six proposed groundwater monitoring well locations. Two soil samples, one surface soil (0 to 12 inches) and one subsurface soil from just above the water table will be collected from each boring. Samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

- Four hand auger locations will be drilled and sampled southeast of the site. Two soil samples will be collected from each of these locations. Soil samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

- Four trenches will be excavated within the boundary of the former burn dump to investigate the existence of any remaining trash or debris. Trench locations will be determined from the soil boring investigation. One composite soil sample, representative of the excavation, will be collected from the bottom of the trench. In order to characterize the soil, samples will be submitted for full TCL organics and TAL metals analyses.

- Three background soil borings will be drilled in an area believed to be unimpacted by past burn practices. Two soil samples, one surficial and one subsurface, will be collected from each boring. Soil samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

Groundwater Investigation

- A groundwater investigation will be conducted to determine the presence or absence of contamination in the surficial aquifer.

- Two rounds of groundwater samples will be collected from the six newly installed shallow monitoring wells. The first round of samples will be collected approximately one week following the development of the wells. The second round will be collected approximately three months following the first sampling round.

- Groundwater samples collected during the first round of sampling will be analyzed for full TCL organics and TAL (total and dissolved) metals in accordance with CLP methods (DQO Level III).

- Static water level measurements will be collected from the newly installed monitoring wells.

- Slug tests will be performed in three of the newly installed shallow monitoring wells.

Surface Water and Sediment Investigation

- Five (5) surface water and sediment sampling locations are proposed along Northeast Creek. One surface water and two sediment samples will be collected from each sampling station. Sediment samples will be collected from depths of 0 to 6 inches and 6 to 12 inches. All surface water and sediment samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III). Additionally, all sediment samples will be analyzed for TOC and grain size.

- Staff gauges will be installed in Northeast Creek to assess tidal influences.

4.3.2 Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump

The following investigations and support activities will be conducted at Site 7.

Surveying

- The site survey will include establishment of a soil grid along the northwestern boundary of the study area. All existing and newly installed monitoring wells and temporary well locations will be surveyed for location and elevation.

Soil Investigation

- The soil investigation will be conducted to define the types and extent of potential contamination within the soil and surficial aquifer at the site.

- Up to five trenches will be excavated in the southwestern corner of the study area. One composite soil sample, representative of the excavation, will be collected from the bottom of the trench. In order to characterize the soil for potential disposal and leaching of contaminants, samples will be submitted for full TCL organics and TAL metals analysis.

- Five soil sampling locations, in the southwestern corner of the study area, will be sampled using a hand auger. Soil characterization in this area will consist of collecting one surface soil sample (0 to 12 inches) and one subsurface soil sample from just above the water table.

- Soil samples will be collected from a total of 23 boring locations in the northern portion of the study area. Twelve soil borings will be performed in the area of the right-of-way using a drill rig. Eleven soil sampling locations within the sampling grids will be sampled using a hand auger. Soil characterization in this area will consist of collecting one surface soil sample (0 to 12 inches) and one subsurface soil sample from just above the water table.

- Two surface soil samples (0 to 12 inches) will be collected via hand auger from the Community Center playground.

- Soil samples will be collected during the drilling of the two permanent groundwater monitoring test borings. Two soil samples, one surface soil (0 to 12 inches) and one from just above the water table, will be collected.

- Three background soil borings will be drilled in an area believed to be unimpacted by past dumping practices. Two soil samples, one surface soil (0 to 12 inches) and one from just above the water table, will be collected.

- All soil samples will be submitted for laboratory analysis of full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

Groundwater Investigation

- A groundwater investigation will be conducted to assess potential impact of the dumping activities on the shallow aquifer.

- One round of groundwater samples will be collected from the three existing and two newly installed shallow monitoring wells. The groundwater samples will be collected one week following the development of the wells.

- One round of groundwater samples will be collected from the three temporary shallow monitoring wells.

- All groundwater samples will be analyzed for full TCL organics and TAL (total and dissolved) metals in accordance with CLP methods (DQO Level III).

- A second round of groundwater samples may be collected and analyzed depending on the results of the proposed round of analyses. This additional round of analyses will be based on chemicals of potential concern detected in the initial round.

- Static water level measurements will be collected from the new and existing monitoring wells.

Surface Water and Sediment Investigation

- Six sampling stations are proposed for Northeast Creek. At each sampling station, one surface water and two sediment samples will be collected. Sediment samples will be collected from 0 to 6 inches and 6 to 12 inches.

- A surface water and sediment investigation will be conducted in the western and eastern tributaries to Northeast Creek. Samples will be collected from three sampling locations in the west tributary and from two in the east tributary. At each sampling station, one surface water and one surface sediment sample (0 to 6 inches) will be collected.

- Two surface water and sediment sampling stations are proposed for the drainage ditch which feed the western tributary. One surface water and one surface sediment sample (0 to 6 inches) will be collected at each station.

- A sediment investigation will be conducted in the marsh area in the southern portion of the study area. Two sediment samples will be collected from four sampling stations. Sediment samples will be collected from 0 to 6 inches and 6 to 12 inches.

- All surface water and sediment samples will be analyzed for TCL organics and TAL metals in accordance with CLP methods (DQO Level III). Additionally, sediment samples will be analyzed for TOC and grain size.

- In addition to the surface water and sediment investigation, benthic samples will be collected in Northeast Creek and the western tributary to Northeast Creek. Samples will be collected from three stations in the tributary and four stations in Northeast Creek.

- A gill net will be positioned where the west tributary feed Northeast Creek in order to determine if this area is a significant ecological area.

Earthworm Bioassays

Earthworm bioaccumulation in-situ bioassays will be conducted in the areas of known PCB contamination. The results of the bioassays will be used to determine contaminant body-burden levels in the earthworm. These levels will be used to develop chronic daily intake exposure values for terrestrial receptors by application of exposure algorithms that convert the environmental (tissue) concentrations into exposure dose.

Two stations will be established in the known area of PCB contamination. At each station, three study site soil test chambers will be located along with an artificial soil control test chamber and a test chamber to record soil moisture and temperature. In addition, two reference test chambers will be located outside the area of known PCB contamination but in soils ecologically similar to the study site soils. At each station, the containers will be placed within a circle of about 1.5 meters in diameter.

The stations will be periodically observed depending upon soil moisture level and temperature. At the end of 28 days, the test chambers will be emptied onto a sheet of plastic, the earthworms hand sorted, counted, rinsed with distilled water, and evaluated for mortality and sublethal endpoints. Mortality will be defined as a lack of response when the earthworms were touched at their anterior end. Each surviving earthworm will be evaluated for the following behavioral and pathological sublethal endpoints, as well as any other obvious anomaly: lesions, segmental swelling, coiling, flaccidity (limp with lack of muscle tone), stiffening and shortening, segmental constriction, and autotomy (separation of a part from the body) of posterior segments. If the full complement of earthworms are not found in a test chamber and no sign of escape or disturbance is noted, it will be assumed that the unaccounted for earthworms will have died and decomposed.

4.3.3 Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area

The following investigations and support activities will be conducted at Site 80.

Surveying

- A site survey will be completed to establish the location and relationships of site features. All existing and newly installed monitoring wells will be surveyed.

Soil Investigation

- The objectives of the soil investigation are to vertically and horizontally delineate potential contaminant levels in four areas of concern.

- A soil investigation will be conducted in the lawn area. Seven test borings will be drilled and two soil samples will be collected from each boring. Soil samples will be collected from the surface (0 to 12 inches) and subsurface from just above the water table.

- A soil investigation will be conducted around the building area. Four test borings will be drilled and two soil samples will be collected from each boring. Soil samples will be collected from the surface (0 to 12 inches) and subsurface from just above the water table.

- Up to seven test borings will be drilled in the "open area" adjacent to the soil mounds in the northeast corner of the study area. Soil characterization in this area will consist of collecting one surface soil sample (0 to 12 inches) and one subsurface soil sample from just above the water table.

- A soil investigation will be conducted within the soil mounds in the northeast corner of the study area. One surface soil sample will be collected from 10 areas representative of the soil mounds. In addition, one subsurface soil sample will be collected from each of three areas within the soil mounds.

- A soil investigation will be conducted in the area where two drums were noted during the site visit. One surface soil sample (0 to 12 inches) will be collected from two locations.

- Soil samples will be collected during the drilling of five monitoring well borings. Two soil samples will be collected per test boring. Soil samples will be collected from the surface (0 to 12 inches) and subsurface from just above the water table.

- Three background soil borings will be drilled and two samples (surface and subsurface) per test boring will be collected.

- All soil samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods (DQO Level III).

Groundwater Investigation

- The groundwater investigation will be conducted to characterize the shallow groundwater conditions both downgradient and upgradient from the former pesticide mixing area and within the "open area" near the soil mounds. In addition, vertical migration of groundwater contamination will be investigated.

- One round of groundwater samples will be collected from eight. three existing, 4 newly installed, and one newly installed intermediate well. All groundwater samples will be analyzed for full TCL organics and TAL (total and dissolved) metals in accordance with CLP methods (DQO Level III).

- A second round of groundwater samples may be collected and analyzed depending on the results of the proposed round of analyses. This additional round of analyses will be based on the COPCs detected in the initial round.

4.3.4 Operable Unit No. 12 (Site 3) - Old Creosote Plant

The following investigations and support activities will be conducted at Site 12.

Surveying

- The site survey will be completed to establish the location and relationship of site features. All existing and newly installed monitoring wells will be surveyed. Additionally, two soil grids will be established one in the north and one in the south portions of the site.

Soil Investigation

- A soil investigation will be conducted over a sampling grid in the northern portion of the site. One surface soil sample will be collected from 13 grid sampling points.

- The soil investigation in the southern portion of the study area will consist of 35 (25 established sample grids, 8 concrete pads, and 2 railroad spurs) sampling points. These sample points will be collected using an established sampling grid. One surface soil sample will be collected from each sampling point.

- All surface soil samples will be analyzed in the field using ENSYS PAH Soil Sensitivity and ENSYS Petro Soil test kits. Sample locations where levels of PAHs and/or creosote are above detection limits for the ENSYS test kits will be expanded to determine the horizontal extent of the constituents. At a minimum, ten percent of "negative" samples will be submitted for laboratory confirmation in accordance with CLP methods (DQO Level III).

- ENSYS sampling locations where PAHs or creosote are detected will be expanded in all directions of the original sampling point to delineate the extent. The extension will be complete when a "nondetect" result is achieved. Sampling will be moved back 5 feet to confirm that horizontal extent has been defined. In areas where contamination is detected with ENSYS screening, a soil boring will be advanced with samples being collected at the surface, just above the water table, and at mid-depth, soil samples will be submitted for laboratory analysis of TCL semivolatile organics in accordance with CLP (DQO Level III).

- Soil samples will be collected during the drilling of three shallow monitoring well borings. A maximum of three soil samples will be collected per test boring. Soil samples collected from the monitoring well test boring will be analyzed for TCL semivolatile organics in accordance with CLP (DQO Level III).

- Soil samples will be collected during the drilling of the intermediate well boring and one shallow well boring. A maximum of three soil samples will be collected. Because these samples will be used to evaluate subsurface background concentrations, soil samples will be analyzed for full TCL organics and TAL metals in accordance with CLP (DQO Level III).

- Three background surface soil samples will be collected and analyzed for TCL semivolatile organics in accordance with CLP methods (DQO Level IV).

- One composite soil sample will be collected from a shallow monitoring well test boring and submitted for engineering parameter analysis.

Groundwater Investigation

- Groundwater samples will be collected from the three existing and four newly installed shallow monitoring wells. These wells will be sampled approximately one week following the development of the wells.

- A groundwater sample will be collected from the newly installed intermediate monitoring well. This well will be sampled approximately one week following the development of the well.

- Six of the seven shallow groundwater samples will be analyzed for TCL semivolatile organics in accordance with CLP methods (DQO Level III).

- The groundwater sample collected from the intermediate monitoring well and one new shallow monitoring well will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods (DQO Level III). Quick turn analysis will be requested.

4.3.5 Investigation Derived Waste Handling

One water sample will be collected from each site containment vessel and analyzed for full TCL organics and TAL metals. Additional details regarding IDW handling and disposal is provided in the FSAP. Soil cuttings generated during soil borings and trenching will be backfilled and graded over. If non-soil debris is unearthed during the trenching activities, this activity will immediately be ceased. Any non-soil debris which is unearthed will be containerized and retained for proper disposal. In remote locations, soil cuttings generated during monitoring well installation will be distributed around the area. Soil containment in drums or roll-off boxes will be employed if contamination is visually observed or if field instrument readings indicate a potential concern.

4.4 Task 4 - Sample Analysis and Validation

This task involves efforts relating to the following post-field sampling activities:

- Sample Management
- Laboratory Analysis
- Data Validation

Sample management activities involve: coordination with laboratories; tracking of samples submitted for analysis; tracking of analyses received; and tracking of information related to samples submitted and received from a third party validator. Sample management also involves resolving technical or administrative problems (e.g., reanalysis, resubmission of information).

Laboratory analysis begins when the samples are shipped from the field and received by the laboratory. Validation begins when the "raw" laboratory data is received by the validator from Baker. Baker will first receive the data from the laboratory, log it into a database for tracking purposes, and then forward it to the validator. A validation report will be expected within three weeks following receipt of laboratory data packages by the validator. CLP data will be validated per the CLP criteria as outlined in the following documents:

- USEPA, Hazardous Site Control Division, Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses, 1991.

- USEPA, Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses, 1988.

All other data will be validated in accordance with the method of analysis using the National Functional Guidelines as a reference.

4.5 Task 5 - Data Evaluation

This task involves efforts related to the data once it is received from the laboratory and is validated. It also involves the evaluation of any field-generated data including: water level measurements, in-situ permeability tests, test boring logs, test pit logs, and other field notes. Efforts under this task will include the tabulation of validated data and field data, generation of test boring logs and monitoring well construction logs, generation of geologic cross-section diagrams, and the generation of other diagrams associated with field notes or data received from the laboratory (e.g., sampling location maps).

4.6 Task 6 - Risk Assessment

This section of the Work Plan will serve as the guideline for the baseline risk assessments (BRAs) to be conducted for MCB Camp Lejeune during the RI.

Baseline risk assessments evaluate the potential human health and/or ecological impacts that would occur in the absence of any remedial action. The risk assessment will provide the basis for determining whether or not remedial action is necessary and the justification for performing remedial actions.

The risk assessments will be performed in accordance with USEPA guidelines. The primary documents that will be utilized include:

- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), EPA 1989.
- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), EPA 1991.
- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives), EPA 1991.
- Risk Assessment Guidance for Superfund: Volume II, Environmental Evaluation Manual, EPA 1989.
- Supplemental Guidance to RAGS: Standard Default Values, EPA 1991a.
- Supplemental Guidance to RAGS: Calculating the Concentration Term, 1992.
- Superfund Exposure Assessment Manual, EPA 1988.
- Exposure Factors Handbook, EPA 1989b.
- Guidance for Data Usability in Risk Assessment, EPA 1990.
- Supplemental USEPA Region IV Risk Assessment Guidance, EPA Region IV, 1991.

USEPA Region IV will be consulted for Federal guidance, and the North Carolina DEHNR will be consulted for guidance in the State of North Carolina.

The technical components of the BRA are contaminant identification, exposure assessment, toxicity assessment, and risk characterization. The objectives of the risk assessment process can be accomplished by:

- Characterizing the toxicity and levels of contaminants in relevant media (e.g., groundwater, surface water, soil, sediment, air, and biota).

- Characterizing the environmental fate and transport mechanisms within specific environmental media.

- Identifying potential current and future human and/or environmental receptors.

- Identifying potential exposure routes and the extent of the actual or expected exposure.

- Defining the extent of the expected impact or threat.

- Identifying the levels of uncertainty associated with the above items.

As outlined in the Scope of Work, a separate BRA will be performed at MCB Camp Lejeune for OU No. 8 (Site 16), OU No. 11 (Sites 7 and 80), and OU No. 12 (Site 3). The BRAs will utilize all available data to date that has been properly validated in accordance with USEPA guidelines plus all data to be collected from additional sampling during this RI.

4.6.1 Human Health Evaluation Process

4.6.1.1 Site Location and Characterization

A background section will be presented at the beginning of each risk assessment to provide an overview of the characteristics of each site. This section will provide a site location, a general site description, and the site-specific chemicals as discussed in past reports. The physical characteristics of the site and the geographical areas of concern will be discussed. This site description will help to characterize the exposure setting.

4.6.1.2 Data Summary

Because decisions regarding data use may influence the resultant risk assessment, careful consideration must be given to the treatment of those data. For purposes of risk evaluation, the sites at MCB Camp Lejeune may be partitioned into operable units, sites, and areas of concern for which chemical concentrations will be characterized and risks will be evaluated. Sites will be grouped into operable units if they are close to one another, have similar contamination, and/or may impact the same potential receptors. In selecting data to include in the risk assessment, the objective is to characterize, as accurately as possible, the distribution and concentration of chemicals in each operable unit.

Data summary tables will be developed for each medium sampled (e.g., surface water, sediment, groundwater, soil). Each data summary table will indicate the frequency of detection, observed range of concentrations, average background concentrations (inorganics), and the means and upper 95 percent confidence limit value for each contaminant detected in each medium. The arithmetic or geometric mean and the upper 95 percent confidence limit of that mean will be used in the summary of potential chemical data. The selection of arithmetic or geometric means will depend on whether the sample data are normally or log-normally distributed. In the calculation of the 95 percent confidence limit mean, concentrations presented as "ND" (nondetect) will be incorporated. In cases where there is a question about the distribution of the data set, a statistical test will be used to determine the best distributional assumption for the data set. The W-test will be employed to determine if the data set is consistent with normal or lognormal distribution.

4.6.1.3 Identifying Chemicals of Potential Concern

The criteria to be used in selecting the Contaminants of Potential Concern (COPCs) from the constituents detected during the sampling and analytical phase of the investigation are: historical information, prevalence, mobility, persistence, toxicity, comparison of the Applicable, Relevant, and Appropriate Requirements (ARARs), comparison to blank data or base-specific naturally occurring levels (i.e., background), and comparison to anthropogenic levels. The criteria chosen to establish the COPC are derived from the USEPA's Risk Assessment Guidance for Superfund (USEPA, 1989).

All of the available sample data will undergo review upon initiation of the risk assessment. Common laboratory contaminants such as acetone, methylene chloride, phthalate esters, toluene, and methyl ethyl ketone will be addressed only if concentrations are 10 times greater than the corresponding blanks. In addition, chemicals that are not common laboratory contaminants will be evaluated if they are greater than five times the laboratory blank. The number of chemicals analyzed in the risk assessment will be a subset of the total number of chemicals detected at a site based on the elimination criteria discussed previously.

Tables will be prepared that list chemical concentrations for all media by site. Data will be further grouped according to organic and inorganic species within each table.

4.6.1.4 Exposure Assessment

The objectives of the exposure assessment at MCB Camp Lejeune will be to characterize the exposure setting, identify exposure pathways, and quantify the exposure. When characterizing the exposure setting, the potentially exposed populations will be described. The exposure pathway will identify the source and the mechanism of medium for the released chemical (e.g., groundwater), the point of potential human contact with the contaminated medium, and the exposure route(s) (e.g., ingestion). The magnitude, frequency, and duration for each exposure pathway identified will be quantified during this process.

The identification of potential exposure pathways at the four sites will include the activities described in the subsections that follow.

Analysis of the Probable Fate and Transport of Site- Specific Chemicals

To determine the environmental fate and transport of the chemicals of concern at the site, the physical/chemical and environmental fate properties of the chemicals will be reviewed. Some of these properties include volatility, photolysis, hydrolysis, oxidation, reduction, biodegradation, accumulation, persistence, and migration potential. This information will assist in predicting potential current and future exposures. It will help in determining those media that are currently receiving site-related chemicals or may receive site-related chemicals in the future. Sources that may be consulted in obtaining this information include computer databases (e.g., AQUIRE, ENVIROFATE), as well as the open literature.

The evaluation of fate and transport may be necessary where the potential for changes in future chemical characteristics is likely and for those media where site-specific data on the chemical distribution is lacking.

Identification of Potentially Exposed Human Populations

Human populations, that may be potentially exposed to chemicals at the MCB Camp Lejeune, include base personnel and their families, base visitors, and on-site workers and recreational fishermen. The Base Master Plan will be consulted to confirm or modify these potential exposures. Nonworking residents who might be exposed to site-specific chemicals could include spouses and/or children of base personnel and resident workers. Resident and nonresident workers could be exposed to chemicals as they carry out activities at any of the sites located at MCB Camp Lejeune. The list of potential receptors and pathways to be evaluated will be refined during discussions with regulators prior to performing the BRA.

Identification of Potential Exposure Scenarios Under Current and Future Land Uses

The exposure scenarios will be finalized after consulting with the Base Master Plan, USEPA and the State of North Carolina. Generally, current and future exposure pathways will be considered preliminarily as follows:

- Soil Pathway
  - Direct ingestion (current base personnel, current/future residents, future construction worker)
  - Inhalation of dust (worker, resident)
  - Dermal contact (worker, resident)

- Sediment Pathway
  - Dermal contact (current base personnel, current/future resident, current recreational user)
  - Ingestion (current base personnel, current/future resident, current recreational user)

- Surface Water
  - Dermal contact (current base personnel, current/future resident, current recreational user)
  - Ingestion (current base personnel, current/future resident, current recreational user)

- Groundwater
  - Direct ingestion (base personnel, future residents)
  - Inhalation (base personnel, future residents)
  - Dermal contact (base personnel, future residents)

Exposure Point Concentrations

After the potential exposure points and potential receptors have been defined, exposure point concentrations must be calculated. The chemical concentrations at these contact points are critical in determining intake and, consequently, risk to the receptor. The data from site investigations will be used to estimate exposure point concentrations.

The upper 95 percent upper confidence limits of the means will be used throughout the risk assessment. In cases where maximum concentrations are exceeded by upper 95 percent confidence limit, the maximum concentrations will be used.

Exposure doses will be estimated for each exposure scenario from chemical concentrations at the point of contact by applying factors that account for contact frequency, contact duration, average body weight, and other route-specific factors such as breathing rate (e.g., inhalation). These factors will be incorporated into exposure algorithms that convert the environmental concentrations into exposure doses. Intakes will be reported in milligrams of chemical taken in by the receptor (i.e., ingested, inhaled, etc.) per kilogram body weight per day (mg/kg-day). Intakes for potentially exposed populations will be calculated separately for the appropriate exposure routes and chemicals.

4.6.1.5 Toxicity Assessment

Toxicity values (i.e., numerical values derived from dose-response toxicity data for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity values may be taken or derived from the following sources (note that the most up-to-date toxicity information obtained from IRIS and/or HEAST will be used in the exposure assessments):

- Integrated Risk Information System (IRIS) - The principal toxicology database, which provides updated information from USEPA on cancer slope factors, reference doses, and other standards and criteria for numerous chemicals.

- Health Effects Assessment Summary Tables (HEAST) - A tabular summary of noncarcinogenic and carcinogenic information contained in IRIS.

For some chemicals, toxicity values (i.e., reference doses) may have to be derived if the principal references previously mentioned do not contain the required information. These derivations will be provided in the risk assessment for review by USEPA Region IV. The toxicity assessment will include a brief description of the studies on which selected toxicity values were based, the uncertainty factors used to calculate noncarcinogenic reference doses (RfDs), the USEPA weight-of-evidence (WOE) classification for carcinogens, and their respective slope factors.

4.6.1.6 Risk Characterization

Risk characterization involves the integration of exposure doses and toxicity information to quantitatively estimate the risk of adverse health effects. Quantitative risk estimates based on the reasonable maximum exposures to the site contaminants will be calculated based on available information. For each exposure scenario, the potential risk for each chemical will be based on intakes from all appropriate exposure routes. Carcinogenic risk and noncarcinogenic hazard indices are assumed to be additive across all exposure pathways and across all of the chemicals of concern for each exposure scenario. Potential carcinogenic risks will be evaluated separately from potential noncarcinogenic effects, as discussed in the following subsections.

Carcinogenic Risk

For the potential carcinogens that are present at the site, the carcinogenic slope factor (q_1*) will be used to estimate cancer risks at low dose levels. Risk will be directly related to intake at low levels of exposure. Expressed as an equation, the model for a particular exposure route is:

$$\text{Excess lifetime cancer risk} = \text{Estimated dose x carcinogenic slope factor;}$$
$$\text{or CDI x } q_1^*$$

Where: CDI = Chronic daily intake

This equation is valid only for risk less than 10^{-2} (1 in 100) because of the assumption of low dose linearity. For sites where this model estimates carcinogenic risks of 10^{-2} or higher, an alternative model will be used to estimate cancer risks as shown in the following equation:

$$\text{Excess lifetime cancer risk} = 1 - \exp(-\text{CDI x } q_1^*)$$

Where: exp = the exponential

For quantitative estimation of risk, it will be assumed that cancer risks from various exposure routes are additive. Since there are no mathematical models that adequately describe antagonism or synergism, these issues will be discussed in narrative fashion in the uncertainty analysis.

Noncarcinogenic Risk

To assess noncarcinogenic risk, estimated daily intakes will be compared with reference doses RfD for each chemical of concern. The potential hazard for individual chemicals will be presented as a hazard quotient (HQ). A hazard quotient for a particular chemical through a given exposure route is the ratio of the estimated daily intake and the applicable RfD, as shown in the following equation:

$$HQ = EDI/RfD$$

Where: HQ = Hazard quotient
EDI = Estimated daily intake or exposure (mg/kg-day)
RfD = Reference dose (mg/kg-day)

To account for the additivity of noncarcinogenic risk following exposure to numerous chemicals through a variety of exposure routes, a hazard index (HI), which is the sum of all the hazard quotients, will be calculated. Ratios greater than one, or unity, indicate the potential for adverse effects to occur. Ratios less than one indicate that adverse effects are unlikely. This procedure assumes that the risks from exposure to multiple chemicals are additive, an assumption that is probably valid for compounds that have the same target organ or cause the same toxic effect. In some cases when the HI exceeds unity it may be appropriate to segregate effects (as expressed by the HI) by target organ since those effects would not be additive. As previously mentioned, where information is available about the antagonism or synergism of chemical mixtures, it will be appropriately discussed in the uncertainty analysis.

4.6.1.7 Uncertainty Analysis

There is uncertainty associated with any risk assessment. The exposure modeling can produce very divergent results unless standardized assumptions are used and the possible variation in others are clearly understood. Similarly, toxicological assumptions, such as extrapolating from chronic animal studies to human populations, also introduce a great deal of uncertainty into the risk assessment. Uncertainty in a risk assessment may arise from many sources including:

- Environmental chemistry sampling and analysis.
- Misidentification or failure to be all-inclusive in chemical identification.
- Choice of models and input parameters in exposure assessment and fate and transport modeling.
- Choice of models or evaluation of toxicological data in dose-response quantification.
- Assumptions concerning exposure scenarios and population distributions.

The variation of any factor used in the calculation of the exposure concentration will have an impact on the total carcinogenic and noncarcinogenic risk. The uncertainty analysis will qualitatively discuss non-site and site-specific factors that may product uncertainty in the risk assessment. These factors may include key modeling assumptions, exposure factors, assumptions inherent in the development of toxicological end points, and spatio-temporal variance in sampling.

This section discusses the Preliminary Remediation Goals (PRGs) (ARAR-based and/or risk-based) which are determined using information on media and chemicals of potential concern, the most appropriate future land use, potential exposure pathways, toxicity information, and potential ARARs. The development of PRGs will assist in the initiation of remedial alternatives and in the selection of analytical limits of detection. Risk-based PRGs established at this time are initial, and do not establish that clean up to meet these goals is warranted. Therefore, a risk-based PRG will be considered a final remediation level only after appropriate analysis in the RI/FS and ROD.

The initial step in developing PRGs is to identify media of potential concern. Important media at these sites include groundwater, soil, surface water, and sediment. Chemicals of potential concern include any chemical reasonably expected to be at the sites. These chemicals may have been previously detected at the site, may be presented based on site history, or may be present as degradation products. Identifying future land use for the site is used to determine risk-based PRGs. In general, residential land use should be used as a conservative estimation for the PRGs. Chemical-specific ARARs are evaluated as PRGs because they are often readily available and provide preliminary indication about the goals that a remedial action may have to attain. For groundwater

SDWA maximum contaminant levels (MCLs), state drinking water standards, and Federal Water Quality Criteria (FWQC) are common ARARs.

FWQCs and state water quality standards (WQS) are common ARARs for surface water. Sediment Screening Values (SSVs) developed by National Oceanic and Atmospheric Administration (NOAA) can be used as ARARs for the evaluation of biological effects for aquatic organisms. In general, chemical-specific ARARs are not available for soil, however, some states have promulgated soil standards (e.g., PCB clean-up levels) that may be criteria appropriate to use as PRGs. Risk-based PRGs will be obtained from USEPA, Region III, Risk-Based Concentration Table (USEPA, 1994). The risk-based PRGs will be reviewed and modified after the completion of the baseline risk assessment. This modification will involve adding or subtracting chemicals of concern, media, pathways or revising individual chemical-specific goals. Tables 4-2, 4-3, and 4-4 provide PRGs for each media at Sites 7, 80, and 3, respectively. (Note: PRGs have not been developed for Site 16 because site characteristics are unknown.)

4.6.2 Ecological Risk Assessment

The overall purpose of an ecological risk assessment is to evaluate the likelihood that adverse ecological effects would occur or are occurring as a result of exposure to one or more physical or chemical stressors. This assessment will evaluate the potential effects of contaminants on sensitive or critical habitats or environments and protected species. The assessment will also employ a phased approach to determine potential adverse effects of contamination on the terrestrial and aquatic receptors (e.g., flora and fauna) on or adjacent to each site at MCB Camp Lejeune. Phase I will consist of a comparison of analytical results for soils, surface water, or sediments to available ecological standards or criteria. The Phase I approach will provide a conservative evaluation of the potential ecological effects associated with site contamination. If contaminant concentrations in environmental media exceed appropriate standards or criteria, additional phases of evaluation may be necessary to fully characterize potential ecological effects at a site.

The risk assessment methodologies will be consistent with those outlined in the Framework for Ecological Risk Assessment (USEPA, 1992b). In addition, information found in the following documents will also be consulted.

- Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989e)

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989a)

The following sections describe the general technical approach that will be used to evaluate the likelihood that adverse ecological effects could occur as a result of exposure to one or more physical or chemical stressors. The ecological risk assessment will consist of five components. These are: problem formulation; characterization of exposure; characterization of ecological effects; risk characterization; and uncertainty analysis.

4.6.2.1 Problem Formulation

Problem formulation is the first step of an ecological assessment and requires an understanding of site habitats, potential receptors, and potential endpoints. Problem formulation will be based on historical information and on the findings of the site visit conducted for each site. Data needs and regulatory issues will also be considered. The components of the problem formulation phase consist of stressor characteristics, ecosystems potentially at risk, ecological effects, endpoint selection, and a conceptual model.

The selection of chemical stressors or COPCs will be based on frequency of detection, background comparison, persistence of the contaminant, bioaccumulation potential, and the toxicity of the contaminant. Because of the differential toxicity of some contaminants to ecological verses human receptors, the COPCs for ecological receptors may differ from those selected for the human health risk assessment. Physical stressors including temperature and hydrologic changes and habitat alteration will also be taken into consideration.

Based on the site visit and historical information, ecological receptors will be identified, and the stressor-ecosystem-receptor relationship will be used to develop exposure scenarios in the characterization of exposure phase. Properties of the ecosystem that may be considered in the problem formulation phase include the abiotic environment (e.g., climatic conditions and soil or sediment properties), ecosystem structure (e.g., abundance and trophic level relationships), and ecosystem function (e.g., energy source, energy utilization, and nutrient processing). In addition, types and patterns of historical disturbances may be used to predict ecological receptor-stressor responses. Spatial and temporal distribution may also be used to define the natural variability in the ecosystem. The potential for indirect effects (e.g., reduction in prey availability or habitat utilization) will also be considered in the selection of ecosystem components.

Ecological effects data will be compiled for the physical and chemical stressors identified. Most of these data are available in the literature. Application of laboratory-based tests to field situations and to the interpretation of field observations that may be influenced by natural variability or non-site stressors that are not the focus of the ecological risk assessment will also be considered. The information compiled will be used to select ecological endpoints or characteristics of an ecological component that may be affected by exposure to a stressor.

A conceptual model of the site will then be developed. This conceptual model will consist of a series of working hypotheses regarding how the stressor might affect ecological components of the ecosystem potentially at risk.

4.6.2.2 Characterization of Exposure

The interaction of the stressor with the ecological component will be evaluated in the characterization of exposure. A quantitative evaluation of exposure will be developed that estimates the magnitude and spatial and temporal distributions of exposure for the various ecological components selected during the problem formulation and serve as input to the risk characterization.

4.6.2.3 Characterization of Ecological Effects

The relationship between the stressors and the assessment and measurement endpoints identified during problem formulation will be quantified and summarized in a stressor-response profile. The stressor-response profile will be used as input to the risk characterization. Scientific literature and regulatory guidelines will be reviewed for media-specific and/or species specific toxicity data. On-line databases will be accessed, such as AQUIRE and PHYTOTOX, to obtain current stressor-response data. Toxicity values will be from the most closely related species, where possible. If necessary, laboratory and in-field exposure response studies including acute and chronic toxicity tests of exposure to individual or multiple stressors may be used to supplement the available toxicological databases. Field studies and biosurveys may also be used to establish whether adverse ecological effects have occurred at the site.

4.6.2.4 Risk Characterization

Risk characterization is the final phase of the ecological risk assessment and integrates the results of the exposure and ecological effects analyses. The likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated.

Individual endpoints may be evaluated by using single effects (e.g, media-specific and/or species specific toxicity data) and exposure values (e.g., dose units or exposure point concentrations) and comparing them using the quotient method for both media exposure and uptake exposure.

For exposure point concentrations that were monitored or modeled in the Characterization of Exposure, water criteria from either the state or from the USEPA will be compared using the quotient method to the ambient surface water concentrations. Likewise, sediment screening values from NOAA will be compared to measured sediment concentrations. These screening values will evaluate the potential for chemical constituents in both the surface water and sediments to cause adverse biological effects. Toxicity values from the literature that represent the toxicological effects on plants and/or invertebrates inhabiting soils will be compared to surface soil concentrations.

For dose unit exposure, terrestrial reference values, developed from No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs), will be compared to an estimate of total exposure to soils, surface water, and vegetation via calculation of a CDI. The exposure parameters used in the CDI equation will represent feeding rates, incidental soil ingestion rates, drinking water rates, body weights, and home range input for selected terrestrial receptors known to inhabit the areas of concern.

Population and community endpoints will be assessed by considering species representation by trophic group, taxa, or habitat. Site-specific field studies and biosurveys, if conducted, on and adjacent to the areas of concern may be compared to either historical population and community endpoint information or project-specific field studies and biosurveys.

The ecological significance of the risks characterized at the site will be discussed considering the types and magnitudes of the effects and their spatial and temporal patterns. Ecologically significant risks will be defined as those potential adverse risks or impacts to ecological integrity that affect populations, communities, and ecosystems, rather than individuals (i.e. measured impacts to individuals does not necessarily indicate impacts to the ecosystem).

4.6.2.5 Uncertainty Analysis

The ecological assessment is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions that contribute to the total uncertainty in the ultimate evaluation of risk. Assumptions are made in the exposure assessment regarding potential for exposure and exposure point locations. An effort is made to use assumptions that are conservative, yet realistic. The interpretation and application of ecological effects data is probably the greatest source of uncertainty in the ecological risk assessment. The uncertainty analysis will attempt to address the factors that affect the results of the ecological risk assessment.

4.6.2.6 Data Gaps

Incomplete exposure data gap pathways will be identified and recommendations for addressing same will be provided.

4.6.2.7 Uncertainty Analysis

An ecological risk assessment, like a human health risk assessment, is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions that contribute to the total uncertainty in the ultimate evaluation of risk. Assumptions are made in the exposure assessment regarding potential for exposure and exposure point locations. An effort is made to use assumptions that are conservative, yet realistic. The interpretation and application of toxicological data in the toxicity assessment is probably the greatest source of uncertainty in the ecological risk assessment. The uncertainty analysis will attempt to address the factors that affect the results of the ecological risk assessment.

4.7 Task 7 - Treatability Study/Pilot Testing

This task includes the efforts to prepare and conduct bench- or pilot-scale treatability studies should they be necessary. This task begins with the development of a Treatability Study Work Plan for conducting the tests and is completed upon submittal of the Final Report. The following are typical activities:

- Work plan preparation
- Test facility and equipment procurement
- Vendor and analytical service procurement
- Testing
- Sample analysis and validation
- Evaluation of results
- Report preparation
- Project management

Based on the preliminary information pertaining to Sites 16, 7, 80, and 3, the following bench or pilot studies may be considered for soils:

Site 16:	None at this time since on-site soil investigations and soil characteristics are unknown.
Site 7:	In-situ solidification/fixation In-situ soil washing
Site 80:	In-situ solidification Soil Washing Soil biodegradation Thermal treatment
Site 3:	Soil washing Soil biodegradation Thermal treatment

Bench- or pilot-scale treatability studies for groundwater may be required to assess pretreatment or treatment options (e.g., metal reduction).

4.8 Task 8 - Remedial Investigation Report

This task is intended to cover all work efforts related to the preparation of the document providing the findings once the data have been evaluated under Tasks 5 and 6. The task covers the preparation of a Preliminary Draft, Draft, Draft Final, and Final RI Report. A separate RI report will be prepared for each OU. This task ends when the Final RI report is submitted.

4.9 Task 9 - Remedial Alternatives Screening

This task includes the efforts necessary to select the alternatives that appear feasible and require full evaluation. The task begins during data evaluation when sufficient data are available to initiate the screening of potential technologies. For reporting and tracking purposes, the task is defined as complete when a final set of alternatives is chosen for detailed evaluation.

4.10 Task 10 - Remedial Alternatives Evaluation

This task involves the detailed analysis and comparison of alternatives using the following criteria:

- Threshold Criteria: Overall Protection of Human Health and the Environment

  Compliance With ARARs

- Primary Balancing Criteria: Long-Term Effectiveness and Permanence

  Reduction of Toxicity, Mobility, and Volume Through Treatment

  Short-Term Effectiveness

  Implementability

  Cost

- Modifying Criteria: State and USEPA Acceptance

  Community Acceptance

4.11 Task 11 - Feasibility Study Report

This task is comprised of reporting the findings of the Feasibility Study. A separate FS will be prepared for each OU. The task covers the preparation of a Preliminary Draft, Draft, Draft Final, and Final FS report. This task ends when the Final FS report is submitted.

4.12 Task 12 - Post RI/FS Support

This task involves the technical and administrative support to LANTDIV to prepare a Draft, Draft Final, and Final Responsiveness Summary, Proposed Remedial Action Plan (PRAP), and Record of Decision (ROD). A PRAP and ROD will be prepared for each OU. These reports will be prepared using USEPA applicable guidance documents.

4.13 Task 13 - Meetings

This task involves providing technical support to LANTDIV during the RI/FS. It is anticipated that the following meetings will be required:

- Meeting between Baker and LANTDIV/EMD to discuss the RI/FS conclusions following submission of the Preliminary Draft RI/FS Report.
- A remedial project management (RPM) meeting with LANTDIV/EMD, USEPA Region IV, and the North Carolina DEHNR.
- A technical review committee (TRC) meeting to present the findings of the RI/FS.

The meetings will be attended by the Baker Activity Coordinator, Project Manager, and Project Engineer or Risk Assessment Specialist.

5.0 PROJECT MANAGEMENT AND STAFFING

The Baker Project Team will be managed by Mr. Matthew D. Bartman. The primary responsibilities of the Project Manager will be to monitor the technical performance, cost, and schedule, and to maintain close communication with the Navy Technical Representative, Ms. Katherine Landman. The Project Manager will report to Mr. Raymond P. Wattras (Activity Coordinator). Mr. John W. Mentz will be responsible for overall quality assurance/quality control.

The Project Team will consist of a Risk Assessment Specialist, Project Engineer, Project Geologist, Health and Safety Specialist, Ecological Scientist, and technical support staff as shown in Figure 5-1.

6.0 SCHEDULE

The proposed project schedule for each Operable Unit has been prepared in accordance with the Federal Facilities Agreement (FFA), and is presented as Figures 6-1, 6-2, and 6-3. The projected start up of the RI/FS field investigation (October 31, 1994) is based on finalization of the RI/FS Project Plans on or before October 31, 1994, as noted in the Fiscal Year 1995 Site Management Plan (FY95 SMP) for MCB Camp Lejeune, North Carolina. The FY95 SMP is based on the requirements established in the Federal Facilities Agreement and between the Navy/Marine Corps, USEPA Region IV, and the North Carolina DEHNR.

7.0 REFERENCES

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WORK PLAN TABLES

TABLE 2-1

GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE
COASTAL PLAIN OF NORTH CAROLINA
MCB CAMP LEJEUNE, NORTH CAROLINA

GEOLOGIC UNITS			HYDROGEOLOGIC UNITS
System	Series	Formation	Aquifer and Confining Unit
Quaternary	Holocene/Pleistocene	Undifferentiated	Surficial Aquifer
Tertiary	Pliocene	Yorktown Formation[1]	Yorktown Confining Unit Yorktown Aquifer
	Miocene	Eastover Formation[1]	
		Pungo River Formation[1]	Pungo River Confining Unit Pungo River Aquifer
		Belgrade Formation[2]	Castle Hayne Confining Unit
	Oligocene	River Bend Formation	Castle Hayne Aquifer
	Eocene	Castle Hayne Formation	Beaufort Confining Unit[3]
	Palocene	Beaufort Formation	Beaufort Aquifer
Cretaceous	Upper Cretaceous	Peedee Formation	Peedee Confining Unit Peedee Aquifer
		Black Creek and Middendorf Formations	Black Creek Confining Unit Black Creek Aquifer
		Cape Fear Formation	Upper Cape Fear Confining Unit Upper Cape Fear Aquifer Lower Cape Fear Confining Unit Lower Cape Fear Aquifer
	Lower Cretaceous[1]	Unnamed Deposits[1]	Lower Cretaceous Confining Unit Lower Cretaceous Aquifer[1]
Pre-Cretaceous Basement Rocks		--	--

(1) Geologic and hydrologic units probably not present beneath Camp Lejeune.
(2) Constitutes part of the surficial aquifer and Castle Hayne confining unit in the study area.
(3) Estimated to be confined to deposits of Paleocene age in the study area.
Source: USGS, 1989.

TABLE 2-2

LAND UTILIZATION: DEVELOPED AREAS ACRES/LAND USE (PERCENT)
MCB, CAMP LEJEUNE, NORTH CAROLINA

Geographic Area	Oper.	Training (Instruc.)	Maint.	Supply/ Storage	Medical	Admin.	Family Housing	Troop Housing	CM	CO	Recreat.	Utility	Total
Hadnot Point	31 (2.9)	15 (1.4)	154 (14.3)	157 (14.4)	10 (0.9)	122 (11.3)	22 (2.0)	196 (18.1)	115 (10.7)	36 (3.3)	182 (16.9)	40 (3.7)	1,080 (100)
Paradise Point	1 (0)		3 (0.4)	1 (0)			343 (34)	19 (1.9)	31 (3.1)		610 (60.4)	2 (0.2)	1,010 (100)
Berkeley Manor/ Watkins Village							406 (80)		41 (8.1)	1 (0.2)	57 (11.2)	2 (0.5)	507 (100)
Midway Park		1 (0.4)		2 (0.7)		2 (0.7)	248 (92.2)		8 (3.0)	3 (1.1)	4 (1.5)	1 (0.4)	269 (100)
Tarawa Terrace I and II			3 (0.5)			1 (0.3)	428 (77.4)		55 (9.9)	11 (2.0)	47 (8.5)	8 (1.4)	553 (100)
Knox Trailer							57 (100)						57 (100)
French Creek	8 (1.4)	1 (0.2)	74 (12.7)	266 (45.6)	3 (0.5)	7 (1.2)		122 (20.9)	22 (3.8)	6 (1.0)	74 (12.7)		583 (100)
Courthouse Bay		**73 (28.6)**	**28 (10.9)**	**14 (5.5)**		**12 (4.7)**	**12 (4.7)**	**43 (16.9)**	**15 (5.9)**	**4 (1.6)**	**43 (16.9)**	**11 (4.3)**	**255 (100)**
Onslow Beach	6 (9.8)	1 (1.6)	3 (4.8)	2 (3.2)	1 (1.6)	2 (3.2)		2 (3.2)	12 (19.3)		25 (40.3)	8 (13.0)	62 (100)
Rifle Range		1 (1.3)	1 (1.3)	7 (8.8)	1 (1.3)	5 (6.3)	7 (8.8)	30 (37.5)	5 (6.3)	1 (1.3)	9 (11.3)	13 (16.3)	80 (100)
Camp Geiger	4 (1.9)	15 (6.9)	19 (8.8)	50 (23.1)		23 (10.6)		54 (25.0)	27 (12.5)	2 (1.0)	16 (7.4)	6 (2.8)	216 (100)
Montford Point	6 (2.6)	48 (20.5)	2 (0.9)	4 (1.7)	2 (0.9)	9 (3.9)		82 (35.2)	20 (8.6)	1 (0.4)	49 (21.0)	10 (4.3)	233 (100)
Base-Wide Misc.	1 (0.8)			87 (68.0)		3 (2.3)			19 (14.8)			18 (14.1)	128 (100)
TOTAL	**57 (1.1)**	**155 (3.1)**	**287 (5.7)**	**590 (11.7)**	**17 (0.38)**	**186 (3.7)**	**1,523 (30.2)**	**548 (10.8)**	**370 (7.4)**	**65 (1.3)**	**1,116 (22.2)**	**119 (2.4)**	**5,033 (100)**

TABLE 2-3

GROUNDWATER INVESTIGATION FINDINGS
OU NO. 11 (SITE 7)
TARAWA TERRACE DUMP
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	North Carolina Standards	USEPA MCLs	No. of Positive Detections/ No. of Samples	Range of Positive Detections	Location of Maximum Concentration
Benzoic Acid	--	--	2/3	9-12	7MW03
Dieldrin	--	--	1/3	0.63	7MW02
Endrin Ketone	2.0	2.0	1/3	0.09	7MW02
Aluminum	--	--	3/3	29,000-137,000	7MW02
Antimony	--	6	1/3	4.75	7MW02
Barium	2,000	2,000	3/3	427-706	7MW02
Beryllium	--	4,000	2/3	3.1-9.4	7MW02
Chromium (Total)	50	1,000	3/3	47.8-251	7MW02
Cobalt	1,000		2/3	9.6-21.7	7MW01
Copper	1,000	--	3/3	17.7-41.6	7MW02
Iron	300	300(1)	3/3	26,400-228,000	7MW02
Lead	15	--	3/3	30.3-37.3	7MW01
Magnesium	--	--	1/3	13,500	7MW01
Manganese	50	50(1)	3/3	56.9-220	7MW01
Mercury	1.1	2	2/3	0.24-0.36	7MW03
Potassium	--	--	1/3	5,240	7MW02
Selenium	50	5	1/3	3.4	7MW01
Sodium	--	--	1/3	156,000	7MW01
Vanadium	--	--	3/3	37.8-442	7MW02
Zinc	2,100	--	3/3	83.6-151	7MW02

(1) Secondary Maximum Contaminant Level
-- = No criteria established.
Concentrations expressed in μg L - microgram per liter
Reference: Halliburton NUS, 1991

TABLE 2-4

SOIL INVESTIGATION FINDINGS
OU NO. 11 (SITE 7)
TARAWA TERRACE DUMP
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil (0-2 feet)		Subsurface Soil (3-12 feet)	
	No. of Positive Detections/ No. of Samples	Range of Positive Detections	No. of Positive Detections/ No. of Samples	Range of Positive Detections
Organics [1]				
Bis(2-ethylhexyl)phthalate	1/8	1,000	0/5	ND
Fluoranthene	2/8	220-290	0/5	ND
Benzoic acid	2/8	6,300-15,000	1/5	7,900
Aldrin	1/8	4.3	0/5	ND
4,4'-DDD	3/8	12-20	2/5	58-190
4,4'-DDE	1/8	240	0/5	ND
Dieldrin	3/8	12-540	3/5	400-2,500
Endosulfan II	3/8	7.6-1,400	3/5	73-2,000
Endrin	2/8	91-140	4/5	14-1,300
PCB-1260	3/8	108-12,000	4/5	660-25,000
Inorganics [2]				
Aluminum	8/8	3,690-9,700	5/5	1,030-5,030
Arsenic	3/8	1.1-1.7	3/5	1.1-1.5
Barium	8/8	9.1-223	5/5	6.6-72.8
Beryllium	4/8	0.26-2.1	3/5	0.29-3.6
Cadmium	8/8	1.1-5.0	5/5	1.2-4.5
Calcium	7/8	190-58,200	3/5	3,660-9,990
Chromium (Total)	8/8	4.2-10.6	5/5	5.2-12.5
Cobalt	8/8	1.7-8.1	5/5	1.9-10.2
Iron	8/8	876-5,330	5/5	981-5,490
Lead	8/8	3.0-114	5/5	2.4-17.0
Magnesium	8/8	104-1,150	4/5	99.9-541
Manganese	8/8	3.2-69.0	5/5	3.0-47.7
Mercury	8/8	0.11-0.53	5/5	0.12-0.45

TABLE 2-4 (Continued)

SOIL INVESTIGATION FINDINGS
OU NO. 11 (SITE 7)
TARAWA TERRACE DUMP
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil (0-2 feet)		Subsurface Soil (3-12 feet)	
	No. of positive Detections/ No. of Samples	Range of Positive Detections	No. of positive Detections/ No. of Samples	Range of Positive Detections
Nickel	8/8	2.8-13.1	5/5	3.1-11.7
Potassium	6/8	110-507	4/5	120-452
Selenium	1/8	0.54	0/5	ND
Silver	8/8	0.66-3.0	5/5	0.72-2.7
Sodium	1/8	754	1/5	1,020
Thallium	8/8	0.44-2.0	5/5	0.47-1.8
Vanadium	8/8	4.5-18.1	5/5	4.5-9.8
Zinc	2/8	1.1-44.5	3/5	1.2-4.5
Cyanide	8/8	0.54-2.5	5/5	0.60-2.3

(1) - Organic concentrations expressed in μg/kg (microgram per kilogram).
(2) - Inorganic concentrations expressed mg/kg (milligram per kilogram).
ND - Not detected.
Reference: Halliburton NUS, 1991

TABLE 2-5

GROUNDWATER INVESTIGATION FINDINGS
OU NO. 11 (SITE 80)
PARADISE POINT GOLF COURSE
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	North Carolina Standards	USEPA MCLs	No. of Positive Detections/ No. of Samples	Range of Positive Detections	Location of Maximum Concentration
Toluene	1,000	1,000	1/3	180	80MW03
Ethylbenzene	29	100	1/3	5	80MW03
Xylenes	530	10,000	1/3	21	80MW03
Carbon Disulfide	--	--	1/3	25	80MW03

-- = Criteria not established.
Concentrations expressed in $\mu g/L$ - microgram per liter
Reference: Halliburton NUS, 1991

TABLE 2-6

SOIL INVESTIGATION FINDINGS
OU NO. 11 (SITE 80)
PARADISE POINT GOLF COURSE
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil (0-6 inches)		Near Subsurface Soil (0-2 feet)		Subsurface Soil (3-17 feet)	
	No. of Positive Detections/ No. of Samples	Range of Positive Detections	No. of Positive Detections/ No. of Samples	Range of Positive Detections	No. of Positive Detections/ No. of Samples	Range of Positive Detections
Methylene Chloride	1/3	7	0/7	ND	0/7	ND
Aldrin	0/3	ND	1/7	6.8-220	0/7	ND
alpha-Chlordane	0/3	ND	1/7	60	0/7	ND
4,4'-DDD	1/3	ND	3/7	20-700	0/7	ND
4,4'-DDE	0/3	ND	5/7	16-210	0/7	ND
4,4'-DDT	0/3	ND	4/7	15-290	0/7	ND
Dieldrin	0/3	ND	4/7	16-440	0/7	ND
PCB-1254	0/3	ND	2/7	830-1,500	0/7	ND

Concentrations expressed in μg/kg - microgram per kilogram
ND - Not detected.
Reference: Halliburton NUS, 1991

TABLE 2-7

SURFACE WATER INVESTIGATION FINDINGS
OU NO. 11 (SITE 80)
PARADISE POINT GOLF COURSE
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Near Site (SW03, SW04, SW05)	
	No. of Positive Detections/ No. of Samples	Range of Positive Detections
Acetone	3/3	11-190
Toluene	2/3	30-104
Carbon Disulfide	1/3	6
Total Petroleum Hydrocarbons	2/3	1390-1660

Concentrations expressed in μg/L - microgram per liter
Reference: Halliburton NUS, 1991

TABLE 2-8

GROUNDWATER INVESTIGATION FINDINGS
OU NO. 12 (SITE 3)
OLD CREOSOTE PLANT
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	North Carolina Standards	USEPA MCLs	No. of Positive Detections/ No. of Samples	Range of Positive Detection	Location of Maximum Concentration
Acenaphthene	--	--	1/3	1,500	3MW02
Anthracene	--	--	1/3	260	3MW02
Chrysene	--	2	1/3	96	3MW02
Fluoranthene	--	--	1/3	640	3MW02
Fluorene	--	--	1/3	890	3MW02
2-Methylnaphthalene	--	--	1/3	1,500	3MW02
Naphthalene	--	--	2/3	9-4,400	3MW02
Phenanthrene	--	--	1/3	1,600	3MW02
Pyrene	--	--	1/3	460	3MW02
Dibenzofuran	--	--	1/3	1,100	3MW02

-- = No criteria established.
Concentrations expressed in µg/L (microgram per liter).
Reference: Halliburton NUS, 1991

TABLE 2-9

SOIL INVESTIGATION FINDINGS
OU NO. 12 (SITE 3)
OLD CREOSOTE PLANT
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil (0-2 feet)		Subsurface Soil (3-12 feet)		Subsurface Soil (> 12 feet)	
	No. of Positive Detections/ No. of Samples	Range of Positive Detections	No. of Positive Detections/ No. of Samples	Range of Positive Detections	No. of Positive Detections/ No. of Samples	Range of Positive Detections
Acenaphthene	0/7	ND	0/5	ND	1/2	37,000
Antracene	1/7	1,900	0/5	ND	1/2	8,600
Benzo(a)anthracene	2/7	460-660	0/5	ND	1/2	5,600
Benzo(b)fluoranthene	2/7	520-2,200	0/5	ND	1/2	2,300
Benzo(k)fluoranthene	2/7	420-1,200	0/5	ND	1/2	2,100
Benzo(g,h,i)perylene	2/7	260-720	0/5	ND	0/2	ND
Benzo(a)pyrene	2/7	320-1,300	0/5	ND	0/2	ND
Chrysene	2/7	750-1,400	0/5	ND	1/2	5,900
Flouranthene	2/7	1,000-1,600	0/5	ND	1/2	35,000
Fluorene	0/7	ND	0/5	ND	1/2	35,000
Indeno(1,2,3-cd)pyrene	2/7	340-1,000	0/5	ND	0/2	ND
2-Methylnaphthalene	0/7	ND	0/5	ND	1/2	26,000
Naphthalene	1/7	550	0/5	ND	1/2	52,000
Phenanthrene	1/7	310	0/5	ND	1/2	81,000
Pyrene	2/7	920-1,400	0/5	ND	1/2	27,000
Dibenzofuran	0/7	ND	0/5	ND	1/2	35,000

Concentrations expressed in μg/kg - microgram per kilogram
Reference: Halliburton NUS, 1991

TABLE 3-1

OPERABLE UNITS NO. 8 (SITE 16), NO. 11 (SITES 7 AND 80), AND NO. 12 (SITE 3)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 16 - Soil	1a. Assess the extent of soil contamination in the former burn dump area.	Characterize contaminant levels in surface and subsurface soils at the former burn dump area.	Soil Investigation
	1b. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface soils at the study area.	Soil Investigation Risk Assessment
	1c. Determine whether contamination from soils is migrating to groundwater	Characterize subsurface soil and leaching potential. Characterize shallow groundwater	Soil Investigation Groundwater Investigation
	1d. Identify residual wastes within the burn dump.	Identify subsurface features and debris.	Test Pit Investigation
	1e. Evaluate treatment alternatives.	Characterize areas of concern above action levels. Evaluate effectiveness and implementability of technologies.	Soil Investigation Feasibility Study Bench or Pilot-Scale Testing
2. Site 16 - Groundwater	2a. Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to groundwater criteria and risk-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess nature and extent of shallow groundwater contamination.	Characterize shallow groundwater quality.	Groundwater Investigation
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation
3. Site 16 - Sediment	3a. Assess human health and ecological risks associated with exposure to sediments in Northeast Creek.	Characterize nature and extent of contamination in sediment	Sediment Investigation in Northeast Creek Risk Assessment
	3b. Assess potential ecological impacts posed by contaminated sediments in Northeast Creek.	Qualitatively evaluate stress to benthic and fish communities.	Evaluation of Surface Water and Sediment Investigation
	3c. Determine extent of sediment contamination for purposes of identifying areas of concern.	Identify extent of sediment contamination where contaminant levels exceed risk-based action levels or USEPA Region IV criteria.	Sediment Investigation in Northeast Creek Risk Assessment
4. Site 16 - Surface Water	4a. Assess the presence or absence of surface water contamination in Northeast Creek.	Determine surface water quality in Northeast Creek.	Surface Water Investigation

TABLE 3-1 (Continued)

OPERABLE UNITS NO. 8 (SITE 16), NO. 11 (SITES 7 AND 80), AND NO. 12 (SITE 3)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 7 - Soil	1a. Assess the extent of soil contamination at the former dump area.	Characterize contaminant levels in surface and subsurface soils at the former dump area.	Soil Investigation
	1b. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface and subsurface soils at the site.	Soil Investigation Risk Assessment
	1c. Determine whether organic or inorganic contamination from soils is migrating to groundwater.	Characterize groundwater quality in the former dump area.	Groundwater Investigation
2. Site 7 - Groundwater	2a. Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess the extent of shallow groundwater contamination.	Determine the horizontal extent of shallow groundwater contamination.	Groundwater Investigation
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation
3. Site 7 - Sediment	3a. Assess human health and ecological risks associated with exposure to sediments in the east and west tributaries and Northeast Creek.	Characterize nature and extent of contamination in sediment	Sediment Investigation in the east and west tributaries and Northeast Creek Risk Assessment
	3b. Assess potential ecological impacts posed by contaminated sediments in the east and west tributaries and Northeast Creek.	Qualitatively evaluate stress to benthic and fish communities.	Evaluation of Surface Water and Sediment Investigation
	3c. Determine extent of sediment contamination for purposes of identifying areas potentially requiring remediation.	Identify extent of sediment contamination where contaminant levels exceed risk-based action levels or EPA Region IV TBCs for sediment.	Sediment Investigation in the east and west tributaries and Northeast Creek Risk Assessment
4. Site 7 - Surface Water	4a. Assess the presence or absence of surface water contamination in the east and west tributaries and Northeast Creek.	Determine surface water quality in the east and west tributaries and Northeast Creek.	Surface Water Investigation

TABLE 3-1 (Continued)

OPERABLE UNITS NO. 8 (SITE 16), NO. 11 (SITES 7 AND 80), AND NO. 12 (SITE 3)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 80 - Soil	1a. Assess the extent of soil contamination in the lawn area, soil mounds, and drum area.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation
	1b. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation Risk Assessment
2. Site 80 - Groundwater	2a. Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess the vertical and horizontal extent of shallow groundwater contamination.	Characterize downgradient shallow groundwater quality. Identify presence or absence of contamination in the deep aquifer.	Groundwater Investigation
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation
	2d. Determine whether current groundwater contamination is due to non-site related UST.	Characterize flow direction. Evaluate migration pathways.	Groundwater Investigation

TABLE 3-1 (Continued)

OPERABLE UNITS NO. 8 (SITE 16), NO. 11 (SITES 7 AND 80), AND NO. 12 (SITE 3)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 3 - Soil	1a. Assess the extent, if any, of soil contamination in the northern portion of the study area.	Characterize semivolatile levels in surface soils.	Soil Investigation - ENSYS Screening
	1b. Assess the extent, if any, of soil contamination around the concrete pads in the southern portion of the study area.	Characterize semivolatile levels in surface soils.	Soil Investigation - ENSYS Screening
	1c. Assess the extent of soil contamination at the former creosote treatment facility.	Characterize semivolatile and creosote levels in surface soil	Soil Investigation - ENSYS Screening
	1d. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation Risk Assessment
2. Site 3 - Groundwater	2a. Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess the horizontal and vertical extent of shallow groundwater contamination.	Characterize downgradient groundwater quality. Identify the presence or absence of contamination in deep groundwater.	Groundwater Investigation
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation

TABLE 4-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis
Site 16 - Montford Point Burn Dump	Soil - Burn Dump Boundary	22 borings/2 samples per boring	TCL Organics[2] TAL Metals[3]
	Soil - Well Borings	6 borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Southeast Portion of Study Area	4 hand auger borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Trenches	4 trenches/1 sample per trench (option)	TCL Organics TAL Metals
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals
	Groundwater - Two rounds sampling	6 new shallow monitoring wells	TCL Organics TAL Metals (total/dissolved)
	Surface Water - Northeast Creek	5 stations	TCL Organics TAL Metals
	Sediment - Northeast Creek	5 stations/2 samples per station	TCL Organics TAL Metals TOC Grain Size
Site 7 - Tarawa Terrace Dump	Soil - Southwest Corner Trench	5 trenches/2 samples per trench	TCL Organics TAL Metals
	Soil - Southwest Corner	5 hand auger borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Northwestern Boundary	23 borings/2 samples per boring (12 drill rigs, 11 hand augers)	TCL Organics TAL Metals

TABLE 4-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis
Site 7 - Tarawa Terrace Dump (Continued)	Soil - Community Center Playground	2 borings/1 sample per boring	TCL Organics TAL Metals
	Soil - Well Borings	2 borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals
	Groundwater - One Round of Sampling	5 (3 existing, 2 newly installed) shallow wells	TCL Organics TAL Metals (total/dissolved)
	Groundwater - One Round of Sampling	3 temporary wells	TCL Organics TAL Metals (total/dissolved)
	Surface Water - Northeast Creek	6 stations	TCL Organics TAL Metals
	Sediment - Northeast Creek	6 stations/2 samples per station	TCL Organics TAL Metals TOC Grain Size
	Surface Water - Western Tributary	3 stations	TCL Organics TAL Metals
	Sediment - Western Tributary	3 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size
	Surface Water - Eastern Tributary	2 stations	TCL Organics TAL Metals
	Sediment - Eastern Tributary	2 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size

TABLE 4-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis
Site 7 - Tarawa Terrace Dump (Continued)	Surface Water - Drainage Ditch	2 stations	TCL Organics TAL Metals
	Sediment - Drainage Ditch	2 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size
	Sediment - Marsh Area	4 stations/2 samples per station	TCL Organics TAL Metals
	Sediment - Northeast Creek	4 stations	Benthic Survey
	Sediment - Western Tributary	3 stations	Benthic Survey
Site 80 - Paradise Point Golf Course Maintenance Area	Soil - Lawn Area	7 borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Between and around Buildings 1916 and 600	4 borings/2 samples per boring	TCL Organics TAL Metals
	Soil - Open Area of Soil Piles	7 boring/2 samples per boring	TCL Organics TAL Metals
	Soil - Mounded Area	10 hand auger borings/1 surficial sample per boring	TCL Organics TAL Metals
		3 power auger borings/1 subsurface sample per boring	TCL Organics TAL Metals
	Soil - Previous Drum Area	2 borings/1 surface sample per boring	TCL Organics TAL Metals
	Soil - Well Borings	5 borings/2 samples per boring	TCL Organics TAL Metals

TABLE 4-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis
Site 80 - Paradise Point Golf Course Maintenance Are (Continued)	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals
	Groundwater - One Round of Sampling	8 (3 existing shallow, 4 newly installed shallow, 1 newly installed intermediate)	TCL Organics TAL Metals (total/dissolved)
Site 3 - Old Creosote Plant	Soil - Northern Portion	13 borings/1 sample per boring	ENSYS PAH[6]* ENSYS Petro Soil[7] TCL Semivolatile Organics[8]
	Soil - Former Creosote Treatment Area	25 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics
	Soil - Concrete Pads	8 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics
	Soil - Railroad Spur	2 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics
	Soil - Well Borings	3 shallow borings/3 samples per boring	TCL Semivolatile Organics
		1 shallow boring/3 samples per boring 1 intermediate boring/3 samples per boring	TCL Organics TAL Metals
		1 composite sample from shallow boring	Engineering Parameters
	Soil - Background	3 borings/1 sample per boring	TCL Semivolatile Organics
	Groundwater - 1 round of sampling	6 (3 existing, 3 newly installed shallow monitoring wells)	TCL Semivolatile Organics
		1 newly installed intermediate well 1 newly installed shallow well	TCL Organics TAL Metals (total and dissolved)

TABLE 4-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples(1)	Analysis
Investigation Derived Waste	Development/ Purge Water	4 (1 sample from each site)	TCL Organics TAL Metals
	Soil/Rolloff Box	3 (1 sample from each site)	TCLP(6) RCRA(7)

* Assume a total of 15 confirmatory soil samples submitted for TCL semivolatile organic analysis.

(1) Baseline number of samples do not include QA/QC samples.

(2) TCL Organics: volatile organics, semivolatile organics, pesticides/PCBs

(3) TAL Metals:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

(4) Routine analytical turnaround is 28 days following receipt of samples.

(5) Engineering Parameters:

Soil:

Atterburg Limits	ASTM D-4318-84
Particle Size Distribution	ASTM D-422-63
Bulk Density	ASTM D-1557-91
Soil Porosity	
Total Organic Carbon (TOC)	EPA 9060

(6) TCLP - TCL VOAs, TCL SVOAs, TCL Pesticides, Herbicides, and Metals

(7) RCRA - Corrosivity, Reactivity, and Ignitability (React Sulfide , React Cyanide)

TABLE 4-2

PRELIMINARY REMEDIATION GOALS
OU NO. 11 (SITE 7) TARAWA TERRACE DUMP
REMEDIAL INVESTIGATION - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	Preliminary Remediation Goal	Unit	Basis of Goal
Groundwater	Dieldrin	0.0042	μg/L[1]	Risk-Ingestion[4]
	Endrin Ketone	2	μg/L	NCWQS[5]
	Barium	1000	μg/L	NCWQS
	Beryllium	4	μg/L	MCL[6]
	Chromium (Total)	50	μg/L	NCWQS[5]
	Lead	15	μg/L	NCWQS
	Manganese	50	μg/L	NCWQS
Soil	Aldrin	38	μg/kg[2]	Risk-Soil Ingestion[4]
	4,4-DDD	2700	μg/kg	Risk-Soil Ingestion[4]
	4,4-DDE	1900	μg/kg	Risk-Soil Ingestion[4]
	Dieldrin	40	μg/kg	Risk-Soil Ingestion[4]
	Endosulfan II	470,000	μg/kg	Risk-Soil Ingestion[4]
	Endrin	23,000	μg/kg	Risk-Soil Ingestion[4]
	PCB-1260	1,000	μg/kg	TSCA (residential)
	Barium	5,500	mg/kg[3]	Risk-Soil Ingestion[4]
	Beryllium	150	μg/kg	Risk-Soil Ingestion[4]
	Cadmium	39,000	μg/kg	Risk-Soil Ingestion[4]
	Chromium	78,000	mg/kg	Risk-Soil Ingestion[4]
	Manganese	390	mg/kg	Risk-Soil Ingestion[4]

(1) μg/L - microgram per liter
(2) μg/kg - microgram per kilogram
(3) mg/kg - milligram per kilogram
(4) Region III Risk-Based Concentration
(5) NCWQS - North Carolina Water Quality Standard
(6) MCL - Maximum Contaminant Level

TABLE 4-3

PRELIMINARY REMEDIATION GOALS
OU No. 11 (SITE 80) PARADISE POINT GOLF COURSE MAINTENANCE AREA
REMEDIAL INVESTIGATION - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	Preliminary Remediation Goal	Unit	Basis of Goal
Groundwater	Toluene	1,000	μg/L[1]	NCWQS[3]
	Ethylbenzene	29	μg/L	NCWQS
	Xylenes	530	μg/L	NCWQS
Soil	Aldrin	38	μg/kg[2]	Risk-Soil Ingestion[4]
	alpha-Chlordane	490	μg/kg	Risk-Soil Ingestion[4]
	4,4-DDD	2700	μg/kg	Risk-Soil Ingestion[4]
	4,4-DDE	1900	μg/kg	Risk-Soil Ingestion[4]
	4,4-DDT	1900	μg/kg	Risk-Soil Ingestion[4]
	Dieldrin	40	μg/kg	Risk-Soil Ingestion[4]
	PCB-1254	1,000	μg/kg	TSCA (residential)

(1) μg/L - microgram per liter
(2) μg/kg - microgram per kilogram
(3) NCWQS - North Carolina Water Quality Standard
(4) Region III Risk-Based Concentration

TABLE 4-4

PRELIMINARY REMEDIATION GOALS
OU NO. 12 (SITE 3) OLD CREOSOTE PLANT
REMEDIAL INVESTIGATION - CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	Preliminary Remediation Goal	Unit	Basis of Goal
Groundwater	Acenaphthene	2,200	μg/L[1]	Risk-Ingestion[3]
	Anthracene	11,000	μg/L	Risk-Ingestion
	Chrysene	2	μg/L	MCL[4]
	Fluoranthene	1,500	μg/L	Risk-Ingestion
	Fluorene	1,500	μg/L	Risk-Ingestion
	Naphthalene	1,500	μg/L	Risk-Ingestion
	Pyrene	1,100	μg/L	Risk-Ingestion
Soil	Anthracene	23,000	mg/kg	Risk-Soil Ingestion
	Acenaphthene	4,700	mg/kg	Risk-Soil Ingestion
	Benzo(a)anthracene	0.88	mg/kg	Risk-Soil Ingestion
	Benzo(b)fluoranthene	0.88	mg/kg	Risk-Soil Ingestion
	Benzo(k)fluoranthene	8.8	mg/kg	Risk-Soil Ingestion
	Benzo(a)pyrene	0.088	mg/kg	Risk-Soil Ingestion
	Chrysene	88	mg/kg	Risk-Soil Ingestion
	Fluoranthene	3,100	mg/kg	Risk-Soil Ingestion
	Fluorene	3,100	mg/kg	Risk-Soil Ingestion
	Indeno(1,2,3-cd)pyrene	0.88	mg/kg	Risk-Soil Ingestion
	Naphthalene	3,100	mg/kg	Risk-Soil Ingestion
	Pyrene	2,300	mg/kg	Risk-Soil Ingestion

(1) μg/L - microgram per liter
(2) mg/kg - milligram per kilogram
(3) Region III Risk-Based Concentration
(4) MCL - Federal Maximum Contaminant Level

WORK PLAN FIGURES

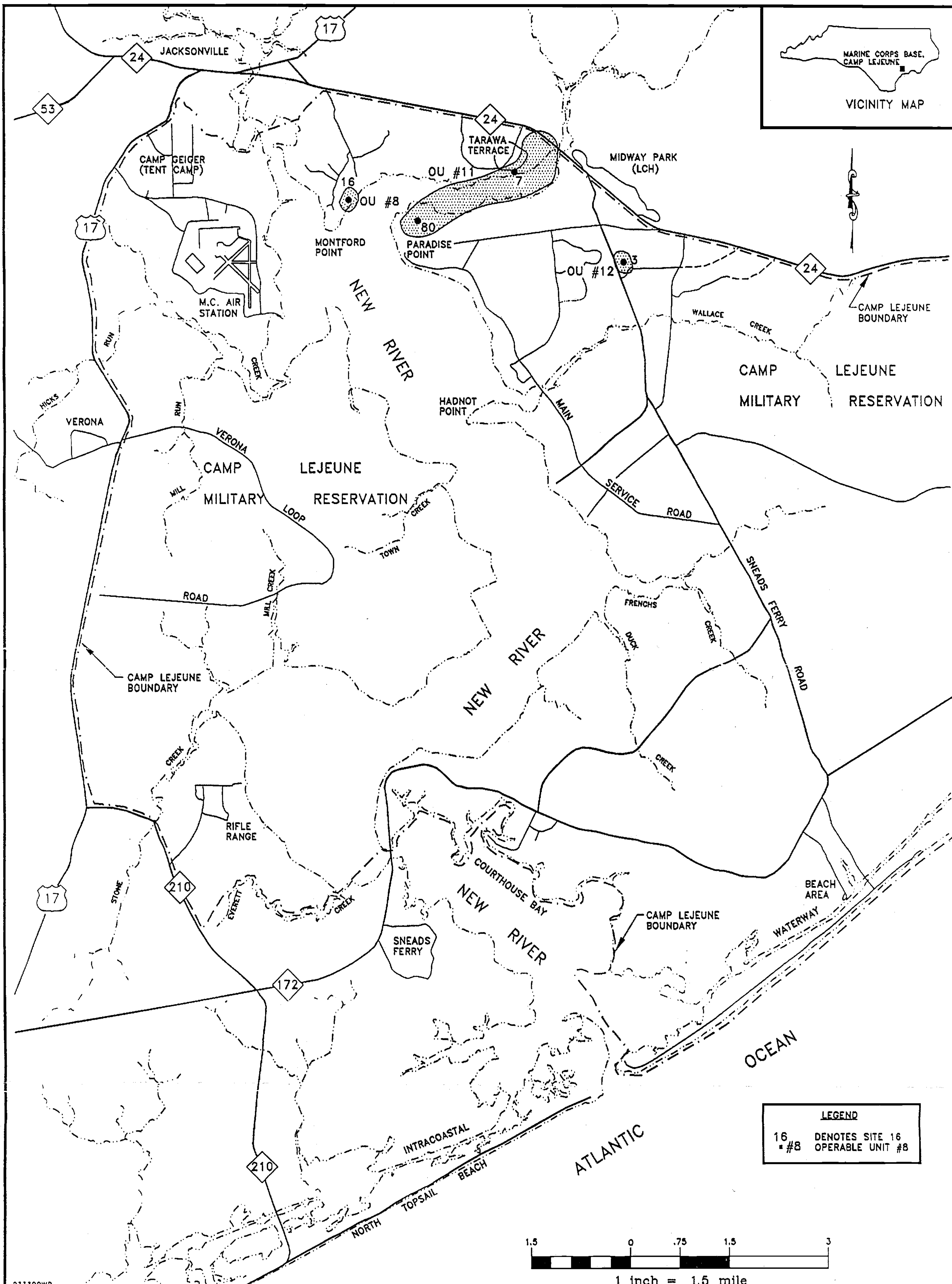
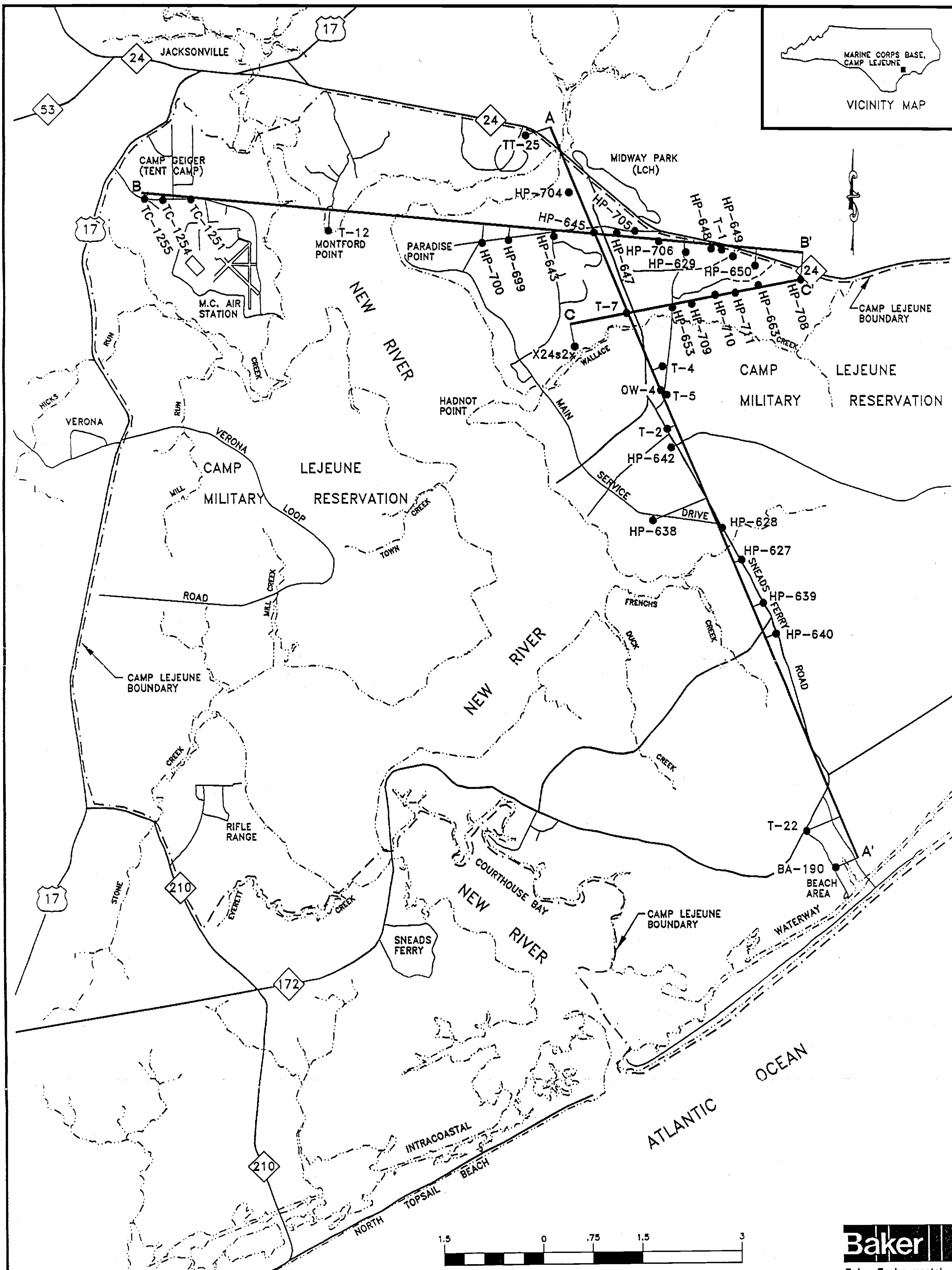


FIGURE 2-1
OPERABLE UNITS AND SITE LOCATIONS AT
MARINE CORPS BASE CAMP LEJEUNE
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

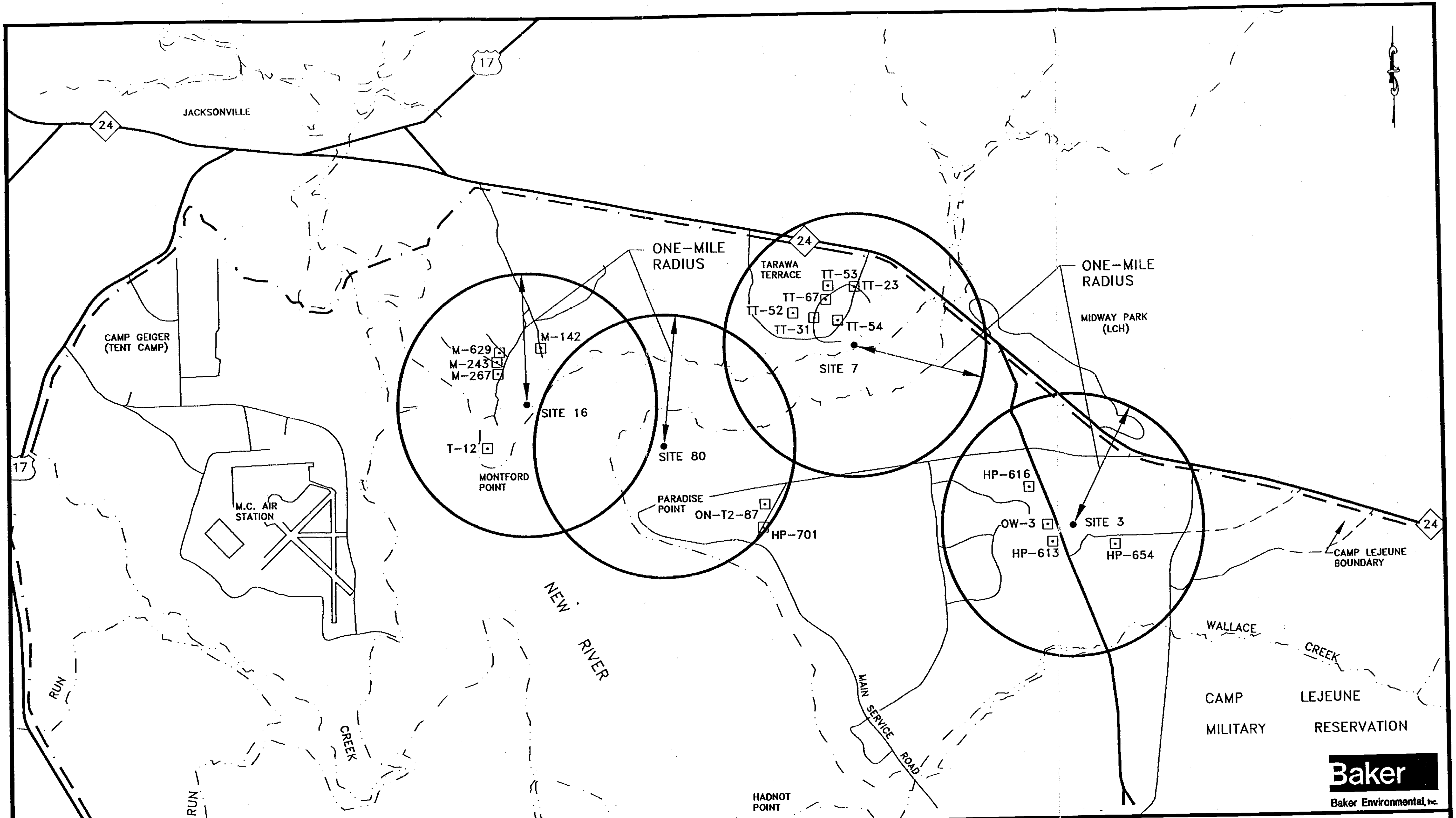
01531ZB1Z



SOURCE: DEPT. OF INTERIOR, WATER-RESOURCES INVESTIGATIONS REPORT, 89-4096, PLATE 4

FIGURE 2-2
LOCATION OF HYDROGEOLOGIC CROSS-SECTIONS
MARINE CORPS BASE, CAMP LEJEUNE
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

T-12 ⊡ WATER SUPPLY WELL

.75 0 .375 .75

1 INCH = .75 MILES

FIGURE 2-2A
SUPPLY WELL LOCATIONS
MARINE CORPS BASE, CAMP LEJEUNE
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

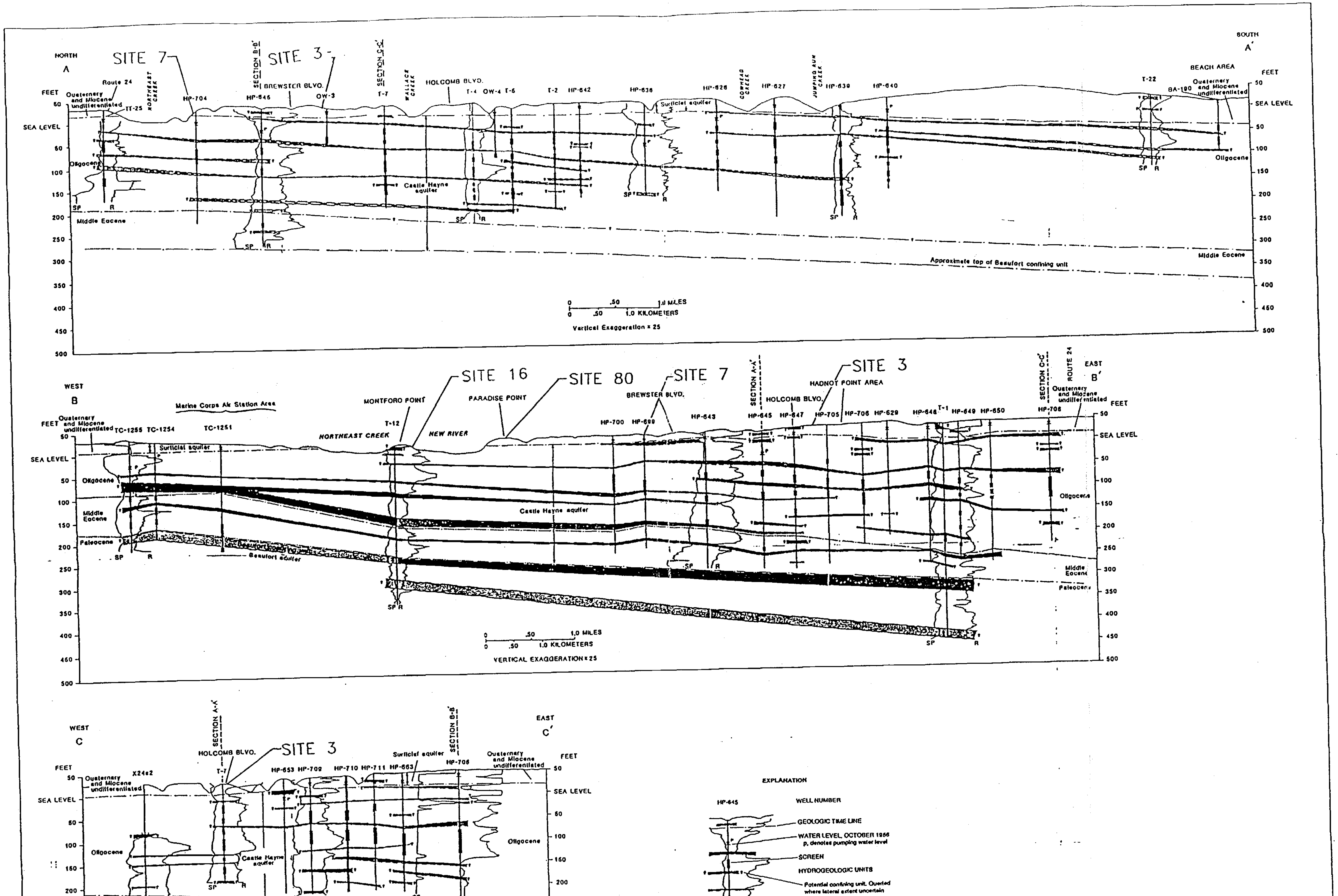
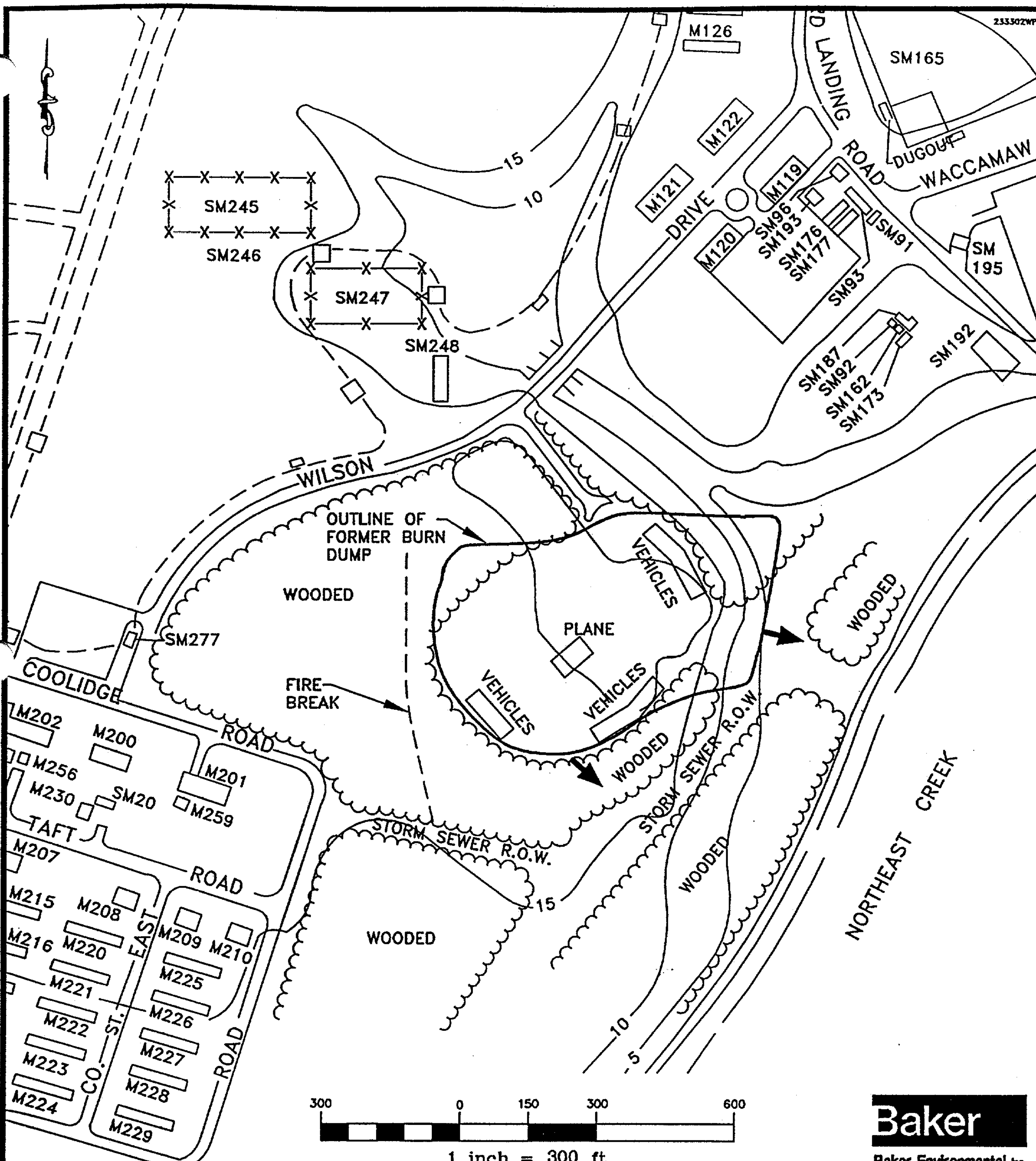


FIGURE 2-3
HYDROGELOGIC CROSS-SECTIONS
OF MCB CAMP LEJEUNE AREA
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

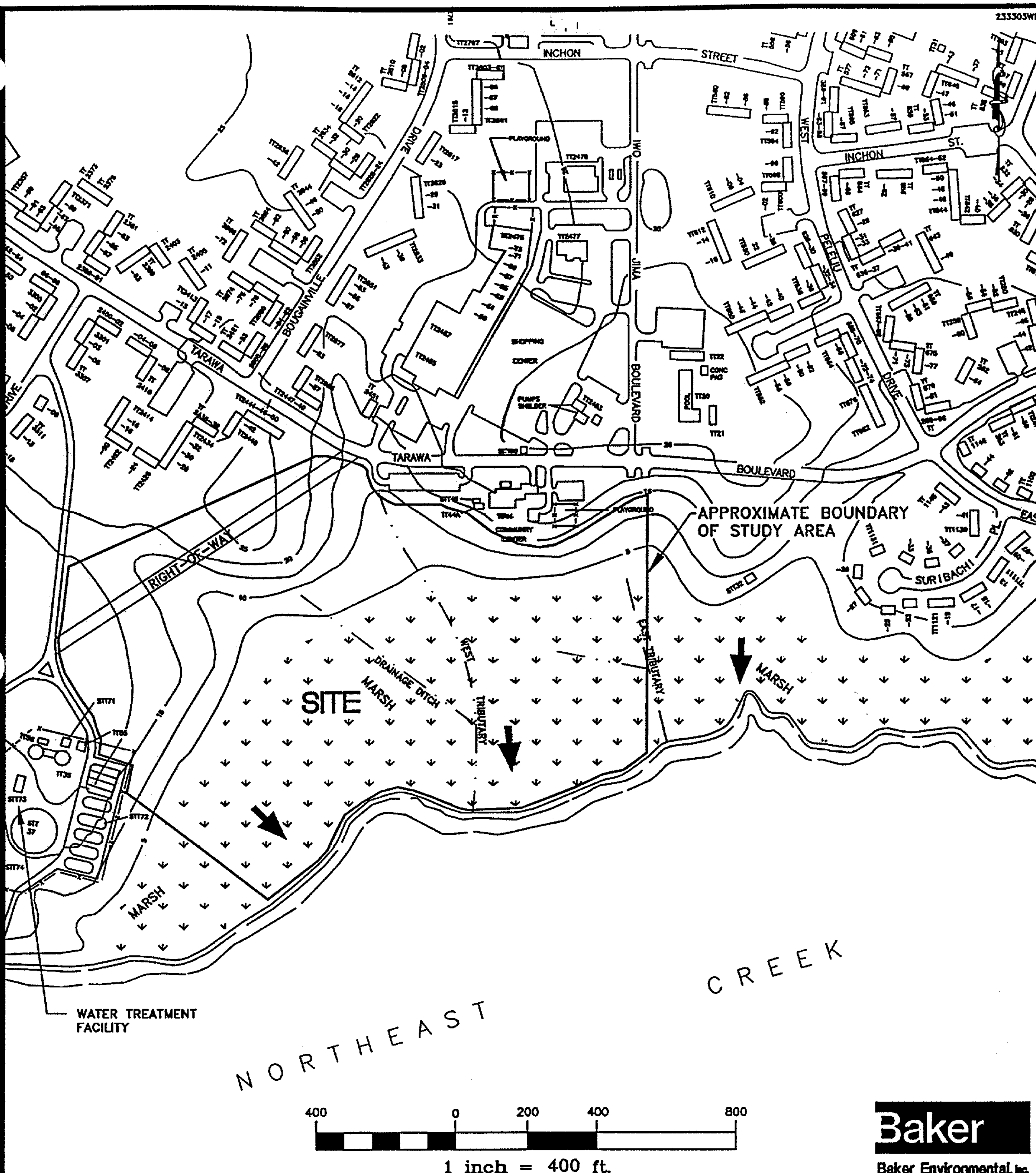


LEGEND

→ ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB., 1992

FIGURE 2-4
SITE LOCATION MAP
SITE 16 – MONTFORD POINT
BURN DUMP
CTO-0233
MARINE CORPS BASE, CAMP LEJUENE
NORTH CAROLINA



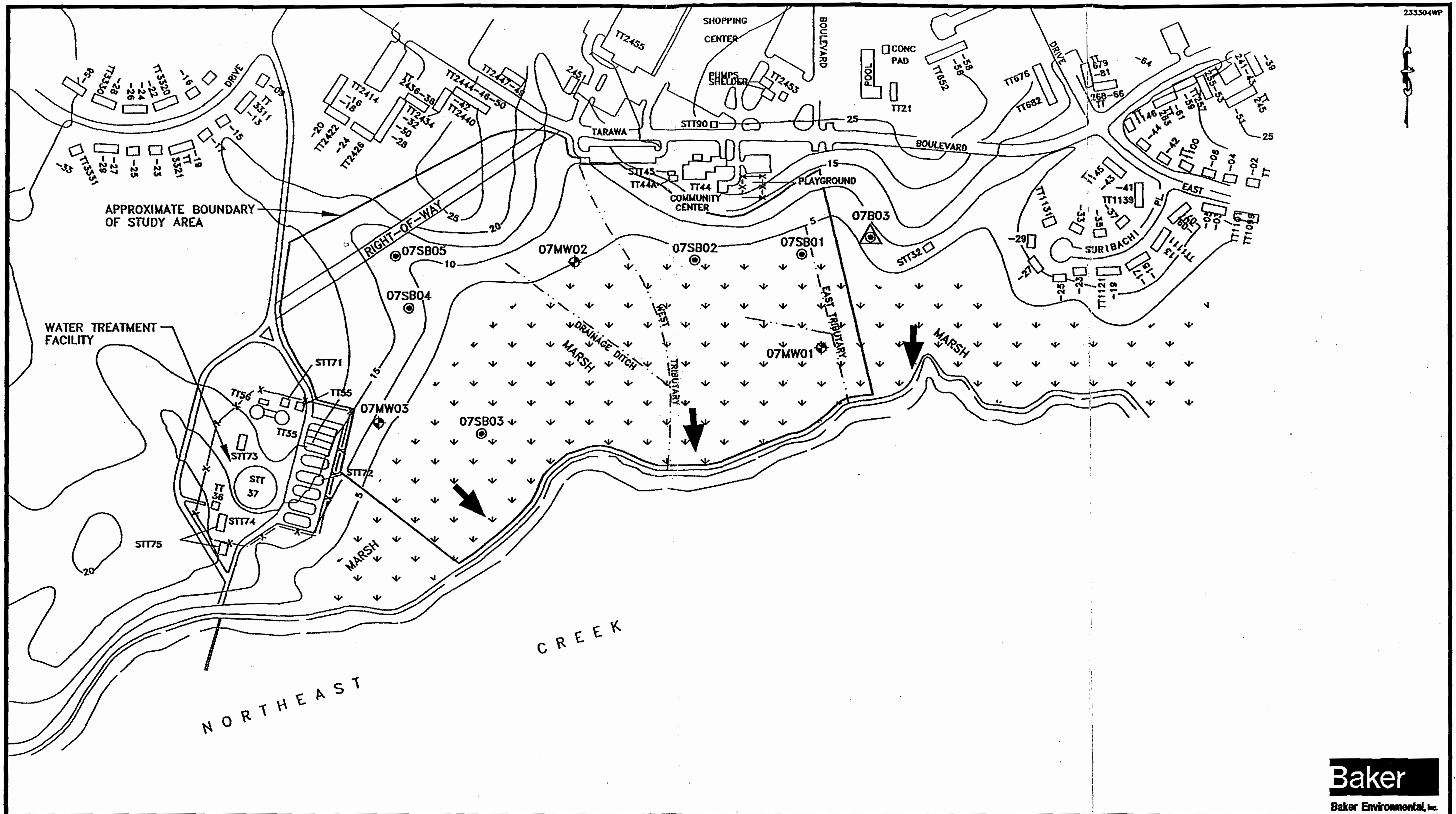
LEGEND

→ ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV., FEB. 1992

FIGURE 2-5
SITE LOCATION MAP
SITE 7 – TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

LEGEND

07MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07B03 EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

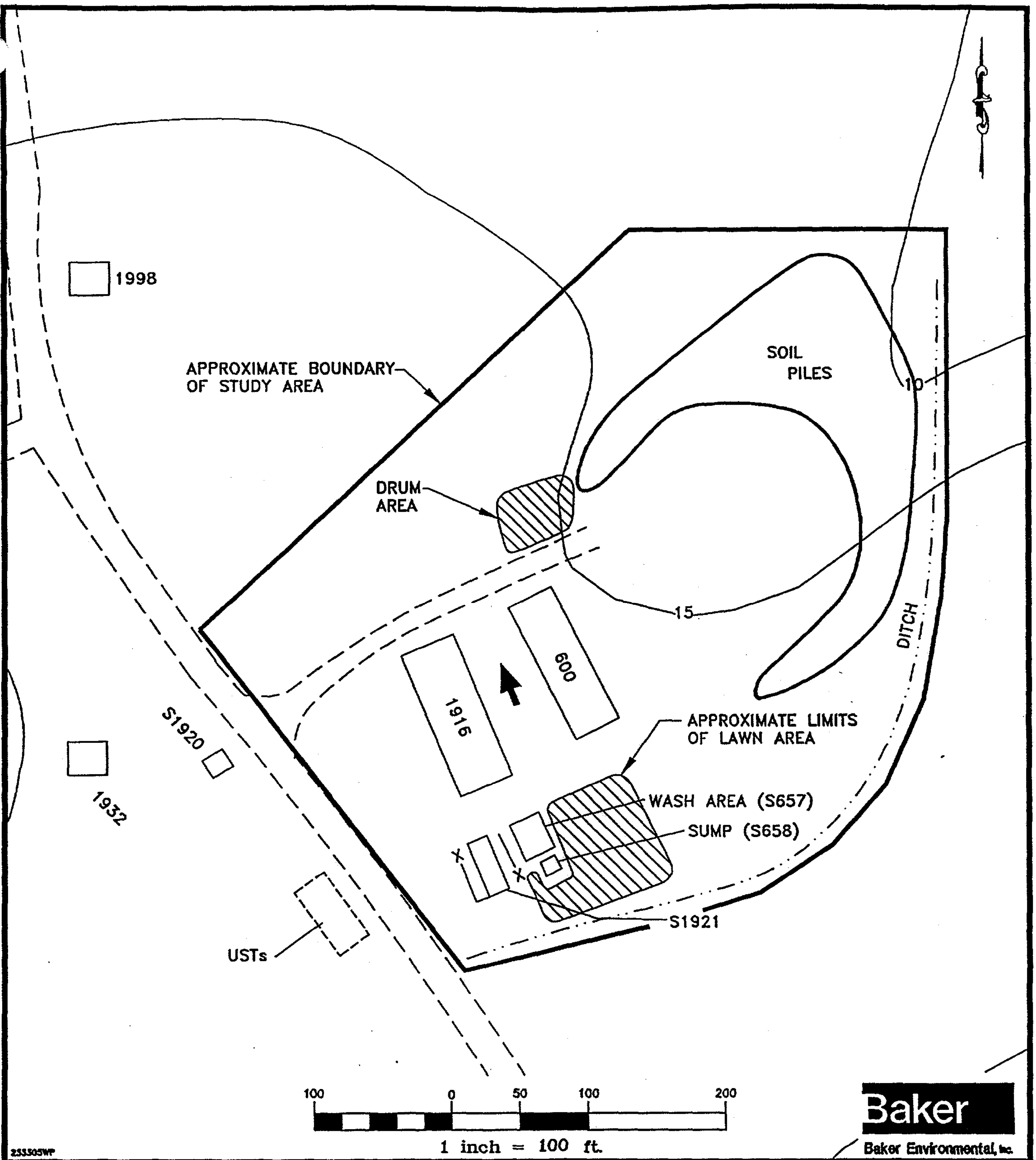
300 0 150 300 600

1 inch = 300 ft.

FIGURE 2-6
PREVIOUS INVESTIGATION SAMPLE LOCATIONS
SITE 7 - TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01531Z017

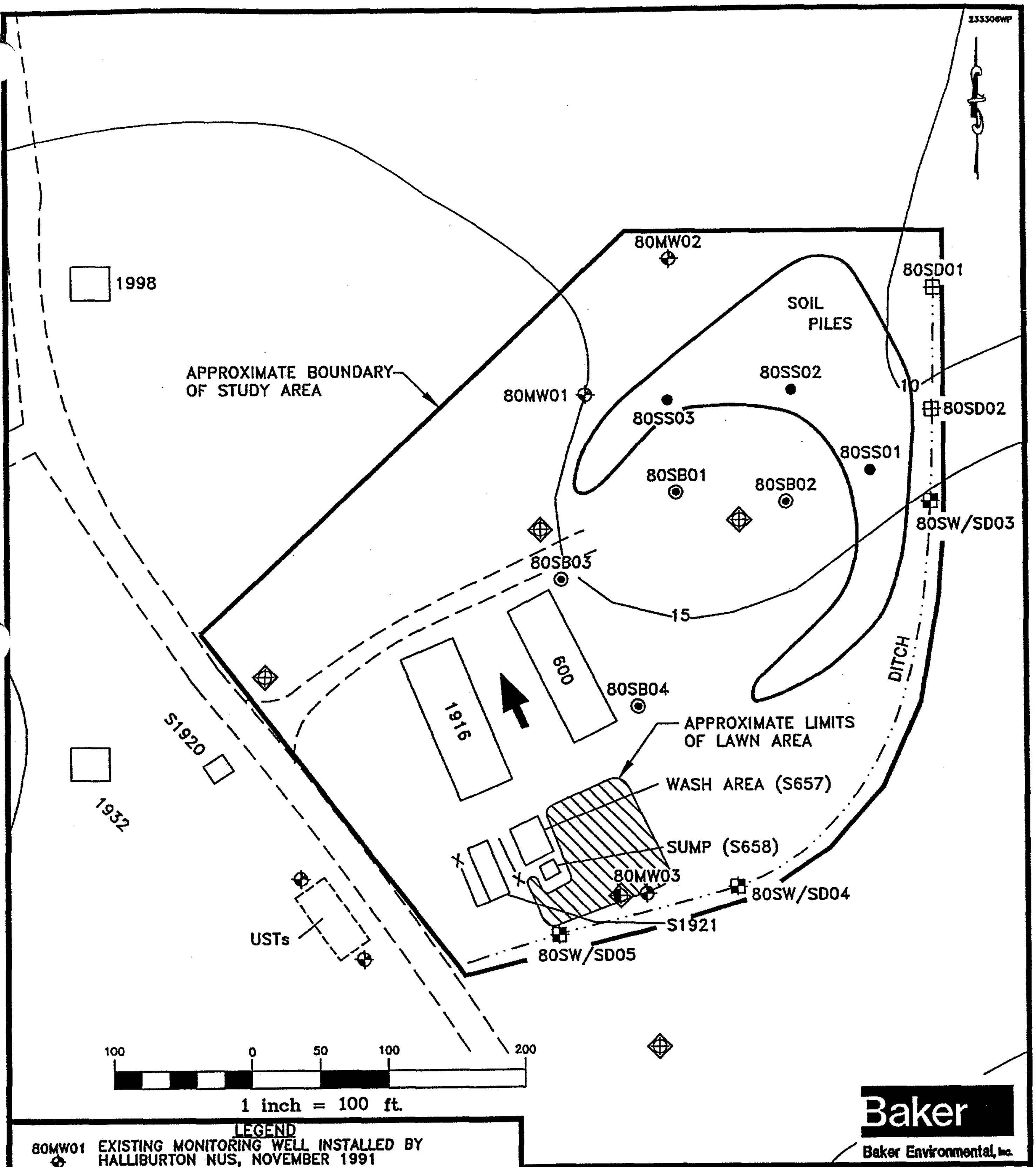


LEGEND

→ ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 2-7
SITE LOCATION MAP
SITE 80 - PARADISE POINT
GOLF COURSE MAINTENANCE AREA
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

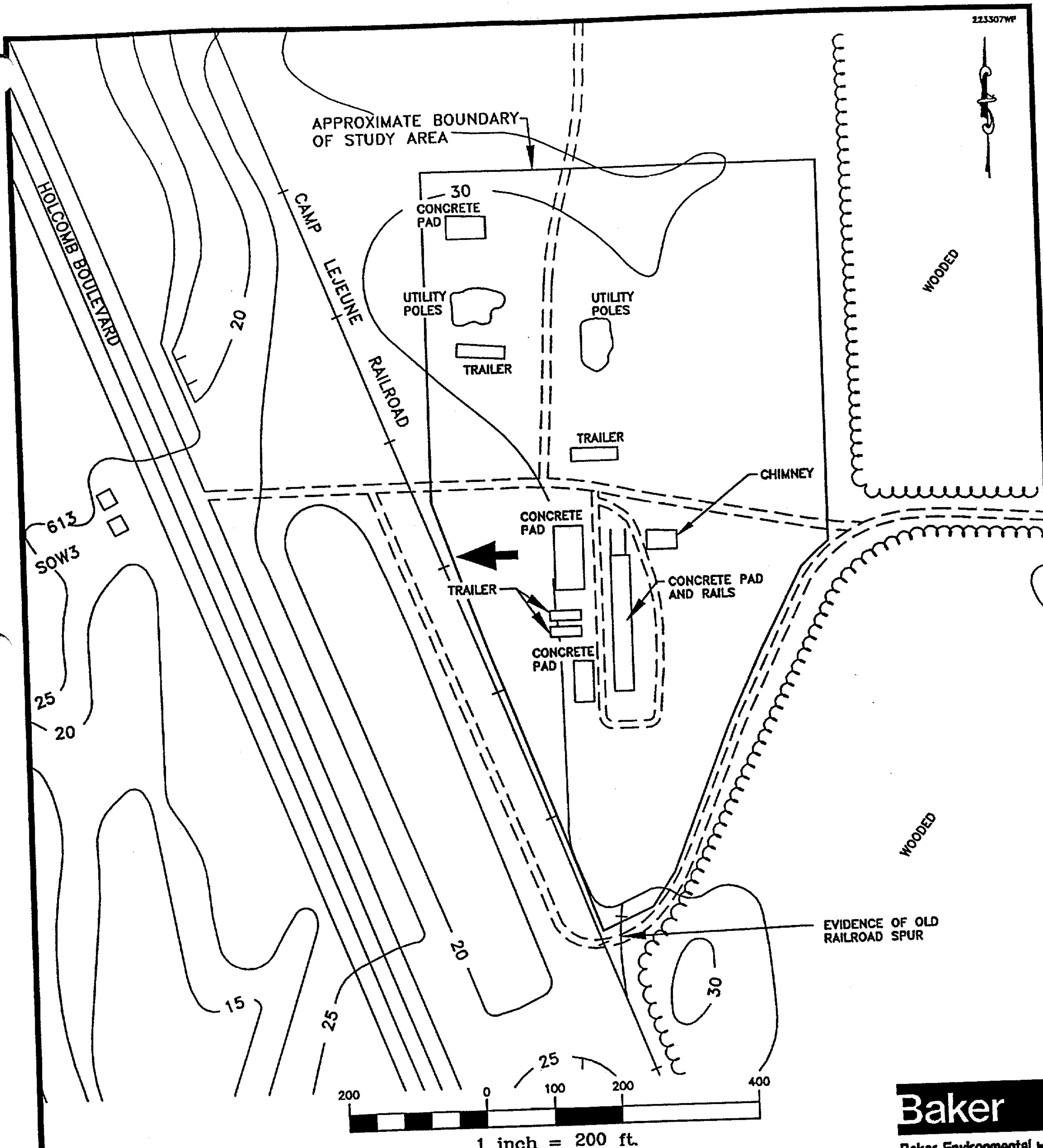


LEGEND

80MW01	EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SB01	EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SD01	EXISTING SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SW/SD03	EXISTING SURFACE WATER/SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SS01	EXISTING SURFACE SOIL SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
	PROPOSED SHALLOW MONITORING WELL
	PROPOSED INTERMEDIATE MONITORING WELL
	ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 2-8
PREVIOUS INVESTIGATION SAMPLING LOCATIONS
SITE 80-PARADISE POINT GOLF COURSE MAINTENANCE AREA
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



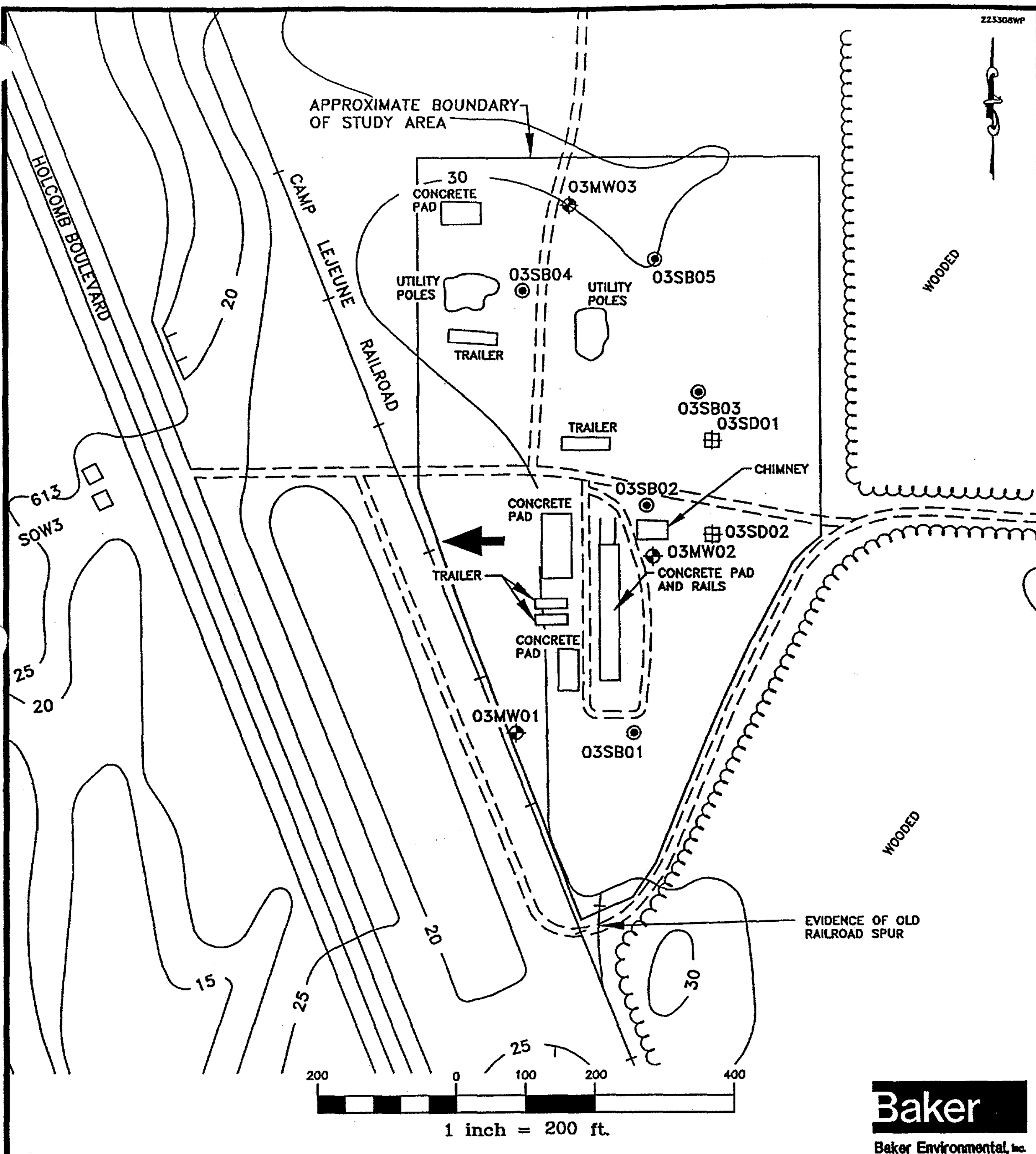
LEGEND

➡ ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 2-9
SITE LOCATION MAP
SITE 3-OLD CREOSOTE PLLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

03MW01 MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SB01 SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SD01 SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 2-10
PREVIOUS INVESTIGATION SAMPLING LOCATIONS
SITE 3-OLD CREOSOTE PLLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 5-1

PROJECT ORGANIZATION

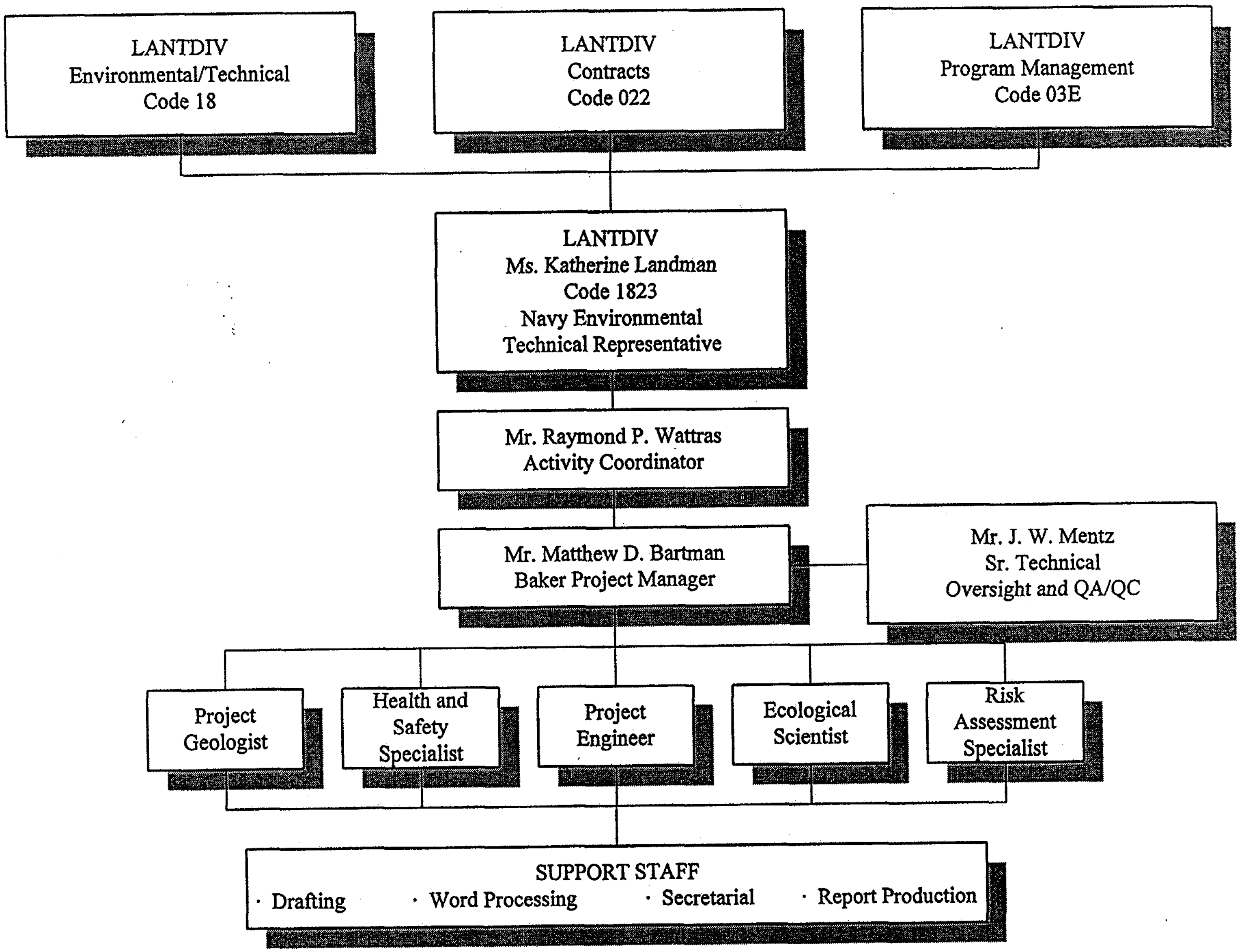


Figure 6 - 1 Project Schedule

Operable Unit No. 8 (Site 16)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
Notice to Proceed	0ed	9/24/94	9/24/94
Mobilization	30ed	9/24/94	10/24/94
Environmental Field Investigation	79ed	10/24/94	1/11/95
Sample Analysis/Validation	159ed	10/24/94	4/1/95
Data Evaluation	28ed	4/1/95	4/29/95
Risk Assessment	48ed	4/29/95	6/16/95
RI Report	200ed	4/1/95	10/18/95
Preliminary Draft RI Report	53ed	3/27/95	5/19/95
Comment period	30ed	5/19/95	6/18/95
Draft RI Report	30ed	6/18/95	7/18/95
Comment period	60ed	7/18/95	9/16/95
Draft Final RI Report	58ed	9/18/95	11/15/95
Comment Period	30ed	11/15/95	12/15/95
Final RI	30ed	12/15/95	1/14/96
FS Report/PRAP	287ed	5/1/95	2/12/96
Prelilminary Draft FS/PRAP	49ed	5/1/95	6/19/95
Comment Period	28ed	6/19/95	7/17/95
Draft FS/PRAP	30ed	7/17/95	8/16/95
Comment Period	60ed	8/16/95	10/15/95
Draft Final FS/PRAP	59ed	10/16/95	12/14/95
Comment Period	30ed	12/14/95	1/13/96
Final FS/PRAP	30ed	1/13/96	2/12/96
Public Comment Period	30ed	2/12/96	3/13/96

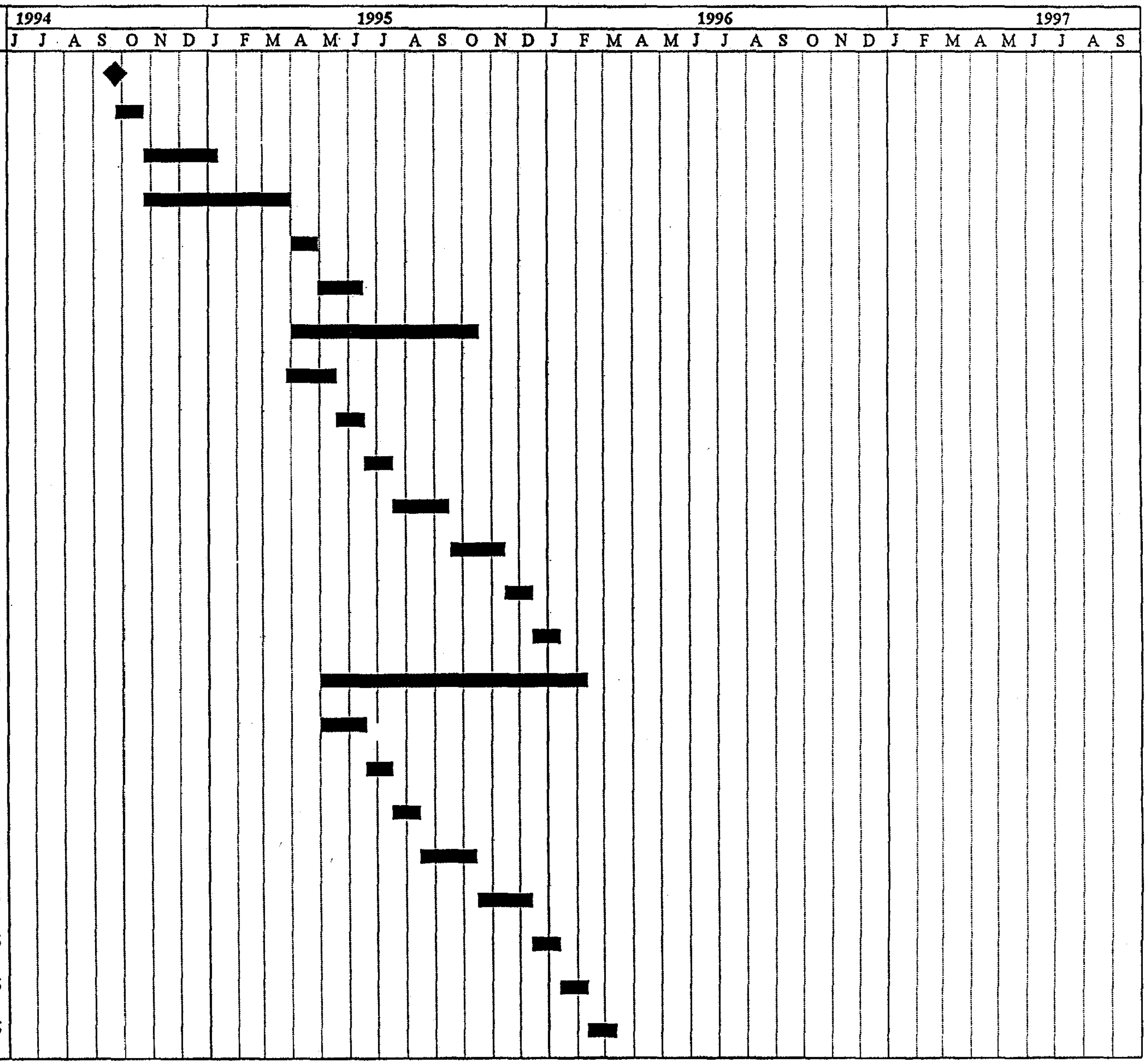


Figure 6 - 1 Project Schedule

Operable Unit No. 8 (Site 16)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
ROD	300ed	6/11/95	4/6/96
Preliminary Draft ROD	21ed	6/11/95	7/2/95
Comment Period	26ed	7/2/95	7/28/95
Draft ROD	27ed	7/28/95	8/24/95
Comment Period	60ed	8/24/95	10/23/95
Draft Final ROD	60ed	10/23/95	12/22/95
Comment Period	30ed	12/22/95	1/21/96
Final ROD	60ed	1/21/96	3/21/96
Remedial Design	380ed	3/21/96	4/5/97
Procure RA Contractor	70ed	4/5/97	6/14/97
Initiate RA	0ed	6/14/97	6/14/97

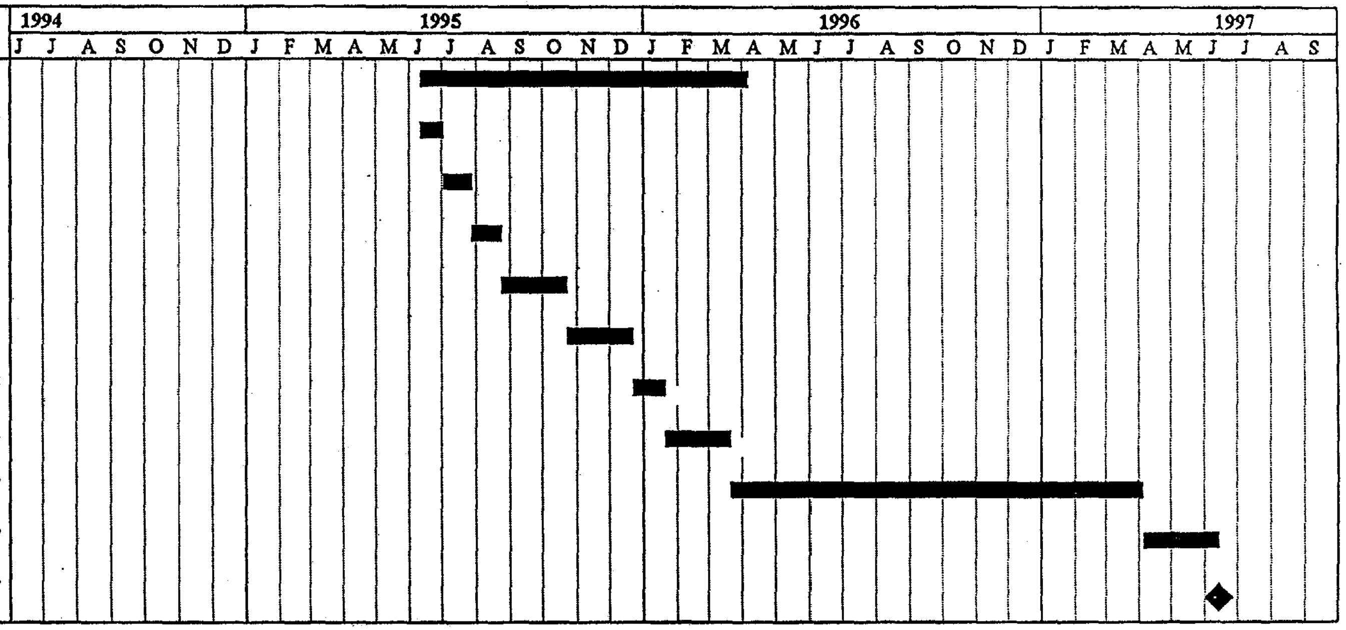


Figure 6 - 2 Project Schedule
Operable Unit No. 11 (Sites 7 and 80)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
Notice to Proceed	0ed	6/15/94	6/15/94
Ecological Field Investigation	10ed	6/20/94	6/30/94
Environmental Field Investigation	79ed	10/24/94	1/11/95
Sample Analysis / Validation	283ed	6/22/94	4/1/95
Data Evaluation	28ed	4/1/95	4/29/95
Risk Assessment	48ed	4/29/95	6/16/95
RI Report	200ed	4/1/95	10/18/95
Preliminary Draft RI Report	53ed	3/27/95	5/19/95
Comment Period	30ed	5/19/95	6/18/95
Draft RI Report	30ed	6/18/95	7/18/95
Comment Period	60ed	7/18/95	9/16/95
Draft Final RI Report	60ed	9/16/95	11/15/95
Comment Period	30ed	11/15/95	12/15/95
Final RI	30ed	12/15/95	1/14/96
FS Report / PRAP	260ed	5/1/95	1/16/96
Preliminary Draft FS / PRAP	49ed	5/1/95	6/19/95
Comment Period	28ed	6/19/95	7/17/95
Draft FS / PRAP	30ed	7/17/95	8/16/95
Comment Period	60ed	8/16/95	10/15/95
Draft Final FS / PRAP	60ed	10/15/95	12/14/95
Comment Period	30ed	12/14/95	1/13/96
Final FS / PRAP	30ed	1/13/96	2/12/96
Public Comment Period	30ed	2/12/96	3/13/96

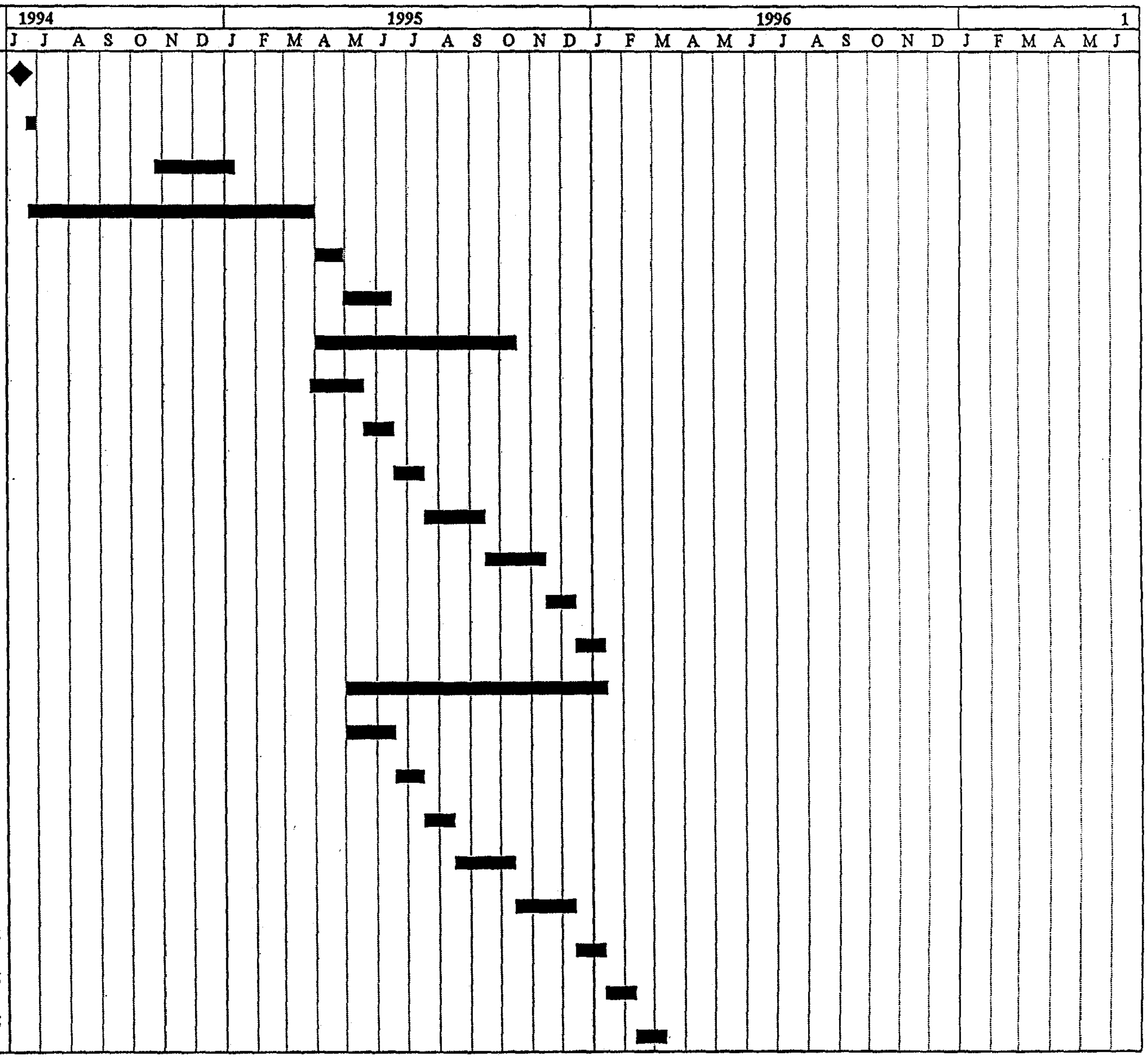


Figure 6 - 2 Project Schedule
Operable Unit No. 11 (Sites 7 and 80)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
ROD	236ed	6/11/95	2/2/96
Preliminary Draft ROD	21ed	6/11/95	7/2/95
Comment Period	26ed	7/2/95	7/28/95
Draft ROD	27ed	7/28/95	8/24/95
Comment Period	60ed	8/24/95	10/23/95
Draft Final ROD	60ed	10/23/95	12/22/95
Comment Period	30ed	12/22/95	1/21/96
Final ROD	60ed	1/21/96	3/21/96
Remedial Design	380ed	3/21/96	4/5/97
Procure RA Contractor	70ed	4/5/97	6/14/97
Initiate RA	0ed	6/14/97	6/14/97

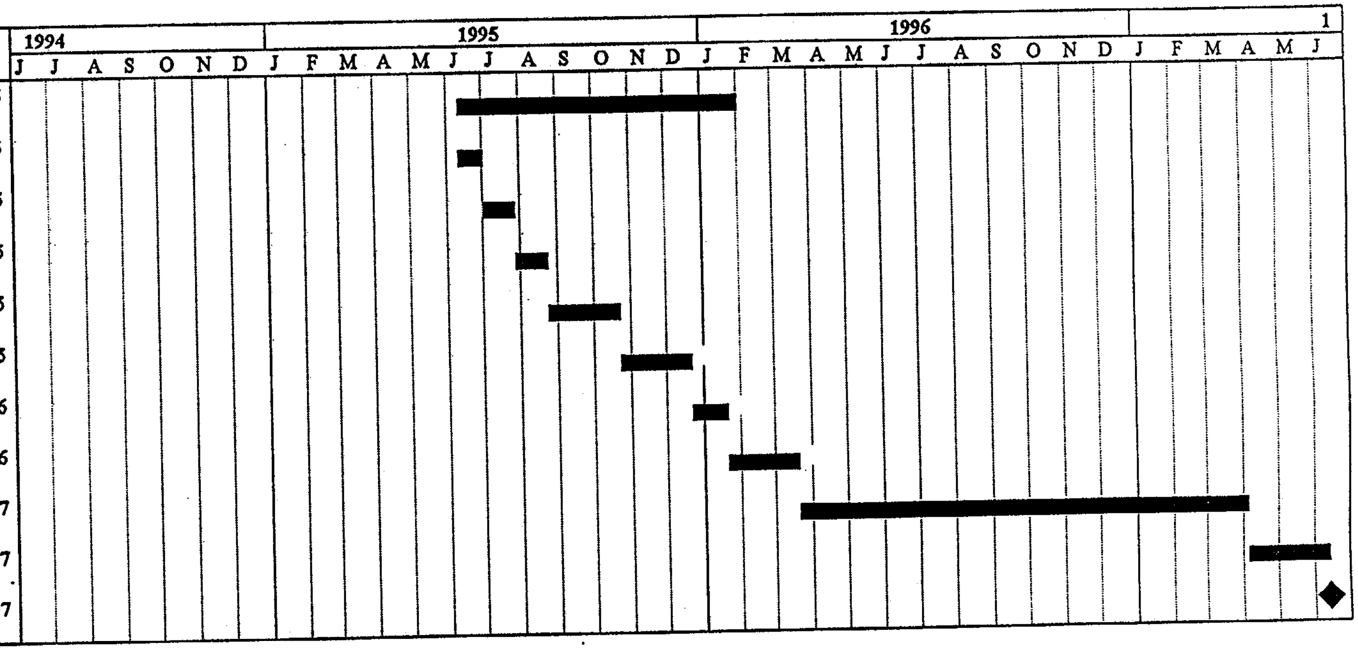


Figure 6 - 3 Project Schedule
Operable Unit No. 12 (Site 3)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
Notice to Proceed	0ed	9/24/94	9/24/94
Mobilization	30ed	9/24/94	10/24/94
Environmental Field Investigation	79ed	10/24/94	1/11/95
Sample Analysis / Validation	159ed	10/24/94	4/1/95
Data Evaluation	28ed	4/1/95	4/29/95
Risk Assessment	48ed	4/29/95	6/16/95
RI Report	200ed	4/1/95	10/18/95
Preliminary Draft RI Report	53ed	3/27/95	5/19/95
Comment Period	30ed	5/19/95	6/18/95
Draft RI Report	30ed	6/18/95	7/18/95
Comment Period	60ed	7/18/95	9/16/95
Draft Final RI Report	60ed	9/16/95	11/15/95
Comment Period	30ed	11/15/95	12/15/95
Final RI	30ed	12/15/95	1/14/96
FS Report / PRAP	260ed	5/1/95	1/16/96
Preliminary Draft FS / PRAP	49ed	5/1/95	6/19/95
Comment Period	28ed	6/19/95	7/17/95
Draft FS / PRAP	30ed	7/17/95	8/16/95
Comment Period	60ed	8/16/95	10/15/95
Draft Final FS / PRAP	60ed	10/15/95	12/14/95
Comment Period	30ed	12/14/95	1/13/96
Final FS / PRAP	30ed	1/13/96	2/12/96
Public Comment Period	30ed	2/12/96	3/13/96

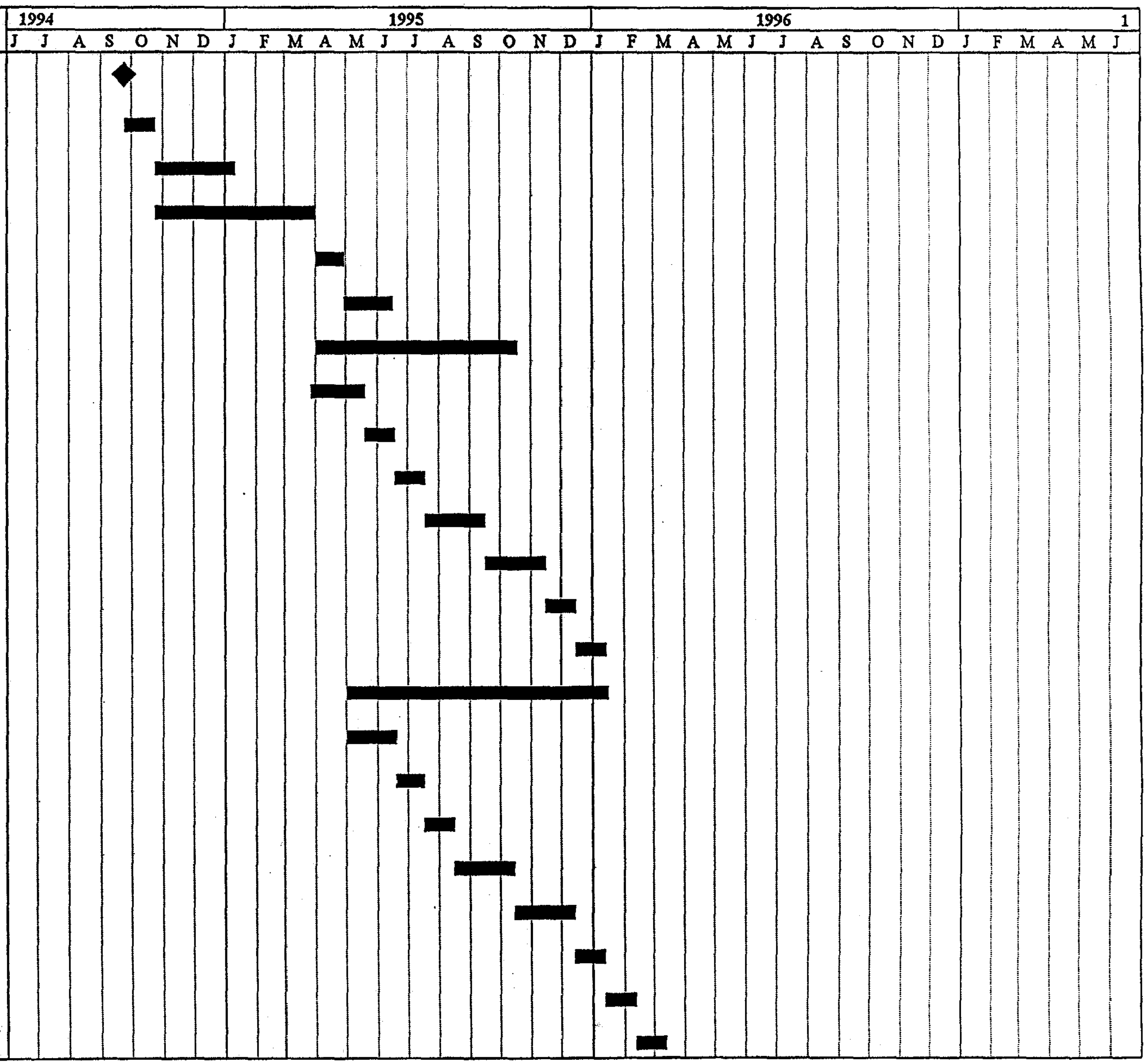
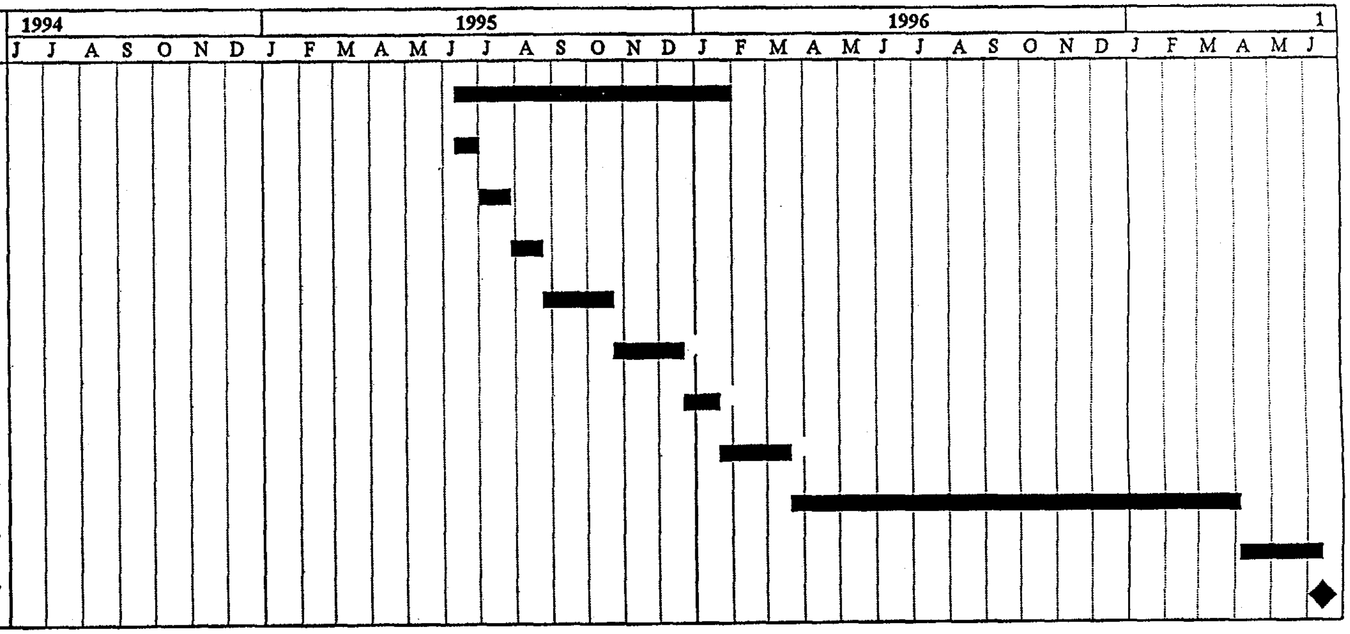


Figure 6 - 3 Project Schedule

Operable Unit No. 12 (Site 3)
MCB Camp Lejeune, NC

Task	Days	Start	Finish
ROD	236ed	6/11/95	2/2/96
Preliminary Draft ROD	21ed	6/11/95	7/2/95
Comment Period	26ed	7/2/95	7/28/95
Draft ROD	27ed	7/28/95	8/24/95
Comment Period	60ed	8/24/95	10/23/95
Draft Final ROD	60ed	10/23/95	12/22/95
Comment Period	30ed	12/22/95	1/21/96
Final ROD	60ed	1/21/96	3/21/96
Remedial Design	380ed	3/21/96	4/5/97
Procure RA Contractor	70ed	4/5/97	6/14/97
Initiate RA	0ed	6/14/97	6/14/97



FINAL

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
FIELD SAMPLING AND ANALYSIS PLAN
FOR OPERABLE UNIT NO. 8 (SITE 16)
OPERABLE UNIT NO. 11 (SITES 7 AND 80)
OPERABLE UNIT NO. 12 (SITE 3)
MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0233

OCTOBER 2, 1994

Prepared for:

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

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

TABLE OF CONTENTS

Page

1.0 INTRODUCTION ... 1-1

2.0 SITE BACKGROUND ... 2-1

3.0 SAMPLING OBJECTIVES ... 3-1

4.0 SAMPLING LOCATIONS AND FREQUENCY ... 4-1
4.1 Operable Unit No. 8 (Site 16) - Montford Point Burn Dump ... 4-1
4.1.1 Surveying ... 4-1
4.1.2 Soil Investigation ... 4-1
4.1.3 Groundwater Investigation ... 4-3
4.1.4 Surface Water and Sediment Investigation ... 4-3
4.2 Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump ... 4-4
4.2.1 Surveying ... 4-4
4.2.2 Soil Investigation ... 4-4
4.2.3 Groundwater Investigation ... 4-5
4.2.4 Surface Water and Sediment Investigation ... 4-6
4.3 Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area ... 4-7
4.3.1 Surveying ... 4-7
4.3.2 Soil Investigation ... 4-8
4.3.3 Groundwater Investigation ... 4-9
4.4 Operable Unit No. 12 (Site 3) - Old Creosote Plant ... 4-10
4.4.1 Surveying ... 4-10
4.4.2 Soil Investigation ... 4-10
4.4.3 Groundwater Investigation ... 4-11
4.5 QA/QC Samples ... 4-12
4.6 Investigative Derived Wastes ... 4-13

5.0 SAMPLE DESIGNATION ... 5-1

6.0 INVESTIGATIVE PROCEDURES ... 6-1
6.1 Soil Sample Collection ... 6-1
6.1.1 Soil Borings Advanced by Hand Auger ... 6-1
6.1.2 Soil Borings and Monitoring Well Boreholes ... 6-1
6.1.3 Test Pits ... 6-3
6.2 Monitoring Well Installation ... 6-4
6.3 In Situ Slug Testing ... 6-9
6.4 Groundwater Sample Collection ... 6-11
6.4.1 Groundwater Samples Collected from Monitoring Wells ... 6-11
6.5 Surface Water Sample Collection ... 6-12
6.6 Sediment Sample Collection ... 6-13

TABLE OF CONTENTS
(CONTINUED)

Page

6.7 Ecological Sampling 6-14
6.7.1 Biota Sampling 6-14
6.7.2 Earthworm Bioassays 6-16
6.8 ENSYS Testing 6-18
6.9 Decontamination 6-18
6.10 Monitoring and Data Collection Equipment 6-18
6.11 Land Survey 6-19
6.12 Investigation Derived Waste Handling 6-19
6.12.1 Responsibilities 6-19
6.12.2 Sources of Investigation Derived Wastes 6-20
6.12.3 Designation of Potentially Hazardous and Nonhazardous Investigative Derived Wastes 6-20
6.12.4 Investigation Derived Waste Sampling and Analysis 6-21
6.12.5 Labeling 6-21
6.12.6 Container Log 6-22
6.12.7 Container Storage 6-22
6.12.8 Container Disposition 6-22
6.12.9 Disposal of Contaminated Materials 6-22

7.0 SAMPLE HANDLING AND ANALYSIS 7-1
7.1 Sample Preservation and Handling 7-1
7.2 Chain-of-Custody 7-1
7.3 Field Logbook 7-1

8.0 SITE MANAGEMENT 8-1
8.1 Field Team Responsibilities 8-1
8.2 Reporting Requirements 8-1

9.0 REFERENCES 9-1

LIST OF TABLES

Number

7-1 Summary of Sampling and Analytical Objectives

LIST OF FIGURES

Number

4-1 Site 16 Soil, Surface Water, and Sediment Investigations
4-2 Site 16 Trench Investigation
4-3 Site 16 Groundwater Investigation
4-4 Site 7 Soil Investigation
4-5 Site 7 Groundwater Investigation
4-6 Site 7 Ecological Investigation
4-7 Site 80 Soil Investigation
4-8 Site 80 Groundwater Investigation
4-9 Site 3 Soil Investigation - North Area
4-10 Site 3 Soil Investigation - South Area
4-11 Site 3 Groundwater Investigation

6-1 Type II Shallow Monitoring Well Construction Diagram
6-2 Type II Intermediate Monitoring Well Construction Diagram

LIST OF APPENDICES

A	Soil and Rock Sample Acquisition
B	Test Pit and Trench Excavation
C	Monitoring Well Installation
D	Slug Testing
E	Groundwater Sample Acquisition
F	Surface Water and Sediment Sample Acquisition
G	Benthic Macroinvertebrate Ponar Sampling
H	Gill Net Procedures
I	ENSYS PAH Field Screening
J	Decontamination of Sampling and Monitoring Equipment
K	Decontamination of Drilling Rigs and Monitoring Well Materials
L	On-Site Water Quality Testing
M	Water Level, Water-Product Level, and Well Depth Measurements
N	Photoionization Detector
O	Bacharach Combustible Gas/Oxygen Meter and Personal Gas Monitor Carbon Monoxide Meter
P	Land Survey
Q	Wastewater Sample Acquisition
R	Sample Preservation and Handling
S	Chain-of-Custody
T	Field Logbook

1.0 INTRODUCTION

This Field Sampling and Analysis Plan (FSAP) presents the proposed Remedial Investigation (RI) field activities that are to be conducted at the following Operable Units (OU) at Marine Corps Base, Camp Lejeune, North Carolina:

- Operable Unit No. 8 (Site 16) - Montford Point Burn Dump
- Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump
- Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area
- Operable Unit No. 12 (Site 3) - Old Creosote Plant

The primary purpose of the FSAP is to provide guidance for all project field activities by describing in detail the sampling and data collection methods to be used to implement the various field tasks identified in the Remedial Investigation/Feasibility Study (RI/FS) Work Plan for Sites 16, 7, 80, and 3. This document also helps to ensure that project activities are carried out in accordance with U.S. Environmental Protection Agency (USEPA) Region IV and Naval Energy and Environmental Support Activity (NEESA) practices, so that data obtained during the field investigation are of sufficient quantity and quality to evaluate the nature and extent of contamination in various media, estimate human health and environmental risks, and to evaluate potential technologies for remediation of contaminated media.

2.0 SITE BACKGROUND

A description of the history and setting of Marine Corps Base (MCB), Camp Lejeune and the four study sites (Sites 16, 7, 80, and 3) is contained in Section 2.0 of the RI/FS Work Plan.

3.0 SAMPLING OBJECTIVES

The sampling and data quality objectives (DQOs) for field investigations at Sites 16, 7, 80, and 3 are summarized in Section 3.0 of the RI/FS Work Plan.

4.0 SAMPLING LOCATIONS AND FREQUENCY

This section of the FSAP describes the location and frequency of environmental samples to be collected during the sampling program for each of the four RI/FS sites. Support activities, sampling locations, sample matrix, and constituents to be analyzed for are discussed within this section. Detailed investigation procedures, sample handling, and analytical requirements are provided in Sections 6.0 and 7.0, respectively.

4.1 Operable Unit No. 8 (Site 16) - Montford Point Burn Dump

The following investigations and support activities will be conducted at Site 16:

- Surveying
- Soil Investigation
- Groundwater Investigation
- Surface Water and Sediment Investigation

Each activity and investigation is described in the following subsections.

4.1.1 Surveying

The site survey will involve the surveying of the current site features, including main roads, nearby buildings, and Northeast Creek; the cleared area; access road to the former burn dump; storm sewer line location and right-of-way; and the fire break.

Prior to commencing the field sampling program, a 150 foot by 100 foot grid will be established within the former burn dump as shown on Figure 4-1. The sampling points within the grid will be surveyed in place and flagged. This will allow the location of the soil sampling points to be determined in the field.

Following the completion of the field program, the location of the four test pit excavations will be surveyed. The length, elevation of both endpoints, and location of each excavation will be surveyed and plotted on a site map.

The location and elevation of a reference point on top of the PVC riser, and elevation of ground surface will be surveyed for each monitoring well. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

4.1.2 Soil Investigation

A soil investigation will be conducted at Site 16 to characterize soil quality at the site and to determine the presence or absence of waste materials within the boundary of the former burn dump. Soil samples will be collected from soil borings (using split-spoon samplers) and hand auger locations to identify and characterize potential soil contamination.

4.1.2.1 Sampling Locations

A series of soil borings will be performed within the boundary of the former burn dump. The soil borings will be drilled using hollow stem augers. A 150 foot by 100 foot sampling grid will be established within the former burn dump. A total of twenty-two (22) borings will be drilled to a depth of approximately 10 feet (or to the top of the groundwater table) to determine the shallow stratigraphy at the site and to collect samples for laboratory analysis. Two (2) soil samples from each soil boring will be submitted for chemical analysis. These samples will be collected from the surface (0 to 12 inches) and just above the groundwater table. It is estimated that the water table is within ten (10) feet of the ground surface. A mid-depth sample may be collected from these soil borings based on field observations and/or monitoring instrument readings.

Soil borings will also be performed at each of the proposed six (6) groundwater monitoring well locations. A minimum of two (2) soil samples will be collected from each of the well locations and submitted for laboratory analysis. The samples will be collected from the surface and just above the groundwater table.

Four (4) hand auger locations will be drilled and sampled southeast of the site. One location is where there is a break in the trees at the southeast corner of the former burn dump and a second location is to the southeast where there is evidence of surface drainage wash. The remaining two hand auger locations will be drilled south of the storm sewer right-of-way leading towards Northeast Creek. Two soil samples (a surficial sample and 3 to 4 feet below ground surface) will also be collected from each of these locations for laboratory analysis.

Four trenches will be excavated within the boundary of the former burn dump to investigate the existence of any remaining trash or debris. The trench locations will be based on visual observations or field instrument screening of the soil borings. These trenches will be approximately twenty (20) feet in length and to a depth of ten (10) feet or to the top of the water table (whichever is encountered first). No soil samples are scheduled to be collected from the trenches for laboratory analyses; however, if potential contamination or elevated HNu readings are detected during the excavation of the trench, then one soil sample per trench will be collected and submitted for analysis. The proposed locations of the trenches are shown on Figure 4-2. These locations may be changed during the field program based on findings of the soil boring program.

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) sample will be submitted for analysis. The three background soil borings will be located to the northwest and west of the former burn dump, within the woods.

The locations of the soil borings and hand augers are shown on Figure 4-1.

Section 6.1 presents details on procedures for collecting soils samples from hand augers and soil boring locations, and from test trenches.

4.1.2.2 Analytical Requirements

All soil samples will be analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) metals in accordance with Contract Laboratory Program (CLP) methods.

4.1.3 Groundwater Investigation

A groundwater investigation will be conducted at Site 16 to determine the presence or absence of contamination in the surficial aquifer resulting from burning and disposal activities. Six (6) shallow groundwater monitoring wells are proposed for this investigation. One well (16-MW01) will serve as an upgradient, background well. Three shallow wells (16-MW02, 16-MW03, and 16-MW04) will be installed downgradient of the site to assess off-site groundwater quality. Two shallow wells (16-MW05 and 16-MW06) will be installed within the boundary of the former burn dump, and their locations will be determined in the field based on field observations and/or HNu readings taken during the drilling of the test borings. All newly installed wells will be approximately 20 feet deep and will be constructed of 2-inch I.D. PVC pipe, with 15 feet of 0.01-inch slot well screen. Section 6.2 presents specific details on procedures for monitoring well installations. The proposed locations are shown on Figure 4-3.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the surficial aquifer. In situ slug tests will be conducted at three of the new well locations to evaluate horizontal hydraulic conductivity. Rising and/or falling head tests will be performed. Water level recovery data will be evaluated using the most appropriate analysis method for each location. Section 6.3 presents specific details on the procedures for performing in situ slug tests.

4.1.3.1 Sampling and Analysis

Two rounds of groundwater samples will be collected from the newly installed monitoring wells using bailers. The first round of samples will be collected approximately one week following the development of the wells. The second round will be collected approximately three months following the first sampling round. Details on the procedures for collecting groundwater samples are presented in Section 6.4.

Groundwater samples collected for this investigation will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

4.1.4 Surface Water and Sediment Investigation

A surface water and sediment investigation will be conducted at Site 16 to assess the possible impact of the former burn dump on Northeast Creek. The following provides a description of the proposed investigation.

4.1.4.1 Sampling and Analysis

Five (5) surface water and sediment sampling stations are proposed along Northeast Creek. Three of the sampling stations will be spaced approximately 400 feet along the creek south of the former burn dump. One surface water and sediment sampling station will be located one-quarter mile upstream from the burn dump and the remaining sampling location will be one-quarter mile downstream from the burn dump. One surface water and two sediment samples will be collected from each sampling station. Sediment samples will be collected from depths of 0 to 6 inches and 6 to 12 inches, and submitted for laboratory analysis. The proposed locations for the surface water and sediment sampling stations are shown on Figure 4-1. Details on the procedures for collecting surface water and sediment samples are presented in Sections 6.5 and 6.6, respectively.

All surface water and sediment samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods. Surface water samples will be analyzed in the field for dissolved oxygen. Sediment samples will also be analyzed in the laboratory for Total Organic Carbon (TOC) and grain size distribution.

Staff gauges will be installed in Northeast Creek to assess tidal influences. A data logger and transducer will be set up and installed in Northeast Creek and also two of the installed monitoring wells to measure groundwater levels over a two to four day period to assess tidal influences.

4.2 Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump

The following investigations and activities will be conducted at Site 7:

- Surveying
- Soil Investigation
- Groundwater Investigation
- Surface Water and Sediment Investigation
- Biota Study
- Earthworm Bioassay Study

Each activity and investigation is described in the following subsections.

4.2.1 Surveying

The site survey tasks will include the establishment of a 300 foot by 300 foot grid along the northwestern boundary of the study area along the slope of the former dump. Within the two identified potential areas of concern (i.e., the "cleared area" and south of the community center) a 150 foot by 150 foot sampling grid will also be established.

Following completion of the field program, the location of the five test pit excavations will be surveyed. The length, elevation of both endpoints, and location of each excavation will be surveyed and plotted on a site map.

All existing and newly installed groundwater monitoring wells will be surveyed for location and elevation of a reference point on top of the PVC riser, and elevation of the ground surface. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

4.2.2 Soil Investigation

The soil investigation at Site 7 will be conducted to define the types and extent of potential contamination within the soil at the site. The activities associated with the investigation are as follows.

4.2.2.1 Sampling Locations

Up to five (5) trenches/test pits will be excavated using a backhoe in the southwestern corner of the study area, where surficial debris was observed during the 1994 site visit, to determine the type of trash/debris that has been disposed of at this dump site. Trenches will be approximately 20 feet in length and excavated to a depth of 10 feet or to the top of the groundwater table. One subsurface soil sample will be collected from each trench location at visual signs of contamination or just above the groundwater table. Additionally, five sampling locations will be drilled with hand augers in the southwest area to collect samples for analysis. Samples will be submitted from the surface (0 to 12 inches) and just above the water table.

Twelve soil borings will be performed in the area of the right-of-way using a drill rig and hollow stem augers. These soil borings will be drilled using hollow stem augers. The remaining eleven soil sampling locations within the 300 foot by 300 foot and 150 foot by 150 foot sampling grids are not accessible to a drill rig due to marshy conditions. These locations will be sampled using hand augers. Soil characterization within these grid areas will consist of one surface soil sample and one subsurface soil sample per grid location. Surface soil samples will be collected from a depth of 0 to 12 inches using hand augers. The subsurface soil sample will be collected from a depth just above the groundwater table, which is estimated to be approximately 5 feet bgs. Two locations inside the Community Center playground will be sampled from 0 to 12 inches and submitted for analysis.

Soil samples will also be collected during the drilling of the two permanent groundwater monitoring well test borings. Two soil samples will be collected from each permanent well location at depths of 0 to 12 inches and just above the groundwater table for analysis.

Three additional borings will be sampled as background locations. These borings are located north of the study area. One surficial sample and one subsurface (just above the water table) sample will be submitted for analysis.

Section 6.1 provides detailed procedures for soil sample collection from hand auger and soil boring locations, and test pits. Trench, soil borings, hand auger and monitoring well test boring locations are shown on Figure 4-4.

4.2.2.2 Analytical Requirements

All soil samples will be submitted for laboratory analysis of full TCL organics and TAL metals in accordance with CLP methods.

4.2.3 Groundwater Investigation

A groundwater investigation will be conducted to assess the potential impact of the disposal activities on the shallow aquifer. The groundwater investigation will consist of installing two shallow groundwater monitoring wells and three temporary shallow monitoring wells. One permanent shallow monitoring well (7-MW05) will be installed in the southern portion of the study area. The second permanent well (7-MW04) will be installed north of the water treatment plant to assess background groundwater quality. Two temporary wells (7-TW01 and 7-TW02) will be positioned in the southwestern portion of the study area, where access with a drill rig is restricted due to the marshy conditions. The third temporary well (7-TW03) will be installed at a location of one of the soil borings south of the Community Center, based on field observations of potential contaminants. The proposed monitoring well locations are shown on Figure 4-5.

Groundwater monitoring wells will be constructed of 2-inch I.D. PVC pipe, with 15 feet of 0.01-inch slot well screen. Section 6.2 provides details on groundwater monitoring well installation procedures.

Information and data will be obtained from the UST investigation identified north/northwest of the Community Center. This information will be used as a comparison to groundwater analysis from newly installed wells at Site 7 to identify potential on site migration of chemicals of potential concern.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the surficial aquifer. In situ slug tests will be conducted at two existing wells and one newly installed well to evaluate horizontal hydraulic conductivity. Rising and/or falling head tests will be performed. Water level recovery data will be evaluated using the most appropriate analysis method for each location. Section 6.3 presents specific details on the procedures for performing in situ slug tests.

4.2.3.1 Sampling and Analysis

One round of groundwater samples will be collected from the three existing, two newly installed and three temporary shallow monitoring wells using bailers. The samples will be collected approximately one week following the development of the wells. A second round of groundwater samples may be collected and analyzed depending on the results of the proposed round of analyses. This additional round of analyses will be based on chemicals of potential concern (COPC) detected in the initial round. Details on the procedures for collecting groundwater samples are presented in Section 6.4.

All groundwater samples will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

4.2.4 Surface Water and Sediment Investigation

Potential impacts to surface water/sediment have not been assessed. There are three surface water bodies within Site 7. A surface water and sediment investigation will be conducted on each of these surface water bodies. The proposed investigation will include: Northeast Creek, the west and east tributaries of Northeast Creek, and the drainage ditch associated with the western tributary.

4.2.4.1 Sampling and Analysis

Six sampling stations are proposed for Northeast Creek. The sampling stations are spaced approximately 600 feet apart beginning upstream of the site and extending to the water treatment plant. At each sampling station, one surface water and two sediment samples (one surface sample from 0 to 6 inches and one subsurface sample from 6 to 12 inches) will be collected using stainless steel trowels, spoons, or augers.

A surface water and sediment investigation will be conducted in the western and eastern tributaries to Northeast Creek. Samples will be collected from three sampling stations in the west tributary and from two sampling stations in the east tributary. At each sampling station, one surface water and one surface sediment (0 to 6 inches) sample will be collected.

Two surface water and sediment sampling stations are proposed for the drainage ditch which feeds the western tributary to Northeast Creek. One surface water and one surface sediment (0 to 6 inches) sample will be collected at each station.

A sediment investigation will be conducted in the marsh area in the southern portion of the study area. Two sediment samples will be collected from four sampling stations. Sediment samples will be collected from the surface (0 to 6 inches) and the subsurface (6 to 12 inches) at each station.

Details on the procedures for collecting surface water and sediment samples are provided in Sections 6.5 and 6.6, respectively.

All surface water and sediment samples will be analyzed for TCL organics and TAL metals in accordance with CLP methods. Surface water samples will be analyzed in the field for dissolved oxygen. Sediment samples will also be analyzed in the laboratory for TOC and grain size distribution.

In addition to the surface water and sediment investigation, benthic samples will be collected in Northeast Creek and the western tributary to Northeast Creek. Samples will be collected from three stations in the tributary and four stations in Northeast Creek. An earthworm bioassay will be conducted in the areas known to have exhibited PCB concentrations. A gill net will be positioned where the west tributary feeds Northeast Creek in order to determine how significant an ecological area this tributary is. Section 6.7 provides details for the Ecological Studies.

Placement of staff gauges within the west and east tributaries of Northeast Creek are proposed. This will enable an assessment of possible tidal influences within the site from Northeast Creek. A data logger and transducer will be set up and installed in Northeast Creek and also in one monitoring well to measure water levels over a two to four day period to assess tidal influences.

Figure 4-6 presents the proposed sampling stations for the surface water, sediment, and benthic investigations.

4.3 Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area

The following investigations and activities will be conducted at Site 80:

- Surveying
- Soil Investigation
- Groundwater Investigation

Each activity and investigation is described in the following subsections.

4.3.1 Surveying

A site survey will be performed to establish the location and relationships of site features (such as buildings, the wash pad and sump, and the configuration of the soil mounds area), and existing groundwater monitoring wells. All existing and newly installed groundwater monitoring wells will be surveyed to establish location and elevation of a reference point on top of the PVC riser, and elevation of the ground surface. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

4.3.2 Soil Investigation

The objectives of the soil investigation are to delineate the vertical and horizontal extent of potential contaminants in four areas of concern (lawn area around the wash pad and sump, the soil mounds located in the northeast corner of the site, the "open area" near the soil mounds, and the soil where drums were formerly located). The activities associated with the investigation are as follows.

4.3.2.1 Sampling Locations

A soil investigation will be conducted in the lawn area adjacent to the collection sump and concrete wash pad. Seven test borings will be augered with a drill rig, and samples collected with a split-spoon sampler to characterize the soils in this area. One surface soil sample (depth 0 to 12 inches) and one subsurface soil sample (depth just above the groundwater table) will be collected from each location for laboratory analysis. The depth to groundwater is estimated to be between 8 and 12 feet below ground surface (bgs).

A total of four borings will be drilled and sampled between Buildings 1916 and 600, and west of Building 1916. Two soil samples will be collected from each boring (one surficial and one subsurface sample just above the water table) and submitted for analysis.

A total of seven test borings will be drilled with hollow stem augers in the "open area" adjacent to the soil mounds in the northeast corner of the study area. Test borings will be drilled using a drill rig, and samples collected with a split-spoon sampler. One surface soil and one subsurface soil sample will be collected from each boring for laboratory analysis. Surface soil samples will from a depth of 0 to 12 inches. Subsurface soil samples will be collected from a depth just above the groundwater table.

A soil investigation will be conducted within the soil mounds in the northeast corner of the study area. One surface soil sample will be collected from ten random areas. Surface soil samples will consist of sampling soils to a depth not to exceed 12 inches. In addition, one subsurface soil sample will be collected from three areas within the mounds. Subsurface soil samples will be collected at a depth of eight feet, which is the approximate depth to the original ground surface. Due to access restrictions, a drill rig will not be used to collect the subsurface samples. These will be obtained by employing a power auger to drill to depth, and using a hand auger to collect the analytical sample.

A soil investigation will be conducted in the area where two drums were formerly located north of the maintenance building. One surface soil sample will be collected from each of two locations using hand augers.

Soil samples will be collected during the drilling of the five monitoring well borings. Two soil samples will be collected per test boring for submittal for laboratory analysis. These samples include a surface sample (0 to 12 inches) and one just above the groundwater table.

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) will be submitted for analysis. The three background soil borings will be located to the east, southeast, and south of the maintenance area.

Details are provided in Section 6.1 on the procedures for collecting soil samples from hand augers, soil borings, and test trenches.

Proposed soil sampling locations are presented on Figure 4-7.

4.3.2.2 Analytical Requirements

All soil samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods.

4.3.3 Groundwater Investigation

The groundwater investigation will consist of the installation of four shallow groundwater monitoring wells to an estimated depth of 20 feet. One intermediate depth well will be installed near existing well 80MW03. This well will be approximately 40 to 50 feet deep. The intermediate well and one shallow well will be installed first during the RI program at the site to facilitate groundwater sampling and laboratory analysis on a "quick turnaround" to determine extent of contamination. Figure 4-8 presents the proposed locations for the groundwater monitoring wells.

Groundwater monitoring wells will be constructed of 2-inch I.D. PVC pipe, with 15 feet of 0.01-inch slot well screen. Details on the procedures for monitoring well installation are presented in Section 6.2.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the aquifers. In situ slug tests will be conducted at three newly installed shallow wells and the newly installed intermediate well to evaluate horizontal hydraulic conductivity. Rising and/or falling head tests will be performed. Water recovery data will be evaluated using the most appropriate analysis method for each location. Section 6.3 presents specific details on the performance of in situ slug tests.

4.3.3.1 Sampling and Analysis

One round of groundwater samples will be collected from all existing and newly installed monitoring wells. The samples will be collected approximately one week following the development of the newly installed monitoring wells using bailers. A second round of groundwater samples may be collected and analyzed depending on the results of the proposed round of analyses. This additional round of analyses will be based on COPCs detected in the initial round. Section 6.4 provides specific details on the procedures for collecting groundwater samples.

All groundwater samples will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

4.4 Operable Unit No. 12 (Site 3) - Old Creosote Plant

The following investigations and activities will be conducted at Site 3:

- Surveying
- Soil Investigation
- Groundwater Investigation

Each activity and investigation is described in the following subsections.

4.4.1 Surveying

A site survey will be performed to establish the location and relationships of site features (such as concrete pads and the chimney), and existing groundwater monitoring wells. A 200 foot by 200 foot sampling grid will be established in the northern portion of the study area. In the southern portion of the study area, a 50 foot by 50 foot sampling grid will be established around the former creosote treatment area. All existing and newly installed groundwater monitoring wells will be surveyed to establish location and elevation of a reference point on top of the PVC riser, and the elevation of the ground surface. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

4.4.2 Soil Investigation

The activities associated with the soil investigation are as follows.

4.4.2.1 Sampling Locations

In the northern portion of the study area, surface soil samples (0 to 12 inches) will be collected from the nine points on the established sampling grid and from the four centers of the grid quadrants. Soil samples will be collected using hand augers.

The soil investigation in the southern portion of the study area will consist of a total of 35 sampling points. These sampling points are distributed on the established sampling grid (25 locations), around the two concrete pads (8 locations), and along the estimated alignment of the railroad spur (2 locations) to the treatment area. All soil samples from the southern portion of the study area will be collected using hand augers from a depth of 0 to 12 inches.

The surficial soil samples collected from the north and south areas of Site 3 will be analyzed in the field using the ENSYS field screening kits for PAHs and creosote. ENSYS sampling locations that detect PAHs and/or creosote will be expanded north, east, south, and west of the original sampling point to delineate the extent of potential contaminants. The sampling point will be extended 10 feet in the four directions and analyzed. If contaminants are detected at the new locations, sampling will be extended another 10 feet. When an extended sampling point is "nondetect," sampling will be moved back 5 feet and analysis performed. No further sampling and analysis will be done after this point. Ten percent of the samples with concentrations below the established soil screening action levels will be submitted from the north and south areas to the laboratory for confirmatory analysis.

In areas delineated as containing potential contaminants, a soil boring will be performed with samples collected at the surface, just above the water table and at the mid-depth, and submitted for laboratory analysis. The number of confirmatory soil borings will be determined by the field geologist in consultation with the site manager and project manager.

Soil samples will be collected during the drilling of monitoring well borings. A maximum of three soil samples will be submitted per test boring. These samples will include a surficial soil (0 to 12 inch depth) and two subsurface soil samples to be obtained from just above the water table and at mid-depth.

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) will be submitted for analysis.

Details on the procedures for collecting soils samples from hand auger and soil borings are provided in Section 6.1.

Figures 4-9 and 4-10 present the locations of the proposed soil sampling points in the northern and southern portions of the study area, respectively. Figure 4-11 presents the location of the proposed monitoring wells.

4.4.2.2 <u>Analytical Requirements</u>

All surface soil samples from both the northern and southern portions of the study area will be analyzed in the field using ENSYS PAH Soil Sensitivity and ENSYS Petro Soil test kits to detect PAHs and total creosote, respectively. Sample locations where levels of PAHs and/or creosote are above detection limits for the ENSYS test kits (1 μg/kg and 10 μg/kg) will be expanded to determine the horizontal extent of the constituents. Based on the quantitative findings of these immunoassay-based testing methods, soil borings will be performed in the center of areas showing positive results for PAHs and/or total creosote, and samples submitted from the surface (0 to 12 inch depth), above the groundwater table, and at a mid-depth (if determined by the field geologist to be warranted) for confirmatory laboratory analysis. In addition, ten percent of soil samples reported as nondetect will be submitted for laboratory analysis. Details on the procedures for ENSYS testing are provided in Section 6.7.

Soil samples collected from three of the shallow monitoring well locations will be submitted for analysis of TCL semivolatile organics. The soil samples collected from one shallow well and the intermediate monitoring well test boring will be analyzed for full TCL organics and TAL metals in accordance with CLP methods.

One composite soil sample will be collected from a shallow monitoring well test boring and submitted for engineering parameters analysis. This analysis will include particle-size distribution, Atterberg limits, bulk density, soil porosity, and TOC.

4.4.3 Groundwater Investigation

The groundwater investigation will consist of the installation of four shallow monitoring wells (estimated depth of 20 feet) and one intermediate depth monitoring well (40 to 50 feet), adjacent to existing shallow monitoring well 03MW02. The locations of the proposed groundwater monitoring wells are presented on Figure 4-11.

Groundwater monitoring wells will be constructed of 2-inch I.D. PVC pipe, with 15 feet of 0.01-inch slot well screen. Section 6.2 provides details on monitoring well installation.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the aquifers. In situ slug tests will be conducted at three newly installed shallow monitoring wells and the newly installed intermediate well to evaluate horizontal hydraulic conductivity. Rising and/or falling head tests will be performed. Water level recovery data will be evaluated using the most appropriate analysis method for each location. Section 6.3 presents details on the performance of in situ slug tests.

4.4.3.1 Sampling and Analysis

One round of groundwater samples will be collected from 3 existing and 4 newly installed shallow monitoring wells, and one newly installed intermediate well using bailers. The samples will be collected approximately one week following the development of the wells. Three shallow groundwater samples will be analyzed for TCL semivolatile organics in accordance with CLP methods. The groundwater sample collected from one shallow well and the intermediate well will be collected first at Site 3 and submitted under 7 day "quick turnaround" for analysis. Analysis will be for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods. Details are provided in Section 6.4 on collecting groundwater samples.

A groundwater sample will be collected from a shallow monitoring well and submitted for analysis of engineering parameters. These parameters consist of microbial count, BOD, COD, NH_4, and alkalinity.

4.5 QA/QC Samples

QA/QC requirements for this investigation are presented in the Quality Assurance Project Plan (QAPP) which is provided as Section II of this FSAP. The following QA/QC samples will be collected at each of the four sites during field sampling activities:

- Trip Blanks

  Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the volatile organic analysis (VOA) samples. One trip blank should accompany each cooler containing samples for volatile organic analysis. The blanks should only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory.

- Equipment Rinsates (Equipment Blanks)

  Equipment rinsates are defined as samples which are obtained by running organic-free water over/through sample collection equipment after it has been cleaned. Equipment rinsates will be collected daily during each sampling event. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsates, the remaining samples must be analyzed. The results from the rinsates will be used to evaluate the decontamination methods. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples.

One equipment rinsate will be collected per day of field sampling.

- Field Blanks

  Organic-free water is taken to the field in sealed containers and poured into the appropriate sample containers at pre-designated locations. This is done to determine if any contaminants present in the area may have an effect on sample integrity. Field blanks should not be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled.

  Two field blanks (ambient condition blanks) will be prepared at the commencement of each sampling event. The field blanks will be prepared by pouring organic-free water directly into a set of sample bottles.

- Field Duplicates

  Field duplicates for soil samples are collected, homogenized, and split. All samples except VOAs are homogenized and split. Volatiles are not mixed, but select segments of soil are taken from the length of the core and placed in 4-ounce glass jars. The duplicates for water samples should be collected simultaneously. The water samples will not be composited.

  Field duplicates will be collected at a frequency of 10 percent.

- Matrix Spike/Matrix Spike Duplicates (MS/MSD)

  MS/MSD samples are collected to evaluate the matrix effect of the sample upon the analytical methodology. A matrix spike and matrix spike duplicate must be performed for each group of samples of a similar matrix

  MS/MSD samples will be collected at a frequency of 5 percent.

4.6 Investigation Derived Waste Handling

Drill cuttings or excavated soils will be collected and contained in drums or roll-off boxes, if they are determined in the field to be potentially contaminated based on visual observations and HNu readings. One roll-off box will be assigned to Site 16 and one to Site 7 to contain excavated soils from the trench excavations. A rigid storage tank with a capacity of 1000 gallons will be stationed at each site for containing groundwater development and purge water. A composite soil sample from each roll-off box and from the drums at the individual sites will be collected and analyzed for full TCLP (organics and inorganics) and RCRA hazardous waste characterization (corrosivity, reactivity, and ignitability). One sample will be collected from each tank and analyzed for full TCL organics and TAL inorganics. Additional details regarding IDW handling and disposal are provided in Section 6.12.

5.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the area within the site, the sample media, sampling location, the depth (soil) or round (groundwater) of sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site#-Location-Media/Station# or QA/QC-Depth/Round

An explanation of each of these identifiers is given below.

Site#	This investigation includes Sites 16, 7, 80, and 3.
Location	The location designation will refer to a surface feature (e.g., LA = Lawn Area) or grid (e.g., NA = Northern Area).
Media	SB = Soil Boring (soil sample from a boring) GW = Groundwater SW = Surface Water SD = Sediment TP = Test Pit
Station#	Each soil test boring or monitoring well will be identified with a unique identification number. The designation "IW" refers to an intermediate well installed below the shallow water-table aquifer. Samples that are being submitted for dissolved metals analyses will be designated by a "D" at the end of the station number designation.
QA/QC	(FB) = Field Blank (D) = Duplicate Sample (following depth/round) (TB) = Trip Blank (ER) = Equipment Rinsate
Depth/Round	Depth indicators will be used for soil samples. The number will reference the depth interval of the sample. For example: 00 = ground surface to 1 foot below ground surface 01 = 1 to 3 feet below ground surface 02 = 3 to 5 feet below ground surface 03 = 5 to 7 feet below ground surface Round indicator will be used for groundwater samples (round one and round two). For example:

Under this sample designation format the sample number 80-GW03IWD-01D refers to:

80-GW03IWD-01D	Site 80
80-GW03IWD-01D	Groundwater sample
80-GW03IWD-01D	Monitoring well #3
80-GW03IWD-01D	Intermediate well
80-GW03IWD-01D	Dissolved metals sample
80-GW03IWD-01D	Round 1
80-GW03IWD-01D	Duplicate (QA/QC) sample

The sample designation 3-NA-SB11-00D refers to:

3-NA-SB11-00D	Site 3
3-NA-SB11-00D	Northern Area
3-NA-SB11-00D	Soil Boring
3-NA-SB11-00D	Test boring #11
3-NA-SB11-00D	Sample depth interval 0 to 12"
3-NA-SB11-00D	Duplicate (QA/QC) sample

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

6.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for Sites 16, 7, 80, and 3 will be discussed in the following subsections. These procedures include soil sample collection, monitoring well installation (both shallow and intermediate), in situ slug tests, groundwater sample collection, surface water sample collection, sediment sample collection, ENSYS testing, surveying, water level measurements, decontamination procedures, and handling of site investigation derived wastes. Note that all of these procedures will follow the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), February 1, 1991. Additional guidance from other sources such as ASTM may be used, but if the ASTM and ESD methods are in conflict, the ESD procedure will be used.

6.1 Soil Sample Collection

Surface and subsurface soil samples will be collected throughout Sites 16, 7, 80 and 3. Soil samples will be collected from borings advanced by a drilling rig and during the installation of monitoring wells. Soil samples will also be collected from borings advanced by hand auger. Some soil samples will be collected from test pits (task at Sites 16 and 7) excavated by a backhoe. All ground penetrations will receive utility clearance from the appropriate on-base personnel. Appendix A contains Baker's standard operating procedures (SOPs) for soil sample acquisition.

6.1.1 Soil Borings Advanced by Hand Auger (Task at Sites 16, 7, 80 and 3)

Hand augering is the most common manual method used to collect subsurface samples. Four inch diameter augers 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. During this investigation, hand augers will be used to collect discrete grab samples of soil from the 0 to 12-inch, and just above the water table.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. Since discrete grab samples are to be collected to characterize each depth, a new bucket will 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 will be decontaminated between samples as outlined in Section 6.9.

6.1.2 Soil Borings and Monitoring Well Boreholes (Task at Sites 16, 7, 80 and 3)

Soil samples from soil borings, advanced by a drilling rig using hollow stem augers, will be collected using a split-spoon sampler. A split-spoon sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This device can be driven into unconsolidated materials using a drive weight connected to the drilling rig. A split-spoon sampler (used for performing Standard Penetration Tests) is two inches outer diameter (OD) 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. Split-spoons capable of obtaining 24-inch long samples will be utilized during this investigation.

Split-spoon samples will be collected continuously from the ground surface to the ground water table in each soil boring. Soil borings that will be converted into shallow monitoring wells (monitoring well boreholes) will be advanced approximately 12 feet below the water table. Soil borings converted into intermediate monitoring wells at Sites 80 and 3 will be advanced to a depth of approximately 40 to 50 feet bgs, based on encountering the upper unit of the Castle Hayne Formation. The physical characteristics of the samples will be described by the site geologist. The soil in the sampler will be classified according to the Unified Soil Classification System (USCS). Soil sample descriptions will be recorded in the field geologist's notebook.

Selected split-spoon samples will be submitted to the laboratory for analysis. Soil samples will be collected continuously in 2-foot increments to the top of the water table. Surface soil samples will not be collected using a split-spoon sampler because a sufficient quantity of sample cannot be retained from 0 to 12 inches using this sampling device. Hence, surface samples will be collected using a stainless-steel spoon, hand auger, or by advancing the augers and retaining the cuttings. For borings only, split-spoon samples will be collected from approximately one foot to the top of the water table; for borings advanced for monitoring well installation, split spoon samples will be collected continuously from ground surface to the top of the water table. Below the water table, soil samples will be collected at 5-foot intervals.

The following procedures for collecting soil samples in split-spoons will be used:

1. The surface sample will be collected by driving the split-spoon with blows from a 140-pound hammer falling 30 inches in accordance with SOP F102 Soil and Rock Sample Acquisition.

2. Advance the borehole to the desired depth using hollow stem auger drilling techniques. The split-spoon will be lowered into the borehole inside the hollow stem auger (this will ensure that undisturbed material will be sampled).

3. Drive the split-spoon using procedures outlined in 1 above.

4. Repeat this operation until the borehole has been advanced to the selected depth. Split-spoon samples will be collected continuously until groundwater is encountered.

5. Record in the 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 6-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 the recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil; then put into sample jars.

7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to procedures outlined in Section 6.9.

The following procedures are to be used for soil samples submitted to the laboratory:

1. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed, in a stainless steel bowl with stainless steel spoons, as 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. Discrete soil samples from different sections of the split-spoon, representative of the soil types encountered, will be placed in the sample jar with a minimum of disturbance. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.

2. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the field logbook. In addition, label, tag, and number the sample bottle(s) as outlined in Section 7.0.

3. Pack the samples for shipping. Attach seal to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 7.0).

4. Decontaminate the split-spoon sampler as described in Section 6.9. Replace disposable latex gloves between sample stations to prevent cross-contamination of samples.

6.1.3 Test Pits (Task at Sites 16 and 7)

Test pits will be excavated using a backhoe. The following procedures apply to the excavation and backfilling of a typical test pit.

- The positions of the test pits shall be located in the field by the Field Team Leader or Site Manager. Utility clearance shall be obtained from Activity personnel for all test pit locations prior to excavation.

- Excavation equipment shall be thoroughly decontaminated prior to and after each test pit excavation according to procedures outlined in ECBSOPQAM (February 1991).

- A safety zone shall be established around the test pit location prior to initiation of excavation.

- Excavation shall commence by removing lifts of no more than approximately 6 to 12-inches of soil.

- Test pit excavation will continue to a depth of 10 feet or to the water table (whichever is encountered first).

- Soil samples may be collected during the excavation. The collected sample shall consist of visually contaminated soil or soils exhibiting elevated levels of organics from monitoring instrument readings encountered during excavation. If no suspected contaminated soil is encountered, then a sample shall not be collected. Samples will be collected from the backhoe bucket using a stainless steel trowel or spoon. Samples from the backhoe bucket will be collected from the center portion of the bucket to avoid contact. These samples will be logged, packaged, and submitted to the laboratory for analysis.

- The field inspector shall log the test pit soils and record observations and the test pit cross-section shall be sketched in the Field Logbook with notable features identified.

- Test pit depths (and water levels) may be measured using an engineers rule (six foot) or a weighted measuring tape. Depths shall be measured from the ground surface.

- Upon completion, test pits shall be immediately backfilled.

- Test pit locations shall be marked with five wooden stakes; one at each corner and one in the center. The test pit number shall be recorded on the centrally located stake.

Backfilling of trenches and test pits is a normally accepted practice to reduce immediate site hazards and minimize the potential for rainwater accumulation and subsequent contaminant migration.

After inspection and completion of the appropriate test pit logs, backfill material should be returned to the pit under the direction of the field inspector. The test pit cover should be inspected and further regraded, if necessary. Where it is safe to do so, the backhoe bucket should be used to compact each one to 2-foot layer of clean backfill as it is placed, to reduce settling and compaction. Appendix B contains the SOP (F106) for Test Pit and Trench Excavations.

6.2 Monitoring Well Installation (Task at Sites 16, 7, 80 and 3)

Shallow monitoring wells will be installed to monitor the shallow (water table) water-bearing zone. It is estimated that these wells will be installed from 15 to 30 feet. Procedures for the installation and construction of shallow monitoring wells are presented below (see Figure 6-1):

- Activity personnel will approve all monitoring well locations. These locations shall be free of underground or overhead utility lines.

- A borehole will be advanced by a drilling rig using hollow stem augers. Initially, the boreholes will be advanced with 3-1/4-inch I.D. augers. After the borehole has been advanced to its final depth, the borehole will be overdrilled with 6-1/4-inch I.D. augers (for well installation only).

- Soil (split spoon) samples will be collected continuously during borehole advancement. Samples will be collected according to the procedures outlined in Section 6.1.2.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed (inside the hollow stem augers).

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. USEPA Region IV requires justification of using PVC.

- Ten feet of 2-inch I.D., Schedule 40, #10 slot (0.010 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend 2 to 3 feet above the surface. A PVC slip-cap vented to the atmosphere, will be placed at the top of the riser. The top of the well screen will be placed such that two feet of the screen (as subsurface conditions permit) extends above the groundwater table to allow for seasonal groundwater fluctuations.

- The annular space around the screen will be backfilled with a well-graded medium to coarse sand (No. 1 or No. 2 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

- A sodium bentonite seal at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement.

- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- The monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than

3-1/2 feet below the ground surface, as space permits. For very shallow wells, a steel casing of less than 5 feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not For Consumptive Use."

Figure 6-1 depicts a typical Type II shallow monitoring well construction diagram.

Procedures for the installation and construction of Type II intermediate wells are presented below:

- Activity personnel will approve all monitoring well locations. These locations will be installed free of underground or overhead utility lines.

- A borehole will be advanced initially using hollow stem augers to just below the water table (so that samples can be collected for laboratory analysis). The augers will be nominal 3/4-inch I.D. Continuous 2-foot split-spoon samples will be collected while the borehole is advanced. Samples will be collected according to the procedures outlined in Section 6.1.2.

- The borehole will be further advanced until completion using mud rotary drilling. The reason mud rotary drilling will be used is because of the unconsolidated formation and drilling depths anticipated. A tricone drill bit with a O.D. of 7-7/8 inches will be used for advancing the borehole.

- Split-spoon samples will be collected at approximate 5 to 10-foot intervals during borehole advancement (mud rotary drilling). If a clay layer is encountered which may serve as a potential confining unit, continuous samples will be collected to determine the thickness of the layer. At that time, a decision will be made as to whether a Type-III well will be installed (described in the next section). Samples will be collected according to the procedures outlined in Section 6.1.2.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed.

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. USEPA Region IV requires justification of using PVC.

- Ten to twenty feet of 2-inch I.D., Schedule 40, # 10 slot (0.010 inch) screen with a bottom cap will be installed. The final determination for the length of the screen will be decided in the field based on the thickness of the upper portion of the Castle Hayne formation.

- The annular space around the screen will be backfilled with a well-graded medium to coarse sand as (No. 1 or No. 2 silica sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

- A sodium bentonite seal (typically bentonite pellets) at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The bentonite seal shall be installed using a tremie pipe, if applicable depths are anticipated (i.e., greater than 25 feet).

- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- The monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits. For very shallow wells, a steel casing of less than 5 feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5 feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4-feet by 4-feet 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not for Consumptive Use."

Figure 6-2 depicts a typical Type II intermediate monitoring well construction diagram.

Procedures for the installation of temporary groundwater monitoring wells is as follows:

- The borehole for the well installation will be drilled with a 4" or 6" diameter hand auger. The total depth of the borehole will be a minimum of six (6) feet.

- Well construction materials will consist of a five (5) foot section of 2" I.D. PVC screen (0.01-inch slot), bottom cap, 2" I.D. PVC riser, sand, and bentonite pellets. The length of PVC riser will depend on the total depth of the borehole.

- Following the completion of the borehole, the PVC screen with bottom cap will be lowered into the borehole. The PVC riser will be attached and the assembly will be lowered to the bottom of the borehole. Enough riser will be attached to allow for a minimum two (2) foot stickup above the ground riser.

- The annular space around the well will be backfilled with a well graded medium to coarse sand, to a minimum of six (6) inches above the top of the screen. A bentonite seal will be placed above the sand backfill, a minimum of one (1) foot thick. No grout will be installed for a temporary well installation.

- Following the one round of sampling, these wells will be pulled and the boreholes backfilled with spoil material from the drilling of the borings.

Appendix C contains the SOPs for monitoring well installations.

All monitoring wells will be developed as specified in the ECBSOPQAM. The purposes of well development is to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation.

Well development shall not be initiated until a minimum of 48 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Shallow wells typically are developed using bailers or low-yield pumping in combination with surging using a surge block. Intermediate monitoring wells are developed using compressed air (equipped with an air filter) in combination with surging. Selection of a development device will be dependent on conditions encountered during monitoring well installation.

All wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination

- A maximum time period (typically one hour for shallow wells)

- A maximum well volume (typically three to five well volumes)

- Stability of pH, specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements)

- Clarity based on turbidity measurements [typically less than 50 Net Turbidity Units (NTU)]

A record of the well development shall be completed to document the development process. Section 6.10 provides information on the use of monitoring and data collection equipment for water level measurements, pH, specific conductance, and temperature.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval.

6.3 In Situ Slug Tests

In situ slug tests will be performed in selected wells at all four sites. The selection of the wells will be made by the field geologist in consultation with the project geologist and the site manager. Both falling head and rising head procedures will be performed in the selected wells. The performance of in situ slug tests will include the following procedures:

1. Measure the static groundwater level and depth of well. Record all measurements in the field notebook.

2. Install the data logger transducer. We will be using an IN SITU Hermit 2000 data logger. The transducer should be positioned approximately one foot off the bottom of the well.

3. Set the parameters for the test as per the instructions provided with the data logger. Note that the rate for taking readings should be set on the logarithmic scale. This will collect readings at the fastest rate at the start of the test when changes in the groundwater level are most rapid, and significant in the analysis of the data.

4. Key in the coefficients for the specific transducer being used.

5. Make sure that all settings are correct.

6. Secure the nylon cord to the solid slug. Measure off a mark on the nylon cord that will place the bottom of the slug a minimum of one foot above the transducer.

7. Press the start button and immediately lower the solid slug into the well to the mark on the cord to begin the falling head test.

8. During the test, groundwater level measurements can be taken with a water level meter to verify the fall in water level towards static.

9. Continue the test until groundwater is within 90 to 100% of the static water level of the well at the start of the test. Set the data logger to begin a step (as per the instrument instructions).

10. Immediately after beginning the step, remove the slug to begin the rising head test.

11. Again take groundwater level measurements with a water level meter to verify the rise in water level to static.

12. The test can be terminated when the groundwater level has returned to within 90 to 100% of the static water level measured at the start of the test.

13. The transducer and cable should be decontaminated with laboratory grade soap and distilled water upon completion of each well testing.

14. At the end of each days testing, the data logger test files should be downloaded through a laptop computer onto a disc. A backup disk should also be made of the projects slug test data files.

The data obtained from the in situ slug tests will be used in connection with Geraghty & Miller's AQTESOLV (Aquifer Test Solver) program to calculate hydraulic conductivity values at the specific wells tested. Appendix D presents the SOP (402) for Slug Testing.

6.4 Groundwater Sample Collection (Task at Sites 16, 7, 80 and 3)

6.4.1 Groundwater Samples Collected from Monitoring Wells

Groundwater samples will be collected from existing and newly installed monitoring wells on site.

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.

3. Lower purging equipment [teflon bailer or submersible pump (RediFlo-2® low yielding pumps)] into the well to a short distance below the water level and begin water removal. Purged water will be temporarily stored in DOT-approved 55-gallon drums. Final containment of purged water is addressed in Section 6.12.

4. Measure the rate of discharge using a bucket and stopwatch.

5. 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.

6. Record measurements of specific conductance, temperature, and pH during purging (i.e., after each volume has been removed) to ensure the groundwater stabilizes. Generally, these measurements are made after each well volume purged.

7. Lower the teflon bailer into the well, submerge into the groundwater, and retrieve. A teflon coated line (only the portion in contact with the water table) will be used for lowering the bailer. Pour groundwater from the bailer into the laboratory-supplied sample bottles.

8. Samples for VOC analysis will be collected first, followed by semivolatiles, PCBs, pesticides, and metals (total and dissolved). Sample bottles will be filled in the same order for all monitoring wells.

9. Samples collected for dissolved metals analysis will be filtered in the field prior to being submitted for analysis. Filtering will be conducted using a 45-micron filter.

Sample preservation handling procedures are outlined in Section 7.0.

Appendix E presents the SOP for groundwater sampling.

6.5 Surface Water Sample Collection (Task at Sites 16 and 7)

The following procedures will be used for the collection of surface water samples at stations located on site. At each station, samples will be collected at the approximate mid-stream point or near the bank of the surface water body. Care will be taken to ensure that the sampler does not contact and/or stir up the sediments, while still being relatively close to the sediment-water interface.

The surface water samples will be collected by dipping the laboratory-supplied sample bottles directly into the water. Clean PVC gloves will be worn by sampling personnel at each sampling station. For those sample bottles that contain preservative (e.g., sulfuric acid), the water will be collected in a clean, decontaminated sampling container, and then slowly transferred into the appropriate laboratory-supplied sample bottle.

The water samples will be collected from near mid-stream at each station, where applicable. Water samples at the furthest downstream station will be collected first, with subsequent samples taken at the next upstream station(s). Sampling technicians, if standing in the water during sample collection, will stand downstream from the sampling container while collecting surface water samples to minimize the effects of disturbed sediments on the samples. Sediment samples will be collected after the water samples to minimize sediment disturbance and suspension.

All sample containers not containing preservative will be rinsed at least once with the sample water prior to final sample collection. In addition, the sampling container used to transfer the water into sample bottles containing preservatives will be rinsed once with sample water.

Care will be taken when collecting samples for analysis of volatile organics compounds (VOCs) to avoid excessive agitation that could result in loss of VOCs. VOC samples will be collected prior to the collection of the samples for analysis of the other parameters. Sample bottles will be filled in the same order at all sampling stations.

Temperature, pH, and specific conductance of the surface water will be measured in the field at each sampling location (at each sampling depth), immediately following sample collection.

The sampling location will be marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sampling location will be marked with indelible ink on the stake. In addition, the distance from the shore and the approximate location will be estimated using triangulation methods, and recorded and sketched in the field log book. If permission is granted, photographs will be taken to document the physical and biological characteristics of the sampling location.

The following information will be recorded in the field logbook:

- Project location, date and time
- Weather
- Sample location, number, and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On site water quality measurements
- Visual description of water (i.e., clear, cloudy, muddy, etc.)

- Sketch of sampling location including boundaries of the 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

Sample preservation and handling procedures are outlined in Section 7.0.

Details on surface water sample acquisition are presented in Appendix F.

6.6 Sediment Sample Collection (Task at Sites 16 and 7)

The following procedures will be used for the collection of sediment samples at stations located on site. At each station, surface and near surface sediment samples will be collected at a depth of 0 to 6-inches, and 6 to 12-inches. These intervals of sediment will be collected using a stainless steel hand-held coring instrument. A new or decontaminated liner tube, fitted with an eggshell catcher to prevent sample loss, will be used at each station.

The coring device will be pushed into the sediments to a minimum depth of 15-inches, or until refusal, whichever is encountered first. The sediments in the 0 to 6-inch interval and 6 to 12-inch interval will be extruded with a decontaminated extruder into separate stainless steel bowls and the sample homogenized prior to being transferred to the laboratory containers. Samples for VOA analysis will not be homogenized. If less than 12-inches of sediments are obtained, the first 6-inches will be placed in a stainless steel bowl and the remaining sediment will be placed into a second stainless steel bowl. These individual samples will be homogenized prior to placement in laboratory containers. VOA samples will not be homogenized.

The sampling procedures for using the hand-held coring instrument (i.e., stainless-steel core sampler) are outlined below:

1. Inspect and prepare the corer:

   a. Inspect the core tube and, if one is being used, the core liner. Core tube and core liner must be firmly in place, free of obstruction throughout its length. Bottom edge of core tube, or of the nose piece, should be sharp and free of nicks or dents.

   b. Check the flutter valve for ease of movement.

   c. Check the flutter valve seat to make sure it is clear of any obstruction that could prevent a tight closure.

   d. Attach a line securely to the core sampler. The line should be free of any frayed or worn sections, and sufficiently long to reach bottom.

2. Get in position for the sampling operation -- keeping in mind that disturbance of the bottom area to be sampled should be avoided.

3. Line up the sampler, aiming it vertically for the point where the sample is to be taken.

4. Push the core sampler, in a smooth and continuous movement, through the water and into the sediments -- increasing the thrust as necessary to obtain the penetration desired.

5. If the corer has not been completely submerged, close the flutter valve by hand and press it shut while the sample is retrieved. Warning: the flutter valve must be kept very wet if it is to seal properly.

6. Lift the core sampler clear of the water, keeping it as nearly vertical as possible, and handle the sample according to the type of core tube.

7. Secure and identify the new sample. Unscrew the nose cone. Pull the liner out. Push out any extra sediments (greater than 12-inches). Push out the sediments within the 6 to 12-inch interval and place it in a stainless steel bowl and homogenize. Push out the 0 to 6-inch sediment interval into another stainless steel bowl and homogenize. Samples for VOC analysis will not be homogenized.

8. Seal all sample jars tightly.

9. Label all samples.

Sample preservation and handling procedures are outlined in Section 7.0.

Appendix F presents the SOP for sediment sampling.

6.7 <u>Ecological Sampling (Task at Site 7)</u>

6.7.1 Biota Sampling

Biota samples collected at the stations will consist of benthic macroinvertebrates and fish. Prior to initiating the sampling event, the following sampling area description information will be recorded at each station:

- Project location, date, and time
- Tide (low vs. high)
- Weather
- Sample location, number, and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On site water quality measurements
- visual description of water (i.e., clear, cloudy, muddy, etc.)

- Sketch of sampling location including boundaries of the 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

- Average width, depth, and velocity of the water body

- Description of substrata

- Descriptions of other "abiotic" characteristics of the reach, such as pools, riffles, runs, channel shape, degree of bank erosion, and shade/sun exposure

- Description of biotic community (i.e., flora, fauna, etc.)

- Description of other "biotic" characteristics of the reach including aquatic and riparian vegetation, and wetlands

After the habitat review is complete, the field team leader will define and locate the stations for biota sampling. Every attempt will be made to define stations to exclude atypical habitats such as bridges and mouths of tributaries. In addition, upstream and downstream locations will be selected to be as ecologically similar as possible in their biotic and abiotic characteristics. Appendix G presents the SOP for benthic sampling.

Field water quality measurements will be conducted at each station, prior to collection of the samples. These measurements include pH, specific conductance, temperature, dissolved oxygen, and salinity. All instruments will be calibrated in accordance with the manufacturers' instructions prior to conducting the measurements. All measurements, including the calibration procedures, will be recorded on field data sheets.

6.7.1.1 Benthic Macroinvertebrate Sample Collection

benthic macroinvertebrates will be collected at each station using a Standard Ponar Grab Sampler. Each station will consist of three replicate samples with one grab per replicate.

After the sediments are collected, the contents of the sample will be placed into a small tub. The sediments in the tub will be transferred to a No. 35 sieve (0.500 mm) and washed with water to remove small sediment particles. The remaining contents in the sieve will be transferred into sample jars. Approximately half of the sample jar will be filled with the sample, and 10% (by weight) buffered formalin will be added to fill the remainder of the jar. A 100%v cotton label will be placed inside the jar, identifying the station location and replicate number. The label will be marked with pencil. The outside of the jar will be labeled using a black permanent marker with the station location and sample number. All the sample jars will be stored in large plastic tubs until transfer to Baker Ecological Services Laboratory in Coraopolis, Pennsylvania.

6.7.1.2 Processing of Macroinvertebrate Samples

The samples will be returned to the Baker Ecological Services laboratory for final processing. The samples will be rewashed using a No. 35 sieve (0.500 mm), to remove any remaining fine sediments, and the remaining portion of the sample will be transferred back into the sample jar containing fresh 90% ethanol. The sediments will be sent to the appropriate laboratory for taxonomic identification.

The same processing procedures outlined above will be repeated as a QA/QC measure, with any additional species identified, being placed into their respective vials. An environmental scientist will perform this QA/QC measure. Fifty percent of the sample will be resorted. If more than five percent of the individuals are missing during the initial sorting, then the rest of the sample will be resorted. Any changes to this procedure will be approved by the project manager. The number of individuals found in the sample will be recorded. The date, sorting time, number of additional individuals found, and individuals will be sent to the appropriate laboratory for taxonomic identification.

6.7.1.3 Analysis of Macroinvertebrates

Results of the benthic macroinvertebrate collection will be used to prepare the following descriptive statistics on a station-by-station basis: 1) a list of taxa collected; 2) a table of numbers of each taxa collected by replicate; and 3) relative pollution tolerance of the species.

The benthic macroinvertebrate communities will be examined using mathematical expression of community structure (i.e., diversity index). Diversity data are useful because they condense a substantial amount of laboratory data into a single value. separate values of the diversity index will be computed for sampling areas within the upstream, downstream, and adjacent reaches. Analysis of the species diversity will be used to compare the community structure between the stations as well as evaluate the impact that the contaminants from the site may be having on the aquatic community.

The species collected during the aquatic surveys will be evaluated to determine their biological relevance and pollution tolerance. A macroinvertbrate Biotic Index, based on North Carolina Biotic Index of benthic macroinvertebrates, will be used to assess stream quality, as appropriate.

6.7.1.4 Fish Sample Collection

Fish will be collected at the designated stations using gill nets. The nets will be deployed either in the evening or the morning and they will be checked for fish within twelve hours after being deployed. The collected fish will be separated into different species and counted. The SOP for the use of gill nets in fish surveys is presented in Appendix H.

6.7.2 Earthworm Bioassays

Earthworm bioaccumulation in-situ bioassays will be conducted in the areas of known PCB contamination. The results of the bioassays will be used to determine contaminant body-burden levels in the earthworm. These levels will be used to develop chronic daily intake exposure values for terrestrial receptors by application of exposure algorithms that convert the environmental (tissue) concentrations into exposure dose.

Two stations will be established in the known area of PCB contamination. At each station, three study site soil test chambers will be located along with an artificial soil control test chamber and a test chamber to record soil moisture and temperature. In addition, two reference test chambers will be located outside the area of known PCB contamination but in soils ecologically similar to the study site soils. At each station, the containers will be placed within a circle of about 1.5 meters in diameter. The surface of the station will be cleared of debris such as leaves and twigs. If a station is located in a grassy area, the grass will be cut to ground level and discarded. If a sod layer is present, a section of the sod will be removed and discarded. Field measurements will include collection of soil temperature, rain fall and soil conditions (pH, moisture, organic matter content, type of soil).

Stations will be set up the day before the earthworms are introduced into the test chambers. Test chambers will be constructed to allow drainage of water through the bottom of the test chambers. The ends of the test chambers will be covered with 30 mesh (600 micron openings) polyester, monofilament screen of 0.76 mm thickness. The screens will be held in place with fastenings rings. Holes for the test chambers will be dug and the test chambers placed into the excavations leaving approximately 25 mm of the container above the ground level. The appropriate soil for each test chamber will be placed into the container up to ground level, and the top screens loosely fitted until introduction of the earthworms. Study site soils will be excavated and placed into the test chambers with minimal disruptions of soil horizons. Excess dirt from the excavation will be used to fill in any space between the test chamber and the wall of the hole.

Adult earthworms to be introduced into the test chambers will be transported to the site in culture trays in coolers with ice. The earthworms will be held in the coolers at a staging area near the site and fed. Because of the potential for overheating, the coolers will be checked daily and ice added as needed to maintain the ambient temperature of the coolers less than 22°C. Adult, fully clitellate earthworms will be used in the testing. Lethargic or damaged earthworms will not be used. Introduced earthworms will be buried to a depth of 25 to 50 mm. The top screens will be tightly secured in place on all containers after introduction of the earthworms. The earthworms will be exposed for 28 days during which time no food will be added.

The stations will be periodically observed depending upon soil moisture level and temperature. At the end of 28 days, the test chambers will be emptied onto a sheet of plastic, the earthworms hand sorted, counted, rinsed with distilled water, and evaluated for mortality and sublethal endpoints. Mortality will be defined as a lack of response when the earthworms were touched at their anterior end. Each surviving earthworm will be evaluated for the following behavioral and pathological sublethal endpoints, as well as any other obvious anomaly: lesions, segmental swelling, coiling, flaccidity (limp with lack of muscle tone), stiffening and shortening, segmental constriction, and autotomy (separation of a part from the body) of posterior segments. If the full complement of earthworms are not found in a test chamber and no sign of escape or disturbance is noted, it will be assumed that the unaccounted for earthworms will have died and decomposed.

6.8 ENSYS Testing (Task at Site 3)

An Enzyme-Linked Immunosorbent Assay (ELISA) field screening kit will be utilized in the field for PAH and creosote contaminated soils. The test kit has a minimum detection limit of 1.0 mg/Kg which is adequate for this site. The manufacturer will provide the field test kit with the following action levels, 1.0 mg/Kg and 10 mg/Kg. These action levels have been established to inform the data users of the presence or absence of PAHs and creosote, and to delineate the extent of contamination based on the action levels established as part of the Remedial Investigation. Because these tests are specific for PAHs and creosote, no interferences are expected. These tests have an accuracy of 95% for samples testing positive.

Samples will be collected from the established grid points with a hand auger or stainless steel scoop and placed into a stainless steel bowl. Samples will be obtained from 0 to 12 inches below ground surface (bgs)(i.e., surface sample). Following collection, each sample will be homogenized to ensure that the sample is mixed in a manner that provides uniformity throughout the sample prior to placing it in the appropriate container. This procedure of sample homogenizing will also ensure that the soil sample is representative of that specific interval. After homogenizing, a representative amount of each sample will be placed in a plastic bag and cooled to 4^0 C. Once the required number of samples are collected, 10 grams from each sample will be selected for analysis via the ELISA screening technique; the results of each sample will establish whether additional sampling is needed to better define the extent of contamination. The screening procedures for PAHs are identified in Appendix I. Creosote is an extract from the PAHs so screening procedures are the same.

Ten percent of the samples with PAH and/or creosote concentrations below the established soil screening action levels will be taken from the north and the south areas of the site and sent to the laboratory for confirmatory analysis of PAHs and/or creosote. The portion sent to the laboratory will be acquired from the homogenized sample; this will ensure that the laboratory portion is identical in composition to the portion which was screened with the ELISA kit. The results of the confirmatory sampling will verify the extent of contamination in the north and south areas.

6.9 Decontamination

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, bailers, split-spoon samplers, hand auger buckets, stainless steel spoons, etc.)

2. Machinery, equipment, and materials (e.g. drilling rigs, backhoes, drilling equipment, monitoring well materials, etc.)

Appendices J and K detail procedures for decontaminating the two categories of equipment and materials, respectively.

6.10 Monitoring and Data Collection Equipment

Field support activities and investigations will require the use of monitoring and data collection equipment. Specific conductance, temperature, and pH readings will be recorded during groundwater and surface water sample collection. In addition, similar specific conductance and pH readings will be recorded during well development. Appendix L, On-Site Water Quality Testing, provides specific procedures for collecting conductance, temperature, and pH readings.

Additional monitoring well information may be obtained using water level meters, water-product level meters, and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix M.

Health and safety monitoring and environmental media screening will be conducted using a photoionization detector (PID) and a combustible gas/oxygen meters (O_2/LEL). The operation and use of the PID is described in Appendix N. The Bacharach O_2/LEL meter will also be used during the sampling program, primarily to monitor health and safety conditions. Appendix O provides a description of the Bacharach O_2/LEL meter and operating procedures.

6.11 Land Survey

Each of the four SI sites require survey information. Horizontal and vertical survey tolerances are addressed within the survey requirements under Section 4.0, for each of the four sites. Appendix P provides a more detailed description of survey procedures and surveyor qualifications.

6.12 Investigation Derived Waste Handling

The following sections deal with the responsibilities, sources, containerization, sampling and analysis, and disposal of Investigation Derived Wastes (IDW). These wastes include soil from borings and trench excavations, groundwater from developing and purging monitoring wells, decontamination fluids, and personal protection equipment.

6.12.1 Responsibilities

LANTDIV - Atlantic Division, Naval Facilities Engineering Command (LANTDIV) or the facility must ultimately be responsible for the final disposition of site wastes. As such, a LANTDIV or MCB Camp Lejeune representative will 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 manifests.

Baker Project Manager - It is the responsibility of the Baker Project Manager to work with the LANTDIV-Technical Representative in determining the final disposition of site investigation wastes. The Baker Project Manager will relay the results and implications of the chemical analysis of waste or associated material, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Baker 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.

Baker Field Team Leader - The Baker Field Team Leader or Site Manager is responsible for the on site supervision of the waste handling procedures during the site investigations. The Baker Field Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

6.12.2 Sources of Investigation Derived Wastes

Field investigation activities often result in the generation and handling of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These wastes may be either hazardous or nonhazardous in nature. The nature of the waste (i.e., hazardous or nonhazardous) will determine how the wastes will be handled during the field investigation.

The sources of waste material depend on the site activities planned for the 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 (drill cuttings)
- Mud rotary drilling (contaminated mud)
- Excavated soils from trenches and test pits
- Monitoring well development (development water)
- Groundwater sampling (purge water)
- Aquifer pump tests (potentially contaminated groundwater)
- Heavy equipment decontamination (decontamination fluids)
- Sampling equipment decontamination (decontamination fluids)
- Personal protection equipment (health and safety disposables)

6.12.3 Designation of Potentially Hazardous and Nonhazardous Investigation Derived Wastes

Wastes generated during the field investigation can be categorized as either potentially hazardous or nonhazardous in nature. The designation of such wastes will determine how the wastes are handled. The criteria for determining the nature of the waste, and the subsequent handling of the waste is described below for each type of anticipated investigative waste.

6.12.3.1 Drill Cuttings

Drill cuttings will be generated during the augering of test borings and monitoring well boreholes. As the borehole is augered, collected soil samples will be monitored with an HNu photoionization (PID) unit for organic vapors and notes made on the physical appearance of the soils. Cuttings that do not indicate elevated levels of organics or have visual signs of contamination will be placed on polyethylene sheeting and backfilled into the borehole following completion of the drilling. Cuttings which, by their appearance or organic vapor readings, appear to be contaminated will be containerized in DOT approved drums for temporary storage on site, and subsequent treatment and/or disposal.

6.12.3.2 Excavated Soils

Excavated soils from trenches and/or test pits will be screened with a PID unit, as the soils are brought to the surface in the backhoe bucket, and described. Soils which do not appear to be contaminated or exhibit elevated levels of organic vapors will be placed on polyethylene sheeting and used to backfill the trench upon completion. Excavated soils which, by their appearance or organic vapor readings, appear to be contaminated will be placed in a lined roll-off box for temporary storage on site, and subsequent treatment and/or disposal. Trash that is removed from the trenches during excavation will also be containerized, and stored on site for subsequent disposal.

6.12.3.3 Monitoring Well Development and Purge Water

All development and purge water shall be containerized in tankers, or large (250-gallon) containers. Groundwater development/purge water that exhibits elevated HNu readings should be kept separate from water that does not exhibit elevated levels for purposes of subsequent treatment and/or disposal.

6.12.3.4 Decontamination Fluids

Equipment and personal decontamination fluids shall be containerized in 55-gallon drums. The fluids shall be collected from the decon/wash pads.

6.12.3.5 Personal Protective Equipment

All personal protective equipment (i.e., tyveks, gloves, and other health and safety disposables) shall be placed in garbage bags and disposed of in trash dump boxes.

6.12.4 Investigation Derived Waste Sampling and Analysis

Composite samples shall be collected from the drums containing apparent contaminated soil cuttings for the four individual sites. These samples will be analyzed for full TCLP (organics and inorganics), and RCRA hazardous waste characterization (corrosivity, reactivity, and ignitability). Appendix P contains procedures for collecting samples from drums.

For each roll-off box of excavated soils, a composite sample shall be collected and analyzed for full TCLP (organics and inorganics), and RCRA hazardous waste characteristics (corrosivity, reactivity, and ignitability).

For each tanker or container of development/purge water, a sample shall be collected for full TCL organic and TAL inorganic analysis. Procedures for collecting waste water samples are presented in Appendix Q.

Decontamination fluids collected during the investigation shall be sampled and analyzed for full TCL organics and TAL inorganics.

6.12.5 Labeling

If 55-gallon drums are used to containerize drill cuttings, the containers will be consequently numbered and labeled by the field team during the site investigation. Information shall be stenciled in paint on both the container lid and side. Container labels shall include, at a minimum:

- LANTDIV CTO (number)
- Project name
- Drum number
- Boring or well number
- Date
- Source
- Contents

If laboratory analysis reveals that containerized materials are hazardous or contain PCBs, additional labeling of containers may be required. The Project Manager 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; USEPA regulations applicable to labeling hazardous and PCB containing wastes are contained in 40 CFR Parts 261, 262, and 761.

6.12.6 Container Log

A container log shall be maintained in the site logbook. The container log shall contain the same information as the container label plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample.

6.12.7 Container Storage

Containers of site investigative wastes shall be stored on site or in a specially designated secure area that is managed by the MCB Camp Lejeune Environmental Management Division until disposition is determined. All containers shall be covered with plastic sheeting to provide protection from the weather.

If the laboratory analysis reveal that the containers hold hazardous or PCB wastes, additionally required storage security may be implemented; in the absence of the investigative 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 is necessary shall be recorded in the site logbook.

6.12.8 Container Disposition

The disposition of the 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.

6.12.9 Disposal of Contaminated Materials

Actual disposal methods for IDW will be determined following receipt of chemical analyses. 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. USEPA 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 (i.e., 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.

7.0 SAMPLE HANDLING AND ANALYSIS

Field activities will be conducted in accordance with the USEPA Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (February 1, 1991).

The number of samples, analytical methods, data quality level, and laboratory turnaround times are presented in Table 7-1. Container and preservation requirements, and sample holding times are provided in Section 6.1 of the Quality Assurance Project Plans (QAPP).

7.1 Sample Preservation and Handling

Sample preservation and handling procedures will be adhered to during the field program in order to maintain sample integrity. Preservation and handling procedures are provided in Appendix R of this FSAP.

7.2 Chain-of-Custody

Chain-of-custody procedures will be followed throughout the field program to ensure a documented, traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping, and analysis. Chain-of-custody procedures to be followed during the field program are contained in Appendix S.

7.3 Field Logbook

Field logbooks will be used to record sampling activities and information. Logbooks will be copied and submitted to the field site manager for filing upon completion of the field program. Entries will include general sampling information so that site activities may be reconstructed. In addition to the field logbook, field forms (e.g. boring logs, well development records, etc) will be completed as support documentation for the field logbook. Appendix T describes the general format of the field logbook and applicable field forms.

8.0 SITE MANAGEMENT

This section outlines the responsibilities and reporting requirements of on-site personnel.

8.1 Field Team Responsibilities

The field portion of this project will consist of one field team. All field activities will be coordinated by a Site Manager. The Site Manager will ensure that all field activities are conducted in accordance with the project plans (the Work Plan, this Field Sampling and Analysis Plan, the Quality Assurance Project Plan, and the Health and Safety Plan).

The Field Team will employ one or more drilling rigs for soil boring and monitoring well installation. Each rig(s) will be supervised by a Baker geologist. Two sampling technicians will be assigned to the field team. One of the sampling technicians will serve as the Site Health and Safety Officer.

8.2 Reporting Requirements

The Site Manager will report a summary of each day's field activities to the Project Manager or his/her designee. This may be done by telephone or telefax. The Site Manager will include, at a minimum, the following in his/her daily report:

- Baker personnel on site.
- Other personnel on site.
- Major activities of the day.
- Subcontractor quantities (e.g., drilling footages).
- Samples collected.
- Problems encountered.
- Planned activities.

The Site Manager will receive direction from the Project Manager regarding changes in scope of the investigation. All changes in scope will be discussed and agreed upon by LANTDIV, Camp Lejeune EMD, EPA Region IV, and the North Carolina DEHNR.

9.0 REFERENCES

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FIELD SAMPLING AND ANALYSIS PLAN TABLES

TABLE 7-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 16 - Montford Point Burn Dump	Soil - Burn Dump Boundary	22 borings/2 samples per boring	TCL Organics[2] TAL Metals[3]	III III	CLP/SOW CLP/SOW	Routine[4] Routine
	Soil - Well Borings	6 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Southeast Portion of Study Area	4 hand auger borings/ 2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Trenches	4 trenches/1 sample per trench (option)	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - Two rounds sampling	6 new shallow monitoring wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Northeast Creek	5 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Northeast Creek	5 stations/2 samples per station	TCL Organics TAL Metals TOC Grain Size	III III II II	CLP/SOW CLP/SOW EPA 415.1 ASTM D 1140	Routine Routine Routine Routine
Site 7 - Tarawa Terrace Dump	Soil - Southwest Corner Trench	5 trenches/2 samples per trench	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Southwest Corner	5 hand auger borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Northwestern Boundary	23 borings/2 samples per boring (12 drill rigs, 11 hand augers)	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 7-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples(1)	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 7 - Tarawa Terrace Dump (Continued)	Soil - Community Center Playground	2 borings/1 sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Well Borings	2 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - One Round of Sampling	5 (3 existing, 2 newly installed) shallow wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - One Round of Sampling	3 temporary wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Northeast Creek	6 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Northeast Creek	6 stations/2 samples per station	TCL Organics TAL Metals TOC Grain Size	III III II II	CLP/SOW CLP/SOW EPA 415.1 ASTM D 1140	Routine Routine Routine Routine
	Surface Water - Western Tributary	3 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Western Tributary	3 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size	III III II II	CLP/SOW CLP/SOW EPA 415.1 ASTM D 1140	Routine Routine Routine Routine

TABLE 7-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples(1)	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 7 - Tarawa Terrace Dump (Continued)	Surface Water - Eastern Tributary	2 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Eastern Tributary	2 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size	III III II II	CLP/SOW CLP/SOW EPA 415.1 ASTM D 1140	Routine Routine Routine Routine
	Surface Water - Drainage Ditch	2 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Drainage Ditch	2 stations/1 sample per station	TCL Organics TAL Metals TOC Grain Size	III III II II	CLP/SOW CLP/SOW EPA 415.1 ASTM D 1140	Routine Routine Routine Routine
	Sediment - Marsh Area	4 stations/2 samples per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Northeast Creek	4 stations	Benthic Survey			Routine
	Sediment - Western Tributary	3 stations	Benthic Survey			Routine

TABLE 7-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples(1)	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 80 - Paradise Point Golf Course Maintenance Area	Soil - Lawn Area	7 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Between and around Buildings 1916 and 600	4 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Open Area of Soil Piles	7 boring/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Mounded Area	10 hand auger borings/ 1 surficial sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		3 power auger borings/ 1 subsurface sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Previous Drum Area	2 borings/1 surface sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Well Borings	5 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - One Round of Sampling	8 (3 existing shallow, 4 newly installed shallow, 1 newly installed intermediate)	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 7-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 3 - Old Creosote Plant	Soil - Northern Portion	13 borings/1 sample per boring	ENSYS PAH[6]* ENSYS Petro Soil[7] TCL Semivolatile Organics[8]	II III	ENSYS CLP/SOW	 Routine
	Soil - Former Creosote Treatment Area	25 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Concrete Pads	8 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Railroad Spur	2 borings/1 sample per boring	ENSYS PAH* ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Well Borings	3 shallow borings/ 3 samples per boring	TCL Semivolatile Organics	III	CLP/SOW CLP/SOW	Routine Routine
		1 shallow boring/ 3 samples per boring 1 intermediate boring/ 3 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		1 composite sample from shallow boring	Engineering Parameters	II	(5)	Routine
	Soil - Background	3 borings/1 sample per boring	TCL Semivolatile Organics	III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - 1 round of sampling	6 (3 existing, 3 newly installed shallow monitoring wells)	TCL Semivolatile Organics	III	CLP/SOW	Routine
		1 newly installed intermediate well 1 newly installed shallow well	TCL Organics TAL Metals (total and dissolved)	III III	CLP/SOW CLP/SOW	Quick turn Quick turn

TABLE 7-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples(1)	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Investigation Derived Waste	Development/ Purge Water	4 (1 sample from each site)	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil/Rolloff Box	3 (1 sample from each site)	TCLP(6) RCRA(7)	III	SW846	Routine

* Assume a total of 15 confirmatory soil samples submitted for TCL semivolatile organic analysis.

(1) Baseline number of samples do not include QA/QC samples.

(2) TCL Organics: volatile organics, semivolatile organics, pesticides/PCBs

(3) TAL Metals:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

(4) Routine analytical turnaround is 28 days following receipt of samples.

(5) Engineering Parameters:

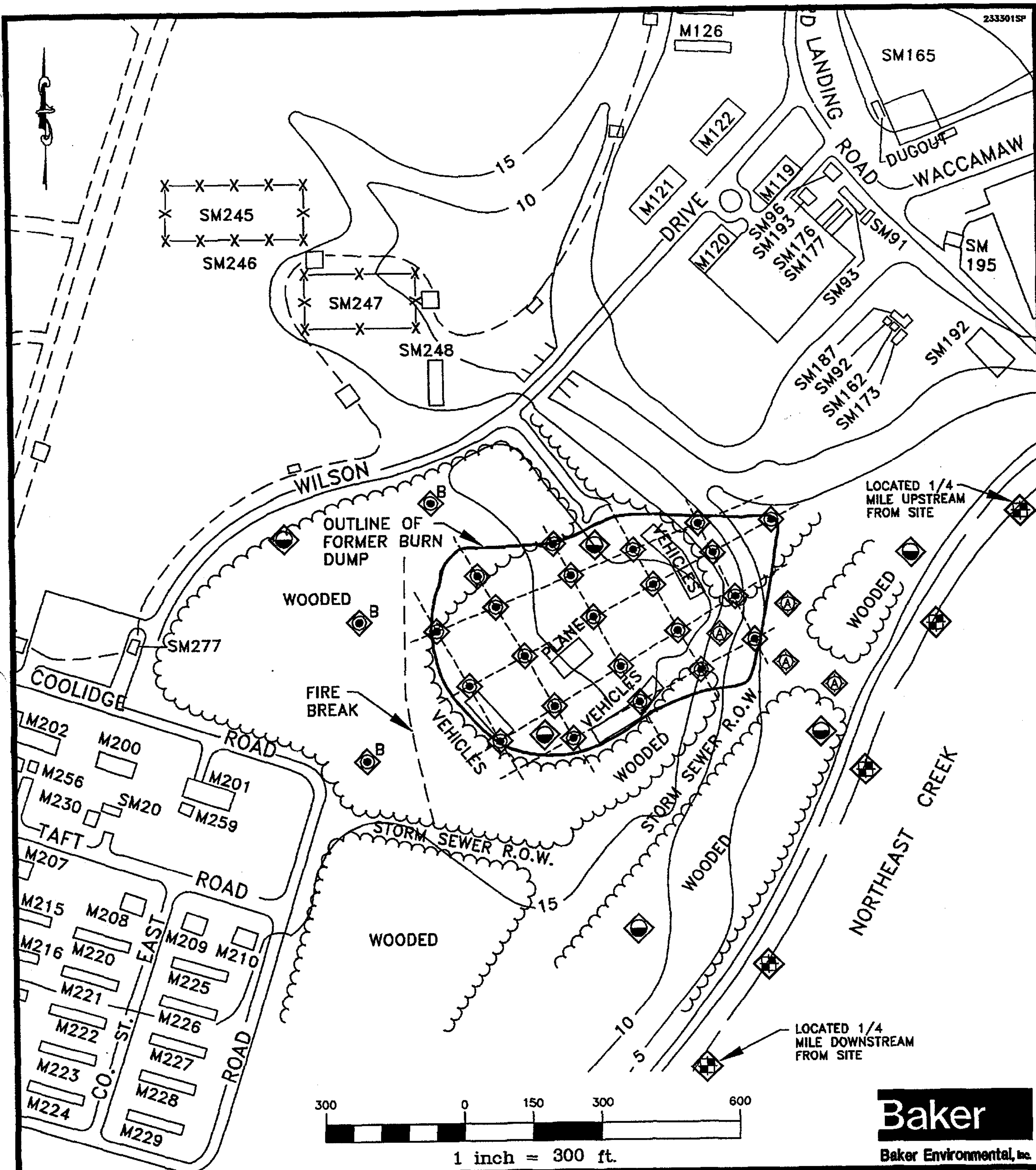
Soil:

Atterburg Limits	ASTM D-4318-84
Particle Size Distribution	ASTM D-422-63
Bulk Density	ASTM D-1557-91
Soil Porosity	
Total Organic Carbon (TOC)	EPA 9060

(6) TCLP - TCL VOAs, TCL SVOAs, TCL Pesticides, Herbicides, and Metals

(7) RCRA - Corrosivity, Reactivity, and Ignitability (React Sulfide , React Cyanide)

FIELD SAMPLING AND ANALYSIS PLAN FIGURES

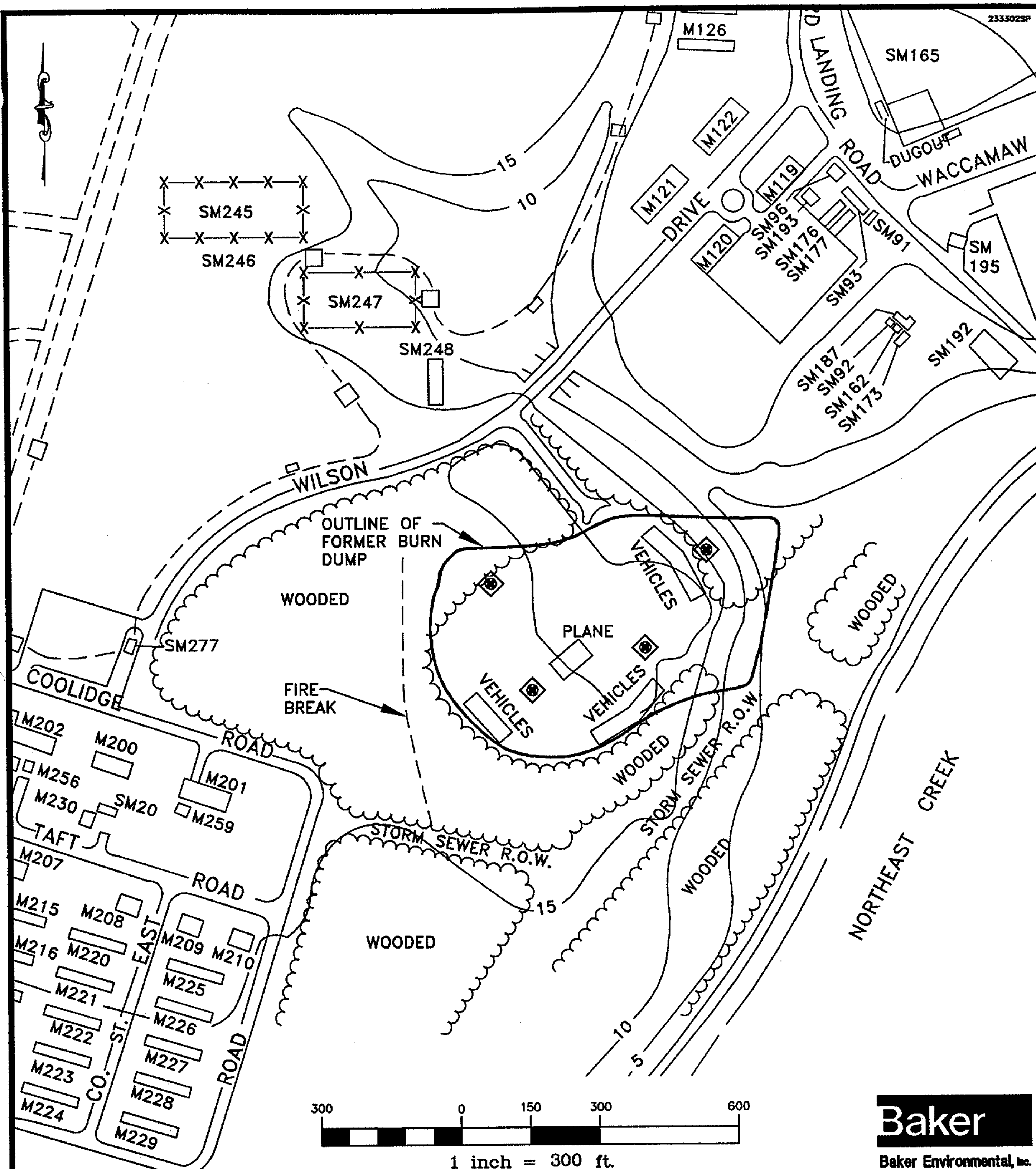


LEGEND

- (A) PROPOSED HAND AUGER SAMPLE LOCATION
- PROPOSED SOIL BORING LOCATION
- PROPOSED SURFACE WATER/SEDIMENT SAMPLE LOCATION
- PROPOSED SOIL BORING (MONITORING WELL TEST BORING)
- B DESIGNATED BACKGROUND LOCATION

SOURCE: LANTDIV, FEB., 1992

FIGURE 4-1
SOIL, SURFACE WATER, AND SEDIMENT INVESTIGATIONS
SITE 16-MONTFORD POINT BURN DUMP
CTO-0233
MARINE CORPS BASE, CAMP LEJUENE
NORTH CAROLINA



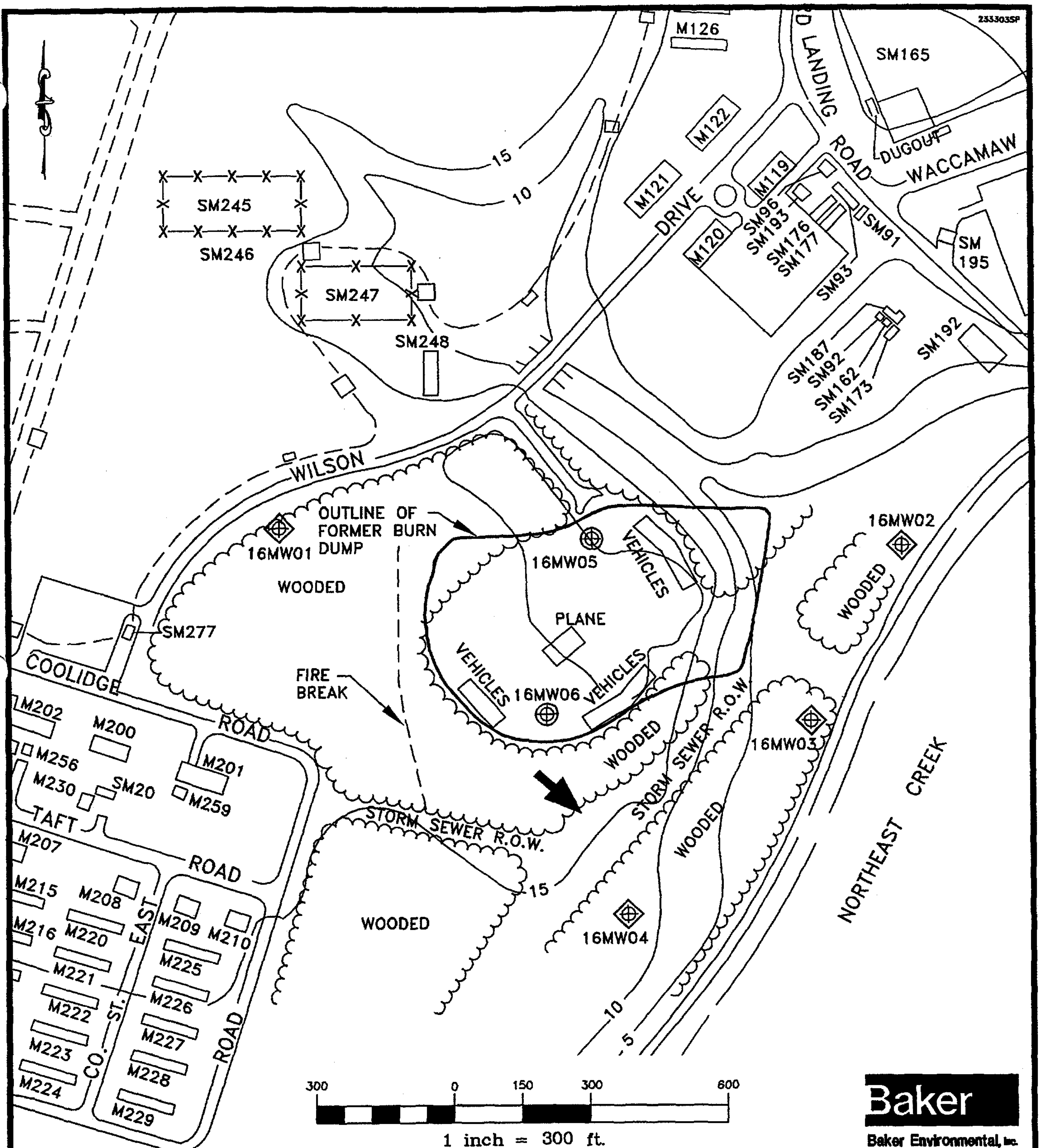
LEGEND

◈ PROPOSED TRENCH LOCATION

SOURCE: LANTDIV, FEB., 1992

FIGURE 4-2
TRENCH INVESTIGATION
SITE 16-MONTFORD POINT BURN DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

16MW01 ⊕ PROPOSED SHALLOW MONITORING WELL

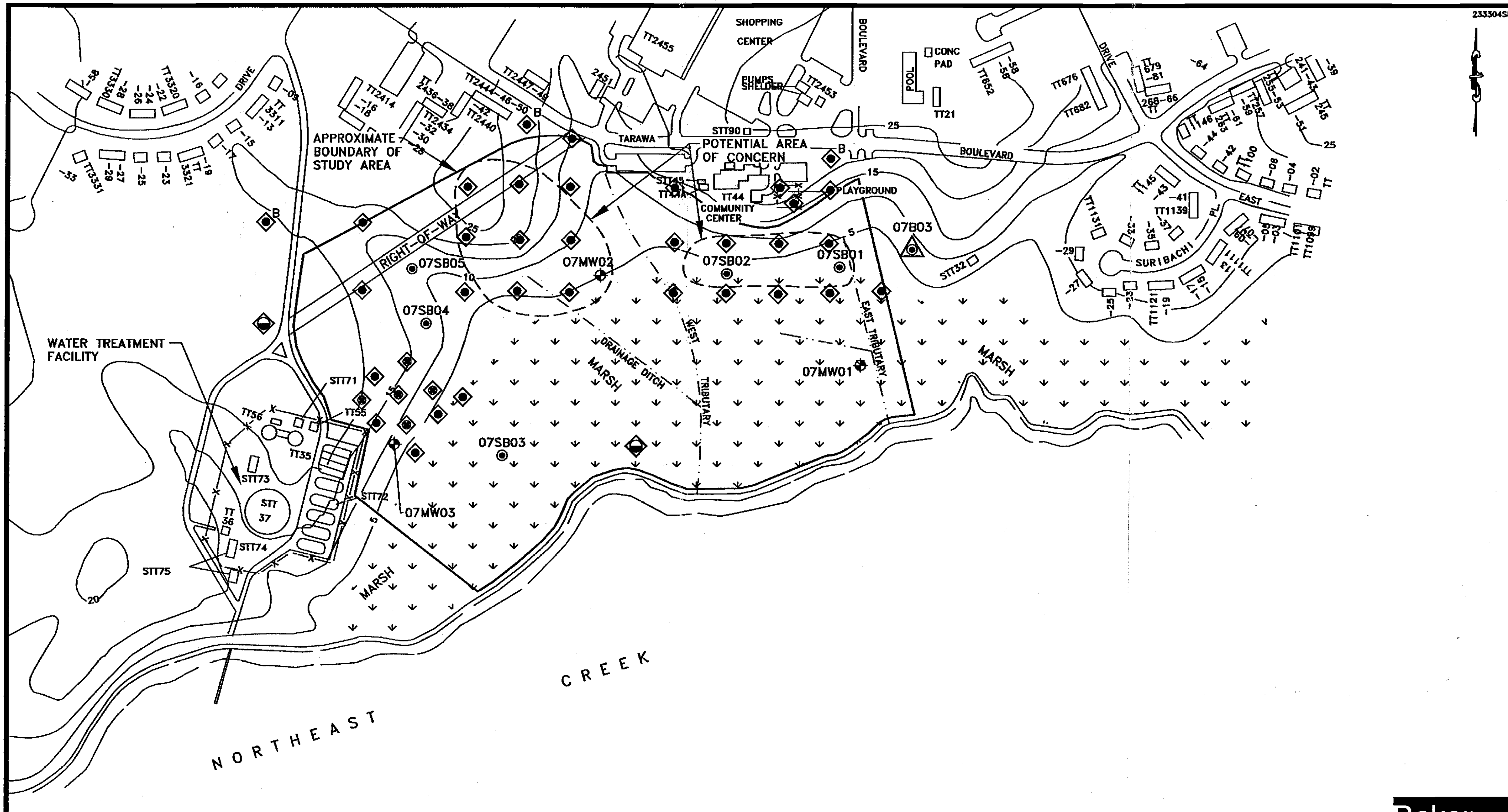
16MW05 ⊕ PROPOSED SHALLOW MONITORING WELL, LOCATION TO BE DETERMINED DURING THE FIELD PROGRAM

➔ ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB., 1992

FIGURE 4-3
GROUNDWATER INVESTIGATION
SITE 16-MONTFORD POINT BURN DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJUENE
NORTH CAROLINA



LEGEND

07MW01 ◆ EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07SB01 ◉ EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07B03 △ EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

◆ PROPOSED SOIL SAMPLE LOCATION

◆ PROPOSED TRENCH

◆ PROPOSED SOIL BORING (MONITORING WELL TEST BORING)

B DESIGNATED BACKGROUND LOCATION

SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

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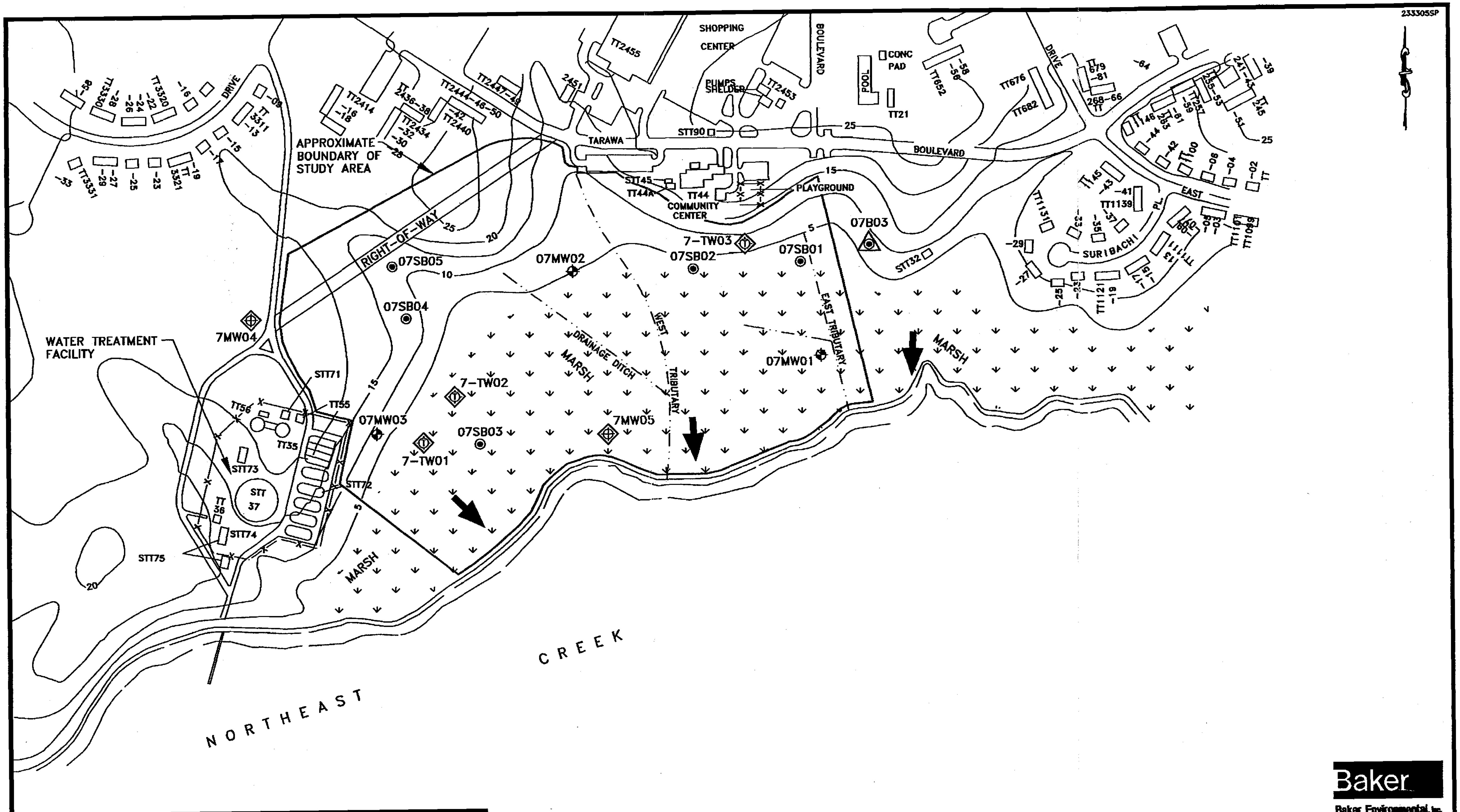
FIGURE 4-4
SOIL INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01531ZB2Z



LEGEND

- 07MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 07SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 07B03 EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- PROPOSED SHALLOW MONITORING WELL
- PROPOSED TEMPORARY WELL
- ESTIMATED GROUNDWATER FLOW DIRECTION

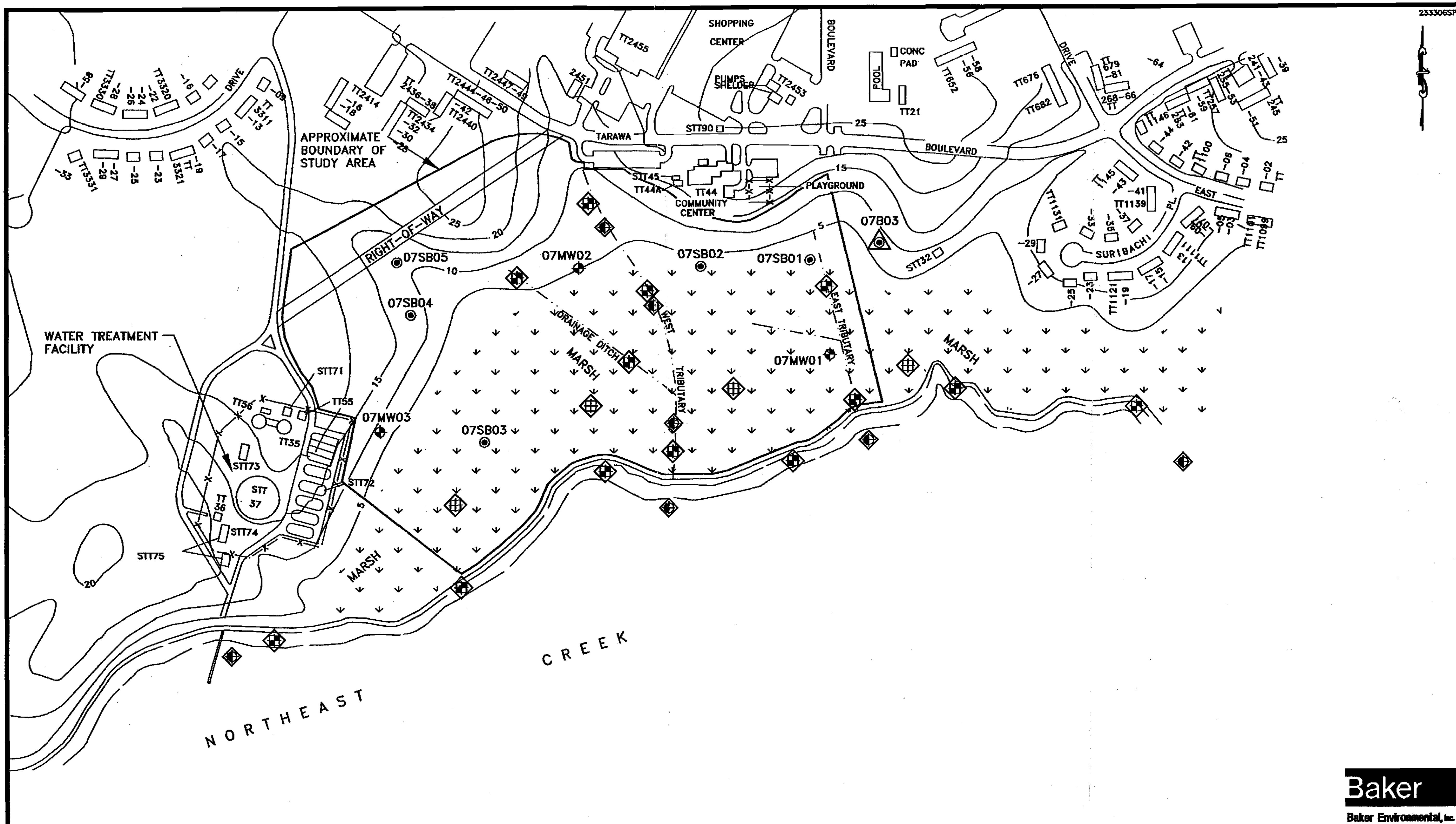
SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

FIGURE 4-5
GROUNDWATER INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

07MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07B03 EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SURFACE WATER/SEDIMENT SAMPLE LOCATION

PROPOSED SEDIMENT SAMPLE LOCATION

PROPOSED BENTHIC SAMPLE LOCATION

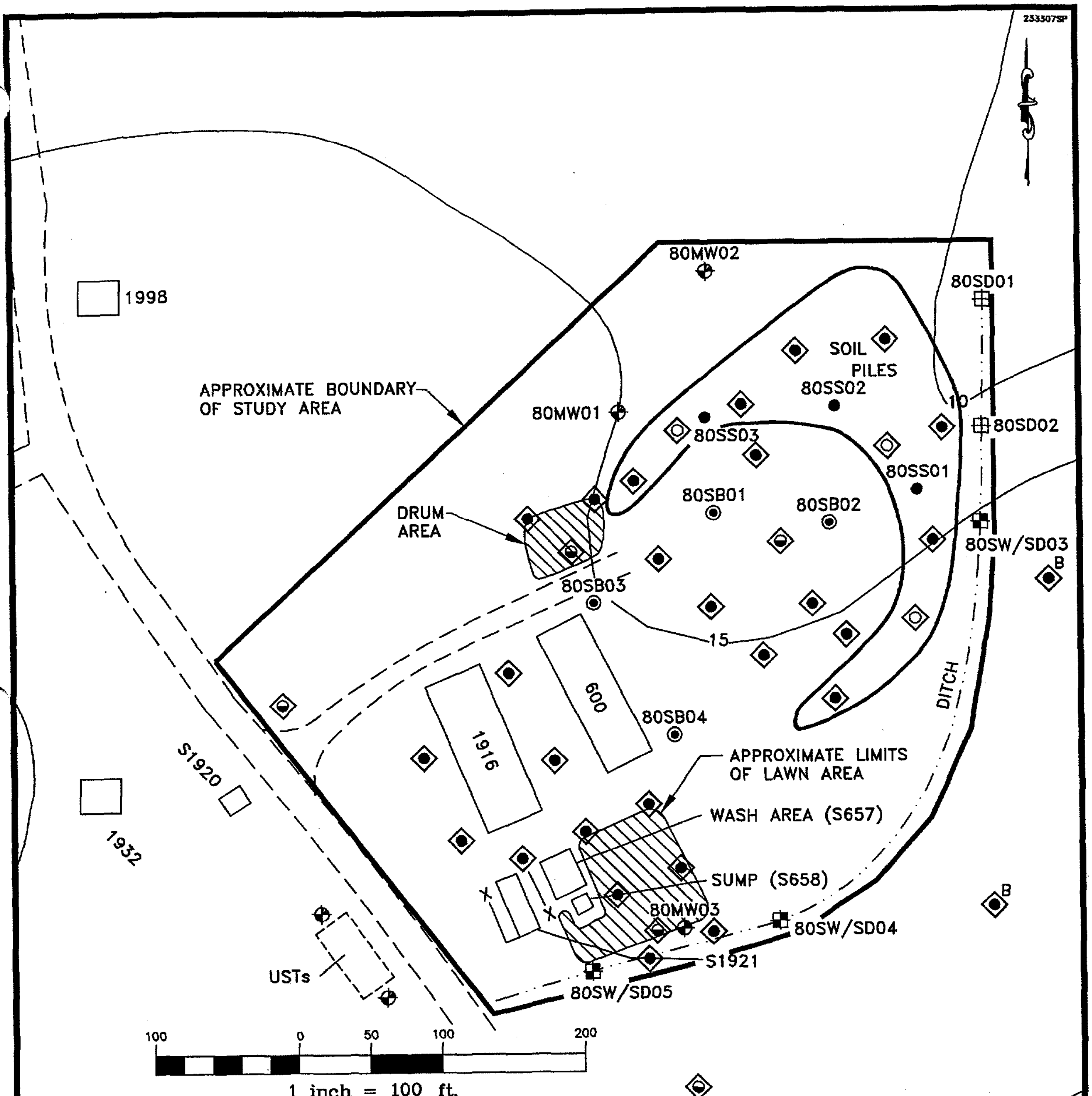
SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

FIGURE 4-6
ECOLOGICAL INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

80MW01	EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SB01	EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SD01	EXISTING SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SW/SD03	EXISTING SURFACE WATER/SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
80SS01	EXISTING SURFACE SOIL SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
	PROPOSED SOIL SAMPLING
	PROPOSED DEEP SOIL SAMPLING
	PROPOSED SOIL BORING (MONITORING WELL TEST BORING)
	AREAS OF CONCERN
B	DESIGNATES BACKGROUND LOCATION

SOURCE: LANTDIV, FEB. 1992

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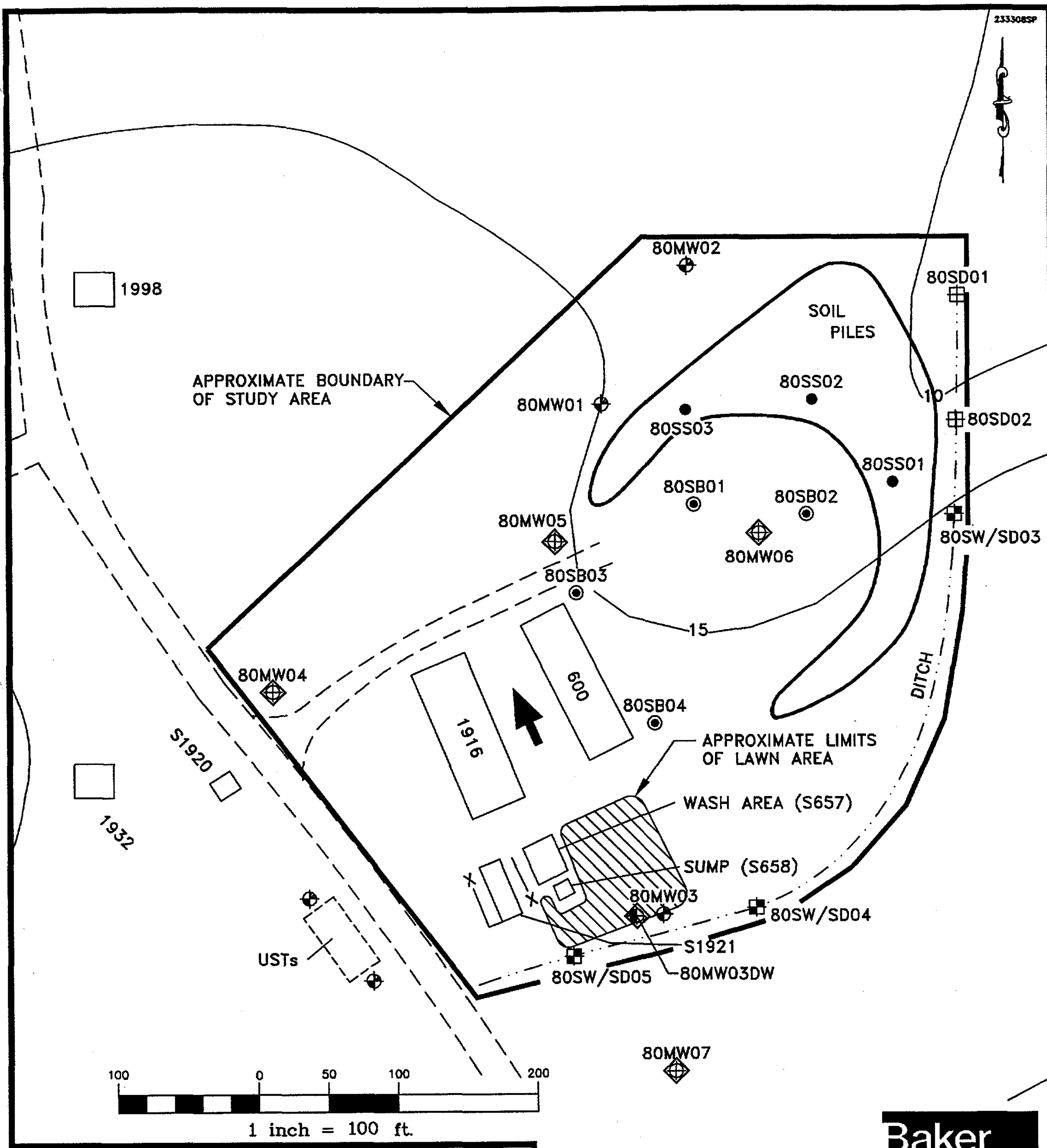
FIGURE 4-7
SOIL INVESTIGATION
SITE 80-PARADISE POINT GOLF COURSE MAINTENANCE AREA
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

80MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SD01 EXISTING SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SW/SD03 EXISTING SURFACE WATER/SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SS01 EXISTING SURFACE SOIL SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SHALLOW MONITORING WELL

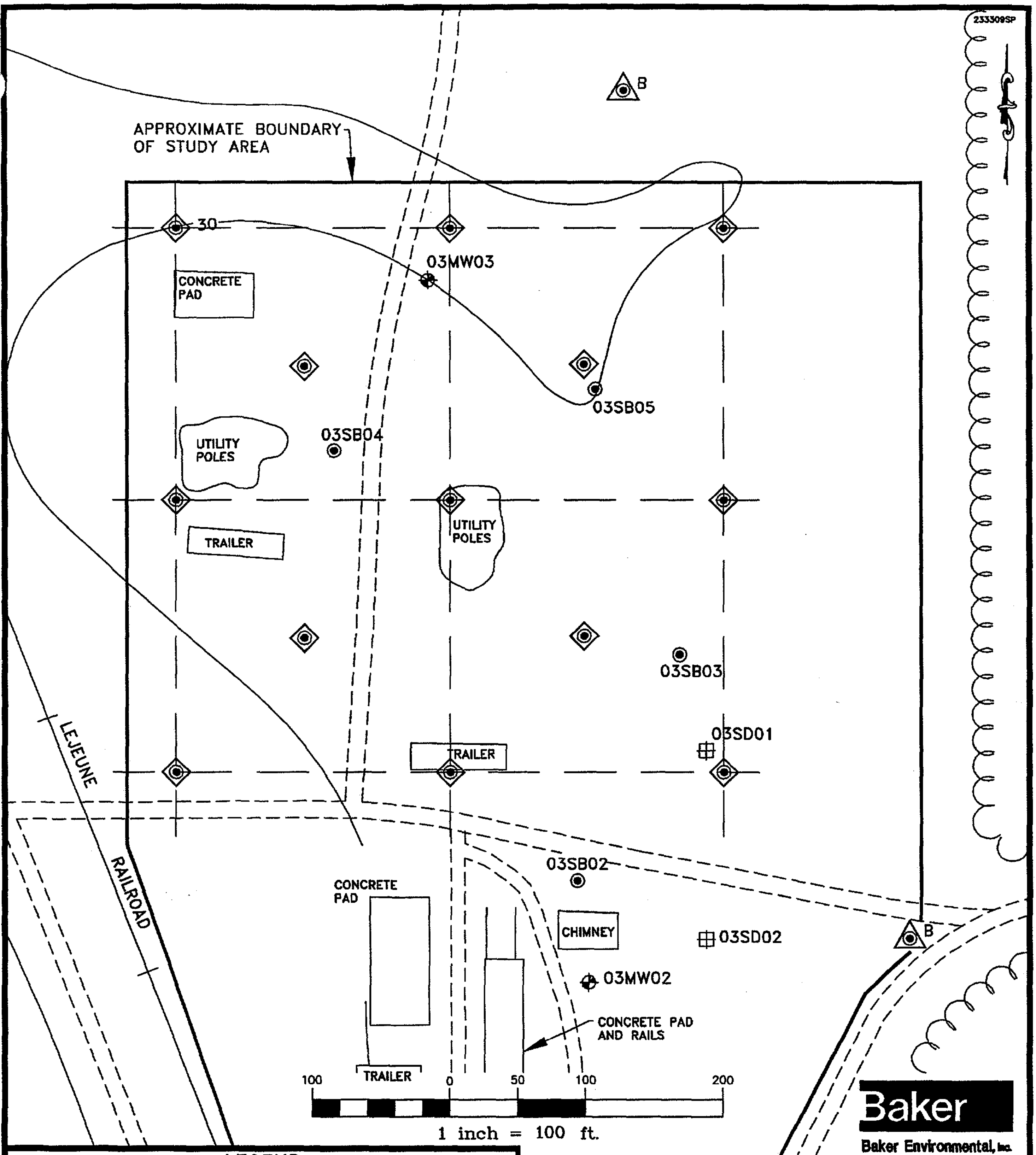
PROPOSED INTERMEDIATE MONITORING WELL

ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 4-8
GROUNDWATER INVESTIGATION
SITE 80-PARADISE POINT GOLF COURSE MAINTENANCE AREA
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

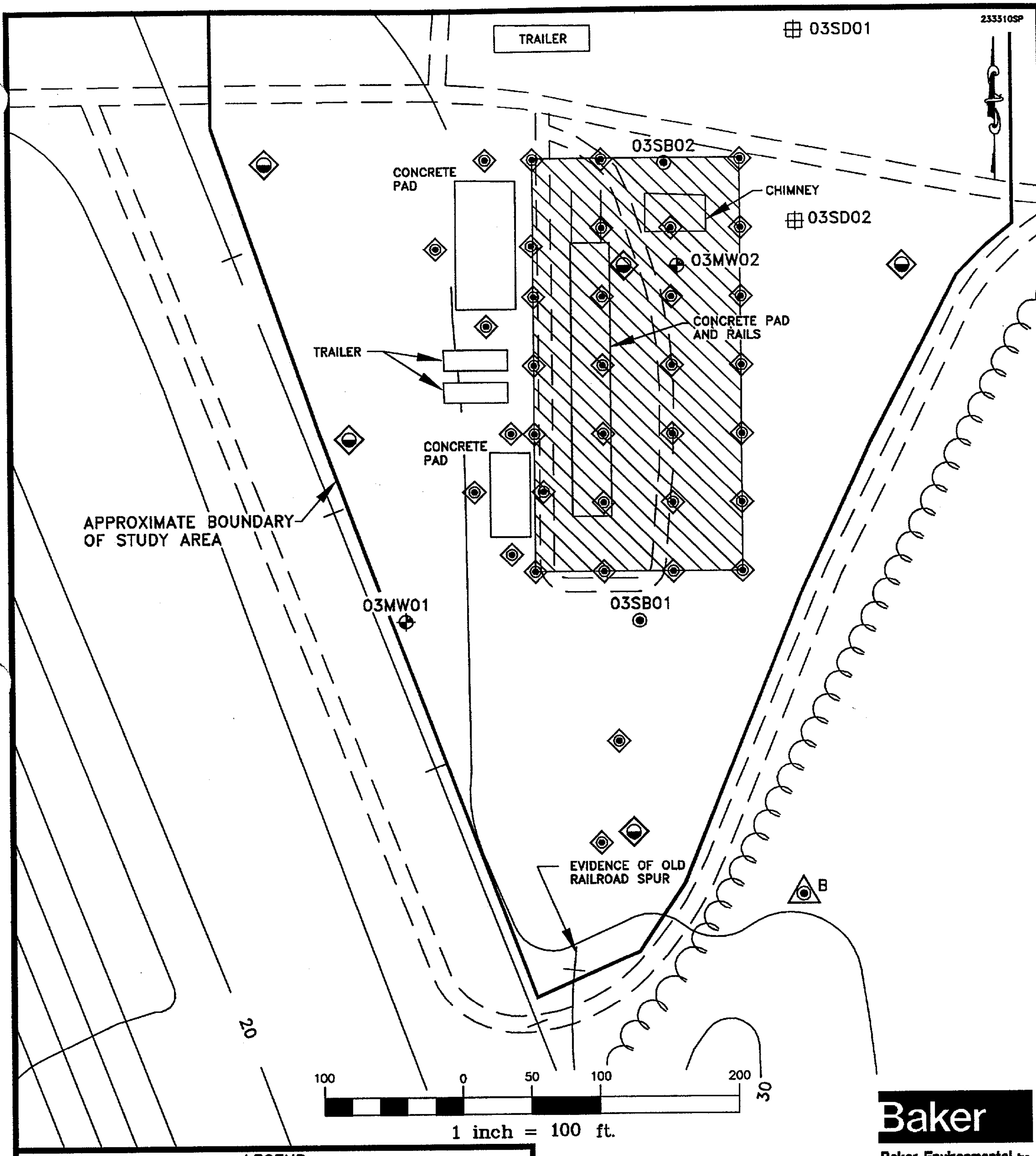


LEGEND

- 03MW01 — MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 03SB01 — SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 03SD01 — SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- PROPOSED ENSYS TESTING
- B — PROPOSED BACKGROUND SOIL SAMPLING LOCATION

SOURCE: LANTDIV, FEB. 1992

FIGURE 4-9
SOIL INVESTIGATION
NORTH AREA - SITE 3
OLD CREOSOTE PLANT
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



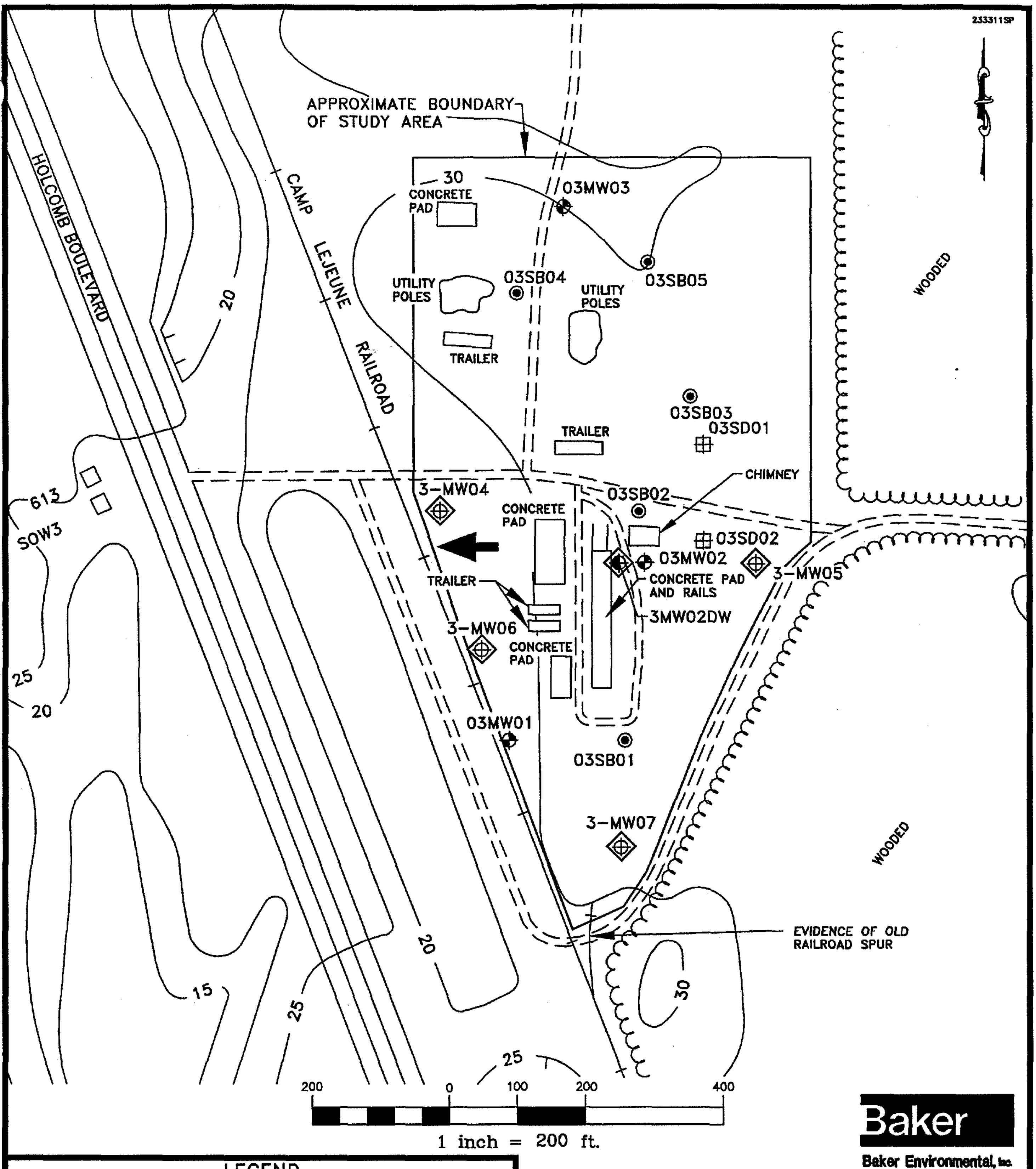
LEGEND

03MW01	MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
03SB01	SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
03SD01	SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
	PROPOSED ENSYS TESTING
	PROPOSED SOIL BORING (MONITORING WELL TEST BORING)
	AREA OF CONCERN
B	PROPOSED BACKGROUND SOIL SAMPLING LOCATION

SOURCE: LANTDIV, FEB. 1992

FIGURE 4-10
SOIL INVESTIGATION
SOUTH AREA – SITE 3
OLD CREOSOTE PLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



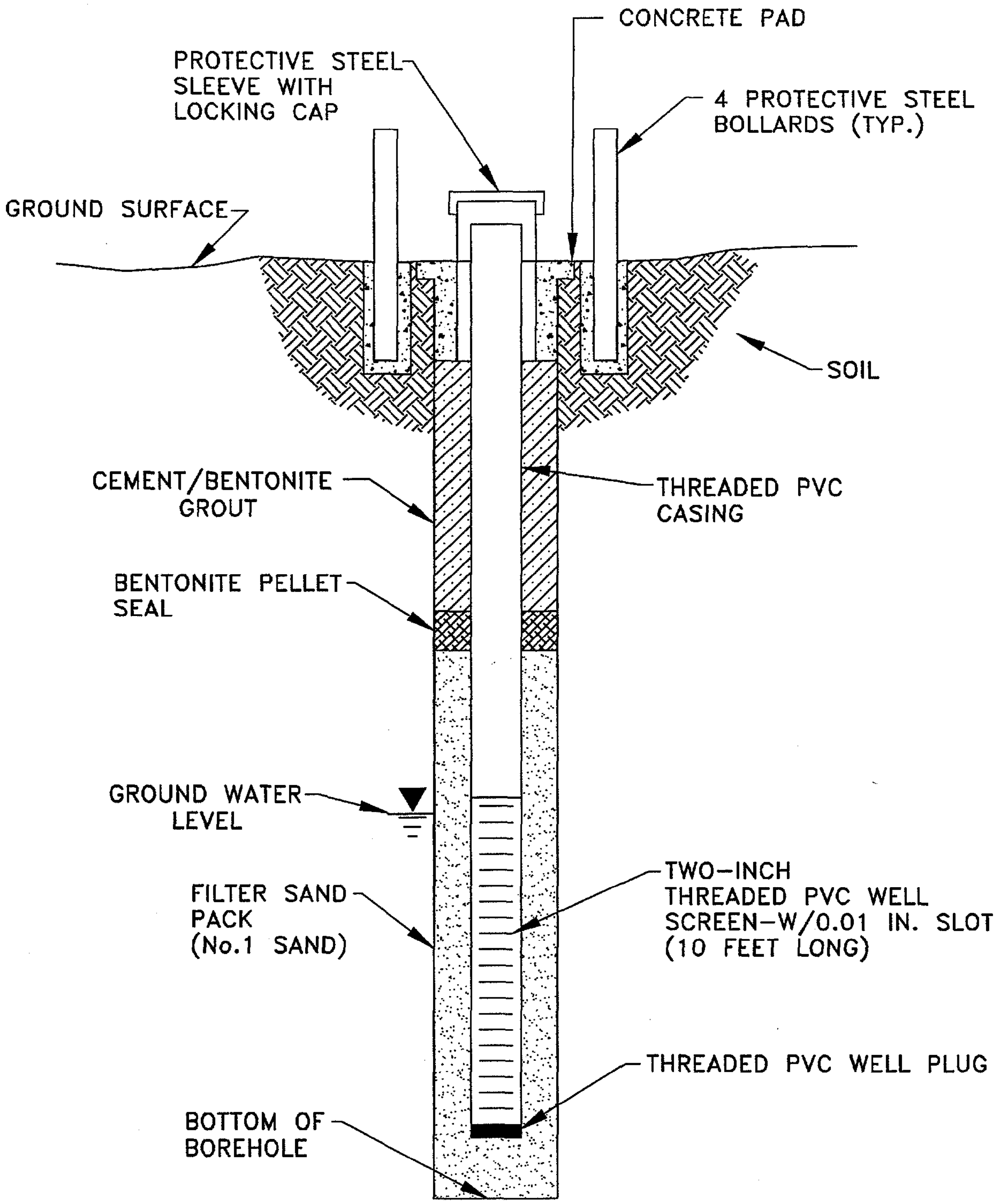
LEGEND

- 03MW01 — MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 03SB01 — SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 03SD01 — SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- PROPOSED SHALLOW MONITORING WELL
- PROPOSED INTERMEDIATE MONITORING WELL
- ESTIMATED GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992

FIGURE 4-11
GROUNDWATER INVESTIGATION
SITE 3-OLD CREOSOTE PLLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



N.T.S.

Baker
Baker Environmental, Inc.

FIGURE 6-1
TYPICAL SHALLOW GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

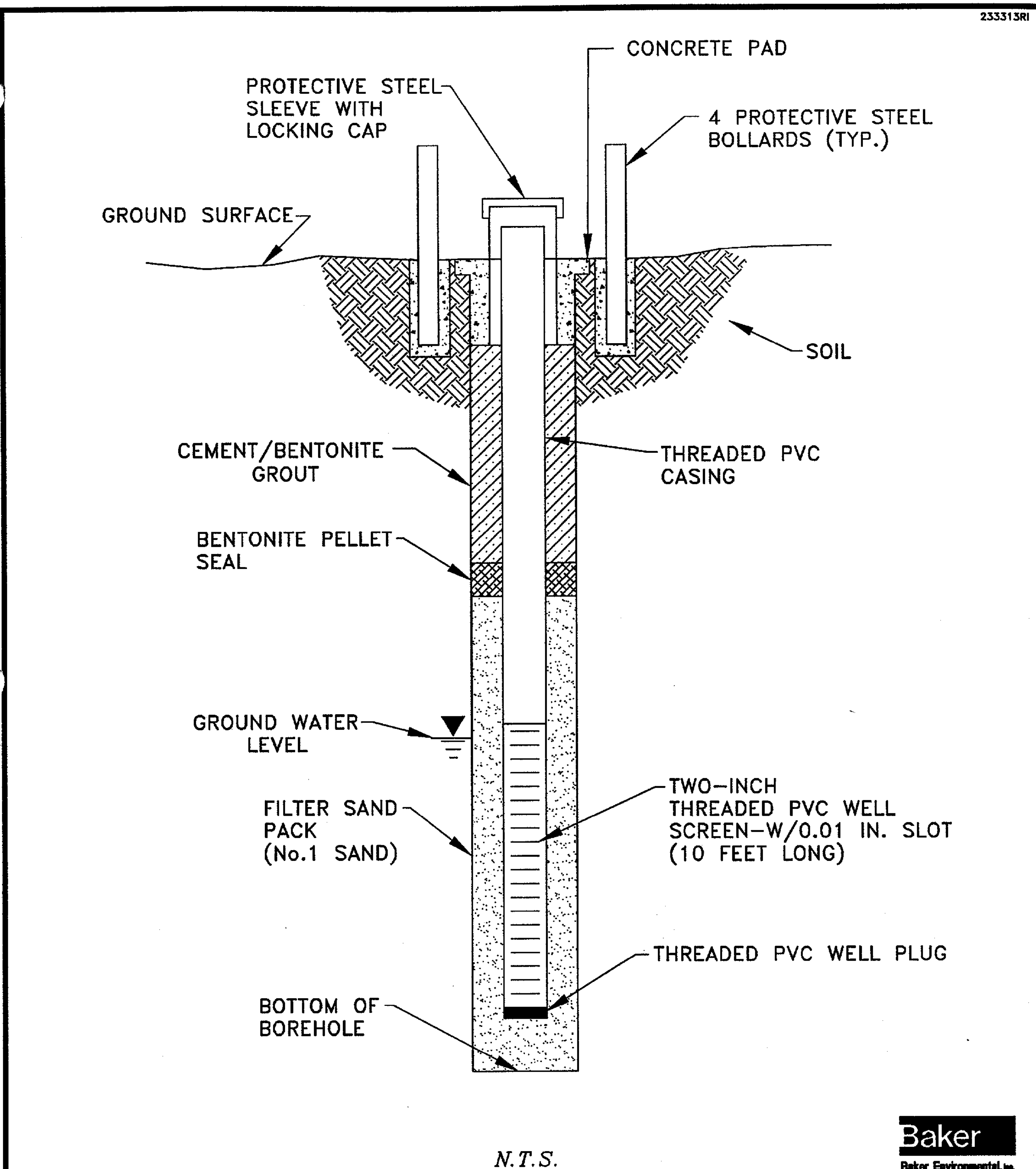


FIGURE 6-2
TYPICAL DEEP GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

APPENDIX A

Soil and Rock Sample Acquisition

SOIL AND ROCK SAMPLE ACQUISITION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Rock Cores
- 5.2 Subsurface Soil Samples
  - 5.2.1 Split-Barrel (Split-Spoon) Samples
  - 5.2.2 Thin-Wall (Shelby Tube) Sampling
  - 5.2.3 Bucket (Hand) Auger Sampling
- 5.3 Surface Soil Samples

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

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 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.

5.1.1 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 (not for geotech) 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 tightly closed, 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.

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 (or other appropriate container) 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. In the event that a composite sample is required, 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.

5.1.2 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 indicate the top 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 Densㅤion 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.

5.1.3 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 decontaminated 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.

5.2 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 F304.

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 (or other appropriate container), mixed thoroughly using a decontaminated 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.

5.3 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 different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate 10 to 20 linear feet of core 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. Arrangements should be made to dispose of or return the core samples to the client for completion of the project.

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 F101 and SOP F302.

7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled

Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D1586-84

STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Standard Test 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 standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

ε1 NOTE—Editorial changes were made throughout October 1992.

1. Scope

1.1 This test 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 does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For 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]

D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems[2]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard*

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *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.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *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.

3.1.6 *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.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *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).

3.1.9 ΔN—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *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).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test 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 test 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

[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.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 67 (1974).

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

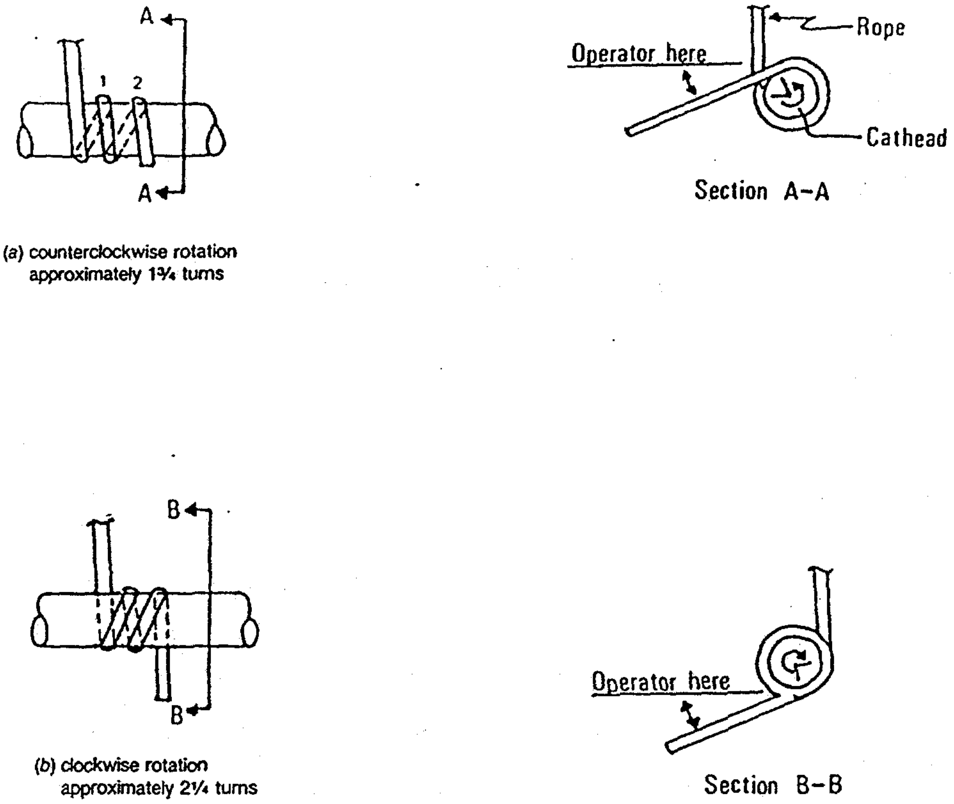


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

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 conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers,* with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers,* less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

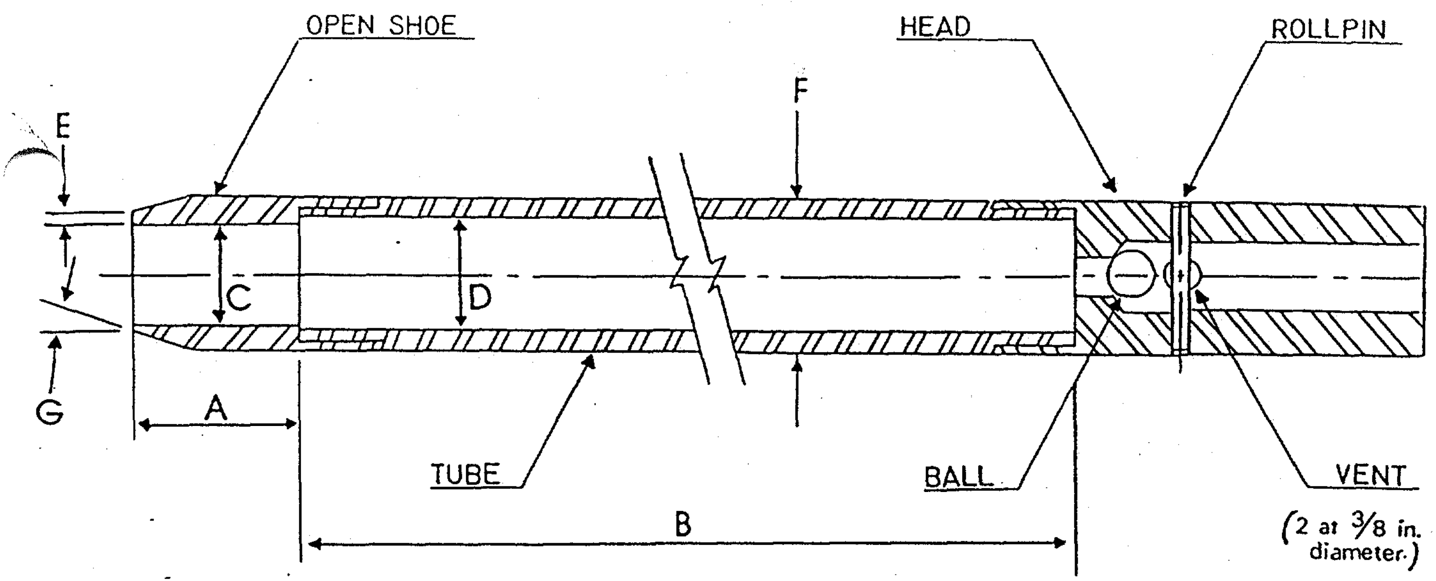
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, ·ple containers, data sheets, and groundwater level mea- .ng devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method ·ıll not be used for advancing the boring below a water · or below the upper confining bed of a confined cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in N-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N-value adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS

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

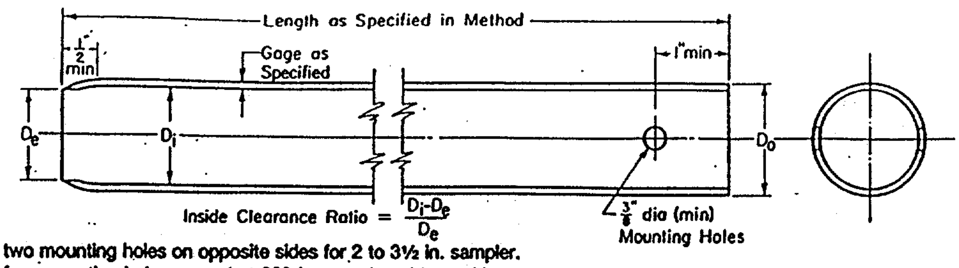
6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

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.

Current edition approved Aug. 17, 1983. Published October 1983. Originally published as D 1587 – 58 T. Last previous edition D 1587 – 74.

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



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
NOTE 3—Tube held with hardened screws.
NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
⅜	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Size Outside Diameter	Nominal Tube Diameters from Table 1[A] Tolerances, in. 2	3	5
Outside diameter	+0.007 −0.000	+0.010 −0.000	+0.015 −0.000
Inside diameter	+0.000 −0.007	+0.000 −0.010	+0.000 −0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.
NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project,

8.1.2 Boring number and precise location on project,

8.1.3 Surface elevation or reference to a datum,

8.1.4 Date and time of boring—start and finish,

8.1.5 Depth to top of sample and number of sample,

8.1.6 Description of sampler: size, type of metal, type of coating,

8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level: date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

ATTACHMENT C

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

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.

[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.

Current edition approved June 24, 1983. Published August 1983. Originally published as D 2113 – 62 T. Last previous edition D 2113 – 70 (1976).

[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.

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.6
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
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

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 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 and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.[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 prevent raveling of the borehole and to prevent loss of drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

6.4 *Compatibility of Equipment:*

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

7. Boring Log

7.1 The boring log shall include the following:

7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.

7.1.2 Elevation of the ground surface.

7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.

7.1.4 Elevations or depths at which drilling fluid return was lost.

7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.

7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.

7.1.7 Geologist's or engineer's description of the formation recovered in each run.

7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.

7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

APPENDIX B

Test Pit and Trench Excavation

TEST PIT AND TRENCH EXCAVATION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Test Pit Sizes
- 5.2 Health and Safety Considerations
- 5.3 Logging and Sampling
- 5.4 Backfilling
- 5.5 Test Pit Excavation Procedures

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

TEST PIT AND TRENCH EXCAVATION

1.0 PURPOSE

The purpose of this procedure is to provide general reference information and technical guidance on the excavation of exploratory test pits and trenches.

2.0 SCOPE

These procedures provide overall technical guidance and may be modified by site-specific requirements for field exploratory trenches and test pits. Conditions which would make trench excavation difficult (such as a shallow water table), dangerous (presence of explosive materials or underground utilities) or likely to cause environmental problems (such as potential rupture of buried containerized wastes), will require modifications to the procedures presented herein and may prevent implementation of the exploratory excavation program. Furthermore, the costs and difficulties in disposing of potentially hazardous materials removed from the test pits may constrain their use to areas where contamination potential is low. Consequently, the techniques described herein are most applicable in areas of low apparent contamination and where potentially explosive materials are not expected to be present.

3.0 DEFINITIONS

Trench - Trench means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet. If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet or less (measured at the bottom of the excavation), the excavation is also considered to be a trench (definition from Federal Register, Vol. 54 No. 209, Tuesday, October 31, 1989, 29 CFR Part 1926 Occupational Safety and Health Standards - Excavations; Final Rule) (see Attachment A).

Test Pit - A test pit is a small excavation made below ground surface to characterize soil type and quality as well as determine the types of wastes buried. In general, a test pit is dug using a backhoe with dimensions measured as follows:

Width -	Typically two to three backhoe buckets wide
Length -	Typically five to 10 feet long
Depth -	Typically to top of water table or one to two feet below base of fill material

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel responsible for trench and test pit excavation are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that all appropriate documents (i.e., Test Pit Logs) have been completely and correctly filled out by the field inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all test pit and trenching activities, and for ensuring that each test pit is properly and completely logged by the field inspector. It also is the responsibility of the Field Team Leader to ensure that all field inspectors have been briefed on these procedures.

Field Inspector - The Field Inspector is responsible for the direct supervision of test pit and trenching activities. It is the Field Inspector's responsibility to log each test pit, document subsurface conditions, complete appropriate forms, and to direct the test pit or trenching activities.

5.0 PROCEDURES

The procedures for test pit sizes, health and safety considerations, sampling, and backfilling are discussed in the following sections. Regulation for trench excavation, including trench sizes are given in the Tuesday October 31, 1989 edition of the Federal Register, 29 CFR Part 1926, "Occupation Safety and Health Standards - Excavations; Final Rule" (see Attachment A).

5.1 Test Pit Sizes

Test pits and trenches permit detailed exploration of the nature and contamination of in-situ materials, and the characteristics and stratification of near surface materials. The size of the excavation will depend on:

- Purpose and extent of the exploration.
- Space limitations imposed by site conditions (i.e., proximity to buildings, utilities, etc.).
- Contaminants present and the potential for release to the environment.
- Stability of the materials being excavated.
- Capabilities and limitations of the excavating equipment.

Test pits normally have a width ranging from two to ten feet or greater, depending on the objectives of the excavation and the equipment used. Test trenches are elongated test pits, usually three- to six-feet wide and extending for any desired length.

Standard equipment (i.e., backhoe) is readily available to excavate to depths of up to about 15 feet. However, larger and deeper excavations may be required. Standard equipment can be used to excavate deeper than their nominal limits by stepping or benching the excavation.

5.2 Health and Safety Considerations

Care must be taken by all on-site personnel during every phase of the test pit or trench excavation operation to avoid possible chemical and physical hazards. Chemical hazards may occur from direct exposure to excavated wastes or inhalation of volatilized materials. Physical hazards include the possible collapse of the trench or test pit, possible injury through violent contact with excavation equipment, or explosion or other forceful reaction upon contact with exposed drums or other wastes.

All test pit and trench excavation activities must be carefully detailed in the site-specific Health and Safety Plan which will specify all precautions to be observed relative to possible chemical or physical hazards associated with these operations. Respiratory and personal protective equipment to be worn by all on-site personnel involved in excavation operations also will be specified in this document.

At locations where access is not restricted, a safety zone shall be established around the excavation. Additionally, personnel should, **NOT** under any circumstances, enter the excavation. Prior written approval and procedures documented in the Sampling and Analysis Plan and Health and Safety Plan, and approved by LANTDIV are required if entry into the excavation is to be considered. Additionally, a site Health and Safety Officer familiar with excavations shall be on site and shall direct the entry procedures.

5.3 Logging and Sampling

Test pits and/or trenches shall be logged and sampled by the Field Inspector. Soils shall be classified and described in accordance with the procedures given in SOP F101. Test Pit Records (see Figure 1) shall be legibly completed for all test pits. Samples shall only be collected from material in the equipment bucket, or from the pile of excavated materials. The excavation shall **NOT** be entered for the purpose of collecting samples.

5.4 Backfilling

Backfilling of trenches and test pits is a normally accepted practice to reduce immediate site hazards and minimize the potential for rainwater accumulation and subsequent contaminant migration.

After inspection and completion of the appropriate test pit logs, backfill material should be returned to the pit under the direction of the field inspector. Any hazardous and/or waste materials which are not returned to the excavation as backfill must be collected and properly disposed. If a low permeability layer is accidentally penetrated, or if a soil layer containing substantial quantities of contaminants is encountered, backfill material must consist of a soil-bentonite mix. The mix should be prepared in a proportion specified by the field inspector and should be covered by "clean" soil and graded to the original land contour. Where it is safe to do so, the backhoe bucket should be used to compact each one to two-foot layer of backfill as it is placed, to reduce settling and compaction. The test pit cover should be inspected and further regraded, if necessary after settling has occurred.

Figure 1

Baker

Baker Environmental, Inc

TEST PIT RECORD

PROJECT: ____________________

CTO NO.: ____________________ TEST PIT NO.: ____________________

COORDINATES: EAST ____________________ NORTH: ____________________

SURFACE ELEVATION: ____________________ WATER LEVEL: ____________________

WEATHER: ____________________ DATE: ____________________

REMARKS: ____________________

DEFINITIONS

HNU = Photo Ionization Detector Reading
OVA = Organic Vapor Analyzer Reading

Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)
Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis

Depth (Ft.)	Sample Type and No.	HNU or (OVA) ppm		Lab. Class.	Lab. Moist %	Soil Strat	Visual Description (Principal Constituents, Gradation, Color, Moisture Content, Organic Content, Plasticity, and Other Observations)	Elevation (MSL)
		Field	Head Space					
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

CONTRACTOR: ____________________ BAKER REP.: ____________________

EQUIPMENT: ____________________ TEST PIT NO.: ____________________ SHEET 1 OF 1

5.5 Test Pit Excavation Procedures

The following procedures apply to the excavation and backfilling of a typical test pit. Note that if a subcontractor is procured to perform the test pit operations, the subcontractor must provide both an equipment operator and a supervisor:

- The positions of the test pits shall be located in the field by the field team leader.
- Utility clearance shall be obtained for all test pit locations prior to excavation. Contact appropriate Base personnel as well as MISS Utility (VA, MD, DC) or ULOCO (NC).

  MISS Utility (1-800-552-7001)
  ULOCO (1-800-632-4949)

- Excavation equipment shall be thoroughly decontaminated prior to and after each test pit excavation.
- A safety zone shall be established around the test pit location prior to initiation of excavation activities.
- Excavation shall commence by removing lifts of no more than approximately 6 to 12 inches of soil.
- The field inspector shall log the test pit soils and record observations on a Test Pit Record (Figure 1). Additionally, the test pit cross-section shall be sketched in the Field Logbook with notable features identified.
- If applicable, soil or waste samples shall be collected either from the backhoe bucket or from the pile of excavated materials following all appropriate SOPs (i.e., F102).
- Test pit depths (and water levels) may be measured using an engineers rule (six foot) or a weighted measuring tape. Depths shall be measured from the ground surface.
- Upon completion, test pits shall be immediately backfilled as described in Section 5.4.
- Test pit locations shall be marked with five wooden stakes; one at each corner and one in the center. The test pit number shall be recorded on the centrally located stake.
- If applicable, the test pit will be surveyed by a registered land surveyor or measured and referenced to nearby permanent site structures (i.e., buildings, curbs, fences, etc.).

6.0 QUALITY ASSURANCE RECORDS

The Quality Assurance Records that should be prepared include Test Pit Records and the Field Logbook.

7.0 REFERENCES

OSHA , 1989. Occupational Safety and Health Standards - Excavations; Final Rule. 29 CFR Part 1926.

ATTACHMENT A

OSHA - EXCAVATIONS, FINAL RULE
29 CFR PART 1926

federal register

Tuesday
October 31, 1989

Part II

Department of Labor

Occupational Safety and Health Administration

29 CFR Part 1926
Occupational Safety and Health Standards—Excavations; Final Rule

PART 1926—[AMENDED]

Subpart M—[Amended]

1. By revising the authority citation for subpart M of part 1926 to read as follows:

Authority: Sec. 107, Contract Work Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12–71 (36 FR 8754), 8–76 (41 FR 25059), or 9–83 (48 FR 35736), as applicable, and 29 CFR part 1911.

2. By revising subpart P of part 1926 to read as follows:

Subpart P—Excavations

Sec.
1926.650 Scope, application, and definitions applicable to this subpart.
1926.651 General requirements.
1926.652 Requirements for protective systems.

Appendix A to Subpart P—Soil Classification

Appendix B to Subpart P—Sloping and Benching

Appendix C to Subpart P—Timber Shoring for Trenches

Appendix D to Subpart P—Aluminum Hydraulic Shoring for Trenches

Appendix E to Subpart P—Alternatives to Timber Shoring

Appendix F to Subpart P—Selection of Protective Systems

Subpart P—Excavations

Authority: Sec. 107, Contract Worker Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12–71 (36 FR 8754), 8–76 (41 FR 25059), or 9–83 (48 FR 35736), as applicable, and 29 CFR part 1911.

§ 1926.650 Scope, application, and definitions applicable to this subpart.

(a) *Scope and application.* This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches.

(b) *Definitions applicable to this subpart.*

Accepted engineering practices means those requirements which are compatible with standards of practice required by a registered professional engineer.

Aluminum Hydraulic Shoring means a pre-engineered shoring system comprised of aluminum hydraulic cylinders (crossbraces) used in conjunction with vertical rails (uprights) or horizontal rails (walers). Such system is designed, specifically to support the sidewalls of an excavation and prevent cave-ins.

Bell-bottom pier hole means a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

Benching (Benching system) means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in means the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Cross braces mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Excavation means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Faces or *sides* means the vertical or inclined earth surfaces formed as a result of excavation work.

Failure means the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere means an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Kickout means the accidental release or failure of a cross brace.

Protective system means a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Ramp means an inclined walking or working surface that is used to gain access to one point from another, and is constructed from earth or from structural materials such as steel or wood.

Registered Professional Engineer means a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

Sheeting means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

Shield (Shield system) means a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either premanufactured or job-built in accordance with § 1926.652 (c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) means a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

Sides. See "Faces."

Sloping (Sloping system) means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Stable rock means natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Structural ramp means a ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock are not considered structural ramps.

Support system means a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation.

Tabulated data means tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Trench box. See "Shield."

Trench shield. See "Shield."

Uprights means the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

§ 1926.651 General requirements.

(a) *Surface encumbrances.* All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported, as necessary, to safeguard employees.

(b) *Underground installations.* (1) The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.

(2) Utility companies or owners shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of actual excavation. When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used.

(3) When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means.

(4) While the excavation is open, underground installations shall be protected, supported or removed as necessary to safeguard employees.

(c) *Access and egress*—(1) *Structural ramps.* (i) Structural ramps that are used solely by employees as a means of access or egress from excavations shall be designed by a competent person. Structural ramps used for access or egress of equipment shall be designed by a competent person qualified in structural design, and shall be constructed in accordance with the design.

(ii) Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.

(iii) Structural members used for ramps and runways shall be of uniform thickness.

(iv) Cleats or other appropriate means used to connect runway structural members shall be attached to the bottom of the runway or shall be attached in a manner to prevent tripping.

(v) Structural ramps used in lieu of steps shall be provided with cleats or other surface treatments on the top surface to prevent slipping.

(2) *Means of egress from trench excavations.* A stairway, ladder, ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

(d) *Exposure to vehicular traffic.* Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable garments marked with or made of reflectorized or high-visibility material.

(e) *Exposure to falling loads.* No employee shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of vehicles being loaded or unloaded when the vehicles are equipped, in accordance with § 1926.601(b)(6), to provide adequate protection for the operator during loading and unloading operations.

(f) *Warning system for mobile equipment.* When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, hand or mechanical signals, or stop logs. If possible, the grade should be away from the excavation.

(g) *Hazardous atmospheres*—(1) *Testing and controls.* In addition to the requirements set forth in subparts D and E of this part (29 CFR 1926.50–1926.107) to prevent exposure to harmful levels of atmospheric contaminants and to assure acceptable atmospheric conditions, the following requirements shall apply:

(i) Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

(ii) Adequate precautions shall be taken to prevent employee exposure to atmospheres containing less than 19.5 percent oxygen and other hazardous atmospheres. These precautions include providing proper respiratory protection or ventilation in accordance with subparts D and E of this part respectively.

(iii) Adequate precaution shall be taken such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20 percent of the lower flammable limit of the gas.

(iv) When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

(2) *Emergency rescue equipment.* (i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, shall wear a harness with a life-line securely attached to it. The lifeline shall be separate from any line used to handle materials, and shall be individually attended at all times while the employee wearing the lifeline is in the excavation.

(h) *Protection from hazards associated with water accumulation.* (1) Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation. The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.

(2) If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations shall be monitored by a competent person to ensure proper operation.

(3) If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains will require an inspection by a competent person and compliance with paragraphs (h)(1) and (h)(2) of this section.

(i) *Stability of adjacent structures.* (1) Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.

(2) Excavation below the level of the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to employees shall not be permitted except when:

(i) A support system, such as underpinning, is provided to ensure the safety of employees and the stability of the structure; or

(ii) The excavation is in stable rock; or

(iii) A registered professional engineer has approved the determination that the structure is sufficently removed from the excavation so as to be unaffected by the excavation activity; or

(iv) A registered professional engineer has approved the determination that such excavation work will not pose a hazard to employees.

(3) Sidewalks, pavements, and appurtenant structure shall not be undermined unless a support system or another method of protection is provided to protect employees from the possible collapse of such structures.

(j) *Protection of employees from loose rock or soil.* (1) Adequate protection shall be provided to protect employees from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection shall consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection.

(2) Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such materials or equipment at least 2 feet (.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

(k) *Inspections.* (1) Daily inspections of excavations, the adjacent areas, and protective systems shall be made by a competent person for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. An inspection shall be conducted by the competent person prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rainstorm or other hazard increasing occurrence. These inspections are only required when employee exposure can be reasonably anticipated.

(2) Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

(l) *Fall protection.* (1) Where employees or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided.

(2) Adequate barrier physical protection shall be provided at all remotely located excavations. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, pits, shafts, etc., shall be backfilled.

§ 1926.652 Requirements for protective systems.

(a) *Protection of employees in excavations.* (1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

(i) Excavations are made entirely in stable rock; or

(ii) Excavations are less than 5 feet (1.52m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

(b) *Design of sloping and benching systems.* The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3), or, in the alternative, paragraph (b)(4), as follows:

(1) *Option (1)—Allowable configurations and slopes.* (i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in Appendix B to this subpart.

(2) *Option (2)—Determination of slopes and configurations using Appendices A and B.* Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and requirements set forth in appendices A and B to this subpart.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and shall include all of the following:

(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include at least the following:

(A) The magnitude of the slopes that were determined to be safe for the particular project;

(B) The configurations that were determined to be safe for the particular project; and

(C) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

(c) *Design of support systems, shield systems, and other protective systems.* Designs of support systems shield systems, and other protective systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (c)(1); or, in the alternative, paragraph (c)(2); or, in the alternative, paragraph (c)(3); or, in the alternative, paragraph (c)(4) as follows:

(1) *Option (1)—Designs using appendices A, C and D:* Designs for timber shoring in trenches shall be determined in accordance with the conditions and requirements set forth in appendices A and C to this subpart. Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

(2) *Option (2)—Designs Using Manufacturer's Tabulated Data.* (i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.

(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

(iii) Manufacturer's specifications, recommendations, and limitations, and manufacturer's approval to deviate from the specifications, recommendations, and limitations shall be in written form at the jobsite during construction of the protective system. After that time this data may be stored off the jobsite, but a copy shall be made available to the Secretary upon request.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and include all of the following:

(A) Identification of the parameters that affect the selection of a protective system drawn from such data;

(B) Identification of the limits of use of the data;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data, which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Support systems, shield systems, and other protective systems not utilizing Option 1, Option 2 or Option 3, above, shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include the following:

(A) A plan indicating the sizes, types, and configurations of the materials to be used in the protective system; and

(B) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite during construction of the protective system. After that time, the design may be stored off the jobsite, but a copy of the design shall be made available to the Secretary upon request.

(d) *Materials and equipment.* (1) Materials and equipment used for protective systems shall be free from damage or defects that might impair their proper function.

(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service, and shall be evaluated and approved by a registered professional engineer before being returned to service.

(e) *Installation and removal of support*—(1) *General.* (i) Members of support systems shall be securely connected together to prevent sliding, falling, kickouts, or other predictable failure.

(ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.

(iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.

(iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.

(v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.

(vi) Backfilling shall progress together with the removal of support systems from excavations.

(2) *Additional requirements for support systems for trench excavations.* (i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

(ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

(f) *Sloping and benching systems.* Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

(g) *Shield systems*—(1) *General.* (i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.

(ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.

(iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

(iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.

(2) *Additional requirement for shield systems used in trench excavations.* Excavations of earth material to a level not greater than 2 feet (.61 m) below the bottom of a shield shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

Appendix A to Subpart P

Soil Classification

(a) *Scope and application*—(1) *Scope.* This appendix describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The appendix contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils.

(2) *Application.* This appendix applies when a sloping or benching system is designed in accordance with the requirements set forth in § 1926.652(b)(2) as a method of protection for employees from cave-ins. This appendix also applies when timber shoring for excavations is designed as a method of protection from cave-ins in accordance with appendix C to subpart P of part 1926, and when aluminum hydraulic shoring is designed in accordance with appendix D. This Appendix also applies if other protective systems are designed and selected for use from data prepared in accordance with the requirements set forth in § 1926.652(c), and the use of the data is predicated on the use of the soil classification system set forth in this appendix.

(b) *Definitions.* The definitions and examples given below are based on, in whole or in part, the following: American Society for Testing Materials (ASTM) Standards D653–85 and D2488; The Unified Soils Classification System, The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS–121.

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

Dry soil means soil that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

Soil classification system means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater or is free seeping.

Type A means cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

(i) The soil is fissured; or

(ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or

(iii) The soil has been previously disturbed; or

(iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or

(v) The material is subject to other factors that would require it to be classified as a less stable material.

Type B means:

(i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or

(ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.

(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.

(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

(v) Dry rock that is not stable; or

(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C means:

(i) Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or

(ii) Granular soils including gravel, sand, and loamy sand; or

(iii) Submerged soil or soil from which water is freely seeping; or

(iv) Submerged rock that is not stable, or

(v) Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

Unconfined compressive strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Wet soil means soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

(c) *Requirements*—(1) *Classification of soil and rock deposits.* Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.

(2) *Basis of classification.* The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses

shall be conducted by a competent person using tests described in paragraph (d) below, or in other recognized methods of soil classification and testing such as those adopted by the America Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

(3) *Visual and manual analyses.* The visual and manual analyses, such as those noted as being acceptable in paragraph (d) of this appendix, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.

(4) *Layered systems.* In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

(5) *Reclassification.* If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

(d) *Acceptable visual and manual tests.*—(1) *Visual tests.* Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

(i) Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

(ii) Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

(iii) Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

(iv) Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

(v) Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

(vi) Observe the area adjacent to the excavation and the sides of the opened excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

(vii) Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

(2) *Manual tests.* Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

(i) *Plasticity.* Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as ⅛-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of ⅛-inch thread can be held on one end without tearing, the soil is cohesive.

(ii) *Dry strength.* If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

(iii) *Thumb penetration.* The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation D2488—"Standard Recommended Practice for Description of Soils (Visual—Manual Procedure).") Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

(iv) *Other strength tests.* Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shearvane.

(v) *Drying test.* The basic purpose of the drying test is to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

(A) If the sample develops cracks as it dries, significant fissures are indicated.

(B) Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as a unfissured cohesive material and the unconfined compressive strength should be determined.

(C) If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

Appendix B to Subpart P

Sloping and Benching

(a) *Scope and application.* This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations from cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in § 1926.652(b)(2).

(b) *Definitions.*

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

(c) *Requirements*—(1) *Soil classification.* Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

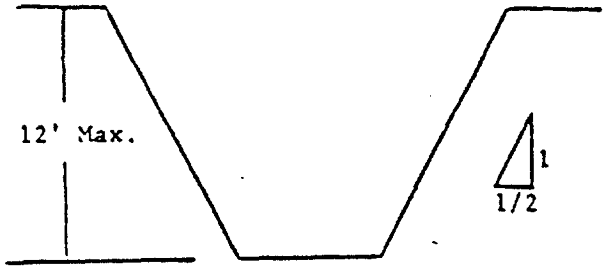
(2) *Maximum allowable slope.* The maximum allowable slope for a soil or rock deposit shall be determined from Table B–1 of this appendix.

(3) *Actual slope.* (i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least ½ horizontal to one vertical (½H:1V) less steep than the maximum allowable slope.

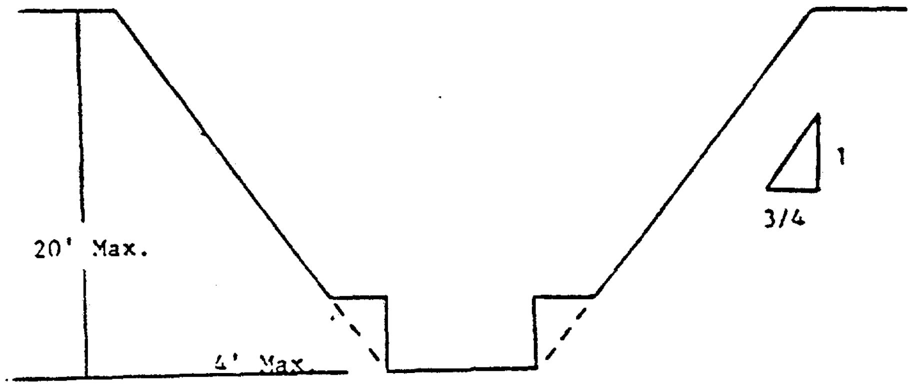
(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with § 1926.651(i).

(4) *Configurations.* Configurations of sloping and benching systems shall be in accordance with Figure B–1.

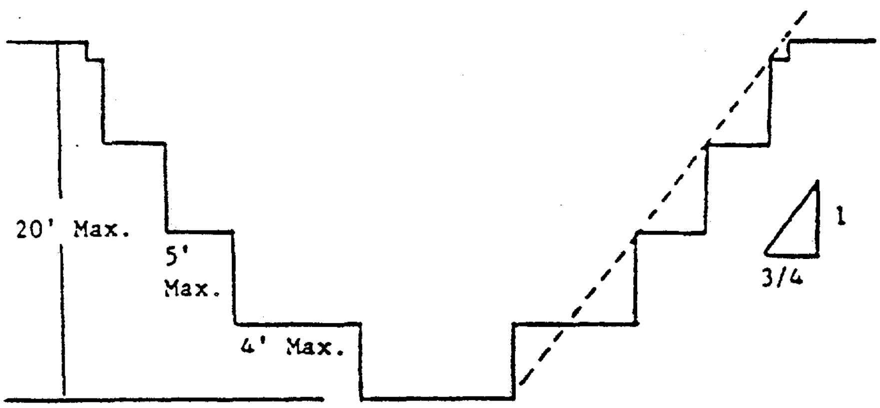


Simple Slope—Short Term

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of ¾ to 1 and maximum bench dimensions as follows:

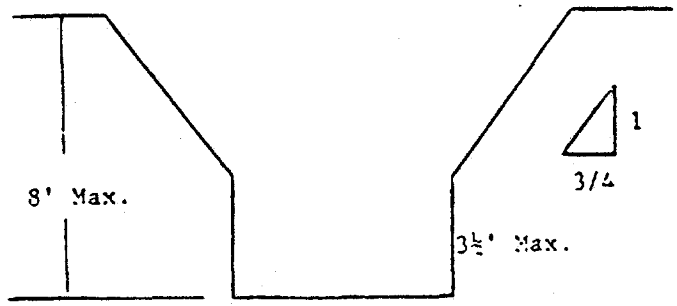


Simple Bench



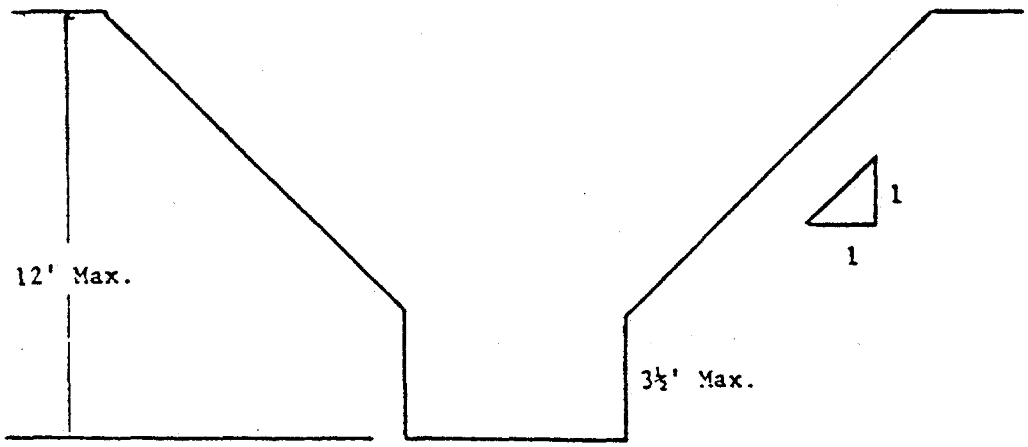
Multiple Bench

3. All excavations 8 feet or less in depth which have unsupported vertically sided lower portions shall have a maximum vertical side of 3½ feet.



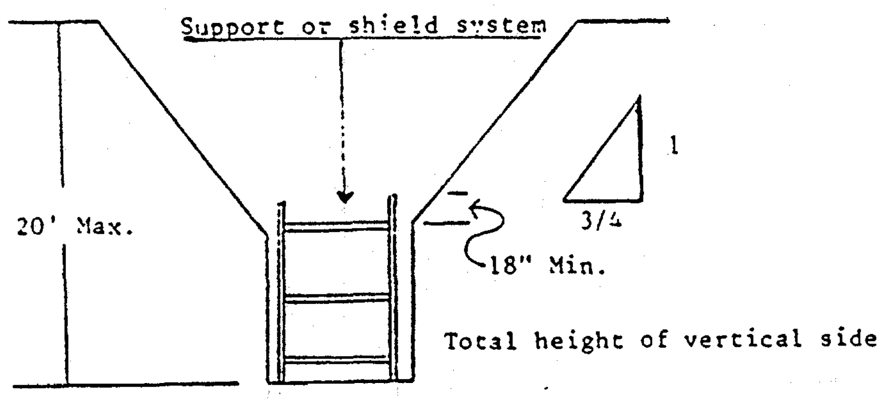
Unsupported Vertically Sided Lower Portion—Maximum 8 Feet in Depth

All excavations more than 8 feet but not more than 12 feet in depth which unsupported vertically sided lower portions shall have a maximum allowable slope of 1:1 and a maximum vertical side of 3½ feet.



Unsupported Vertically Sided Lower Portion—Maximum 12 Feet in Depth

All excavations 20 feet or less in depth which have vertically sided lower portions that are supported or shielded shall have a maximum allowable slope of ¾:1. The support or shield system must extend at least 18 inches above the top of the vertical side.

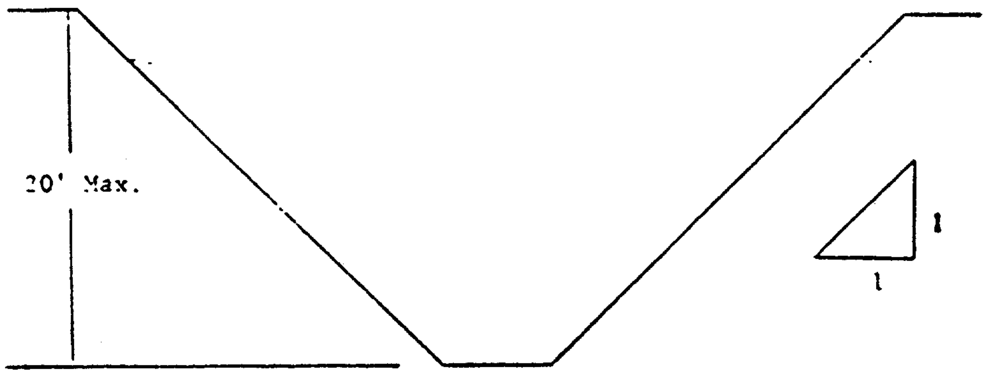


Suported or Shielded Vertically Sided Lower Portion

4. All other simple slope, compound slope, and vertically sided lower portion excavations shall be in accordance with the other options permitted under § 1926.652(b).

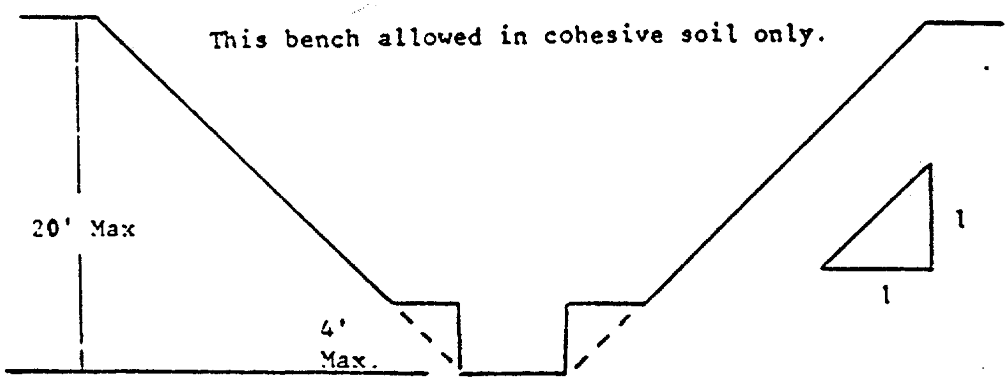
B-1.2 Excavations Made in Type B Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1.

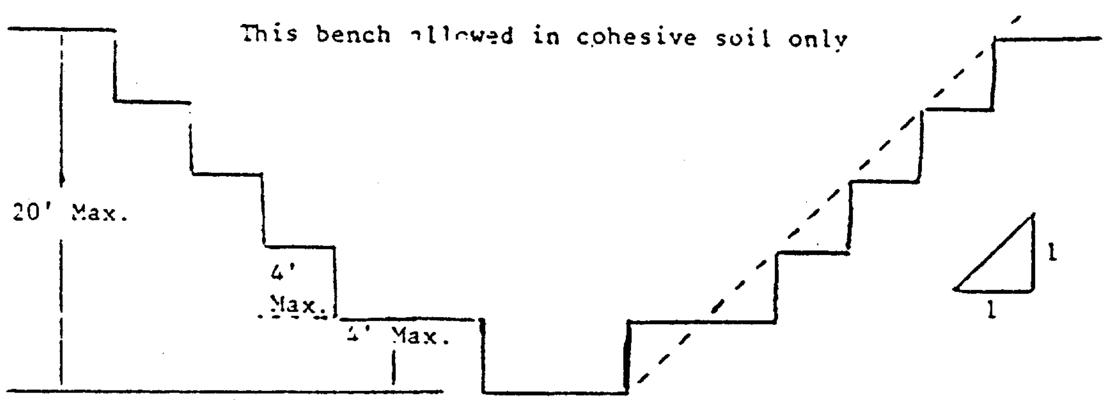


Simple Slope

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1 and maximum bench dimensions as follows:

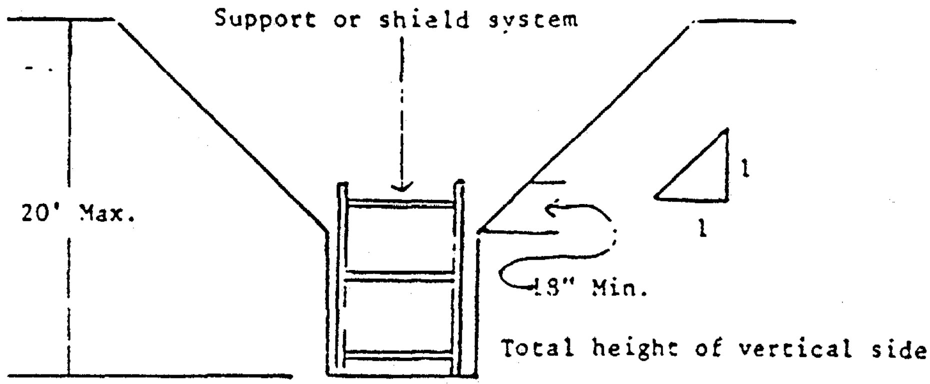


Single Bench



Multiple Bench

3. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1:1.

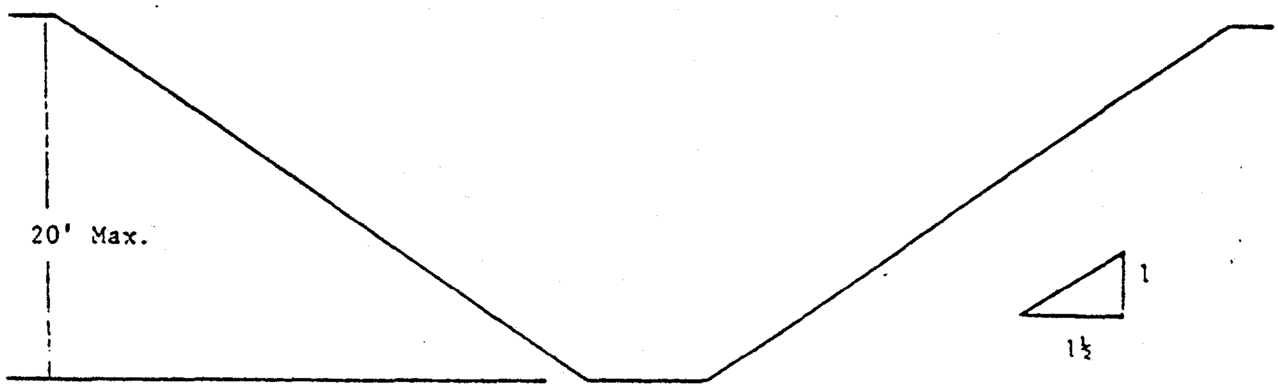


Vertically Sided Lower Portion

4. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

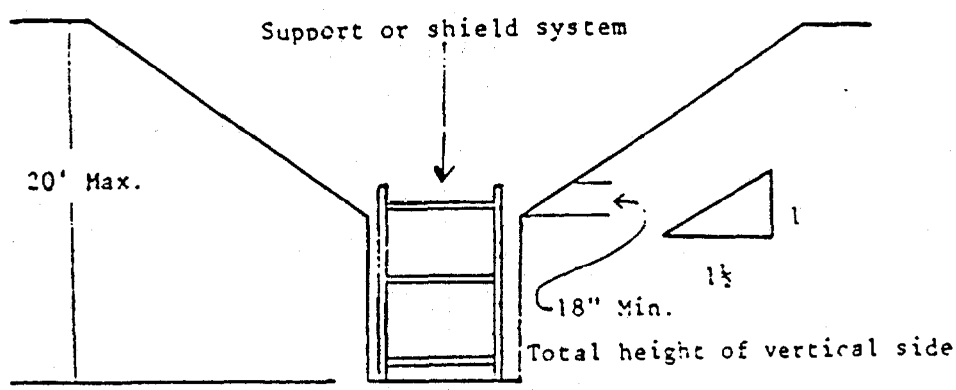
B-1.3 Excavations Made in Type C Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1½:1.



Simple Slope

2. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1½:1.

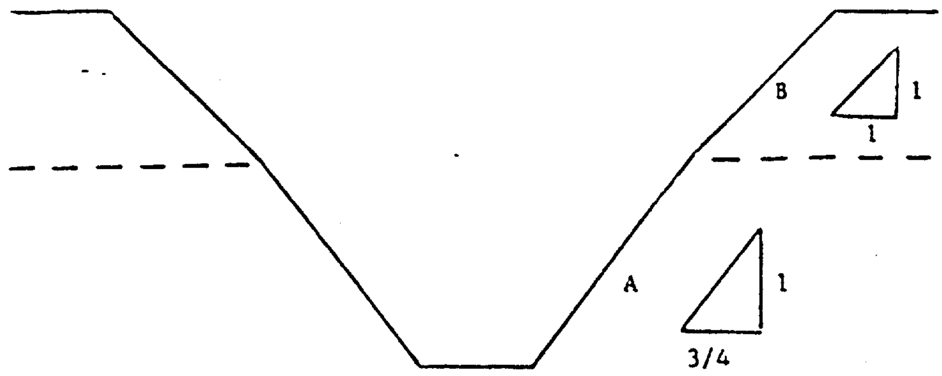


Vertical Sided Lower Portion

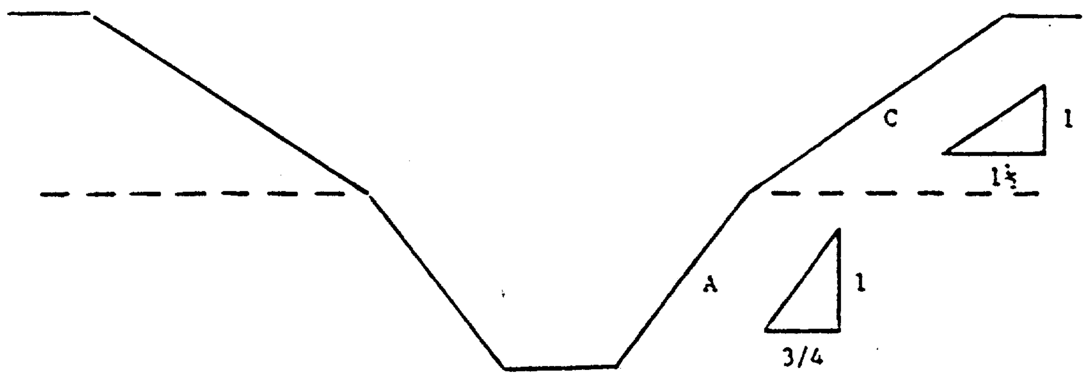
3. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

B-1.4 Excavations Made in Layered Soils

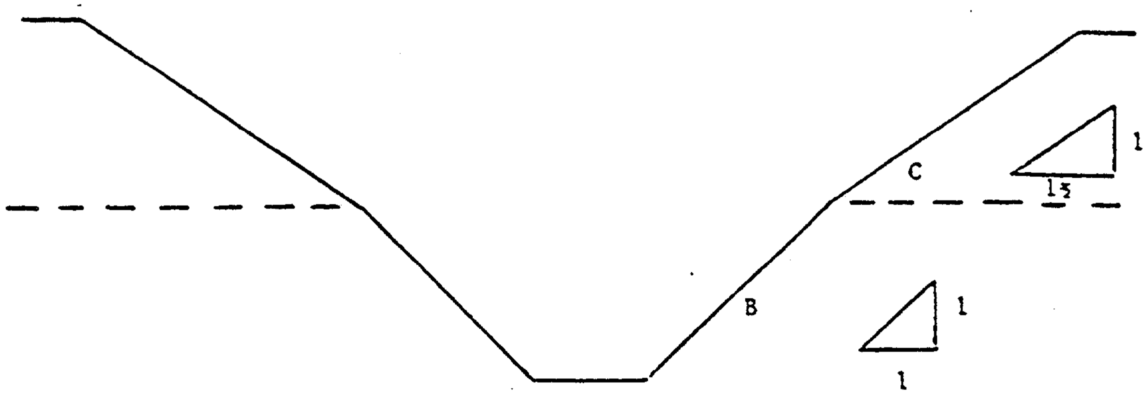
1. All excavations 20 feet or less in depth made in layered soils shall have a maximum allowable slope for each layer as set forth below.



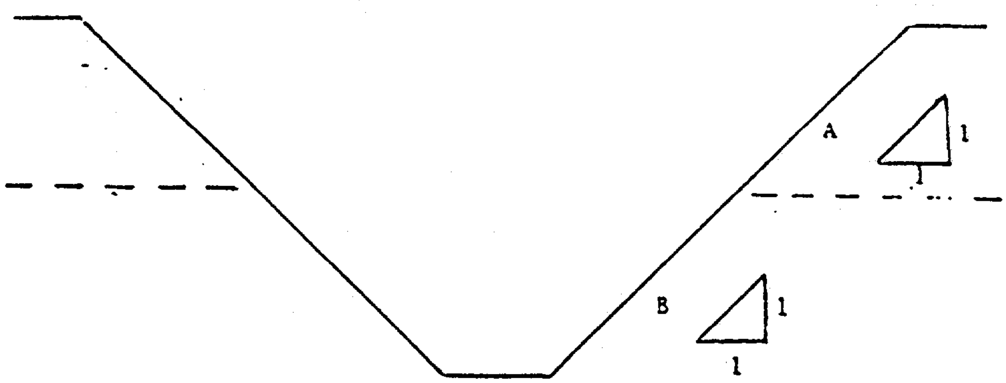
B OVER A



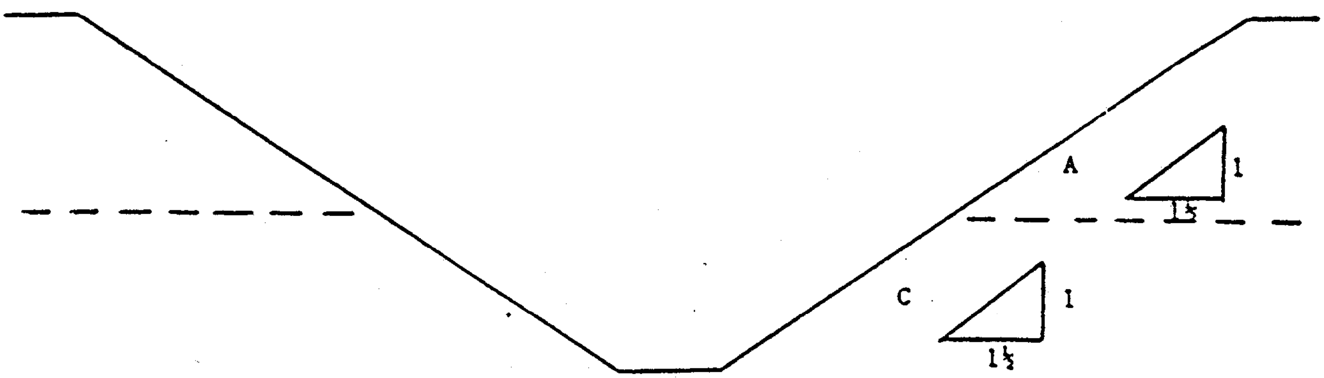
C OVER A



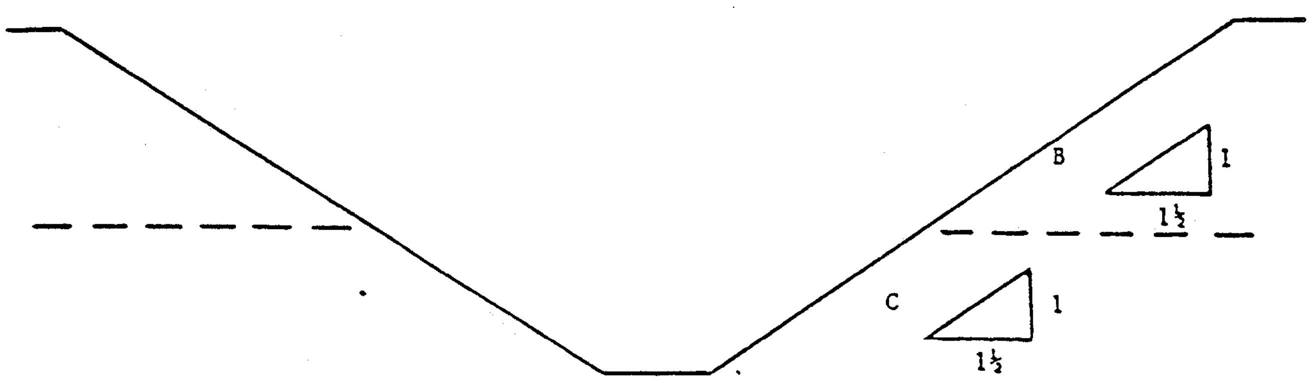
C OVER B



A OVER B



A OVER C



B OVER C

2. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

Appendix C to Subpart P

Timber Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used timber shoring is provided as a method of protection from cave-ins in trenches that do not exceed 20 feet (6.1 m) in depth. This appendix must be used when design of timber shoring protective systems is to be performed in accordance with § 1926.652(c)(1). Other timber shoring configurations; other systems of support such as hydraulic and pneumatic systems; and other protective systems such as sloping, benching, shielding, and freezing systems must be designed in accordance with the requirements set forth in § 1926.652(b) and § 1926.652(c).

(b) *Soil Classification.* In order to use the data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of this part.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables C–1.1, C–1.2, and C–1.3, and Tables C–2.1, C–2.2 and C–2.3 following paragraph (g) of the appendix. Each table presents the minimum sizes of timber members to use in a shoring system, and each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. The data are arranged to allow the user the flexibility to select from among several acceptable configurations of members based on varying the horizontal spacing of the crossbraces. Stable rock is exempt from shoring requirements and therefore, no data are presented for this condition.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix, and on the tables themselves.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations regarding Tables C–1.1 through C–1.3 and Tables C–2.1 through C–2.3 are presented in paragraph (g) of this Appendix.

(d) *Basis and limitations of the data.*—(1) *Dimensions of timber members.* (i) The sizes of the timber members listed in Tables C–1.1 through C–1.3 are taken from the National Bureau of Standards (NBS) report, "Recommended Technical Provisions for Construction Practice in Shoring and Sloping of Trenches and Excavations." In addition, where NBS did not recommend specific sizes of members, member sizes are based on an analysis of the sizes required for use by existing codes and on empirical practice.

(ii) The required dimensions of the members listed in Tables C–1.1 through C–1.3 refer to actual dimensions and not nominal dimensions of the timber. Employers wanting to use nominal size shoring are directed to Tables C–2.1 through C–2.3, or have this choice under § 1926.652(c)(3), and are referred to The Corps of Engineers, The Bureau of Reclamation or data from other acceptable sources.

(2) *Limitation of application.* (i) It is not intended that the timber shoring specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the tables are not considered adequate. Either an alternate timber shoring system must be designed or another type of protective system designed in accordance with § 1926.652.

(A) When loads imposed by structures or by stored material adjacent to the trench weigh in excess of the load imposed by a two-foot soil surcharge. The term "adjacent" as used here means the area within a horizontal distance from the edge of the trench equal to the depth of the trench.

(B) When vertical loads imposed on cross braces exceed a 240-pound gravity load distributed on a one-foot section of the center of the crossbrace.

(C) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(D) When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables.* The members of the shoring system that are to be selected using this information are the cross braces, the uprights, and the wales, where wales are required. Minimum sizes of members are specified for use in different types of soil. There are six tables of information, two for each soil type. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is then made. The selection is based on the depth and width of the trench where the members are to be installed and, in most instances, the selection is also based on the horizontal spacing of the crossbraces. Instances where a choice of horizontal spacing of crossbracing is available, the horizontal spacing of the crossbraces must be chosen by the user before the size of any member can be determined. When the soil type, the width and depth of the trench, and the horizontal spacing of the crossbraces are known, the size and vertical spacing of the crossbraces, the size and vertical spacing of the wales, and the size and horizontal spacing of the uprights can be read from the appropriate table.

(f) *Examples to Illustrate the Use of Tables C–1.1 through C–1.3.*

(1) *Example 1.*

A trench dug in Type A soil is 13 feet deep and five feet wide.

From *Table C–1.1,* for acceptable arrangements of timber can be used.

Arrangement #1

Space 4×4 crossbraces at six feet horizontally and four feet vertically.

Wales are not required.

Space 3×8 uprights at six feet horizontally. This arrangement is commonly called "skip shoring."

Arrangement #2

Space 4×6 crossbraces at eight feet horizontally and four feet vertically.

Space 8×8 wales at four feet vertically.

Space 2×6 uprights at four feet horizontally.

Arrangement #3

Space 6×6 crossbraces at 10 feet horizontally and four feet vertically.

Space 8×10 wales at four feet vertically.

Space 2×6 uprights at five feet horizontally.

Arrangement #4

Space 6×6 crossbraces at 12 feet horizontally and four feet vertically.

Space 10×10 wales at four feet vertically.

Spaces 3×8 uprights at six feet horizontally.

(2) *Example 2.*

A trench dug in Type B soil in 13 feet deep and five feet wide. From Table C–1.2 three acceptable arrangements of members are listed.

Arrangement #1.

Space 6×6 crossbraces at six feet horizontally and five feet vertically.

Space 8×8 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #2

Space 8×8 crossbraces at eight feet horizontally and five feet vertically.

Space 10×10 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #3

Space 8×8 crossbraces at 10 feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Space 2×6 uprights at two feet vertically.

(3) *Example 3.*

A trench dug in Type C soil is 13 feet deep and five feet wide.

From Table C–1.3 two acceptable arrangements of members can be used.

Arrangement #1

Space 8×8 crossbraces at six feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Position 2×6 uprights as closely together as possible.

If water must be retained use special tongue and groove uprights to form tight sheeting.

Arrangement #2

Space 8×10 crossbraces at eight feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Position 2×6 uprights in a close sheeting configuration unless water pressure must be resisted. Tight sheeting must be used where water must be retained.

(4) *Example 4.*

A trench dug in Type C soil is 20 feet deep and 11 feet wide. The size and spacing of members for the section of trench that is over 15 feet in depth is determined using Table C–1.3. Only one arrangement of members is provided.

Space 8×10 crossbraces at six feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Use 3×6 tight sheeting.

Use of Tables C–2.1 through C–2.3 would follow the same procedures.

(g) *Notes for all Tables.*

1. Member sizes at spacings other than indicated are to be determined as specified in § 1926.652(c), "Design of Protective Systems."

2. When conditions are saturated or submerged use Tight Sheeting. Tight Sheeting refers to the use of specially-edged timber planks (e.g., tongue and groove) at least three inches thick, steel sheet piling, or similar construction that when driven or placed in position provide a tight wall to resist the lateral pressure of water and to prevent the loss of backfill material. Close Sheeting refers to the placement of planks side-by-side allowing as little space as possible between them.

3. All spacing indicated is measured center to center.

4. Wales to be installed with greater dimension horizontal.

5. If the vertical distance from the center of the lowest crossbrace to the bottom of the trench exceeds two and one-half feet, uprights shall be firmly embedded or a mudsill shall be used. Where uprights are embedded, the vertical distance from the center of the lowest crossbrace to the bottom of the trench shall not exceed 36 inches. When mudsills are used, the vertical distance shall not exceed 42 inches. Mudsills are wales that are installed at the toe of the trench side.

6. Trench jacks may be used in lieu of or in combination with timber crossbraces.

7. Placement of crossbraces. When the vertical spacing of crossbraces is four feet, place the top crossbrace no more than two feet below the top of the trench. When the vertical spacing of crossbraces is five feet, place the top crossbrace no more than 2.5 feet below the top of the trench.

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TABLE C-1.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A P_a = 25 X H + 72 psf (2 ft Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS **													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				2X6	
	UP TO 8	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---					2X8
	UP TO 10	4X6	4X6	4X6	6X6	6X6	4	8X8	4			2X6		
	UP TO 12	4X6	4X6	6X6	6X6	6X6	4	8X8	4				2X6	
10 TO 15	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				3X8	
	UP TO 8	4X6	4X6	6X6	6X6	6X6	4	8X8	4		2X6			
	UP TO 10	6X6	6X5	6X6	6X8	6X8	4	8X10	4			2X6		
	UP TO 12	6X6	6X6	6X6	6X8	6X8	4	10X10	4				3X8	
15 TO 20	UP TO 6	6X6	6X6	6X6	6X8	6X8	4	6X8	4	3X6				
	UP TO 8	6X6	6X6	6X6	6X8	6X8	4	8X8	4	3X6				
	UP TO 10	8X8	8X8	8X8	8X8	8X10	4	8X10	4	3X6				
	UP TO 12	8X8	8X8	8X8	8X8	8X10	4	10X10	4	3X6				
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may by substituted for wood.

TABLE C-1.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3		
5 TO 10	UP TO 6	4X6	4X6	6X6	6X6	6X6	5	6X8	5			2X6		
	UP TO 8	6X6	6X6	6X6	6X8	6X8	5	8X10	5			2X6		
	UP TO 10	6X6	6X6	6X6	6X8	6X8	5	10X10	5			2X6		
	See Note 1													
10 TO 15	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5		2X6			
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5		2X6			
	UP TO 10	8X8	8X8	8X8	8X8	8X10	5	10X12	5		2X6			
	See Note 1													
15 TO 20	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	3X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	3X6				
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6				
	See Note 1													
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may by substituted for wood.

TABLE C-1.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C $P_a = 80 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**													
	CROSS BRACES									UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN.)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE				
5 TO 10	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	2X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6				
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6				
	See Note 1													
10 TO 15	UP TO 6	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6				
	UP TO 8	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6				
	See Note 1													
	See Note 1													
15 TO 20	UP TO 6	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6				
	See Note 1													
	See Note 1													
	See Note 1													
OVER 20	SEE NOTE 1													

* Mixed Oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A P_a = 25 X H + 72 psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **														
	CROSS BRACES							WALES		UPRIGHTS					
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)					
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP TO 6	4X4	4X4	4X4	4X4	4X6	4	Not Req'd	Not Req'd				4X6	
	UP TO 8	4X4	4X4	4X4	4X6	4X6	4	Not Req'd	Not Req'd					4X8
	UP TO 10	4X6	4X6	4X6	6X6	6X6	4	8X8	4			4X6		
	UP TO 12	4X6	4X6	4X6	6X6	6X6	4	8X8	4				4X6	
10 TO 15	UP TO 6	4X4	4X4	4X4	6X6	6X6	4	Not Req'd	Not Req'd				4X10	
	UP TO 8	4X6	4X6	4X6	6X6	6X6	4	6X8	4		4X6			
	UP TO 10	6X6	6X6	6X6	6X6	6X6	4	8X8	4			4X8		
	UP TO 12	6X6	6X6	6X6	6X6	6X6	4	8X10	4		4X6		4X10	
15 TO 20	UP TO 6	6X6	6X6	6X6	6X6	6X6	4	6X8	4	3X6				
	UP TO 8	6X6	6X6	6X6	6X6	6X6	4	8X8	4	3X6	4X12			
	UP TO 10	6X6	6X6	6X6	6X6	6X8	4	8X10	4	3X6				
	UP TO 12	6X6	6X6	6X6	6X8	6X8	4	8X12	4	3X6	4X12			
OVER 20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS ** — CROSS BRACES: HORIZ. SPACING (FEET)	CROSS BRACES — WIDTH OF TRENCH (FEET): UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15	CROSS BRACES: VERT. SPACING (FEET)	WALES: SIZE (IN.)	WALES: VERT. SPACING (FEET)	UPRIGHTS — MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET): CLOSE	2	3	4	6
5 TO 10	UP TO 6	4X6	4X6	4X6	6X6	6X6	5	6X8	5			3X12 4X8		4X12
	UP TO 8	4X6	4X6	6X6	6X6	6X6	5	8X8	5		3X8		4X8	
	UP TO 10	4X6	4X6	6X6	6X6	6X8	5	8X10	5			4X8		
	See Note 1													
10 TO 15	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5	3X6	4X10			
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5	3X6	4X10			
	UP TO 10	6X8	6X8	8X8	8X8	8X8	5	10X12	5	3X6	4X10			
	See Note 1													
15 TO 20	UP TO 6	6X8	6X8	6X8	6X8	8X8	5	8X10	5	4X6				
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X12	5	4X6				
	UP TO 10	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6				
	See Note 1													
OVER 20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C $P_a = 80 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **														
	CROSS BRACES							WALES		UPRIGHTS					
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN.)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)					
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE					
5 TO 10	UP TO 6	6X6	6X6	6X6	6X6	8X8	5	8X8	5	3X6					
	UP TO 8	6X6	6X6	6X6	8X8	8X8	5	10X10	5	3X6					
	UP TO 10	6X6	6X6	8X8	8X8	8X8	5	10X12	5	3X6					
	See Note 1														
10 TO 15	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	10X10	5	4X6					
	UP TO 8	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6					
	See Note 1														
	See Note 1														
15 TO 20	UP TO 6	8X8	8X8	8X8	8X10	8X10	5	10X12	5	4X6					
	See Note 1														
	See Note 1														
	See Note 1														
OVER 20	SEE NOTE 1														

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

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Appendix D to Subpart P

Aluminum Hydraulic Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used when aluminum hydraulic shoring is provided as a method of protection against cave-ins in trenches that do not exceed 20 feet (6.1m) in depth. This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with § 1926.652(c)(2).

(b) *Soil Classification.* In order to use data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of part 1926.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables D–1.1, D–1.2, D–1.3 and E–1.4. Each table presents the maximum vertical and horizontal spacings that may be used with various aluminum member sizes and various hydraulic cylinder sizes. Each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. Tables D–1.1 and D–1.2 are for vertical shores in Types A and B soil. Tables D–1.3 and D1.4 are for horizontal waler systems in Types B and C soil.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations (footnotes) regarding Table D–1.1 through D–1.4 are presented in paragraph (g) of this appendix.

(6) Figures, illustrating typical installations of hydraulic shoring, are included just prior to the Tables. The illustrations page is entitled "Aluminum Hydraulic Shoring; Typical Installations."

(d) *Basis and limitations of the data.*

(1) Vertical shore rails and horizontal wales are those that meet the Section Modulus requirements in the D–1 Tables. Aluminum material is 6061–T6 or material of equivalent strength and properties.

(2) Hydraulic cylinders specifications. (i) 2-inch cylinders shall be a minimum 2-inch inside diameter with a minimum safe working capacity of no less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufaturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe working capacity of not less than 30,000 pounds axial compressive load at extensions as recommended by product manufacturer.

(3) Limitation of application.

(i) It is not intended that the aluminum hydraulic specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be otherwise designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the Tables are not considered adequate. In this case, an alternative aluminum hydraulic shoring system or other type of protective system must be designed in accordance with § 1926.652.

(A) When vertical loads imposed on cross braces exceed a 100 Pound gravity load distributed on a one foot section of the center of the hydraulic cylinder.

(B) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(C) When only the lower portion or a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables D–1.1, D–1.2, D–1.3 and D–1.4.* The members of the shoring system that are to be selected using this information are the hydraulic cylinders, and either the vertical shores or the horizontal wales. When a waler system is used the vertical timber sheeting to be used is also selected from these tables. The Tables D–1.1 and D–1.2 for vertical shores are used in Type A and B soils that do not require sheeting. Type B soils that may require sheeting, and Type C soils that always require sheeting are found in the horizontal wale Tables D–1.3 and D–1.4. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is made. The selection is based on the depth and width of the trench where the members are to be installed. In these tables the vertical spacing is held constant at four feet on center. The tables show the maximum horizontal spacing of cylinders allowed for each size of wale in the waler system tables, and in the vertical shore tables, the hydraulic cylinder horizontal spacing is the same as the vertical shore spacing.

(f) *Example to Illustrate the Use of the Tables:*

(1) Example 1:

A trench dug in Type A soil is 6 feet deep and 3 feet wide. From Table D–1.1: Find vertical shores and 2 inch diameter cylinders spaced 8 feet on center (o.c.) horizontally and 4 feet on center (o.c.) vertically. (See Figures 1 & 3 for typical installations.)

(2) Example 2:

A trench is dug in Type B soil that does not require sheeting, 13 feet deep and 5 feet wide. From Table D–1.2: Find vertical shores and 2 inch diameter cylinders spaced 6.5 feet o.c. horizontally and 4 feet o.c. vertically. (See Figures 1 & 3 for typical installations.)

(3) A trench is dug in Type B soil that does not require sheeting, but does experience some minor raveling of the trench face. The trench is 16 feet deep and 9 feet wide. From Table D–1.2: Find vertical shores and 2 inch diameter cylinder (with special oversleeves as designated by footnote #2) spaced 5.5 feet o.c. horizontally and 4 feet o.c. vertically, plywood (per footnote (g)(7) to the D–1 Table) should be used behind the shores. (See Figures 2 & 3 for typical installations.)

(4) Example 4: A trench is dug in previously disturbed Type B soil, with characteristics of a Type C soil, and will require sheeting. The trench is 18 feet deep and 12 feet wide. 8 foot horizontal spacing between cylinders is desired for working space. From Table D–1.3: Find horizontal wale with a section modulus of 14.0 spaced at 4 feet o.c. vertically and 3 inch diameter cylinder spaced at 9 feet maximum o.c. horizontally. 3×12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(5) Example 5: A trench is dug in Type C soil, 9 feet deep and 4 feet wide. Horizontal cylinder spacing in excess of 6 feet is desired for working space. From Table D–1.4: Find horizontal wale with a section modulus of 7.0 and 2 inch diameter cylinders spaced at 6.5 feet o.c. horizontally. Or, find horizontal wale with a 14.0 section modulus and 3 inch diameter cylinder spaced at 10 feet o.c. horizontally. Both wales are spaced 4 feet o.c. vertically. 3×12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(g) *Footnotes, and general notes, for Tables D–1.1, D–1.2, D–1.3, and D–1.4.*

(1) For applications other than those listed in the tables, refer to § 1926.652(c)(2) for use of manufacturer's tabulated data. For trench depths in excess of 20 feet, refer to § 1926.652(c)(2) and § 1926.652(c)(3).

(2) 2 inch diameter cylinders, at this width, shall have structural steel tube (3.5×3.5×0.1875) oversleeves, or structural oversleeves of manufacturer's specification, extending the full, collapsed length.

(3) Hydraulic cylinders capacities. (i) 2 inch cylinders shall be a minimum 2-inch inside diameter with a safe working capacity of not less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe work capacity of not less than 30,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(4) All spacing indicated is measured center to center.

(5) Vertical shoring rails shall have a minimum section modulus of 0.40 inch.

(6) When vertical shores are used, there must be a minimum of three shores spaced equally, horizontally, in a group.

(7) Plywood shall be 1.125 in. thick softwood or 0.75 inch. thick, 14 ply, arctic white birch (Finland form). Please note that plywood is not intended as a structural member, but only for prevention of local raveling (sloughing of the trench face) between shores.

(8) See appendix C for timber specifications.

(9) Wales are calculated for simple span conditions.

(10) See appendix D, item (d), for basis and limitations of the data.

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ALUMINUM HYDRAULIC SHORING
TYPICAL INSTALLATIONS

FIGURE NO. 1
VERTICAL ALUMINUM HYDRAULIC SHORING (SPOT BRACING)

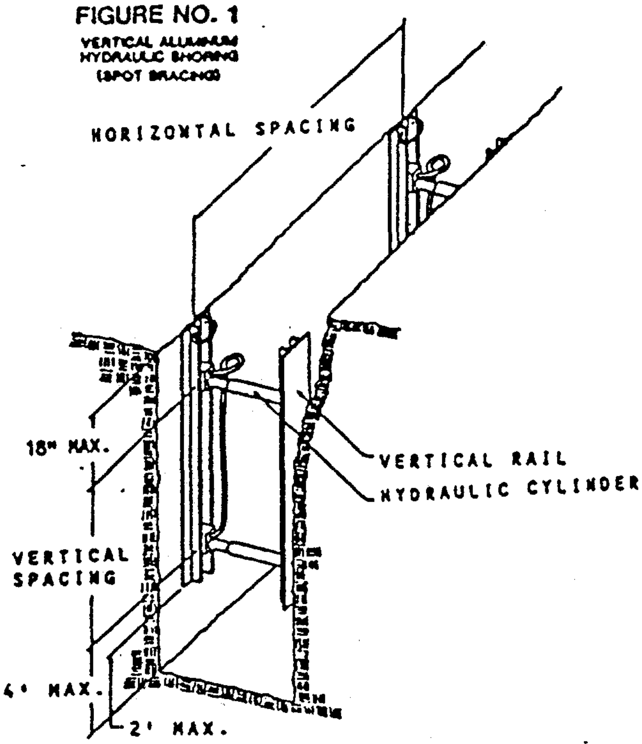

FIGURE NO. 2
VERTICAL ALUMINUM HYDRAULIC SHORING (WITH PLYWOOD)

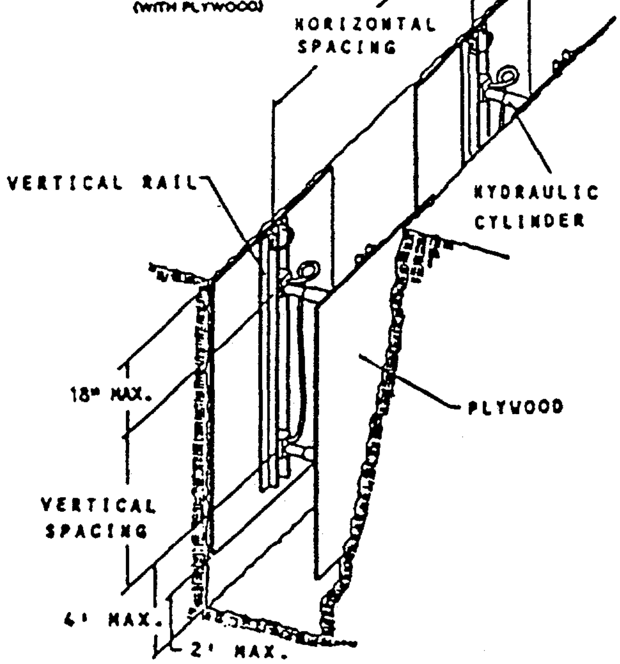

FIGURE NO. 3
VERTICAL ALUMINUM HYDRAULIC SHORING (STACKED)

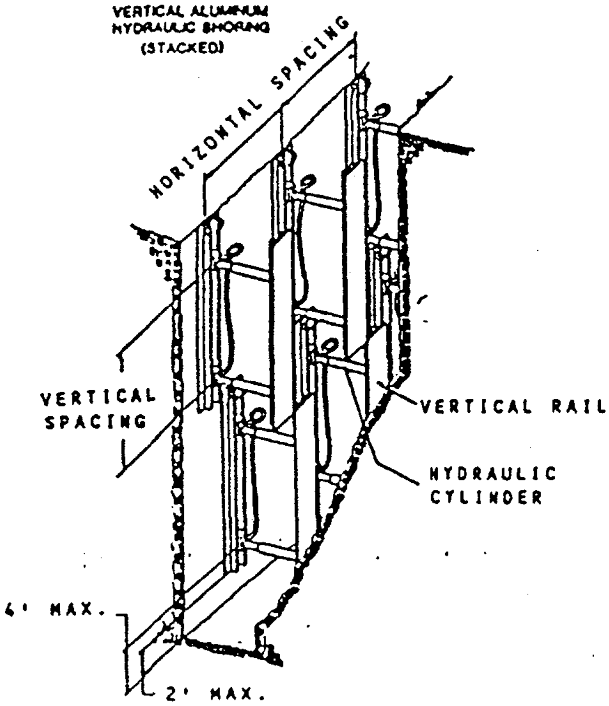

FIGURE NO. 4
ALUMINUM HYDRAULIC SHORING WALER SYSTEM (TYPICAL)

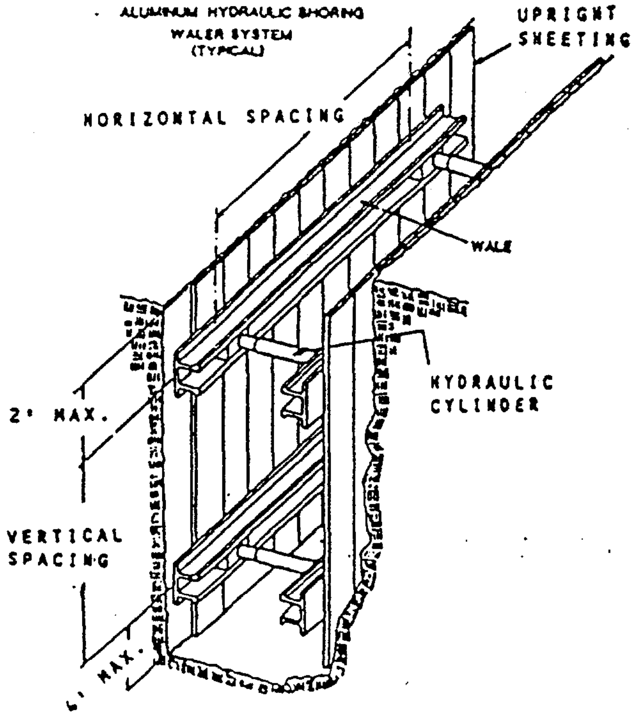

TABLE D - 1.1
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE A

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	8				
OVER 15 UP TO 20	7				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)

TABLE D - 1.2
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE B

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8				
OVER 10 UP TO 15	6.5	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 15 UP TO 20	5.5				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)

TABLE D - 1.3
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE B

DEPTH OF TRENCH (FEET)	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX.HORIZ.SPACING (ON CENTER)		
	VERTICAL SPACING (FEET)	SECTION MODULUS* (IN³)	UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO15		SOLID SHEET	2 FT.	3 FT.
			HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	8.0	2 IN	8.0	2 IN NOTE(2)	8.0	3 IN	—	—	3x12
		7.0	9.0	2 IN	9.0	2 IN NOTE(2)	9.0	3 IN			
		14.0	12.0	3 IN	12.0	3 IN	12.0	3 IN			
OVER 10 UP TO 15	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	—	3x12	—
		7.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 15 UP TO 20	4	3.5	5.5	2 IN	5.5	2 IN NOTE(2)	5.5	3 IN	3x12	—	—
		7.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
		14.0	9.0	3 IN	9.0	3 IN	9.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Notes (1): See Appendix D, item (g) (1)
Notes (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

TABLE D - 1.4
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE C

DEPTH OF TRENCH (FEET)	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX.HORIZ SPACING (ON CENTER)		
	VERTICAL SPACING (FEET)	* SECTION MODULUS (IN³)	UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15		SOLID SHEET	2 FT.	3 FT.
			HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	3x12	—	—
		7.0	6.5	2 IN	6.5	2 IN NOTE(2)	6.5	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 10 UP TO 15	4	3.5	4.0	2 IN	4.0	2 IN NOTE(2)	4.0	3 IN	3x12	—	—
		7.0	5.5	3 IN	5.5	3 IN	5.5	3 IN			
		14.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
OVER 15 UP TO 20	4	3.5	3.5	2 IN	3.5	2 IN NOTE(2)	3.5	3 IN	3x12	—	—
		7.0	5.0	3 IN	5.0	3 IN	5.0	3 IN			
		14.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Notes (1): See Appendix D, item (g) (1)
Notes (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

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Appendix E to Subpart P—Alternatives to Timber Shoring

Figure 1. Aluminum Hydraulic Shoring

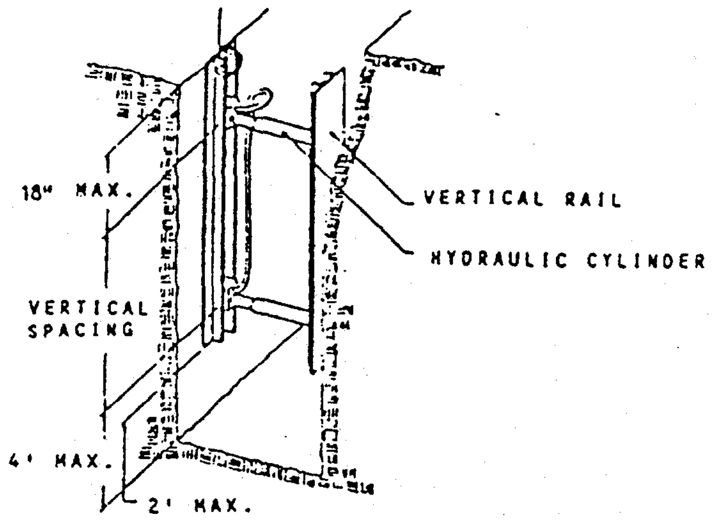
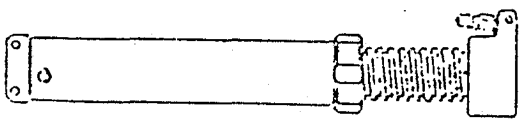


Figure 2. Pneumatic/hydraulic Shoring



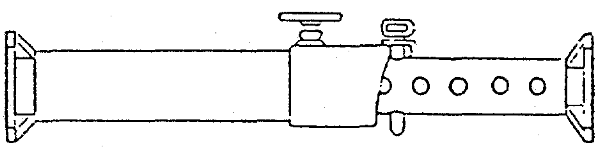


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Figure 3. Trench Jacks (Screw Jacks)

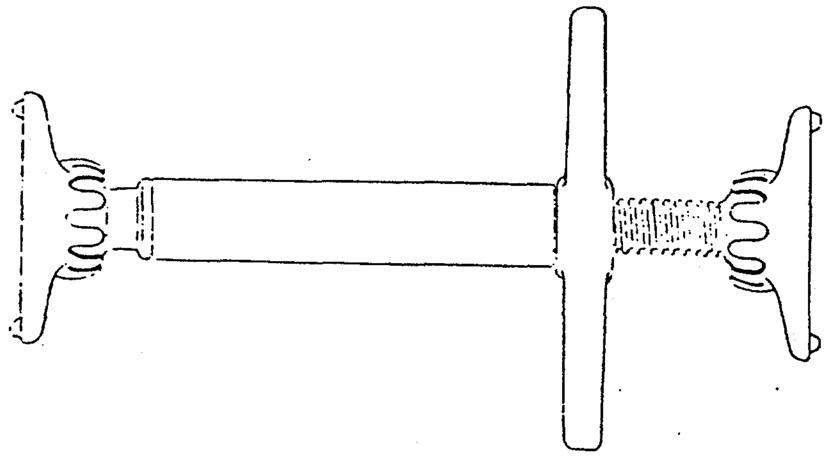
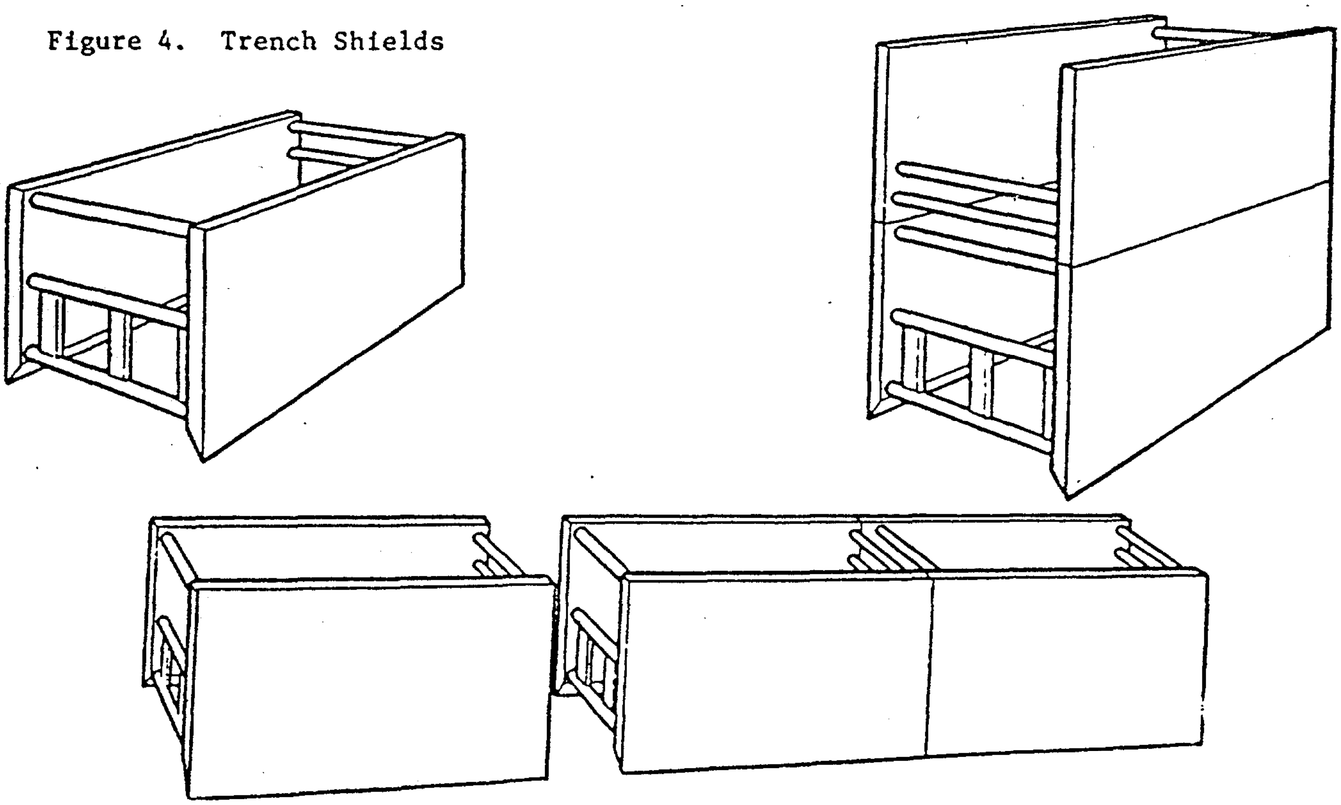


Figure 4. Trench Shields



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Appendix F to Subpart P—Selection of Protective Systems

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with § 1926.652 (b) and (c).

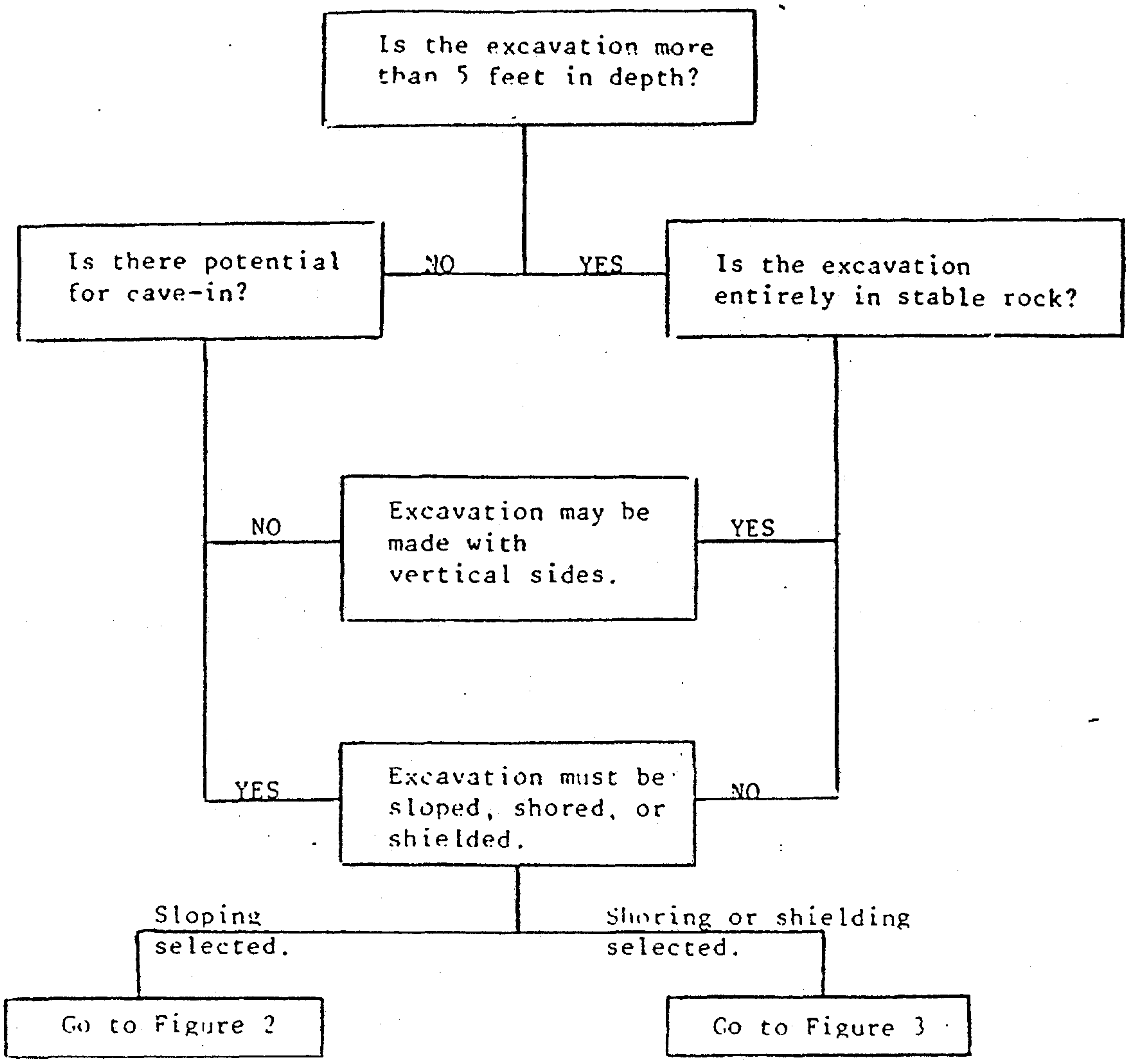

FIGURE 1 - PRELIMINARY DECISIONS

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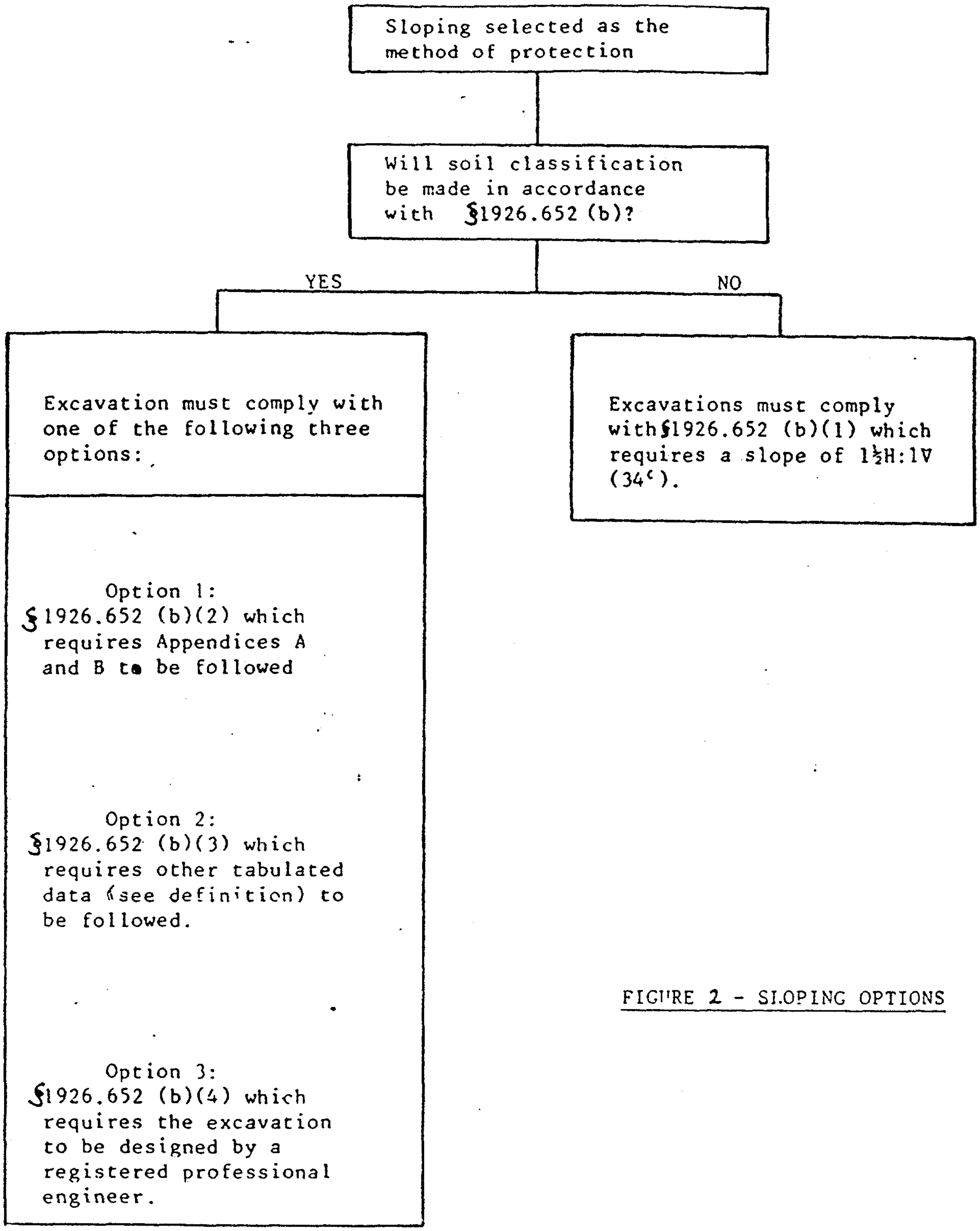


FIGURE 2 - SLOPING OPTIONS

Shoring or shielding selected as the method of protection.

Soil classification is required when shoring or shielding is used. The excavation must comply with one of the following four options:

Option 1
§1926.652 (c)(1) which requires Appendices A and C to be followed (e.g. timber shoring).

Option 2
§1926.652 (c)(2) which requires manufacturers data to be followed (e.g. hydraulic shoring, trench jacks, air shores, shields).

Option 3
§1926.652 (c)(3) which requires tabulated data (see definition) to be followed (e.g. any system as per the tabulated data).

Option 4
§1926.652 (c)(4) which requires the excavation to be designed by a registered professional engineer (e.g. any designed system).

FIGURE 3 - SHORING AND SHIELDING OPTIONS

[FR Doc. 89-25217 Filed 10-30-89; 8:45 am]
BILLING CODE 4510-26-C

APPENDIX C

Monitoring Well Installation

MONITORING WELL INSTALLATION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Well Installation
- 5.2 Drive Points
- 5.3 Surface Completion
- 5.4 Well Development
- 5.5 Contaminated Materials Handling
- 5.6 Well Construction Logs

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

MONITORING WELL INSTALLATION

1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at various sites.

2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities. These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

3.0 DEFINITIONS

Monitoring Well - A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer - A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

Drive Point - A monitoring well which includes a screen casing and hardened point fabricated from stainless steel that is driven into the soil to complete the well. The drive point can also be installed by hand augering to try to formulate a sand pack around the screen.

4.0 RESPONSIBILITIES

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

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The Field Team Leader is responsible to provide copies of the well construction logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.

Drilling Inspector (Site Geologist) - The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to record details of the well installation, document subsurface conditions, complete the appropriate forms, supervise the drilling crew (or drilling supervisor), and record quantities of the drillers billable labor and materials.

5.0 PROCEDURES

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used.

The objectives for installing monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Facilitating site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic determination, monitoring wells or cluster wells should be used. In areas that are inaccessible to drill rigs (i.e., unstable surface soils), driven wells (drive points) may be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account for site conditions (e.g., underground utilities). The elevation and horizontal location of all monitoring wells shall be determined through a site survey upon completion of well installation.

Guidelines for Navy underground storage tank (UST) monitoring well construction are given in Attachment A.

5.1 Well Installation

The methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types. Typical shallow monitoring well construction details are shown in Figures A-1 and A-2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon also are available. However, PVC generally is much less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials, or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment B provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually be constructed using either two-inch or four-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. A larger or smaller diameter screen may be used to accommodate site-specific geologic conditions. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from 1 to 20 feet depending on site-specific conditions. For UST and/or light non-aqueous phase liquid (INAPL) applications, the screen should be installed such that at least two-feet of screen is above the water table and the remainder of the screen extends below the water surface so that free product can enter the well. Should very shallow water table conditions be encountered, the screened interval in both the saturated and unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A six-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids *(DNAPLS)* may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either six inches below the ground surface (for flush-mounted wells) to between approximately one and two feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successfully backfilled with a well graded quartz-sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. The sand size used in well construction will be appropriate for the formation monitored by the well. Sand shall carefully be placed, preferably via tremie pipe, from the bottom of the boring to a minimum of two feet (or 20 percent of the total screen length) above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least two- to three-foot thick shall be place above the sand pack. The bentonite shall be allowed to hydrate for at least 20 minutes before further completion of the well. Deionized water will be added to the well to hydrate the bentonite, if necessary. For deep wells, a bentonite slurry may be more appropriate than pellets due to problems with bridging in the annular space.

The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space, preferably with a side-discharge tremie pipe, into annular spaces greater than ten feet high. If the annular space is less than ten feet high, the grout may be poured directly into the annular space.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Monitoring Well Construction Record or in a field logbook.

5.2 Drive Points

Drive points may be constructed in one of two ways. If the drive point is hammered into place, no other well construction will take place. (Note that the well assembly is fabricated from 2-inch diameter stainless steel and includes a screen casing, and hardened point). If a hand augered borehole is used, the following procedure will be utilized: a 4-inch diameter hand auger will be advanced to the desired depth below the water table. If the borehole collapses, a 5-inch diameter PVC pipe could be hammered into the collapsing borehole and reaugered to clean out the soils until final depth is achieved. A 2-inch diameter drive point will be placed in the open borehole. A sand pack will be placed around the drive point to a depth that is approximately 1 foot above the screened interval (if conditions permit). A bentonite seal will be placed above the sand pack to the top of the borehole. Grout will not be used in drive points. Because of the anticipated marsh conditions, concrete surface completion will not be required. The drive points will be sampled according to SOP F104, "Groundwater Sample Acquisition." After installation, the drive points will be developed. To assist with the development, the well screens will be cleaned with a wire brush and distilled water, and then developed according to Section 5.3 of SOP F103 "Monitoring Well Installation."

5.3 Surface Completion

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a four or six-inch diameter, five-foot long steel casing with locking cap and lock into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

The top of each well will be protected with the installation of three, three-inch diameter, five-foot long steel pipes for UST projects (four for IR projects) and have a concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5-feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete apron approximately five-feet by five-feet by 0.5-feet thick shall be placed at the same time the pipes are installed. The steel pipes shall be painted with day-glo yellow paint, or equivalent.

The second method considers flush-mounted wells, typically installed in traffic areas. The monitoring well shall be completed at the surface using a "flush" mount type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a five-foot by five-foot by 0.5-foot thick apron made of 3,000 psi concrete. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

Project specific tasks may require that all monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing locking cap, and also by labeling on the exterior of the steel casing or manhole cover in accordance with applicable state and local requirements. For underground storage tank applications, the labeling shall consist of the letters UGW (UST Groundwater), and a number specific to each well. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron, if appropriate.

5.4 Well Development

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501, entitled "Decontamination of Drilling Rigs and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

In general, all wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A minimum pumping time period (typically one hour for shallow wells 10 to 30 feet deep).
- A minimum borehole volume (typically five borehole volumes) or until well goes dry.
- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Well development limits shall be specified in project-specific plans. A record of the well development (Figure A-3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of two weeks should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. However, this stabilization period may be adjusted based upon project-specific requirements.

5.5 Contaminated Materials Handling

SOP F504, entitled "Handling of Site Investigation Derived Waste," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the project plans. In general, all site investigation generated wastes shall be containerized unless otherwise specified by LANTDIV. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

5.6 Well Construction Logs

Field Well Construction Logs shall be completed by the Drilling Inspector for each monitoring well installed. These logs preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook and later transfer it to the Well Construction Log. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within five days, and prior to demobilization from the field.

Field Well Construction Logs (in Attachment C), shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Log, or in the field logbook, as appropriate:

- Project name and location.
- CTO number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Log will be used to generate a final Well Construction Log which combines the Field Boring and Well Construction Logs into one package. An example of all three documents is presented in Attachment C.

6.0 QUALITY ASSURANCE RECORDS

The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

7.0 REFERENCES

1. Driscoll, Fletcher, G. Groundwater and Wells , Johnson division. St. Paul, Minnesota. 2nd ed. 1986.

2. Roscoe Moss Company. Handbook of Ground Water Development. John Wiley & Sons. New York. 1990.

3. USEPA. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. September, 1986.

4. Aller, L. et al. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. Dublin, Ohio. June, 1989.

ATTACHMENT A

MONITORING WELL CONSTRUCTION

ATTACHMENT A

UST MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

SPECIFICATIONS

Well permits required by state agencies are the responsibility of the contractor. All monitoring wells will be installed in accordance with Navy UST monitoring well specifications. The wells will be constructed of either a 2-inch or 4-inch inside diameter (I.D.) flush joint threaded PVC well screen and riser casing depending on conditions encountered during borehole completion.

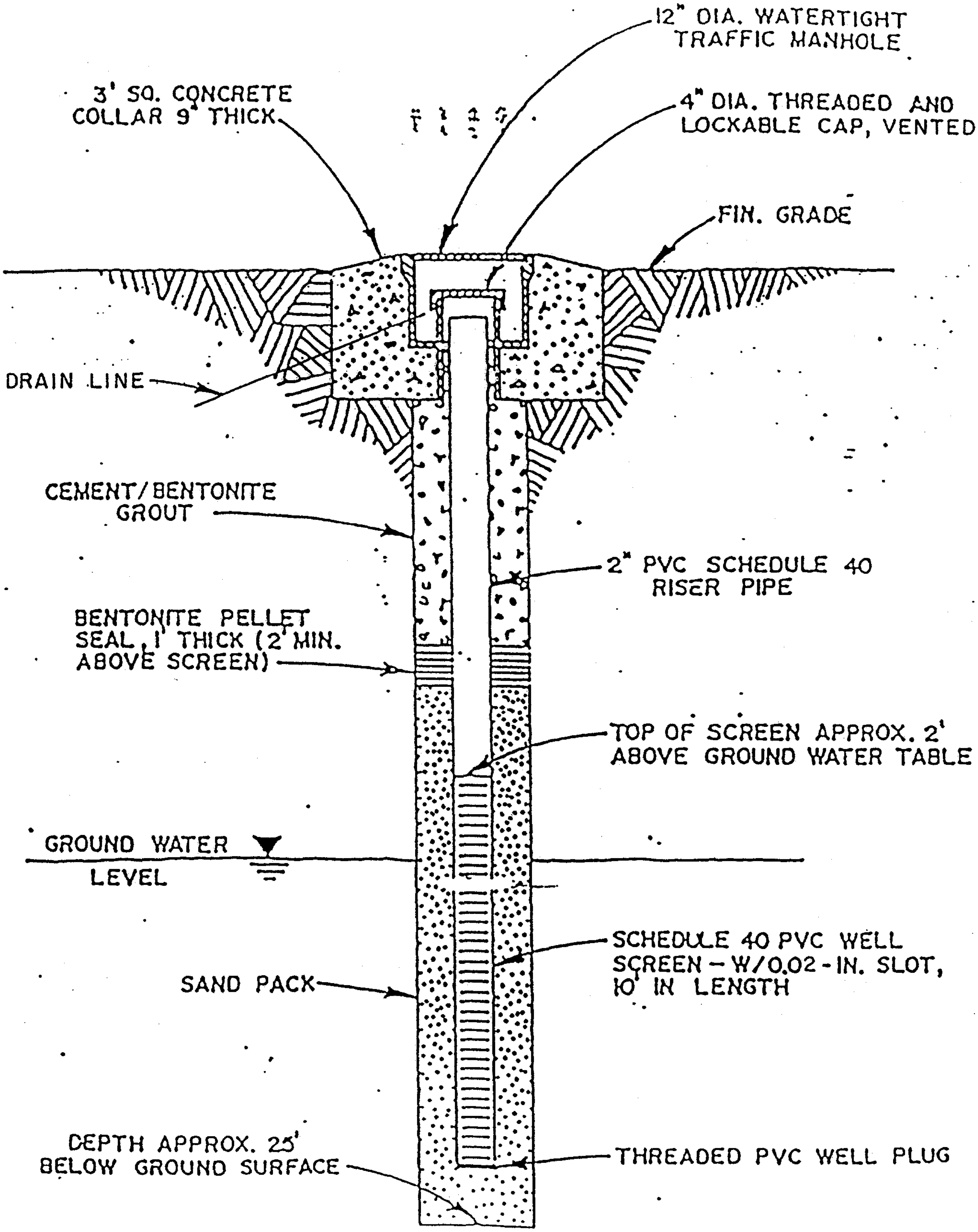
DRILLING

During the drilling program, boreholes will be advanced using conventional hollow-stem auger drilling methods. If it is the opinion of the contractor that air or mud rotary drill methods are necessary, approval must be obtained from the Engineer-in-Charge (EIC). Presentation of justification for a boring method change shall be presented prior to drilling.

Well construction details are shown in Figures A-1 and A-2. A drill mounted on an All-Terrain-Vehicle (ATV) may be required for access to remote areas. Each rig will use necessary tools, supplies and equipment supplied by the contractor to drill each site. Drill crews should consist of an experienced driller and a driller assistant for work on each rig. A geologist, experienced in hazardous waste site investigations, shall be on site to monitor the drillers efforts and for air monitoring/safety control. Additional subcontractor personnel may be needed to transport water to the rigs, clean tools, assist in the installation of the security and marker pipes, construct the concrete aprons/collars and develop the wells. A potable water source on base will be designated by the Government.

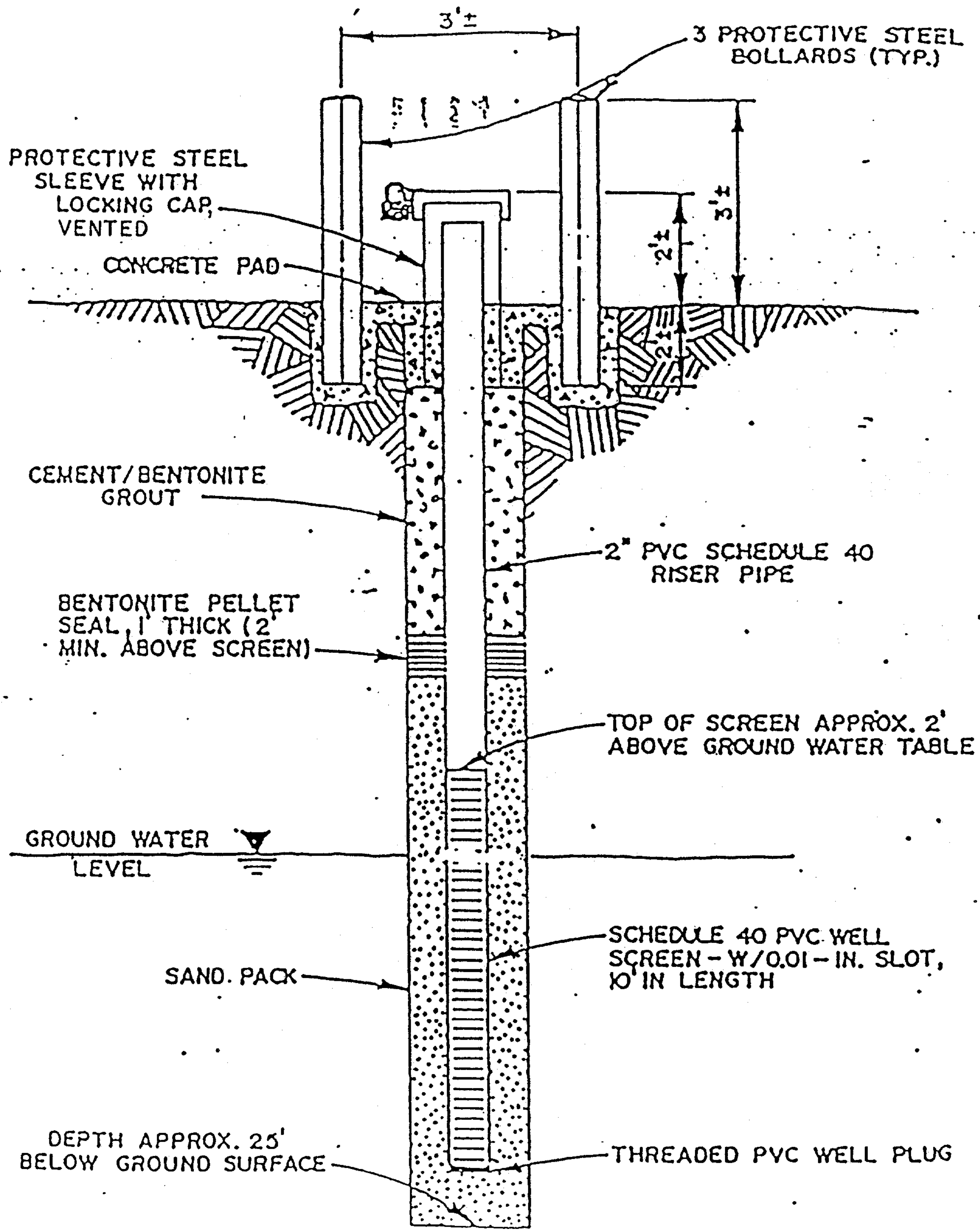
Standard Penetration Tests (SPTs) will be performed in accordance with ASTM D-1586. Standard penetration tests will be performed at the following depths: 0.0-1.5 feet; 1.5-3.0 feet; 3.0-4.5 feet; and 5-foot centers thereafter. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels may be used in the SPT to obtain a sufficient amount of sample for required analysis. A boring log of the soil type, stratification, consistency, and groundwater level will be prepared.

FIGURE A-1



MONITORING WELL CONSTRUCTION DETAIL
(TRAFFIC AREA)
NOT TO SCALE

FIGURE A-2



MONITORING WELL CONSTRUCTION DETAIL
(NON TRAFFIC AREA)
NOT TO SCALE

SAMPLING

Soil samples of the subsurface materials will be collected every five feet or change in formation throughout the borehole in accordance with ASTM Method D-1586. Each soil sample will be screened in the field using an HNu photoionizer, organic vapor detector or similar type direct readout instrument to identify the presence of petroleum product within the soils. This field screening will provide a preliminary indication of the vertical and horizontal extent of contamination in order to select the optimum locations of other monitoring wells during the drilling program. Based on the field screening, two-inch or four-inch diameter monitoring wells will be installed at the locations where the most significant accumulation of fuel is encountered.

WELL INSTALLATION

After completion of soil sampling and drilling to the specified depth, two-inch and/or four-inch (as required by the EIC) inside-diameter, flush-threaded Schedule 40 PVC (Schedule 80 in traffic areas) monitoring wells with slotted screens and well casings will be installed in the borehole. A 5- to 15-foot section of 0.01-inch slotted PVC well screen shall be used in each well. A sand pack will be placed around the slotted well screen extending to 2 feet above the top of the screen. A bentonite seal (minimum thickness of 1 foot) will be placed on top of the sand pack. Finally, a grout mixture of three to four percent bentonite powder (by dry weight) and seven gallons of water per 94 pound bag of cement, thoroughly mixed, will be placed in the borehole to insure a proper seal.

WELL DEVELOPMENT

All wells will be developed not less than 24 hours following their installation to remove fine ground materials that may have entered the well during construction. Wells shall be developed until water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A maximum time period (typically one hour for shallow wells, well depth of 10 to 30 feet).
- A maximum well volume (typically three to five well volumes).

- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).
- Clarity based on turbidity measurements (typically less than 50 NTU).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Figure A-3 presents the Field Well Development Log used to document development data. This will be accomplished by either bailing or continuous, low-yield pumping. Equipment used for well installation that may have come in contact with potentially contaminated material will be decontaminated with a high pressure steam wash followed by a potable water rinse. It is assumed that all fluid generated from well development and equipment decontamination can be disposed of on the ground at each respective well site, unless otherwise specified.

The soil removed from the borehole will be piled beneath the drill rig while drilling. The drill equipment and tools will be cleaned prior to drilling each well using a portable decontamination system supplied by the contractor. Washwater at the sites will not be contained, unless otherwise directed by the Government, and may seep into the ground locally.

Supplies and equipment will be transported to the lay-down area designated on the station by the Government. Any office space, trailers, etc., required for drilling, subsequent sampling and shipping shall be arranged and provided by the contractor.

WELLHEAD COMPLETION

A four-inch diameter security pipe with a hinged locking cap will be installed over the well casing top and will be embedded approximately 2.5 feet into the grout.

There are two acceptable methods of completing the wellheads.

In traffic areas (and non-traffic areas where required), a "flush" mount type cover shall be built into a concrete pad as shown in Figure A-1. If the well is installed through a paved or concrete surface, the annular space between the casing and the borehole shall be grouted to a depth of at least 2.5 feet and finished with a concrete collar. If the well is not installed through

FIELD WELL DEVELOPMENT RECORD

Baker

Baker Environmental, Inc.

PROJECT: ______________________

CTO NO.: ______________ WELL NO.: ______________

DATE: ______________

GEOLOGIST/ENGINEER: ______________________

TIME START	
TIME FINISH	
INITIAL WATER LEVEL (FT)	
TOTAL WELL DEPTH (TD)	
WELL DIAMETER (INCHES)	
CALCULATED WELL VOLUME	
BOREHOLE DIAMETER (INCHES)	
BOREHOLE VOLUME	
AMOUNT OF WATER ADDED DURING DRILLING	
DEVELOPMENT METHOD	
PUMP TYPE	
TOTAL TIME (A)	
AVERAGE FLOW (GPM)(B)	
TOTAL ESTIMATED WITHDRAWAL AxB=	
HNU/OVA READING	

DEVELOPMENT DATA

TIME	CUMULATIVE VOLUME (gallons)	pH	TEMP (°C)	SPEC. COND. (µmhos/cm)	TEMP (°C)	COLOR AND TURBIDITY

OBSERVATIONS/NOTES

a concrete or paved medium and still finished as a high traffic area well, a concrete apron measuring 5-foot by 5-foot by 0.5 foot will be constructed around each well. This apron/collar will be constructed of 3,000 psi ready-mixed concrete. The concrete will be crowned to provide and to meet the finished grade of surrounding pavement as required. The concrete pads can be constructed within five days after all of the wells have been installed.

In non-traffic areas the acceptable method of finishing a wellhead is shown in Figure A-2. Each well will be marked with three, Schedule 40 steel pipes, three-inch I.D., embedded in a minimum of 2.5-foot of 3,000 psi concrete. (The concrete used to secure the three pipes will be poured at the same time and be an integral part of the 5-foot by 5-foot by 0.5-foot concrete apron described above.) The security pipes will extend a minimum of 2.5 feet and maximum of 4.0 feet above the ground surface. The steel marker pipes will be filled with concrete and painted day-glo yellow or an equivalent. Attachment C presents Sample Field Test Boring Records and Field Well Construction Record Forms.

In all finishing methods, the well covers will be properly labeled by metal stamping on the exterior of the security pipe locking cap and by labeling vertically on the exterior of the security pipe or manhole cover, as appropriate. The labeling shall consist of the letters UGW (UST Groundwater) (to describe the medium and the reason for the well) and a number specific to each well.

A sign reading "NOT FOR POTABLE USE OR DISPOSAL" shall be firmly attached to each well.

* The contractor or project team may supplement these requirements, but may not modify or delete them, in total or in part, without prior approval of the EIC.

If any part of the above specifications is in conflict with the regulations set forth by the State, the State regulations take precedent.

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."

2. The anticipated compounds and their concentration ranges.

3. The anticipated residence time of the sample in the well and the aquifer's productivity.

4. The reasons for not using other casing materials.

5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.

6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.

7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

ATTACHMENT C

FIELD TEST BORING RECORD AND FIELD WELL CONSTRUCTION RECORD FORMS

Baker

Baker Environmental, Inc

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: ____________________

S.O. NO.: ____________________ BORING NO.: ____________________

COORDINATES: EAST: ____________________ NORTH: ____________________

ELEVATION: SURFACE: ____________________ TOP OF PVC CASING: ____________________

RIG:					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
SIZE (DIAM.)									
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

SAMPLE TYPE

S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston
N = No Sample

WELL INFORMATION	DIAM	TYPE	TOP DEPTH (FT)	BOTTOM DEPTH (FT)

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevation Ft. MSL
1								
2								
3								
4								
5								
6								
7								
8								
9								
10						Match to Sheet 2		

DRILLING CO.: ____________________ BAKER REP.: ____________________

DRILLER: ____________________ BORING NO.: ____________________ SHEET 1 OF 2

TEST BORING AND WELL CONSTRUCTION RECORD

Baker
Baker Environmental, Inc.

PROJECT:
S.O. NO.: BORING NO.:

SAMPLE TYPE

S = Split Spoon
T = Shelby Tube
R = Air Rotary
D = Denison
A = Auger
W = Wash
C = Core
P = Piston
N = No Sample

DEFINITIONS

SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5')
RQD = Rock Quality Designation (%)
Lab. Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)
Lab. Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis

Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevation Ft. MSL
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

DRILLING CO.: BAKER REP.:
DRILLER: BORING NO.: SHEET 2 OF

FIELD WELL CONSTRUCTION LOG

Baker
Baker Environmental, Inc.

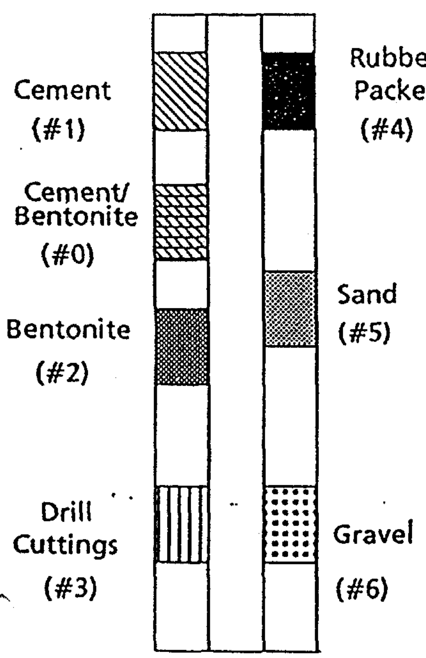
PROJECT: ______________________ DATE: ________
CTO NO.: ______________________ BORING NO.: ________
COORDINATES: EAST: ____________ NORTH: ________
ELEVATION: SURFACE: ___________ TOP OF STEEL CASING: ________

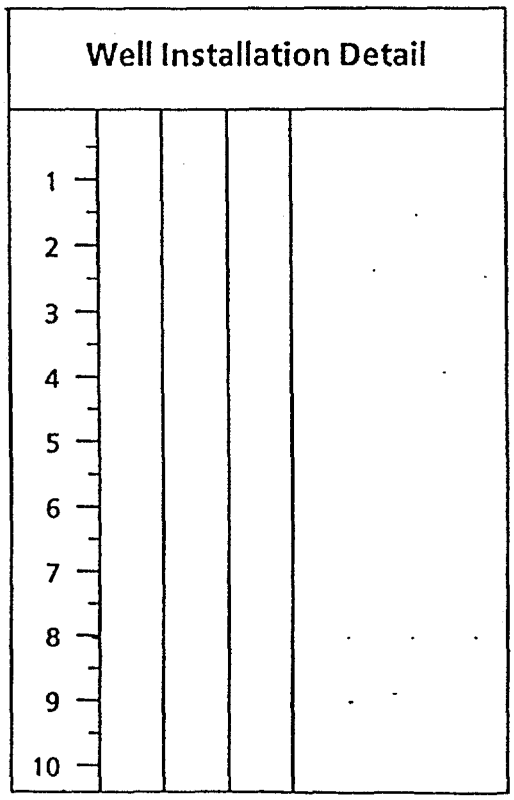
Pay Items

Item	Quantity	Unit	Remarks

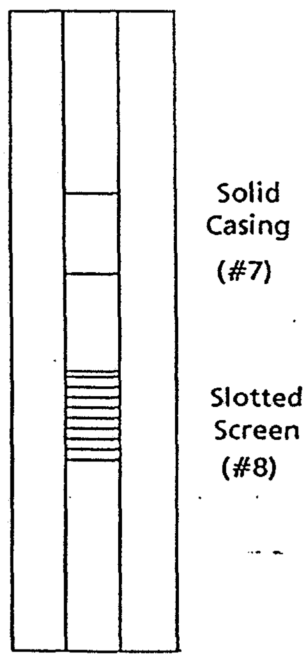
WELL INFORMATION	DIAM. (INCHES)	TYPE	TOP DEPTH (FT.)	BOTTOM DEPTH (FT.)
Well Casing				
Well Screen				

Backfill Key





Well Key

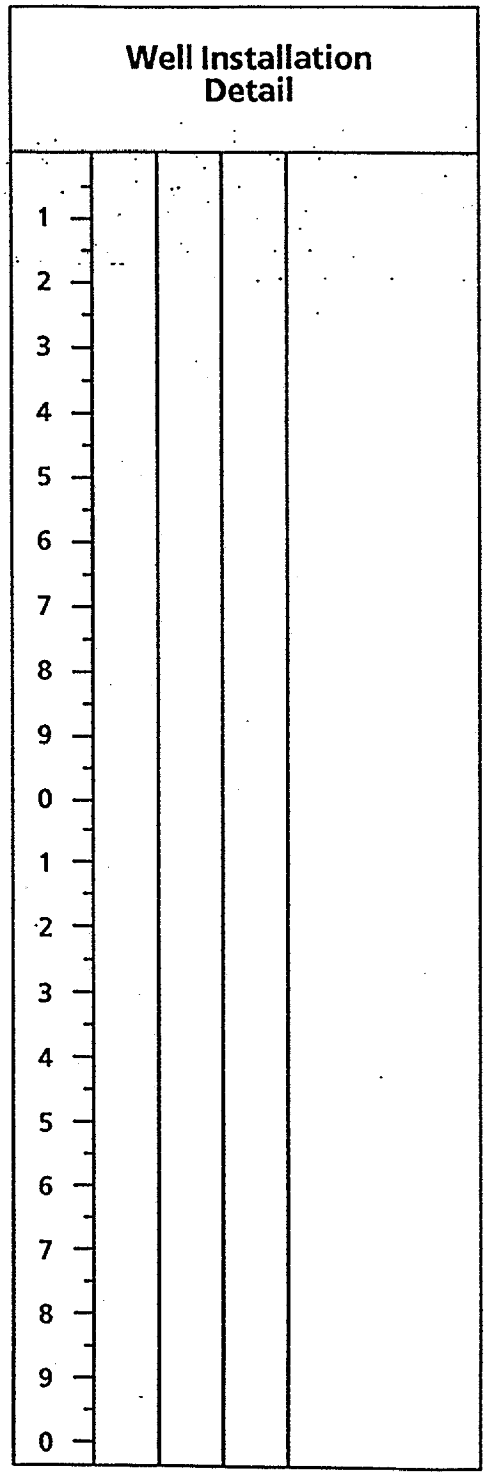


DRILLING CO.: ______________________ BAKER REP.: ______________________
DRILLER: ______________________ BORING NO.: ______________ SHEET ___ OF ___

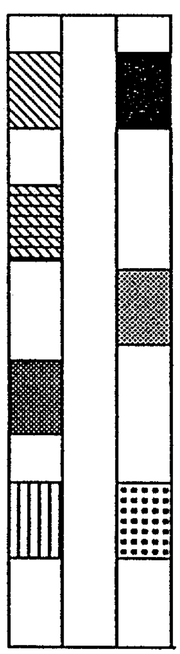
FIELD WELL CONSTRUCTION LOG

PROJECT: ____________________

S.O. NO.: ____________________ BORING NO.: ____________________



Backfill Key



Cement (#1)

Cement/ Bentonite (#0)

Bentonite (#2)

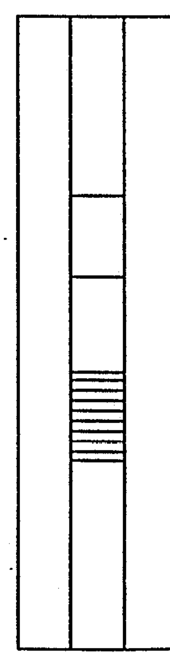
Drill Cuttings (#3)

Rubber Packer (#4)

Sand (#5)

Gravel (#6)

Well Key



Solid Casing (#7)

Slotted Screen (#8)

DRILLING CO.: ____________________ BAKER REP.: ____________________

DRILLER: ____________________ BORING NO.: ____________________ SHEET __ OF __

APPENDIX D

Slug Testing

WELL-HEAD TESTING (SLUG-TESTS)

TABLE OF CONTENTS

1.0 PURPOSE
2.0 SCOPE
3.0 DEFINITIONS
4.0 RESPONSIBILITIES
5.0 PROCEDURES
- 5.1 Overview
- 5.2 Applications
- 5.3 Measurements and Measurement Intervals
- 5.4 Calculation Methods

6.0 QUALITY ASSURANCE RECORDS
7.0 REFERENCES

**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 and the Hydraulic Conductivity.

3.0 DEFINITIONS

The following definitions are extracted or abstracted from standard references (Section 7); further discussions are available in those references.

Hydraulic Conductivity (K) - A medium has a hydraulic conductivity (K) of unit length per unit time (for example, feet per day [ft/d]) if it will transmit in unit time a unit volume of groundwater at the prevailing viscosity through a cross-section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman 1979).

Coefficient of Transmissivity (T) - The transmissivity (T) is the rate (for example, in gallons per day per foot of drawdown [gpd/ft]) at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman 1979). The transmissivity is mathematically equivalent to the hydraulic conductivity multiplied by the saturated thickness: $T = Kb$.

Saturated Thickness (b) - The saturated thickness (b) is the distance (for example, in feet [ft]) from the elevation of the upper groundwater surface in either a phreatic system (the water table) or a confined or semiconfined system (the lower boundary of the upper confining or semiconfining layer, but not the potentiometric surface in a well) to the elevation of the upper boundary of the lower confining or semiconfining layer for the aquifer or water-bearing layer.

Drawdown (s) - The drawdown (s) in any well affected by a well-head test is the differential distance, usually in feet (ft), between the static (unstressed) water level in the well measured immediately prior to the test, and the (stressed) water level at the specified time during the test.

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.

Site Manager - It is the responsibility of the Site Manager 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.

Field 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 Field 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 practice described in SOP F504 (Handling of Site Investigation Wastes).

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

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

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APPENDIX E

Groundwater Sample Acquisition

GROUNDWATER SAMPLE ACQUISITION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
5.1 Sampling, Monitoring, and Evaluation Equipment
5.2 Calculations of Well Volume
5.3 Evacuation of Static Water (Purging)
5.3.1 Evacuation Devices
5.4 Sampling
5.4.1 Sampling Methods
5.4.2 Sample Containers
5.4.3 Preservation of Samples and Sample Volume Requirements
5.4.4 Field Filtration
5.4.5 Handling and Transportation Samples
5.4.6 Sample Holding Times

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

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. Wells that can be pumped or bailed to dryness with the sampling equipment being used, 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 lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging 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: PID; Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.
3. Pumps
    a. Shallow-well pumps: Centrifugal, Packer Pumps, 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, Packer Pumps, 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 equipment and materials: 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 purging and sample collection.

5.2 Calculations of Well Volume for Purging

The volume of the cylinder of water in a well is given by:

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

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

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 (D).

3. Measure and record static water level (DW-depth to water 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 (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.

5. Calculate number of linear feet of static water (total well depth minus the depth to static water level).

6. Calculate the volume of water in the casing:

$$V_W = \Pi \left(\frac{D}{2} \right)^2 (TD - DW)$$

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

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

Where:

V_W	=	Volume of water standing 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.)

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

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 depth (in feet) 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 = 12.419×10^{-3} cubic meters per meter of depth

5.3 Evacuation of Static Water (Purging)

The amount of purging 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 purged when the values have stabilized.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

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 and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

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, measure the total depth and water level (with 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 distance just 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. Record the method of discharge measurement.

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 that the groundwater level has stabilized. Generally, these measurements are made after the removal of 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 groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of 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. Volatile organics septum 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. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

    Fill the remaining sample containers in order of decreasing volatilability (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

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 for dissolved inorganics 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 analyzed as "total metals" and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of groundwater 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 double-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.

APPENDIX F

Surface Water and Sediment Sample Acquisition

SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Defining the Sampling Program
  - 5.1.1 Sampling Program Objectives
  - 5.1.2 Location of Sampling Stations
  - 5.1.3 Frequency of Sampling
- 5.2 Surface Water Sample Collection
  - 5.2.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)
  - 5.2.2 Lakes, Ponds and Reservoirs
  - 5.2.3 Estuaries
  - 5.2.4 Surface Water Sampling Equipment
  - 5.2.5 Surface Water Sampling Techniques
- 5.3 Sediment Sampling
  - 5.3.1 Sampling Equipment and Techniques
  - 5.3.2 Sediment Sampling Procedure

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

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 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 <u>representative</u> 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
- Bucket/hand auger
- Stainless steel spoon or trowel

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.

5.3.1.3 Bucket (Hand) Auger

Bucket (hand) augering is a viable method for collecting sediment samples in narrow, intermittent streams or tidal flats. Typically, a 4-inch auger bucket with a cutting head is pushed and twisted into the ground and removed as the bucket is filled. The auger hole is advanced one bucket at a time, to a depth specified in the project plans.

When a specific vertical sampling interval is required, 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 sediment should be removed from the bucket to minimize the changes 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.

5.3.1.4 Stainless Steel Spoon or Trowel

For loosely packed sediments, a stainless steel scoop or trowel can be used to collect a representative sample, in narrow intermittent streams or tidal flats.

Use the scoop or trowel to collect the sample from a desired depth. Remove heavy debris, rocks, and twigs before collecting the sample. 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.

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

6.0 QUALITY ASSURANCE RECORDS

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

7.0 REFERENCES

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APPENDIX G

Benthic Macroinvertebrate Ponar Sampling

BENTHIC MACROINVERTEBRATE PONAR SAMPLING PROCEDURES
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Sampling Equipment
- 5.2 Preliminary Activities
- 5.3 Operating Procedure

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

BENTHIC MACROINVERTEBRATE PONAR SAMPLING PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the procedure to sample and characterize benthic macroinvertebrate populations using a Ponar grab. The collected samples provide information used in the determination of population statistics of the benthic macroinvertebrate community. This information will be used in the assessment of risks to the environment.

2.0 SCOPE

This guideline provide information on proper sampling techniques for the collection of benthic macroinvertebrates living in various types of sludges and sediments from silts to granular. This technique may not be appropriate if the sediment is hard and/or rocky.

Review of the information contained herein will facilitate the 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 the methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Benthic Macroinvertebrate - Organisms living on the bottom of water bodies.

Biotic - Biological components of the environment, including organisms and vegetation.

Bow - The front of the boat.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Runs - A stretch of water flowing without any disturbances.

Stern - The back of the boat.

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 that 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.

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.

5.0 PROCEDURES

The primary considerations in collecting benthic macroinvertebrate samples include proper operation of the ponar sampler and proper techniques for sample preparation. Proper benthic macroinvertebrate sampling procedures using the ponar are described in the sections to follow.

5.1 Sampling Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting benthic macroinvertebrate samples with the ponar:

- Sampling Boat
- Ponar
- 1/2" Nylon Rope or Crane with Winch and Aircraft Cable
- Plastic Tub (approximate size 2'x2'x6")
- Wash Tub
- 12" sieve (0.500mm)
- 16 oz Straight Side Widemouth Polypropylene Jars
- 70% Isopropyl Alcohol
- Buffered Formalin®
- Teflon Spatula
- Wash Bottles
- 100% Rag Paper Labels
- Black Permanent Marker
- Camera
- Required Personal Protective Equipment

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact local fish or game officials and inform them of the proposed sampling activities.

Collect and determine all information pertinent to the benthic sampling project, including water depth, station locations, nearby boat access locations, sediment composition, known sediment contamination, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), and any other biological studies previously conducted on or near the site.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic" characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Ensure adequate number of sample collection jars and volume of Formalin® and alcohol for entire trip. If regional area dictates, additional alcohol may be purchased at site.

5.3 Operating Procedure

Prior to launching, check to the boat's gasoline tank to ensure that there is a sufficient amount of gasoline (oil mixture 50:1) for the daily activities. Load and launch the boat at access ramp. Set up the boat for most comfortable and efficient working conditions. When the boat's engine is operating properly, drive to the first station location.

After arriving at the station, drop and secure the anchor. Try to position the boat parallel with direction of water flow, if applicable. Fill the wash tub about half-full with site water.

Attach a 1/2" nylon rope to the ponar, placing the rope through the pulley located on the shocking rail at the bow of the boat. If the crane and winch is used, attach the aircraft cable from the winch to the ponar. Secure the ponar open, maintaining tension on the line, and lower it slowly until the ponar reaches the sediments. Do not allow the ponar to free-fall, because the ponar may twist during descent and land improperly. In addition, a free-falling ponar may cause a pressure wave and blowout the sediment surface layer when the grab reaches the bottom.

When the ponar contacts the sediment, release the tension in the line to close the ponar. After the ponar closes, lift it at a slow but steady rate to prevent sample loss or washout. Place the ponar into the small tub, and open it to release the contents. Discard sample and repeat the procedure if debris prevented complete closure of the ponar and/or little or no sediment was collected.

Transfer the contents in the tub to the sieve, keeping the sieve over the wash tub. Shake the sieve in the wash tub to remove small particles (less than 0.500 mm) and transfer the remaining contents into sample jars. Use a teflon spatula to transfer the bulk of the sample to the jars, and wash down the remaining portion of the sample into the jars using a wash bottle. Decant off the overlying water in jar through the sieve. Wash down any remaining sample in the sieve into the jars using a minimal amount of water.

Fill approximately half of the sample jar with sample, and add 70% isopropyl alcohol for freshwater samples or 10% buffered Formalin® for saltwater samples to the fill the remainder of the jar. Place a 100% cotton paper label inside the jar, identifying the project, station location, date, and replicate number, and close the lid tightly. Use a pencil to mark the label. Label the outside of jar with the project, station location, date, and replicate number using a black permanent marker, and store in jars in containers.

Collect a minimum of three replicate samples at each sampling location unless otherwise specified in the project proposal.

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).
- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F201 describes requirements for completing a chain-of-custody form. Chain of custody forms are considered quality assurance records.

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APPENDIX H

Gill Net Procedures

FISH POPULATION SAMPLING USING GILL NET PROCEDURES

TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Equipment
- 5.2 Preliminary Activities
- 5.3 Operating Procedure

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

FISH POPULATION SAMPLING USING GILL NET PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the procedure to sample and characterize fish communities using gill net procedures. The collected samples provide information used in the determination of population statistics of the fish community and can be used to collect fish samples for chemical analysis of tissues. This information will be used in the assessment of risks to human health and the environment.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for the collection of fish in streams, ponds, and nearshore areas of lakes, impoundments, bays, and estuaries, and the ocean shoreline. This technique is most effective in slow moving streams and rivers, and open areas in lakes and impoundments. Swift moving water bodies tend to tangle the nets.

Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The technique described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Bow - The front of a boat.

Biotic - Biological components of the environment, including organisms and vegetation.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Stern - The back of a boat.

Runs - A stretch of water flowing without any disturbances.

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 that 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.

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.

5.0 PROCEDURES

The primary consideration for collecting fish using gill nets is identifying sampling locations where there is a steady traffic of fish. Accurate and timely deployment and retrieval of the gill nets is a key variable in the success of the fish collection effort. Detailed procedures for conducting fish populations utilizing gill nets are described in the sections to follow.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting fish samples with gill net:

- Sampling boat
- Gill nets (the size mesh is dependent on the size fish desired for collection)
- Flotation and weights to properly set the nets
- Fish Measuring Board
- 0-16 oz scale, 1-4 lb scale, 1-15 lb scale
- Live Well (large tub) with overflow pipe to outside of boat
- Appropriate sampling keys for species to be sampled, and any required instruments to aid in the identification
- Field sampling data sheets
- Glass jars for storage of fish
- Formalin®
- Black Permanent Marker
- Camera
- Required Personal Protective Equipment
- Portable Air Pumps

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact local fish or game officials and inform them of your activities.

Collect and determine all information pertinent to the fish sampling project, including water depth, station locations, nearby boat access locations, known sediment contamination, tidal variation, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), any other biological studies previously conducted on or near the site, species used locally for human consumption and the degree of such consumption, species most likely present, and the most appropriate sampling method for the species of interest that is permitted by law.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic" characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Ensure adequate number of sample collection jars and volume of Formalin® for entire trip.

Set up a continuous flow through water system using the live wells and the pumps. Place the overflow pipes about five inches from the top of the well. Attach a mesh/screen over the inlet of the overflow pipe to prevent loss of small fish species.

5.3 Operating Procedure

Determine the area to be sampled, and mark it with flagging, if possible. Field personnel that are setting the net should be standing on the platform on the bow of the boat. Place one end of the gill net with a weight attached to the bottom and a buoy attached to the top into the water, stretch the gill net across the area to be sampled by pulling it along with the boat. If there is a discernible flow, the net will be set in the upstream direction.

The net should remain in the sample location for 8 to 12 hours before retrieving. Field personnel that are collecting the fish should be standing on the platform on the bow of the boat. The net should be pulled slowly from the water and the collected fish removed as the net is being removed from the water. Place the collected fish into the live wells.

Conduct sampling in areas that will ensure adequate qualitative and/or quantitative representation of the fish community, whichever is necessary. These areas should include riffles/runs, shorelines, snags, natural fish holding areas, vegetation beds and other habitats.

Upon retrieval of a gill net, identify, measure, weigh and release the specimens. Record the proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, skeletal anomalies, and any other pertinent information on a field data sheet.

To the extent possible, process all species in the field and return them to the stream alive. If specimens present taxonomic difficulties, or are too numerous for effective field processing, preserve them in 10% Formalin®, and transport them to the Baker Ecological Services Laboratory for taxonomic work and measurements.

At a minimum, preserve one representative fish from each species in 10% Formalin® as a voucher specimen. Record the station location, date sampled, and species name on the label.

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).

- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).

- Additional remarks, as appropriate.

Record all observations in the Field Logbook as described in SOP F202. Complete field sheets for the collected samples.

7.0 REFERENCES

Brower, 1977. James E. Brower and H. Jerrold Zar. Field and Laboratory Methods for General Ecology. Wm. C. Brown Company Publishers. 1977.

Ricker, 1971. Ricker, W.E. Methods for Assessment of Fish Production in Fresh Waters. International Biological Programme Handbook No. 3. 1971.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1989. Warren-Hicks, William, Parkhurst, Benjamin R., Baker, Samuel S. Jr. Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. U.S. EPA, Environmental Research Laboratory, Corvallis, OR 97333. March 1989.

APPENDIX I

ENSYS PAH Field Screening

Rev. 3 9/30/93

ENSYS INC.
ENVIRONMENTAL PRODUCTS

PAH RISC® SOIL TEST SYSTEM

RAPID IMMUNOASSAY SCREEN

User's Guide

This method correctly identifies 95% of samples that are PAH-free and those containing 1ppm or 10 ppm of PAHs. A sample that develops less color than the standard is interpreted as positive. It contains PAHs. A sample that develops more color than the standard is interpreted as negative. It contains less than 1 ppm or 10 ppm PAHs.

IMPORTANT NOTICE

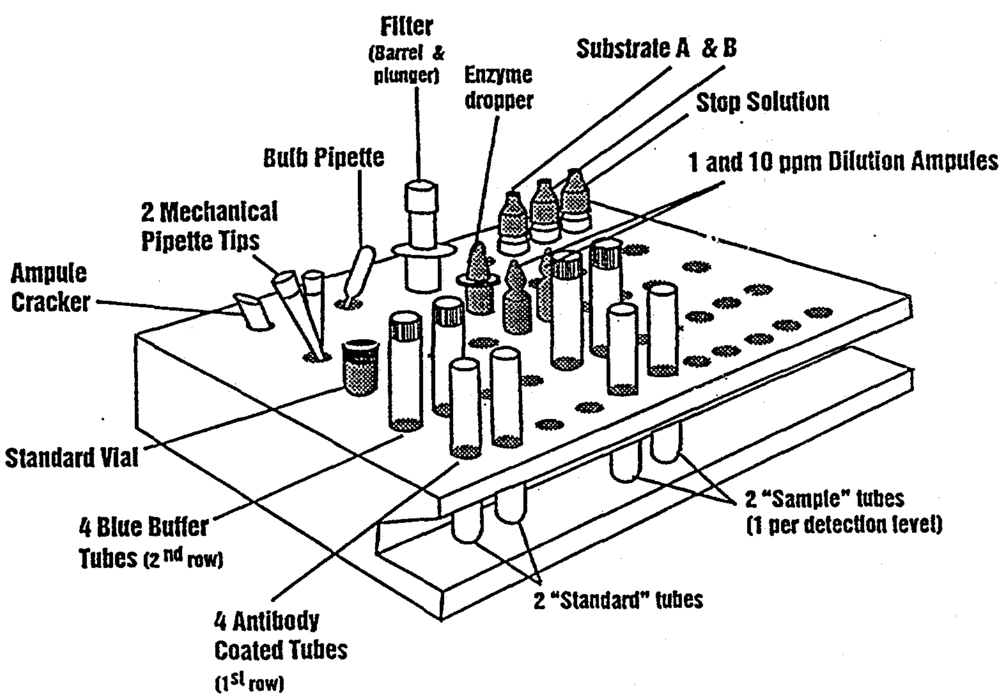
This test system should be used only under the supervision of a technically qualified individual who is capable of understanding any potential health and environmental risks of this product as identified in the product literature. The components must only be used for the analysis of soil samples for the presence of PAHs. After use, the kits must be disposed of in accordance with applicable federal and local regulations.

WORKSTATION SET-UP

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

WORKSTATION SET-UP

- ☐ Mechanical pipette tip
- ☐ Filtration barrel & plunger
- ☐ Standard vial
- ☐ 4 blue buffer tubes
- ☐ Substrate A
- ☐ Bulb pipette
- ☐ 1 and 10 ppm dilution ampules
- ☐ 4 antibody coated tubes
- ☐ Substrate B
- ☐ Ampule cracker
- ☐ Enzyme dropper
- ☐ Stop solution



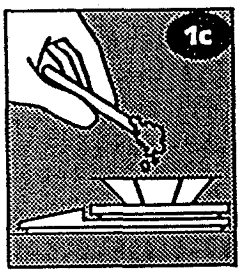
READ BEFORE PROCEEDING

- Follow diagram above to setup workstation.
- Items that you will need that are not provided in the test kit include:
  a permanent marking pen, laboratory tissue (or paper towels), a liquid waste container, and disposable gloves.
- Do not attempt to run more than 12 tubes, two of which must be Standard tubes.
- Operate test at temperatures greater than 4°C / 40°F and less than 32°C / 90°F.

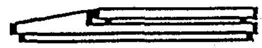
PHASE 1 EXTRACTION & PREPARATION OF THE SAMPLE

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

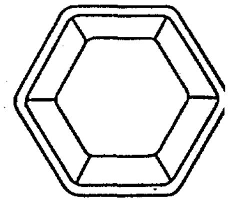
WEIGH SAMPLE



- **1a** Place unused weigh boat on pan balance.
- **1b** Press ON/MEMORY button on pan balance. Balance will beep and display 0.0.
- **1c** Weigh out 10 +/- 0.1 grams of soil.
- **1d** If balance turns off prior to completing weighing, use empty weigh boat to retare, then continue.



Pan balance

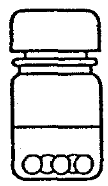


Weigh Boat

Wooden spatula

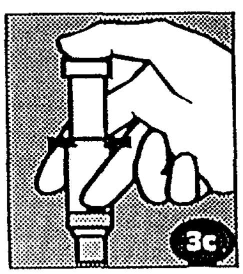
EXTRACT PAHS

- **2a** Uncap extraction jar and place on flat surface. Without contacting liquid, puncture foil seal with ampule cracker or sharp object. Peel the remainder of the seal off extraction jar.
- **2b** Using wooden spatula, transfer 10 grams of soil from weigh boat into extraction jar.
- **2c** Recap extraction jar tightly and shake **vigorously** for one minute.
- **2d** Allow to settle for one minute. Repeat steps 1a -2c for each sample to be tested.



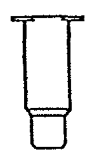
Sample extraction jar

FILTER SAMPLE



- **3a** Remove lid from extraction jar.
- **3b** Disassemble filtration plunger from filtration barrel.
- **3c** Insert bulb pipette into top (liquid) layer in extraction jar and draw up sample. Transfer at least ½ bulb capacity into filtration barrel. **Do not use more than one full bulb.**
- **3d** Press plunger firmly into barrel until adequate filtered sample is available (place on table and press if necessary).

Filtration plunger



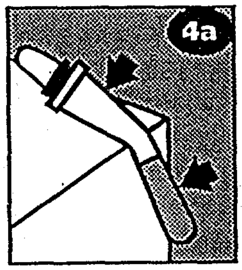
Filtration barrel

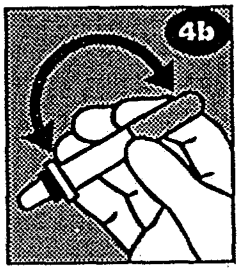
Bulb pipette

PHASE 1 EXTRACTION & PREPARATION OF THE SAMPLE

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

PREPARE ENZYME DROPPER





4a Crush glass ampule contained within enzyme dropper by pressing tube against hard edge.

4b Mix enzyme by turning dropper end-over-end 5 times. Do not shake.

4c Remove seal from enzyme dropper.

Repeat steps 4a - 4c to prepare one enzyme dropper for every 5 antibody coated tubes.

Enzyme dropper

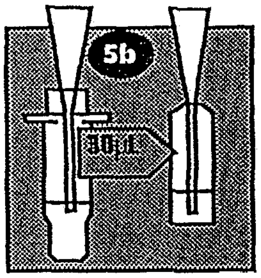
READ BEFORE PROCEEDING

- Label the blue buffer and plastic antibody coated tubes with a permanent marking pen. Uncap blue buffer tubes.
- When using the mechanical pipette always withdraw and dispense below the liquid level. Instructions for operating the Mechanical Pipette are found on page 10.
- "Shake tubes" means to throughly mix the contents with special care not to spill or splash.

PHASE 2 SAMPLE & STANDARD PREPARATION

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

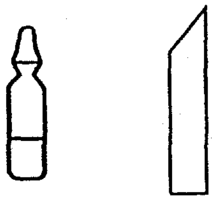
DILUTE SAMPLE AND STANDARD

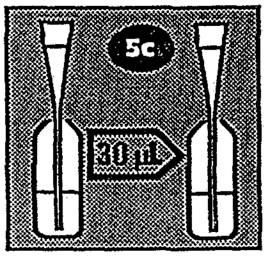


1 ppm

5a Open 1 and 10 ppm* dilution ampules by slipping ampule cracker over tip, and then breaking top at scored neck.

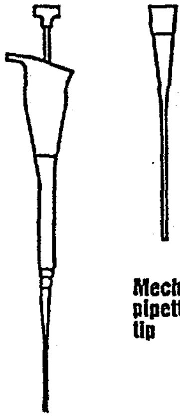
5b Withdraw 30 µL of filtered sample using mechanical pipette and dispense below the liquid level in 1 ppm dilution ampule. Gently shake ampule for 5 seconds.


Dilution ampules (1 & 10 ppm)   Plastic Safety Sleeve

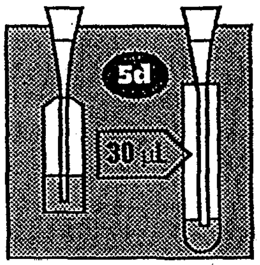


1 ppm   10 ppm

5c Withdraw 30 µL of diluted sample from the 1 ppm dilution ampule and dispense below the liquid level in the 10 ppm dilution ampule. Gently shake ampule for 5 seconds.


Mechanical pipette tip

Mechanical pipette

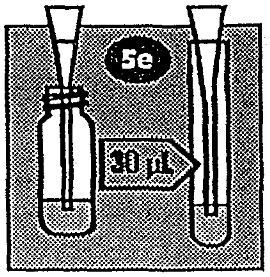


1 & 10 ppm   1 & 10 ppm

5d Withdraw 30 µL of diluted sample from each dilution ampule and dispense below the liquid level in corresponding blue buffer tube. Do not recap blue buffer tube. Always wipe tip after dispensing into buffer tube.

* For other test concentrations, follow steps 5b - 5d, transferring from lowest level dilution ampule to higher level dilution ampules. You may be provided with additional dilution ampules to achieve higher test concentrations

If you need assistance call technical support 1-800-242-7472



PAH Standard

5e Assemble new tip onto mechanical pipette and withdraw 30 µL of PAH Standard and dispense below the liquid level in two blue buffer tubes. Immediately replace cap on PAH Standard vial.

5f Gently shake all blue buffer tubes for 5 seconds.


Blue buffer tube   PAH Standard vial

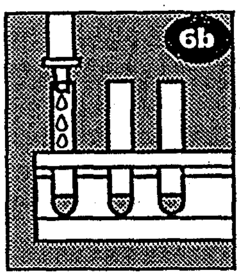
PHASE 3 THE IMMUNOASSAY

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ BEFORE PROCEEDING

- This phase of the procedure requires critical timing and care in handling the antibody coated tubes.

ADD ENZYME



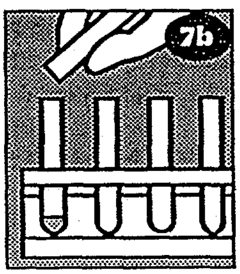
6a Dispense first drop from enzyme dropper into liquid waste container.

Note: before dispensing drops, tap capped tip on hard surface to avoid dispensing air bubbles.

6b Dispense 3 drops of enzyme into each blue buffer tube by squeezing the dropper.

6c Shake buffer tubes for 5 seconds.

INCUBATION



7a Set timer for 10 minutes.

7b Start timing and immediately pour solution from each blue buffer tube into appropriate antibody coated tube.

7c When pouring is complete, gently shake for 5 seconds.

Antibody coated tubes (contained in resealable "zip-seal" aluminized pouch)

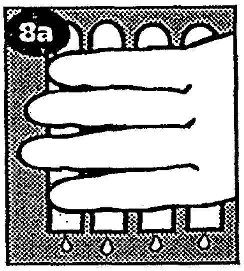
PHASE 3 THE IMMUNOASSAY

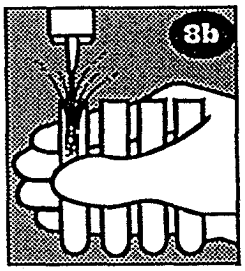
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ BEFORE PROCEEDING

- An accurate test requires a vigorous wash accomplished by directing a strong stream into the antibody coated tubes.
- The wash solution is a harmless, dilute solution of detergent.

WASHING

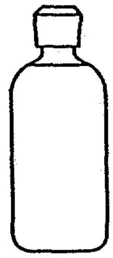




8a After the 10 minute incubation, empty antibody coated tubes into liquid waste container.

8b Wash antibody coated tubes by vigorously filling and emptying a total of 4 times.

8c After final wash, tap antibody coated tubes upside down on the laboratory tissue. Residual foam in the tubes will not interfere with test results.



Wash Bottle

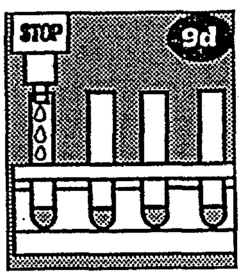
PHASE 3 THE IMMUNOASSAY

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ BEFORE PROCEEDING

- Keep Substrate Dropper bottles vertical and direct each drop to bottom of antibody coated tubes. Addition of more or less than indicated number of drops (of Substrate A or B) may give inaccurate results.
- This phase requires accurate timing.

COLOR DEVELOPMENT



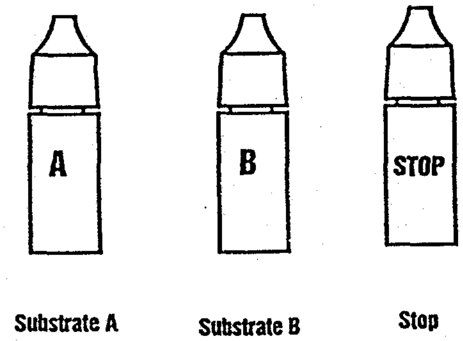
9a Add 5 drops of Substrate A (yellow cap) to each antibody coated tube.

9b Set timer for 2 1/2 minutes. Start timing and immediately add 5 drops of Substrate B to each antibody coated tube.

9c Shake all tubes for 5 seconds and let stand for exactly 2 1/2 minutes.

9d Stop reaction at end of 2 1/2 minutes by adding 5 drops of Stop Solution (red cap). Shake all tubes for 5 seconds.

Note: Blue solution will turn yellow when Stop Solution is added.



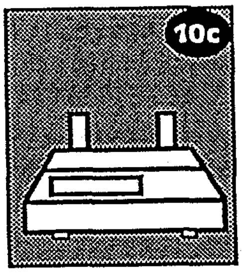
PHASE 4 INTERPRETATION

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

SELECT DARKER STANDARD

10a Wipe outside of all antibody coated tubes.

10b Place both Standard tubes in photometer.

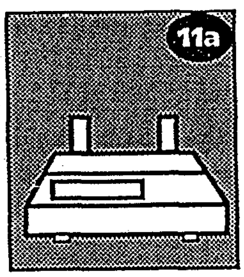


10c Switch tubes until the photometer reading is negative or zero. Record reading.

If reading is greater than 0.25 in magnitude (+ or -), results are outside of QC limits. Retest the sample(s).

10d Remove and discard tube in right well. The tube in the left well is the darker standard.

MEASURE SAMPLE



11a Place 1 ppm tube in right well of photometer and record reading shown on display.

If photometer reading is negative or zero, PAHs are present.

If photometer reading is positive, concentration of PAHs are less than 1 ppm.

11b Place 10 ppm tube in right well of photometer and record reading shown on display.

If photometer reading is negative or zero, PAHs are present.

If photometer reading is positive, concentration of PAHs are less than 10 ppm.

QUALITY CONTROL

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

How It Works

Standards, Samples, and color-change reagents are added to test tubes coated with a chemical specific to PAHs. The concentration of PAHs in an unknown Sample is determined by comparing its color intensity with that of a Standard.

Note: PAH concentration is inversely proportional to color intensity; the lighter the color development of the sample, the higher the concentration of PAHs.

Quality Control

Standard precautions for maintaining quality control:

- Do not use reagents or test tubes from one Test System with reagents or test tubes from another Test System.
- Do not use the Test System after its expiration date.
- Each analysis must include 2 Standards, with no more than a total of 12 antibody coated tubes.
- Do not exceed incubation periods prescribed by the specific steps.
- Results may not be valid if photometer reading for Standards exceeds 0.2 in magnitude.

Storage and Handling Precautions

- Wear protective gloves and eyewear.
- Store kit at room temperature and out of direct sunlight (less than 80°F).
- Keep aluminized pouch (containing unused antibody coated tubes) sealed when not in use.
- If liquid from the extraction jar, or PAH Standard comes into contact with eyes, wash thoroughly with cold water and seek immediate medical attention.
- Operate test at temperatures greater than 4°C/ 40° F and less than 39° C/100° F.
- After use, dispose of kit components in accordance with applicable federal and local regulations.

System Description

Each PAH RISc Soil Test System contains enough material to perform four complete tests, each at 1 and 10 ppm.

The PAH RISc Soil Test is divided into four phases. The instructions and notes should be reviewed before proceeding with each phase.

Hotline Assistance

If you need assistance or are missing necessary Test System materials, call toll free: 1-800-242-RISC (7472).

Validation and Warranty Information

Product claims are based on validation studies carried out under controlled conditions. Data has been collected in accordance with valid statistical methods and the product has undergone quality control tests of each manufactured lot.

PAH-free soil and soil containing 1 ppm and 10 ppm of PAHs were tested with the EnSys PAH RISc analytical method. The method correctly identified 95% of these samples. A sample that has developed less color than the standard is interpreted as positive. It contains PAHs. Eithe a 1 ppm or a 10 ppm sample that has developed more color than the standard is interpreted as negative. It contains less than the indicated level of PAHs (1 ppm or 10 ppm).

The company does not guarantee that the results with the PAH RISc Soil Test System will always agree with instrument-based analytical laboratory methods. All analytical methods, both field and laboratory, need to be subject to the appropriate quality control procedures.

EnSys, Inc. warrants that this product conforms to the descriptions contained herein. No other warranties, whether expressed or implied, including warranties of merchantability and of fitness for a particular purpose shall apply to this product.

EnSys, Inc. neither assumes nor authorizes any representative or other person to assume for it any obligation or liability other than such as is expressly set forth herein.

Under no circumstances shall EnSys, Inc. be liable for incidental or consequential damages resulting from the use or handling of this product.

MECHANICAL PIPETTE

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

HOW TO OPERATE THE MECHANICAL PIPETTE

To Set Or Adjust Volume

Remove push-button cap and use it to loosen volume lock screw. Turn lower part of push-button to adjust volume up or down. Meter should read "030". Tighten volume lock screw and replace push-button cap.

To Assemble Pipette Tip

Slide larger mounting end of pipette tip onto end of pipette. Holding tip in place, press push-button until plunger rod enters pipette tip. Ensure no gap exists between piston and plunger rod (see illustration).

To Withdraw Sample

With tip mounted in position on pipette, press push-button to first stop and hold it.

Place tip at bottom of liquid sample and slowly release push-button to withdraw measured sample. Ensure that no bubbles exist in liquid portion of sample. If bubbles exist, dispense sample and re-withdraw sample.

To Dispense Sample

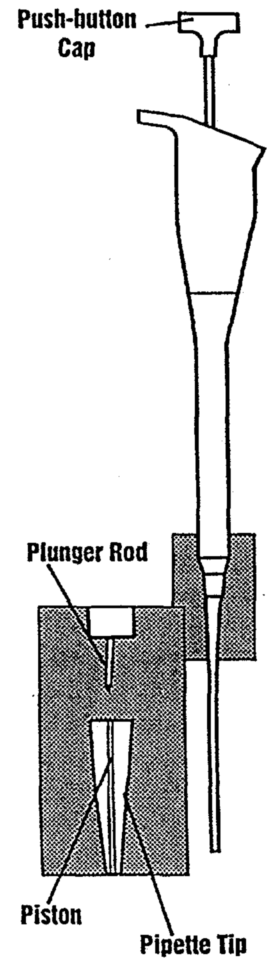
Place tip into dispensing vessel (immersing end of the tip if vessel contains liquid) and slowly press push-button to first stop. (Do not push to second stop or tip will eject).

Remove tip from vessel and release push-button.

To Eject Tip

Press push-button to second stop. Tip is ejected.

For additional information regarding operation and use of pipette, please refer to your pipette manual.



APPENDIX J

Decontamination of Sampling and Monitoring Equipment

1.0 PROCEDURES

Sampling and monitoring equipment decontamination procedures are described below.

1.1 Sampling Equipment Decontamination Procedures

Equipment and materials utilized during this investigation that will require decontamination includes:

- Field measurement and sampling equipment: water level meters, bailers, compositing bottles, hand corers, hydropunch tool, etc.

The following decontamination procedures are taken from USEPA IV Standard Operating Procedures (1991).

1.1.1 Cleaning Procedures for Teflon® or Glass Field Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses

1. Equipment will be washed thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.

2. The equipment will be rinsed thoroughly with hot tap water.

3. Rinse equipment with isopropyl alcohol.

4. Rinse equipment thoroughly with deionized water.

6. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.

7. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.

8. Rinse the Teflon® or glass sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with Step 1. If the field equipment cannot be cleaned utilizing these procedures, it should be discarded.

Small and awkward equipment such as vacuum bottle inserts and well bailers may be soaked in the nitric acid solution instead of being rinsed with it. Fresh nitric acid solution should be prepared for each cleaning session.

1.1.2 Cleaning Procedures for Stainless Steel or Metal Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses

1. Wash equipment thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.

2. Rinse equipment thoroughly with hot tap water.

3. Rinse equipment thoroughly with deionized water.

4. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.

5. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.

6. Rinse the stainless steel or metal sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, when equipment is painted, badly rusted, or coated with materials that are difficult to remove, it may be necessary to steam clean, wire brush, or sandblast equipment before proceeding with Step 1. Any metal sampling equipment that cannot be cleaned using these procedures should be discarded.

1.1.3 Reusable Glass Composite Sample Containers

1. Wash containers thoroughly with hot tap water and laboratory detergent, using a bottle brush to remove particulate matter and surface film.

2. Rinse containers thoroughly with hot tap water.

3. Rinse containers with at least 10 percent nitric acid.

4. Rinse containers thoroughly with tap water.

5. Rinse containers thoroughly with deionized water.

6. Rinse twice with solvent and allow to air dry for at least 24 hours.

7. Cap with aluminum foil or Teflon® film.

8. After using, rinse with tap water in the field, seal with aluminum foil to keep the interior of the container wet, and return to the laboratory.

When these containers are used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the container several times with pesticide-grade acetone before proceeding with Step 1. If these materials cannot be removed with acetone, the container should be discarded. Glass reusable composite containers used to collect samples at pesticide, herbicide, or other chemical manufacturing facilities that produce toxic or noxious compounds shall be properly disposed of (preferably at the facility) at the conclusion of sampling activities and shall not be returned for cleaning. Also, glass composite containers used to collect in-process wastewater samples at industrial facilities shall be discarded after sampling. Any bottles that have a visible film, scale, or discoloration remaining after this cleaning procedure shall also be discarded.

1.1.4 Plastic Reusable Composite Sample Containers

1. Proceed with the cleaning procedures as outlined in Section 1.1.3 but omit the solvent rinse.

Plastic reusable sample containers used to collect samples from facilities that produce toxic or noxious compounds or are used to collect in-process waste stream samples at industrial facilities will be properly disposed (preferably at the facility) of at the conclusion of the sampling activities and will not be returned for cleaning. Any plastic composite sample containers that have a visible film, scale, or other discoloration remaining after this cleaning procedure will be discarded.

1.1.5 Well Sounders or Tapes Used to Measure Ground Water Levels

1. Wash with laboratory detergent and tap water.

2. Rinse with tap water.

3. Rinse with deionized water.

4. Allow to air dry overnight.

5. Wrap equipment in aluminum foil (with tab for easy removal), seal in plastic, and date.

1.1.6 Submersible Pumps and Hoses Used to Purge Ground Water Wells

1. Using a brush, scrub the exterior of the contaminated hose and pump with <u>soapy water</u>.

2. Rinse the soap from the outside of pump and hose with <u>tap water</u>.

3. Rinse the tap water residue from the outside of pump and hose with <u>deionized water</u>.

4. Equipment should be placed in a polyethylene bag or wrapped with polyethylene film to prevent contamination during storage or transit.

APPENDIX K

Decontamination of Drilling Rigs and Monitoring Well Materials

1.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site, and were taken from U.S.EPA IV Standard Operating Procedures (1991).

1.1 Large Machinery and Equipment

All drilling rigs, drilling and sampling equipment, backhoes, and all other associated equipment involved in the drilling and sampling activities shall be cleaned and decontaminated before entering the designated drill site. All equipment should be inspected before entering the site to ensure that there are no fluids leaking and that all gaskets and seals are intact. All drilling and associated equipment entering a site shall be clean of any contaminants that may have been transported from another hazardous waste site, thereby minimizing the potential for cross-contamination. Before site drilling activities are initiated, all drilling equipment shall be thoroughly cleaned and decontaminated at the designated cleaning/decontamination area. The following requirements and procedures are to be strictly adhered to on all drilling activities.

Any portion of the drill rig, backhoe, etc., that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chain pulldowns, spindles, cathead, etc.) shall be steam cleaned before being brought on the site to remove all rust, soil and other material which may have come from other hazardous waste sites. The drill rig and/or other equipment associated with the drilling and sampling activities shall be inspected to insure that all oil, grease, hydraulic fluid, etc., have been removed, and all seals and gaskets are intact and there are no fluid leaks. No oils or grease shall be used to lubricate drill stem threads or any other drilling equipment being used over the borehole or in the borehole without EPA approval. If drill stems have a tendency to tighten during drilling, Teflon® string can be used on the drill stem threads. The drill rig(s) shall be steam cleaned prior to drilling each borehole. In addition, all downhole sampling equipment that will come into contact with the downhole equipment and sample medium shall be cleaned and decontaminated by the following procedures.

1. Clean with tap water and laboratory grade, phosphate-free detergent, using a brush, if necessary, to remove particulate matter and surface films. Steam cleaning and/or high pressure hot water washing may be necessary to remove matter that is difficult to remove with the brush. Hollow-stem augers, drill rods, shelby tubes, etc., that are hollow or have holes that transmit water or drilling fluids, shall be cleaned on the inside and outside. The steam cleaner and/or high pressure hot water washer shall be capable of generating a pressure of at least 2500 PSI and producing hot water and/or steam (200°F plus).

2. Rinse thoroughly with tap water (potable).

   NOTE: Tap water (potable) may be applied with a pump sprayer. All other decontamination liquids (D.I. water, organic-free water, and solvents), however, must be applied with non-interferring containers. These containers shall be made of glass, Teflon®, or stainless steel. This aspect of the decontamination procedures used by the driller will be inspected by the site geologist and/or other responsible person prior to beginning of operations.

3. Rinse thoroughly with deionized water.

4. Rinse twice with solvent (pesticide grade isopropanol).

5. Rinse thoroughly with organic-free water and allow to air dry. Do not rinse with deionized or distilled water.

   Organic-free water can be processed on site by purchasing or leasing a mobile deionization-organic filtration system.

   In some cases when no organic-free water is available, it is permissible (with approval) to leave off the organic-free water rinse and allow the equipment air dry before use.

6. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported. Clean plastic can be used to wrap augers, drill stems, casings, etc., if they have been air dried.

7. All downhole augering, drilling and sampling equipment shall be sandblasted before Step #1 if painted, and/or if there is a buildup of rust, hard or caked matter, etc., that cannot be removed by steam and/or high pressure cleaning. All sandblasting shall be performed prior to arrival on site.

8. All well casing, tremie tubing, etc., that arrive on site with printing and/or writing on them shall be removed before Step #1. Emery cloth or sand paper can be used to remove the printing and/or writing. Most well material suppliers can supply materials without the printing and/or writing if specified when materials are ordered.

9. Well casing, tremie tubing, etc., that are made of plastic (PVC) shall not be solvent rinsed during the cleaning and decontamination process. Used plastic materials that cannot be cleaned are not acceptable and shall be discarded.

Cleaning and decontamination of all equipment shall occur at a designated area on the site, downgradient, and downwind from the clean equipment drying and storage area. All cleaning of drill rods, auger flights, well screen and casing, etc., will be conducted above the plastic sheeting using saw horses or other appropriate means. At the completion of the drilling activities, the pit shall be backfilled with the appropriate material designated by the Site Manager, but only after the pit has been sampled, and the waste/rinse water has been pumped into 55-gallon drums. No solvent rinsates will be placed in the pit unless prior approval is granted. All solvent rinsates shall be collected in separate containers for proper disposal.

APPENDIX L

On-Site Water Quality Testing

1.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance/ salinity, and temperature.

1.1 Measurement of pH

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

1.1.1 Equipment

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

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

1.1.2 Measurement Techniques for Field Determination of pH

1. pH Meter

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

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

   b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.

   c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.

   d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).

   e. Immerse the electrode(s) in a pH-7 buffer solution.

   f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.

g. Adjust the pH meter to read 7.0.

h. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.

i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.

j. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.

k. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.

l. The electrode(s) shall remain immersed in deionized water when not in use.

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

2. pH Paper

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

1.2 <u>Measurement of Specific Conductance/Salinity</u>

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

1.2.1 Equipment

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

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

1.2.2 Measurement Techniques for Specific Conductance/Salinity

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

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the electrode in the sample and measure the conductivity and salinity. If specified, adjust the temperature setting to the sample temperature.
- Read and record the results on the Calibration Form (in the absence of the Calibration Form, the Field Logbook will be used).
- If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
- On some meters, specific conductivity and salinity measurements may need to be reported with the associated temperature measurement. If the conductivity and salinity has been corrected, the measurements shall be reported as "corrected to 25°C." (See Attachment A)

1.3 Measurement of Temperature

Procedures for measuring temperature are described below.

1.3.1 Equipment

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or

such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

1.3.2 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.

- Record values in a Field Logbook to the nearest 0.5 or 0.1°C, depending on the measurement device used.

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

APPENDIX M

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

1.0 PROCEDURES

The following 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 PVC or stainless steel 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.

1.1 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 of the electric cord/tape against the measuring point on the top of the PVC or stainless steel casing is marked for surveys. 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/tape to the nearest 0.01 foot using an engineers scale. The measurements are combined (feet plus hundredths of a foot) to yield a measurement of the depth to water below the top of the PVC or stainless 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).

1.2 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.

1.3 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 PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook.

APPENDIX N

Photoionization Detector (PID)

1.0 PROCEDURES

The following subsection will discuss HNu operation.

1.1 Operation

PI 101

Note: IMPORTANT - The HNu should be "zeroed" in a fresh air environment if at all possible. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the HNu, check that the battery is fully charged by turning the dial to BATT and making sure that it is within range. Also make sure that the ultraviolet lamp and the fan are working properly.

- Select your desired range. HNu ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range, however, in most instances the range will be set initially at 0-20.

- When HNu is used intermittently, turn knob to STANDBY to help in extending the life of the UV lamp when operating in a low humidity environment. Otherwise, leave the knob set to the range desired so that the UV lamp will "burn off" any accumulated moisture.

Note: When using the PI 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

DL 101

The DL 101 is designed to default to the survey mode when initially powered up, therefore once the calibration has been completed, the instrument is ready to go. Within the survey mode several options are available, briefly these options include:

(1) The Site Function

The Site function assigns a number to a site that is being analyzed. Press the Site Key on the keypad to enter a specific site number, or press the gray button on the rear of the probe to increment a site number.

(2) Logging Data

The Log function stores data in memory. To log data, press the Log key on the keypad or the Log button on the back of the probe. "Log" will appear in the upper right corner of the display when activated and disappears when not activated. To turn logging off, press either the Log key on the keypad or the red Log button on the rear of the probe.

- The DL 101 allows for the interchanging of different voltage lamps, however, refer to the manufacturer's instructions before attempting to change the lamp.

- The DL 101 also offers three other modes of operation, the Hazardous Waste Mode, the Industrial Hygiene Mode, and the Leak Detection Mode. Each of these modes

APPENDIX O

Bacharach Combustible Gas/Oxygen Meter and Personal Gas Monitor Carbon Monoxide Meter

1.0 OPERATION

The following describes the operation of the Bacharach Sentinel 4 and Sniffer 503-A.

1.1 Sentinel 4

Due to the Sentinel 4 having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 6-1 to 6-34. NOTE: Since the Sentinel 4 is capable of measuring four different parameters, an understanding of the alarm, error, and fault messages must be obtained. This can be done by reviewing the troubleshooting table found on pages 9-2 to 9-9.

1.2 Site Maintenance

After each use, the meters should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

APPENDIX P

Land Survey

1.0 PROCEDURES

Baker requires the services of a Land Surveyor reistered in the State of North Carolina to determine by survey the elevations and horizontal locations of monitoring wells and other site structures, and topographic features associated with study areas. The surveyor will mobilize to the site within seven days upon receiving the notice-to-proceed. All site surveys must be completed in the time frame agreed upon. The site map shall be completed within ten days of completion of the site survey.

1.1 Requirements

Specifically, Baker requires the following:

- Delineate the elevations of groundwater monitoring wells to an accuracy of 0.01 feet, referenced to United States Geological Survey Mean Sea Level (msl) from the nearest datum bench mark. The Activity has identified existing bench marks that may be used for control; however, these bench marks may not be directly adjacent to the survey sites.

- Determine the elevation point for each well casing and a permanent mark designating the elevation point shall be established on each well. In addition, the ground surface elevation for each well shall be established. Some of the wells will be flush-mounted level with the pavement; thus the land surface elevation will be above the "top of casing" elevation for those wells.

- Determine the elevation of the directly adjacent ground surface to an accuracy of 0.1 feet.

- Delineate the horizontal location of each well from surveyed corners or other features on permanent land monuments in the immediate site area to an accuracy of 0.1 foot, referenced to North American Datum (NAD). Baker will supply an existing Activity property plot plan or CADD file for each site to the subcontractor that will serve as the base map for locating surveyed points. All permanent points established during control traverses shall be shown.

- Locate various drainage trenches/structures and significant topographic features at Baker's request via the survey. A Baker representative may be present during survey activities to identify points and features to be located. If no Baker representative will be present, the subcontractor will be notified in advance as to what features or types of features are to be included in the survey.

- In the absence of Activity-established horizontal and vertical control, all survey points will be based on North American Datum (NAD) for horizontal control and MSL for vertical control.

- The subcontractor shall provide Baker with a letter report containing all relevant survey information along with one legible copy of the field survey notes recorded when determining the surveyed elevations, location of wells, and requested topographic information. The subcontractor shall also provide one reproducible, legible copy of the property map showing the well designation, "top-of-casing" elevation and location at each well, and a table listing the well designation, "top-of-casing" ground surface elevations, coordinates for each well, and plotted horizontal features. Baker cannot verify the accuracy of Navy-supplied site maps, it is recognized that the subcontractor's responsibility in plotting features is to provide most accurate locations possible on mapping available. Tabulated data provided by the subcontractor, however, must be accurate on an MSL datum specified above. All deliverables must be in ACAD R12.

The subcontractor shall perform these services in accordance with standard, acceptable surveying practices as required by the state in which the work is performed and all work shall be conducted under the supervision of a Registered Land Surveyor, duly licensed to work in the State of North Carolina.

APPENDIX Q

Wastewater Sample Acquisition

WASTEWATER SAMPLE ACQUISITION
TABLE OF CONTENTS

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 On-Shore
- 5.2 Off-Shore

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

WASTEWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for collecting wastewater samples.

2.0 SCOPE

This procedure provides information for the acquisition of waste water samples. Review of the information contained herein will ensure that sample acquisition is properly conducted.

3.0 DEFINITIONS

Sampling Plan - A "plan of action" that guides the implementation of methods that will lead to achieving the plans objective(s).

Grab Sample - An entire sample which is collected at one specific sample location at a specific point in time.

Composite Sample - A sample which is collected at several different locations and/or at different points in time.

Environmental Sample - Samples of naturally occurring materials; soil, sediment, air, water.

Waste Sample - Samples which are comprised of process wastes or other manmade waste material(s).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project specific plans are in accordance with 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 waste water sample acquisition techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing the sample acquisition 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 outlined in the Work Plan and as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all wastewater sampling activities and ambient air monitoring results in the field log book.

5.0 PROCEDURES

This protocol outlines procedures and equipment for the collection of representative liquid samples and sediment/sludge samples from standing lakes, ponds and lagoons, and flowing streams, rivers, channels, sewers and leachate seeps.

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine (e.g., collecting a surface water sample from a two foot deep stream). Other times, the nature of site specific conditions may dictate that: 1) special equipment is needed to access the sample, 2) appropriate health and safety measures are critical, 3) proper timing is essential due to waste release times or tidal fluctuations, and/or 4) wastewater flow rate is a factor for consideration.

Prior to sample collection, impoundment characteristics (size, depth, flow) should be recorded in the field log book. Sampling should proceed from downstream locations to upstream locations so that sediment disturbance (turbidity) caused by sampling does not affect sample quality. Additionally, if a sediment sample will be collected at the same location as a liquid sample, the liquid sample must be collected first to minimize sample turbidity.

If the Sampling Plan requires that samples are to be collected from the shore of an impoundment, specific health and safety considerations must be addressed. The person collecting the sample should be fitted with a safety harness and rope secured to a sturdy, immobile object on shore. Backup personnel should be available to assist in sample collection and should be prepared and able to pull the sampler to safety if unstable banks are encountered.

To more adequately characterize the content and/or quality of an impoundment, samples may be collected away from the shoreline, often at various depths. If the content of the impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. If a barge or boat is used, each person on the vessel must be equipped with a life preserver and/or lifeline.

The sampling of liquids in lakes, ponds, lagoons, streams, rivers, channels, sewers and leachate seeps is generally accomplished through the use of one of the following samplers:

- Laboratory cleaned sample bottle
- Pond sampler
- Weighted bottle sampler
- Wheaton dip sampler
- Kemmerer Depth Sampler
- Bacon Bomb Sampler

The factors that will contribute to the selection of a sampler include the width, depth and flow of the location being sampled, and whether the sample will be collected from the shore or a vessel.

For flowing liquids, tidal influence on the collected sample is an additional concern and should be addressed in the Sampling Plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages as well as seasonally. Tidal information can be obtained from local bait shops, newspaper listings and/or local radio or television news reports.

Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and steams it may be nearly impossible to collect a mid-channel sample at a specific point. Low flowing streams and leachate seeps present the opposite problem. In these cases the sampler should attempt to locate an area where flow is obstructed and a pool is created. If this is not possible, sediment may be dug with a decontaminated trowel to create a pooled area where sufficient liquid will accumulate for sampling.

5.1 On-Shore

If the banks are not sloped, sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where access is limited, a pond sampler, by virtue of its extension capabilities, may be necessary. For a stream, channel or river, collect the sample at mid-depth. For standing liquid, collect the sample from just below the surface or at mid-depth. Once the sample is obtained by sample vessel, transfer it directly into the sample bottle. If volatile organic compounds (VOCs) are to be analyzed, fill the appropriate sample containers for VOCs first, then fill sample containers for other chemical analyses. Decontaminate the sampling device following procedures outlined in the Sampling Plan and/or SOP F502 before obtaining the next sample.

5.2 Off-Shore

Collect a liquid sample using the sample bottle or decontaminated pond sampler, if necessary. If the liquid has stratified, a sample of each strata should be collected. One of the depth samplers listed above will allow collection of discrete representative liquid samples at various depths. Proper use of the chosen sampling device includes slowly lowering and careful retrieval of the sample, immediate transfer of the liquid into the appropriate sampling container, and logbook notation of the depth at which the sample was collected. After collection, the sampling device must be decontaminated prior to obtaining the next sample.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records shall consist of recording sample date and acquisition time(s), sample number, sample location(s), sample depth(s), name of the Field Investigation Personnel collecting the sample(s), and Service Order Number in the field logbook. The type of container used to hold the sample and preservative agent, if needed, also will be documented, as will the method of sampling equipment decontamination. In addition, if photographs are taken of the sample site, the photograph number and direction of view shall be recorded as well.

7.0 REFERENCES

Field Sampling Procedures Manual. Chapter 8. New Jersey Department of Environmental Protection, Trenton, New Jersey. February 1988.

Sampling and Analysis Methods. Compilation of EPA's Sampling and Analysis Methods, USEPA, Washington, D.C. 1991.

Characterization of Hazardous Waste Sites. USEPA, Washington, D. C. 1990.

APPENDIX R

Sample Preservation and Handling

ATTACHMENT A

REQUIRED CONTAINERS, PRESERVATIVE TECHNIQUES AND HOLDING TIMES

Parameter	EPA Document SW-846 (3rd Ed.)				Contract Laboratory Protocol			
	Container	Preservative	Holding Time(1)		Container	Preservative	Holding Time(2)	
			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	10 days	14 days (7 days if unpreserved)	Water - 40 mL glass vial with Teflon-lined septa Soil-glass with Teflon-lined septa	Conc. HCl Cool to 4°C	10 days	14 days (7 days if unpreserved)
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 7 days, analyze 40 days	Extract within 7 days, analyze 40 days
Semivolatiles	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 7 days, analyze 40 days	Extract within 7 days, analyze 40 days
Metals(3)	P, G	HNO_3 to pH <2(4)	6 months	6 months	P, G	HNO_3 to pH <2(4)	6 months	6 months
Mercury	P, G	HNO_3 to pH <2(4)	28 days	28 days	P, G	HNO_3 to pH <2(4)	28 days	28 days

(1) From date of sample collection in field.

(2) From date of sample receipt at laboratory.

(3) Dissolved metals (liquid) must be field filtered prior to preservation.

(4) Soil samples collected for metals and Mercury analyses are not preserved with acids, only cooled to 4°C.

Note: Check with laboratory for specific volume requirements.

Revised: April 21, 1994

APPENDIX S

Chain-of-Custody

1.0 PROCEDURES

Chain-of-custody procedures are presented in this section.

1.1 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.

1.1.1 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. 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, SVOAs, 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).

1.2 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.

1.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan and Appendices. 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.

1.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. When transferring the possession of samples, the individual(s) 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 airbill number under "Remarks," in the bottom right corner;

- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other 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. 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 shipping container (enclosed with other documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

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.

APPENDIX T

Field Logbook

1.0 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.

1.1 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.

1.2 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, an ongoing record of all site activities should be written 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 initialed 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.

1.3 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.

FINAL

REMEDIAL INVESTIGATION/FEASIBILITY STUDY QUALITY ASSURANCE PROJECT PLAN FOR OPERABLE UNIT NO. 8 (SITE 16) OPERABLE UNIT NO. 11 (SITES 7 AND 80) OPERABLE UNIT NO. 12 (SITE 3) MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0233

OCTOBER 2, 1994

Prepared for:

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

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

TABLE OF CONTENTS

Section		Page
1.0	**INTRODUCTION**	**1-1**
2.0	**SCOPE OF QUALITY ASSURANCE PROJECT PLAN**	**2-1**
3.0	**PROJECT DESCRIPTION**	**3-1**
4.0	**PROJECT ORGANIZATION**	**4-1**
5.0	**QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT**	**5-1**
5.1	Project Quality Assurance Objectives	5-1
5.2	Data Quality Objectives	5-2
6.0	**SAMPLE AND DOCUMENT CUSTODY PROCEDURES**	**6-1**
6.1	Sampling Handling	6-1
6.2	Chain-of-Custody Procedures	6-1
6.3	Document Custody Procedures	6-5
7.0	**CALIBRATION PROCEDURES AND FREQUENCY**	**7-1**
7.1	Field Instruments	7-1
7.2	Laboratory Instruments	7-1
8.0	**ANALYTICAL PROCEDURES**	**8-1**
8.1	Field Analysis	8-1
8.2	Laboratory Analysis	8-1
9.0	**DATA REDUCTION, VALIDATION, AND REPORTING**	**9-1**
9.1	Field Data Procedures	9-1
9.2	Laboratory Data Procedures	9-1
9.3	Independent (Third Party) Data Validation	9-2
10.0	**QUALITY CONTROL CHECKS**	**10-1**
10.1	Field Quality Control Checks	10-1
10.2	Laboratory Quality Control Checks	10-3
10.3	Laboratory Control Limits	10-5
11.0	**PERFORMANCE AND SYSTEM AUDITS**	**11-1**
12.0	**PREVENTIVE MAINTENANCE**	**12-1**
12.1	Field Maintenance	12-1
12.2	Laboratory Maintenance	12-1

TABLE OF CONTENTS
(CONTINUED)

Section		Page
13.0	**DATA MEASUREMENT ASSESSMENT PROCEDURES**	**13-1**
13.1	Overall Project Assessment	13-1
13.2	Field Quality Assessment	13-1
13.3	Laboratory Data Quality Assessment	13-1
14.0	**CORRECTIVE ACTION**	**14-1**
14.1	Limits of Operation	14-1
14.2	Corrective Action	14-1
15.0	**QUALITY ASSURANCE REPORTING PROCEDURES**	**15-1**

LIST OF FIGURES

Number		Page
4-1	Project Organization Chart	4-2

LIST OF TABLES

Number		Page
5-1	Definitions of Data Quality Indicators	5-3
6-1	Summary of Containers, Preservation, and Holding Times for Water Samples	6-2
6-2	Summary of Containers, Preservation, and Holding Times for Solid Samples	6-3
8-1	Method Performance Limits	8-2
10-1	QC Analysis Frequency	10-2
10-2	QA/QC Sample Frequency	10-4
11-1	System Audit Checklist - Project Office	11-2

1.0 INTRODUCTION

This Quality Assurance Project Plan (QAPP) has been developed for the field investigation of the following Operable Units (OUs) at Marine Corps Base, Camp Lejeune, North Carolina:

- Operable Unit No. 8 (Site 16) - Montford Point Burn Dump
- Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump
- Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area
- Operable Unit No. 12 (Site 3) - Old Creosote Plant

The preparation of this QAPP, and other related project plans, is being performed under the Navy CLEAN Contract No. N62470-89-D-4814, Contract Task Order 0233. Baker Environmental, Inc., is the prime contractor for the implementation of this project.

This QAPP addresses the quality assurance and quality control steps and procedures that will be administered for the sample collection and analysis for this Remedial Investigation/Feasibility Study (RI/FS). Detailed information regarding sample handling and analytical methods are provided in Sections 6.0 and 9.0, respectively. Sample collection procedures are provided in the Field Sampling and Analysis Plan (FSAP).

2.0 SCOPE OF QUALITY ASSURANCE PROJECT PLAN

This Quality Assurance Project Plan (QAPP) addresses sample collection and analysis to be conducted for the field investigation of Sites 16, 7, 80 and 3 of Camp Lejeune, North Carolina. The QAPP has been developed for the Department of Navy (DoN) in accordance with U.S. Environmental Protection Agency (USEPA) guidelines. Contractors will follow QA/QC practices and procedures, including chain-of-custody procedures, while conducting all sample collection and analysis activities.

In order to provide adequate QA/QC, this investigation will require:

1. The use of a NEESA-certified analytical laboratories;

2. The use of accepted analytical methods for the samples discussed in the FSAP. Analysis of samples for hazardous constituents parameters will be performed using the following documents:

   - "Statement of Work for Organic Analysis," USEPA, OLM01.8, August 1991

   - "Statement of Work for Inorganic Analysis," USEPA, ILM03.0, March 1990

   - "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983

   - "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136

   - "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition

   - "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886

3. The conducting of field audit(s) during initial sampling activities to verify that sampling is being performed according to the Plan.

The structure of this QAPP and the QA elements addressed are:

- Title Page
- Table of Contents
- Introduction
- QAPP Scope
- Project Description
- Project Organization
- QA Objectives for Data Measurement
- Sampling Procedures
- Sample and Document Custody
- Calibration Procedures and Frequency
- Analytical Procedures
- Data Reduction, Validation, and Reporting
- Internal QC Checks
- Performance and System Audits
- Preventive Maintenance
- Data Measurement Assessment Procedures

- Corrective Action
- QA Reports to Management

3.0 PROJECT DESCRIPTION

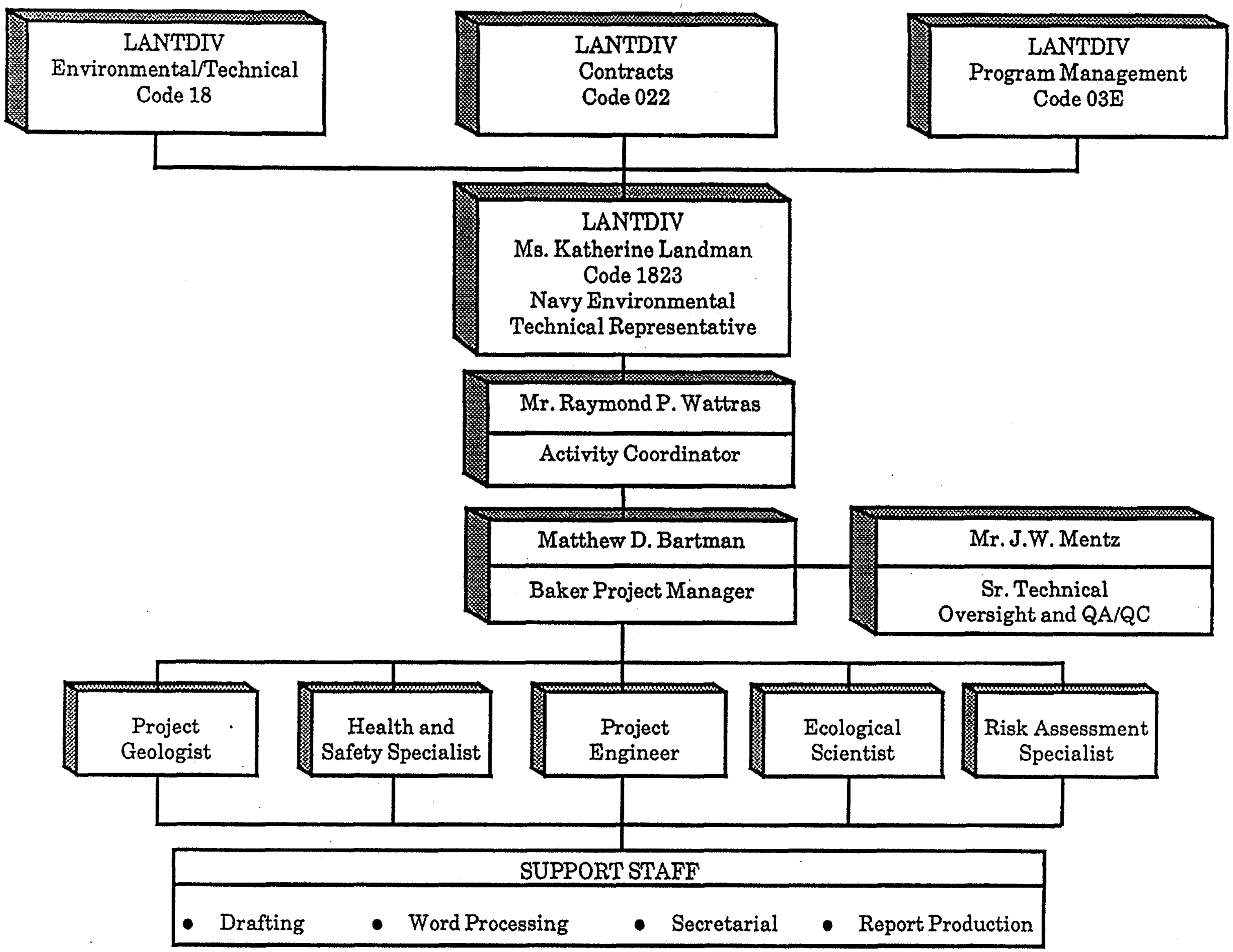
An introduction to the field investigation of Sites 16, 7, 80 and 3 describing the project objectives and scope are given in Sections 4.0 and 5.0 of the RI/FS Work Plan. These sections discuss the objectives of the RI/FS, and the various field sampling and analytical programs. A detailed description of the field investigations, including sample location and designation and sampling procedures and frequency, is presented in Sections 3.0, 4.0, and 5.0 of the FSAP.

4.0 PROJECT ORGANIZATION

Technical performance of the investigation of Sites 16, 7, 80 and 3 at Camp Lejeune and key personnel responsible for quality assurance throughout its duration are described in Section 5.0 of the RI/FS Work Plan. The contractor will utilize subcontractors to perform laboratory analysis, data validation, drilling and monitoring well installation, ordnance clearance (if required), geophysical investigation, and surveying. Specific subcontractors have not yet been identified. Figure 4-1 shows the project organization, lines of authority, and support personnel/organizations.

FIGURE 4-1

PROJECT ORGANIZATION



5.0 QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT

The purpose of a QA Program is to establish policies for the implementation of regulatory requirements and to provide an internal means for control and review so that the work performed is of the highest professional standards.

5.1 Project Quality Assurance Objectives

The following is a list of QA objectives which will be implemented at Camp Lejeune Sites 16, 7, 80, and 3.

- Obtain scientific data of a quality sufficient to meet scientific and legal scrutiny.
- Gather/develop data in accordance with procedures appropriate for its intended use.
- Ensure that data is of acceptable precision, accuracy, completeness, representative-ness, and comparability as required by the project.

The fundamental mechanisms that will be employed to achieve these quality goals can be categorized as prevention, assessment and correction where:

- Prevention of errors through planning, documented instructions and procedures, and careful selection and training of skilled, qualified personnel.
- Assessment of all quality assurance sampling reports furnished by the contract laboratory.
- Assessment of data through data validation, and of procedures through laboratory and field audits.
- Correction for prevention of reoccurrence of conditions adverse to quality.

This QAPP, prepared in direct response to these goals, describes the QA Program to be implemented and the quality control (QC) procedures to be followed by field and laboratory personnel during the course of the project.

This QAPP presents the project organization and specifies or references technical procedures, documentation requirements, sample custody requirements, audit, and corrective action provisions to be applied to provide confidence that all activities meet the intent of the QA program. This QAPP has been prepared in accordance with USEPA guidance as presented in "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80.

The procedures contained or referred to herein have been taken from:

- "Statement of Work for Organic Analysis," USEPA , OLM01.8, August 1991
- "Statement of Work for Inorganic Analysis," USEPA , ILM03.0, March 1990
- "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983
- "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136
- "Test Methods for Evaluating Solid Waste," USEPA SW846, November 1986, 3rd Edition

- "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886

- "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," USEPA, (QAMS 005/80).

5.2 Data Quality Objectives

Data quality objectives (DQOs) are qualitative or quantitative statements developed by the data users to specify the quality of data needed from a particular data collection activity to support a specific decision. The DQOs are expressed in terms of precision, accuracy, representativeness, completeness, and comparability. Definitions for these terms, as well as for the more general term uncertainty, are given in Table 5-1

TABLE 5-1

DEFINITIONS OF DATA QUALITY INDICATORS

PRECISION - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is expressed in terms of the standard deviation. Comparison of replicate values is best expressed as the relative percent difference (RPD). Various measures of precision exist depending upon the "prescribed similar conditions".

ACCURACY - The degree of agreement of a measurement (or an average of replicate measurements), X, with an accepted reference or true value, T, expressed as the difference between the two values, X-T. Accuracy is a measure of the bias in a system.

REPRESENTATIVENESS - Expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental concern.

COMPLETENESS - A measure of the amount of the valid data obtained from the measurement system compared to the amount that was expected under "normal" conditions.

COMPARABILITY - Expresses the confidence with which one data set can be compared with another.

UNCERTAINTY - The likelihood of all types of errors associated with a particular decision.

The Project Manager, in conjunction with the Navy Environmental Technical Representative (NTR), is responsible for defining the DQOs. The intended use of the data, analytical measurements, and the availability of resources are integral in development of DQOs. DQOs define the level of uncertainty in the data that is acceptable for each specific activity during the investigation. This uncertainty includes both field sampling error and analytical instrument error. Ideally, zero uncertainty is the goal; however, the variables associated with sampling and analysis contribute to a degree of uncertainty in any data generated. It is an overall program objective to keep the total uncertainty within an acceptable range, so as not to hinder the intended use of the data. To achieve this objective, specific data quality requirements such as detection limits, criteria for accuracy and precision, sample representativeness, data comparability, and data completeness have been specified.

The data collected will be used:

- To evaluate the presence or absence of contamination resulting from previous disposal activities.
- To assess potential contaminant migration and exposure pathways.
- To monitor health and safety conditions during field activities.
- To identify releases or suspected releases of hazardous waste and/or constituents.
- To screen from further investigation those areas which do not pose a threat to human health or environment.

All samples for characterizing the site or qualitatively assessing human health and environmental risks will be analyzed and reported by the laboratory as Level III data (NEESA Level C). Field parameters including temperature (aqueous only) and specific conductance will be Level I (NEESA Level A) data quality.

6.0 SAMPLE AND DOCUMENT CUSTODY PROCEDURES

Descriptions of the procedures to be used for sampling the groundwater, surface water, sediment and soil at the site are provided in the FSAP. The number of samples, sampling locations, and sampling rationale by media also are presented in Section 5.0 of the FSAP.

Sample custody procedures outlined in this section have been developed from "User's Guide to the Contract Laboratory Program," December 1988, OSWER Directive No. 9240.0-01. These procedures are in accordance with "EPA NEIC Policies and Procedure Manual," May 1978, revised November 1984, EPA 330-78-001-R and "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," December 1980, QAMS-005/80.

The purpose of this section is to outline the sample handling and sample documentation procedures to be used during implementation of the FSAP. The objective of the sample handling procedures is to deliver representative samples to the laboratories for analysis. The objectives of the sample documentation procedures are to: (1) ensure complete analysis of the requested parameters within the required turnaround times; and (2) document the sample from the point of collection to the final data report.

6.1 Sampling Handling

New polyethylene or glass bottles containing the proper preservatives will be provided by the laboratory for sample collection. In addition to the chemical preservatives, samples will be stored on ice at 4°C in a waterproof metal or sturdy plastic cooler, if required (see Tables 6-1 through 6-2 for summaries of containers, preservation, and holding times for water and solids, respectively).

6.2 Chain-of-Custody Procedures

A sample is considered to be in an individual's possession if:

- It is in the sampler's possession or it is in the sampler's view after being in his or her possession.
- It was in the sampler's possession and then locked or sealed to prevent tampering.
- It is in a secure area.

Five kinds of documentation will be used in tracking and shipping the analytical samples:

- Field log book
- Sample labels
- Chain-of-Custody (COC) records
- Custody seals
- Commercial carrier airbills

At a minimum, the label for each sample bottle will contain the following information:

- Site name
- Sample number
- Date and time of collection
- Sample type (grab or composite)
- Matrix
- Sampler's initials

TABLE 6-1

SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR AQUEOUS SAMPLES

Parameter	Container	Preservation	Holding Time
TCL Volatiles	Two 40-ml vials with teflon septum caps	Cool, 4°C HCl pH <2	14 days (7 days if unpreserved)
TCL Semivolatiles	1-liter amber glass bottle with teflon caps	Cool, 4°C	7 days to extraction; 40 days from extraction to analysis
TCL Pesticides/PCBs	1-liter amber glass bottle with teflon caps	Cool, 4°C	7 days to extraction; 40 days after extraction for analysis
TAL Metals	1-500 ml polyethylene bottle	HNO_3 pH<2	6 months; Mercury 28 days
Fluoride	1-500 ml polyethylene	--	28 days
Alkalinity	1-250 ml polyethylene	Cool, 4°C	14 days
Kjeldahl and Organic Nitrogen	1-liter polyethylene	Cool, 4°C H_2SO_4 <2	28 days

TCL - Target Contaminant List
TAL - Target Analyte List

TABLE 6-2

SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR SOLID SAMPLES

Parameter	Container	Preservation	Holding Time
TCL Volatiles	One 4-ounce wide-mouth glass jars	Cool, 4°C	10 days
TCL Semivolatiles	One 8-ounce wide-mouth glass jar	Cool, 4°C	7 days to extraction; 40 days from extraction to analysis
TCL Pesticides/PCBs	One 8-ounce wide-mouth glass jar	Cool, 4°C	7 days to extraction; 40 days after extraction for analysis
TAL Metals	One 8-ounce wide-mouth glass jar	Cool, 4°C	6 months; Mercury, 28 days
TCLP Metals	Two 8-ounce wide-mouth glass jar	Cool, 4°C	14 days
Corrosivity	One 4-ounce wide-mouth glass jar	Cool, 4°C	10 days
Ignitability	One 4-ounce wide-mouth glass jar	Cool, 4°C	14 days
Reactivity	One 4-ounce wide-mouth glass jar	Cool, 4°C	10 days
TOC	One 4-ounce wide-mouth glass jar	Cool, 4°C	N/A

TCL - Target Contaminant List
TAL - Target Analyte List
TCLP - Toxicity Characteristic Leaching Procedure
TOC - Total Organic Carbon

The sample information, as well as the analysis to be performed on the sample, will be entered in the field log book for each sampling point. Additionally, the following items will be entered:

- Dates and times of entry
- Names of field personnel on site
- Names of visitors on site
- Field conditions
- Description of activities
- Sampling remarks and observations
- QA/QC samples collected
- List of photographs taken
- Sketch of site conditions

Custody of the samples will be maintained by field personnel from the time of sampling until the time they are forwarded to the analytical laboratory.

The sample custody is documented using Chain-of-Custody (COC) records. Field personnel will complete a COC record, in waterproof ink, to accompany each cooler forwarded from the site to the laboratory. Chemical reagents used to preserve the samples will be recorded on the COC record. Any errors on the COC records will not be erased; instead, a line will be drawn through the error and initialed by the person completing the form. The original copy will be placed in a sealable plastic bag and put inside the appropriate cooler, secured to the cooler's lid.

If the sample cooler is to be shipped by commercial air carrier, the cooler must be secured with custody seals so that the seals would be broken if the cooler was opened. 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.

If the sample shipment is hand delivered to the laboratory by field personnel or retrieved by laboratory personnel at the site, then the custody seals are not necessary. The laboratory sample custodian, or his/her designee accepting the sample shipment, whether it is from the air carrier or the field personnel, signs and dates the COC record upon sample receipt. The original COC record will be returned along with the final data report. The laboratory will be responsible for maintaining internal log books and records that provide a custody record during sample preparation and analysis.

Laboratory Chain-of-Custody Procedures

Upon sample receipt the steps below will be performed.

- Samples will be received and unpacked in the laboratory where the staff checks for bottle integrity (loose caps, broken bottles, etc.).

- Samples will be verified with incoming paperwork (packing slip, etc.) by type of bottle and stabilizer. The paperwork must be either signed or initialed.

- Information concerning the sample (from the sampling record, Chain-of-Custody, and observation) will be recorded along with parameters to be analyzed, date of sampling, and date the sample is received in the laboratory.

- Samples will be placed in an appropriate secured storage area until analysis.

- When analysis is complete, samples will be stored for a 30-day period unless otherwise specified.

If collected samples arrive without Chain-of-Custody or incorrect Chain-of-Custody records, the following steps will be taken:

- The laboratory will prepare a nonconformance form stating the problem.
- The site supervisor and Project Manager will be notified.
- If the missing information cannot be provided by the field staff, the samples affected will not be analyzed.

Primary considerations for sample storage are:

- Secured storage.
- Maintain prescribed temperature, if required, which is typically four degrees Celsius.
- Extract and/or analyze samples within the prescribed holding time for the parameters of interest.

6.3 Document Custody Procedures

Project records are necessary to support the validity of the work and to furnish documentary evidence of quality. The evidentiary value of data is dependent upon the proper maintenance and retrieval of quality assurance records. Therefore, procedures will be established to assure that all documents attesting to the validity of work can be accounted for when the work is completed.

Records must be legible, filled out completely, and adequately identified as to the item or activity involved. Records will be considered valid only if initialed, signed, or otherwise authenticated and dated by authorized personnel. These records may either be originals or reproduced copies. Records submitted to the files, with the exception of correspondence, will be bound, placed in folders or binders, or otherwise secured for filing.

Following receipt of information from external sources, completion of analyses, and issuance of reports or other transmittals, associated records will be submitted to the proper file. In addition, transmitted records must be adequately protected from damage and loss during transfer (e.g, hand carrying or making copies prior to shipment).

The following documents will be transferred to the proper files during the course of the project: calculations and checkprints; reports and other data transmittals; copies of proposals, purchase orders for project services, and contracts; correspondence including incoming and outgoing letters, memoranda, and telephone records; and reference material.

All individuals on the project staff will be responsible for reporting obsolete or superseded project-related information to the Project Manager. In turn, the Project Manager will notify the project and laboratory staffs of the resulting status change in project documents, such as drawings and project procedures.

In general, outdated drawings and other documents will be marked "void." However, the Project Manager may request the copies be destroyed. One copy of void documents is maintained in the project files with the reasons, and date of voiding clearly indicated.

Documents will be marked "preliminary" to denote calculations and other material which have not been formally checked, or based on information which has not been checked, or do not contribute to final project information.

7.0 CALIBRATION PROCEDURES AND FREQUENCY

The following section describes calibration procedures and frequency.

7.1 Field Instruments

Two field instruments will be used for health and safety monitoring: the O_2/LEL meter, and the HNu System portable photoionizer. These instruments will be calibrated on site daily according to the manufacturer's instructions in addition to the factory calibration it will receive prior to the start of site sampling. The calibration standards will be recorded in the field log book.

A pH meter and a conductivity meter will be used to analyze groundwater and surface water samples. Procedures from "Test Methods for Evaluating Solid Waste," USEPA, SW846, November 1986, 3rd Edition will be used to calibrate these meters. Specific procedures for the calibration of water quality instruments are presented in the FSAP.

7.2 Laboratory Instruments

The laboratory's procedures for calibration and related quality control measures will be conducted according to the protocols presented in the following documents:

- "Statement of Work for Organic Analysis," USEPA, OLM01.8, August 1991
- "Statement of Work for Inorganic Analysis," USEPA, ILM03.0, March 1990
- "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," USEPA, July 1982
- "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983
- "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136
- "Test Methods for Evaluating Solid Waste," USEPA SW848, November 1986, 3rd Edition
- "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886

Formal calibration procedures will be established to ensure that instrumentation and equipment used for sample analysis are accurately calibrated and properly functioning. These procedures will apply to all instruments and equipment quantities. All calibrations will be performed by laboratory personnel or external agencies using standard reference materials.

All calibrations will be recorded on in-house calibration forms or instrument vendor forms or in dedicated bound notebooks. The following data will be recorded for all calibrations: the date, target readings, actual readings, instrument identification number, and the analyst's initials. Other data may be recorded depending upon the calibration performed.

Only properly calibrated and operating equipment and instrumentation will be used. Equipment and instrumentation not meeting the specified calibration criteria will be segregated from active equipment whenever possible. Such equipment will be repaired and recalibrated before reuse.

All equipment will be uniquely identified, either by serial number or internal calibration number, to allow traceability between equipment and calibration records. Recognized procedures (ASTM, USEPA, or manufacturer's procedures) will be used for calibration whenever available.

7.2.1 Method Calibration

Method calibration will be performed as part of the laboratory analytical procedure (calibration curves, tuning). Calibration curves will be prepared using five standards in graduated amounts across the appropriate range of analysis. New calibration curves will be prepared whenever new reagents or standards are prepared or yearly, whichever is more frequent.

7.2.2 GC/MS System Calibration Procedure

This section outlines the requirements for the calibration of GC/MS systems for the determination of organic compounds. The following operations will be performed in support of these requirements:

- Documentation of GC/MS mass calibration and abundance pattern
- Documentation of GC/MS response factor stability
- Internal standard response and retention time monitoring

Tuning and Mass Calibration

It will be necessary to establish that a given GC/MS system meets the standard mass spectral abundance criteria prior to initiating data collection. This will be accomplished through the analysis of p-bromofluorobenzene (BFB) for volatile compounds or decafluorotri-phenylphosphine (DFTPP) for semivolatile compounds. The BFB or DFTPP criteria must be met before any blanks, standards, or samples are analyzed.

A GC/MS system used for organic compound analysis will be tuned to meet the criteria specified for BFB analysis (volatile compounds) or DFTPP (semivolatile compounds) for an injection of 50 nanograms (ng) of BFB or DFTPP. The analysis must be performed separately from standard or blank analysis. These criteria will be demonstrated every 12 hours of operation. Professional judgment must be used to determine whether background subtraction is required to eliminate column bleed or instrument background (i.e., noise). Calibration documentation will be in the form of a bar graph spectrum and a mass listing.

GC/MS System Calibration

After tuning criteria have been met and prior to sample analysis, the GC/MS system is initially calibrated at five concentrations utilizing the compounds to be analyzed to determine the linearity of response. Internal and surrogate standards will be used with each calibration standard. Standards will be analyzed under the same conditions as the samples.

- Relative Response Factor (RRF) Calculation - The USEPA specifies the internal standard to be used on a compound-by-compound basis for quantification. The relative response factor (RRF) will be calculated for each compound at each concentration level.

- Continuing Calibration - A calibration check standard containing all semivolatile or volatile compounds and surrogates will be run every 12 hours of analysis. A system performance check will also be performed. The criteria will be the same as for the initial calibration system performance check. A calibration check will also be performed. The percent difference will be determined for each Calibration Check Compound (CCC).

The percent Difference for each CCC must be less than or equal to 25.0 percent. The system performance check and calibration check criteria must be met before sample analysis can be performed. The continuing calibration will be recorded on the continuing calibration forms.

7.2.3 GC System Calibration Procedure for Pesticides/PCBs

This section outlines the requirements for the calibration of GC systems for the determination of pesticides/PCBs. The following operations are performed in support of these requirements:

Three types of analyses will be used to verify the calibration and evaluate instrument performance. The analyses of instrument blanks, Performance Evaluation mixtures (PEMs), and the mid-point concentration of the the individual standard mixtures A and B constitute the continuing calibration.

For pesticide/PCB analysis it is necessary to establish resolution criteria by performing a Resolution Check Mixture where the depth of the valley of two adjacent peaks must be greater than or equal to 60.0 percent of the height of the shorter peak.

The breakdown of DDT and Endrin in both of the PEMs must be less than 20.0 percent and the combined breakdown of DDT and Endrin must be less than 30.0 percent. All peaks in both the Performance Evaluation Mixtures must be 100 percent resolved on both columns.

The absolute retention times of each of the single component pesticides and surrogates in both of the PEMs must be within the retention time windows determined from the three point initial calibration.

The relative percent difference of the calculated amount and the true amount for each of the single component pesticides and surrogates in both of the PEMs must be less than or equivalent to 25.0 percent.

At least one chromatogram between any two adjacent peaks in the midpoint concentrations of Individual Standard Mixtures A and B in the initial calibration must be greater than or equal to 90.0 percent.

7.2.4 System Calibration Procedure for Metals Analysis

This section outlines the requirements for the calibration of atomic absorption (AA) and Inductively Coupled Plasma (ICP) systems for the determination of metals. The following will be performed in support of these requirements:

- Documentation of standard response
- Correlation coefficient monitoring

The AA system utilized for direct aspiration technique analysis will be initially calibrated with a calibration blank and five calibration standards. The standard concentrations will be determined as follows. One standard will be at a concentration near, but above, the MDL. The other concentrations will correspond to the expected range of concentrations found in the actual samples. This five-point calibration must be performed daily.

The AA system utilized for graphite furnace technique analysis will be initially calibrated with a calibration blank and three calibration standards. The standard concentrations will be determined as follows. One standard will be at a concentration at the Contract Required Detection Limit (CRDL). The other concentrations will correspond to the expected range of concentrations found in the actual samples. This three-point calibration must be performed daily.

For AA systems, the calibration standards will be prepared fresh each time an analysis is to be performed and discarded after use. The standards contain the same reagents at the same concentrations as will result in the samples following preparation.

The ICP system will be calibrated initially with a calibration blank and one calibration standard. This calibration must be performed daily. In addition, ICP systems must undergo quarterly linearity checks.

Correlation Coefficient Calculation

The data points of the blank and the five calibration standards will be utilized to calculate the slope, the intercept, and the correlation coefficient of the best fit line. An acceptable correlation coefficient must be achieved before sample analysis may begin. An acceptable correlation coefficient will be >0.995 for AA analyses and >0.995 for ICP analysis.

Calibration Verification

The initial calibration curve will be verified on each working day by the measurement of one mid-range calibration standard. The calibration verification acceptance criterion will be as follows:

- ICEP/GFAA - 90 to 110 percent of true value
- Cold Vapor AA - 80 to 120 percent of true value

When measurements exceed the control limits, the analysis will be terminated, the problem corrected, the instrument recalibrated, and the calibration reverified.

7.2.5 System Calibration Procedure for Inorganic Analyses

This section outlines the requirements that will be used for calibration of colorimetric systems for analyses of inorganic parameters. The following will be performed in support of these requirements:

- Documentation of standard response
- Correlation coefficient monitoring

The system will be initially calibrated with a blank and five calibration standards. Standard concentrations will be at a concentration near, but above, the MDL with additional concentrations corresponding to the expected range of concentrations found in actual samples. Standards contain the same reagents at the same concentrations as will be present in samples following preparation.

Correlation Coefficient Calculation

Data points of the blank and five calibration standards will be utilized to calculate slope, intercept, and correlation coefficient of a best fit line. An acceptable correlation coefficient must be achieved before sample analysis may begin. An acceptable correlation coefficient will be >0.995 for all systems.

Calibration Verification

The initial calibration curve will be verified on each working day by the measurement of two calibration standards. One standard will be at a concentration near the low end of the calibration curve and one standard will be at the high end. The acceptance criteria for recovery of verification standards will be within 15 percent of the expected recovery for cyanide analyses and 10 percent of the expected recovery for other inorganic analyses. When measurements exceed control limits, analysis will be terminated, the problem will be corrected, the instrument will be recalibrated, and calibration will be reverified.

7.2.6 Periodic Calibration

Periodic calibration must be performed on equipment required in analyses but not routinely calibrated as part of the analytical methodology. Equipment that falls within this category includes ovens, refrigerators, and balances. The calibration will be recorded either on specified forms or in bound notebooks. Discussed below are the equipment, the calibration performed, and the frequency at which the calibration must be performed.

- Balances will be calibrated weekly with class S weights.
- The pH Meter meter will be calibrated daily with pH 4 and 7 buffer solutions and checked with pH 10 buffer solution.
- The temperatures of the refrigerators will be recorded daily.
- All liquid in glass thermometers will be calibrated annually with the N.B.S. certified thermometer. Dial thermometers will be calibrated quarterly.
- The N.B.S. Certified Thermometer will be checked annually at the ice point.

The following equipment must maintain the following temperatures:

- Sample Storage and Refrigerators - within 2 degrees of 4 degrees Celsius
- Water Bath, Mercury - within 2 degrees of 95 degrees Celsius

8.0 ANALYTICAL PROCEDURES

This next section discusses analytical procedures.

8.1 Field Analysis

A O_2/LEL and HNu PI-101 meters will be used to analyze ambient air for health and safety monitoring, as well as to screen soil during the soil sampling. The O_2/LEL meter detects explosive gases that may be present (i.e., methane). The HNu PI-101 detects total organic vapor. These instruments will be operated in accordance with the manufacturer's instructions.

The pH, temperature, and specific conductivity of aqueous samples also will be measured in the field. These analyses will be obtained in accordance with "Handbook for Sampling and Sample Preservation of Water and Wastewater," September 1982, EPA/600/4-82-029.

8.2 Laboratory Analysis

The samples that will be collected during the investigation will be analyzed for constituents listed in Table 8-1. Parameters will be analyzed using USEPA methods as noted in Table 8-1. Compounds and the corresponding method performance limits also are listed in Table 8-1.

TABLE 8-1

METHOD PERFORMANCE LIMITS

Compound	Water CRQL(1) (µg/L)	Soil/Sediment CRQL(1) (µg/kg)	Method
Volatiles			CLP/SOW
Chloromethane	10	10	
Bromomethane	10	10	
Vinyl Chloride	10	10	
Chloroethane	10	10	
Methylene Chloride	10	10	
Acetone	10	10	
Carbon Disulfide	10	10	
1,1-Dichloroethene	10	10	
1,1-Dichloroethane	10	10	
1,2-Dichloroethene (total)	10	10	
Chloroform	10	10	
1,2-Dichloroethane	10	10	
2-Butanone	10	10	
1,1,1-Trichloroethane	10	10	
Carbon Tetrachloride	10	10	
Bromodichloromethane	10	10	
1,2-Dichloropropane	10	10	
cis-1,3-Dichloropropene	10	10	
Trichloroethene	10	10	
Dibromochloromethane	10	10	
1,1,2-Trichloroethane	10	10	
Benzene	10	10	
trans-1,3-Dichloropropene	10	10	
Bromoform	10	10	
4-Methyl-2-pentanone	10	10	
2-Hexanone	10	10	
Tetrachloroethene	10	10	
Toluene	10	10	
1,1,2,2-Tetrachloroethane	10	10	
Chlorobenzene	10	10	
Ethyl Benzene	10	10	
Styrene	10	10	
Xylenes (total)	10	10	

(1) Contract Required Quantitation Limit
(2) "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

METHOD PERFORMANCE LIMITS

Compound	Water CRQL[(1)] (µg/L)	Soil/Sediment CRQL[(1)] (µg/kg)	Method
Semivolatiles			CLP/SOW
Phenol	10	330	
bis(2-Chloroethyl) ether	10	330	
2-Chlorophenol	10	330	
1,3-Dichlorobenzene	10	330	
1,4-Dichlorobenzene	10	330	
Benzyl alcohol	10	330	
1,2-Dichlorobenzene	10	330	
2-Methylphenol	10	330	
bis(2-Chloroisopropyl)ether	10	330	
4-Methylphenol	10	330	
N-Nitroso-di-n-dipropylamine	10	330	
Hexachloroethane	10	330	
Nitrobenzene	10	330	
Isophorone	10	330	
2-Nitrophenol	10	330	
2,4-Dimethylphenol	10	330	
Benzoic acid	25	1600	
bis(2-Chloroethoxyl)methane	10	330	
2,4-Dichlorophenol	10	330	
1,2,4-Trichlorobenzene	10	330	
Naphthalene	10	330	
4-Chloroaniline	10	330	
Hexachlorobutadiene	10	330	
4-Chloro-3-methylphenol (para-chloro-meta-cresol)	10	330	
2-Methylnaphthalene	10	330	
Hexachlorocyclopentadiene	10	330	
2,4,6-Trichlorophenol	10	330	
2,4,5-Trichlorophenol	25	1600	
2-Chloronaphthalene	10	330	
2-Nitroaniline	25	1600	
Dimethylphthalate	10	330	
Acenaphthylene	10	330	

(1) Contract Required Quantitation Limit

(2) "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

METHOD PERFORMANCE LIMITS

Compound	Water CRQL[1] (µg/L)	Soil/Sediment CRQL[1] (µg/kg)	Method
2,6-Dinitrotoluene	10	330	CLP/SOW
3-Nitroaniline	25	1600	
Acenaphthene	10	330	
2,4-Dinitrophenol	25	1600	
4-Nitrophenol	25	1600	
Dibenzofuran	10	330	
2,4-Dinitrotoluene	10	330	
Diethylphthalate	10	330	
4-Chlorophenyl-phenyl ether	10	330	
Fluorene	10	330	
4-Nitroaniline	25	1600	
4,6-Dinitro-2-methylphenol	25	1600	
N-nitrosodiphenylamine	10	330	
4-Bromophenyl-phenylether	10	330	
Hexachlorobenzene	10	330	
Pentachlorophenol	25	1600	
Phenanthrene	10	330	
Anthracene	10	330	
Di-n-butylphthalate	10	330	
Fluoranthene	10	330	
Pyrene	10	330	
Butylbenzylphthalate	10	330	
3,3'-Dichlorobenzidine	10	660	
Benzo(a)anthracene	10	330	
Chrysene	10	330	
bis(2-Ethylhexyl)phthalate	10	330	
Di-n-octylphthalate	10	330	
Benzo(b)fluoranthene	10	330	
Benzo(k)fluoranthene	10	330	
Benzo(a)pyrene	10	330	
Indeno(1,2,3-cd)pyrene	10	330	
Dibenz(a,h)anthracene	10	330	
Benzo(g,h,i)perylene	10	330	

(1) Contract Required Quantitation Limit

(2) "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.9.

TABLE 8-1 (Continued)

METHOD PERFORMANCE LIMITS

Compound	Water CRQL(1) (µg/L)	Soil/Sediment CRQL(1) (µg/kg)	Method
<u>Pesticides/PCBs</u>			
alpha-BHC	0.05	8.0	CLP/SOW
beta-BHC	0.05	8.0	
delta-BHC	0.05	8.0	
gamma-BHC (Lindane)	0.05	8.0	
Heptachlor	0.05	8.0	
Aldrin	0.05	8.0	
Heptachlor epoxide	0.05	8.0	
Endosulfan I	0.05	8.0	
Dieldrin	0.10	16.0	
4,4'-DDE	0.10	16.0	
Endrin	0.10	16.0	
Endosulfan II	0.10	16.0	
4,4'-DDD	0.10	16.0	
Endosulfan sulfate	0.10	16.0	
4,4'-DDT	0.10	16.0	
Methoxychlor	0.5	80.0	
Endrin ketone	0.10	16.0	
alpha-Chlordane	0.5	80.0	
gamma-Chlordane	0.5	80.0	
Toxaphene	5.0	160.0	
Aroclor-1016	1.0	80.0	
Aroclor-1221	2.0	80.0	
Aroclor-1232	1.0	80.0	
Aroclor-1242	1.0	80.0	
Aroclor-1248	1.0	80.0	
Aroclor-1254	1.0	160.0	
Aroclor-1260	1.0	160.0	

(1) Contract Required Quantitation Limit,
(2) "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

METHOD PERFORMANCE LIMITS

Analyte	Method Number(1)	CRDL(2) (μg/L)	Method Description
Metals			
Aluminum	200.7	200	Inductively Coupled Plasma
Antimony	200.7 204.2	60	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Arsenic	200.7 206.2	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Barium	200.7	200	Inductively Coupled Plasma
Beryllium	200.7 210.2	5	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Cadmium	200.7 213.2	5	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Calcium	200.7 215.1	5000	Inductively Coupled Plasma Atomic Absorption, Direct Aspiration
Chromium	200.7 218.2	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Cobalt	200.7	50	Inductively Coupled Plasma
Copper	200.7	25	Inductively Coupled Plasma
Iron	200.7	100	Inductively Coupled Plasma
Lead	200.7 239.2	3	Inductively Coupled Plasma Atomic Absorption, Furnace Technique

(1) Methods taken from "Statement of Work for Inorganic Analysis," USEPA Contract Laboratory Program, ILM03.0, March 1990.

(2) Contract Required Detection Limit.

(3) Extraction method for arsenic, lead, selenium, and thallium taken from USEPA Method 3020, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

(4) Extraction method for all other metals taken from USEPA Method 3010, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

TABLE 8-1 (Continued)

METHOD PERFORMANCE LIMITS

Analyte	Method Number[1]	CRDL[2] (µg/L)	Method Description
Magnesium		5000	
	200.7		Inductively Coupled Plasma
	242.1		Atomic Absorption, Direct Aspiration
Manganese		15	
	200.7		Inductively Coupled Plasma
Mercury		0.2	
	245.1		Water by manual cold vapor technique
	245.2		Water by automated cold vapor technique
	245.5		Soil/sediment by manual cold vapor technique
Nickel		40	
	200.7		Inductively Coupled Plasma
Potassium		5000	
	200.7		Inductively Coupled Plasma
	258.1		Atomic Absorption, Direct Aspiration
Selenium		5	
	200.7		Inductively Coupled Plasma
	270.2		Atomic Absorption, Furnace Technique
Silver		10	
	200.7		Inductively Coupled Plasma
	272.2		Atomic Absorption, Furnace Technique
Sodium		5000	
	200.7		Inductively Coupled Plasma
	273.1		Atomic Absorption, Direct Aspiration
Thallium		10	
	200.7		Inductively Coupled Plasma
	279.2		Atomic Absorption, Furnace Technique
Vanadium		50	
	200.7		Inductively Coupled Plasma
Zinc		20	
	200.7		Inductively Coupled Plasma

(1) Methods taken from "Statement of Work for Inorganic Analysis," USEPA Contract Laboratory Program, ILM03.0, March 1990.

(2) Contract Required Detection Limit.

(3) Extraction method for arsenic, lead, selenium, and thallium taken from USEPA Method 3020, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

(4) Extraction method for all other metals taken from USEPA Method 3010, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

TABLE 8-1 (Continued)
METHOD PERFORMANCE LIMITS
MCB CAMP LEJEUNE, NORTH CAROLINA

Parameter	Aqueous PQL(1) (µg/l)	Solid PQL(1) (µg/kg)	Method
TCLP Volatiles			EPA Method 3550/ EPA Method 8240
Benzene	5	10	
Carbon Tetrachloride	5	5	
Chloroform	5	5	
1,2-Dichloroethane	5	5	
1,1-Dichloroethylene	5	5	
Methyl ethyl ketone	N/A	N/A	
Tetrachloroethylene	5	5	
Trichloroethylene	5	5	
Vinyl Chloride	10	10	
TCLP Semivolatiles			EPA Method 3550/ EPA Method 8270
o-Cresol	10	660	
m-Cresol	10	660	
p-Cresol	10	660	
Cresol	10	660	
1,4-Dichlorobenzene	10	660	
2,4-Dinitrotoluene	10	660	
Hexachlorobenzene	10	660	
Hexachlorobutadiene	10	660	
Hexachloroethane	10	660	
Nitrobenzene	10	660	
Pentachlorophenol	50	3300	
Pyridine	50	660	
2,4,5-Trichlorophenol	10	660	
2,4,6-Trichlorophenol	10	660	

(1) Practical Quantitation Limit, taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.

Note: These methods will be used to analyze the Toxicity Characteristic Leaching Procedure (TCLP) extract. The extract will be prepared using Method 1311, described in "Hazardous Waste Management Systems; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52FR 26886.

TABLE 8-1 (Continued)
METHOD PERFORMANCE LIMITS
MCB CAMP LEJEUNE, NORTH CAROLINA

Parameter	Aqueous PQL(1) (µg/l)	Solid PQL(1) (µg/kg)	Method
TCLP Pesticides			EPA Method 3550/
Chlordane	0.14	9.4	EPA Method 8080
Endrin	0.06	4.0	
Heptachlor (and its hydroxide)	0.03	2.0	
Lindane	0.04	2.7	
Methyoxychlor	1.8	120	
Toxaphene	2.4	160	
TCLP Herbicides			
2,4-D	12	240	EPA Method 8150
2,4,5-TP Silvex	1.7	34	

Analyte	Water PQL(1) (µg/L)	Soil PQL(1) (mg/kg)	Method	Method Description
TCLP Metals				
Arsenic	10	30	6010 7060	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Barium	20	1	6010	Inductively Coupled Plasma
Cadmium	1	2	6010 7131	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Chromium	20	4	6010 7191	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Lead	10	2	6010 7421	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Mercury	2	0.002	7470	Water by manual cold vapor technique Water by automated cold vapor technique
Selenium	20	40	6010 7740	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Silver	2	4	6010 7760	Inductively Coupled Plasma Atomic Absorption, Furnace Technique

(1) Practical Quantitation Limit, taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.

Note: These methods will be used to analyze the Toxicity Characteristic Leading Procedure (TCLP) extract. The extract will be prepared using Method 1311, described in "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52FR 26886.

TABLE 8-1 (Continued)
METHOD PERFORMANCE LIMITS
MCB CAMP LEJEUNE, NORTH CAROLINA

Parameter	Aqueous Performance Limit	Solid Performance Limit	Method
RCRA			
pH/Corrosivity	N/A(1)	N/A(1)	SW-846 9010
Ignitability	N/A(1)	N/A(1)	SW-846 1010
Reactive Cyanide	10 mg/l(1)	10 mg/l(1)	SW-846 9012
Reactive Sulfide	50 mg/l(1)	50 mg/kg(1)	SW-846 9030
Engineering Parameters			
Total Organic Carbon (TOC)	N/A(2)	N/A(2)	EPA 415.1
Particle Size Distribution	N/A	N/A	ASTM D 422-63

(1) Practical Quantitation Limit, taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.

(2) Method Detection Limit taken from "Methods for Chemical Analysis of Water and Wastes," USEPA, 1979, Revised March 1983.

N/A - Not Applicable

9.0 DATA REDUCTION, VALIDATION AND REPORTING

The following section presents data reduction, validation, and reporting procedures.

9.1 Field Data Procedures

Data validation practices as described by "Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses," USEPA, June 1988, and "Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses - Draft," USEPA, June 1991 will be followed to insure that raw data are not altered and that an audit trail is developed for those data which require reduction. The documentation of sample collection will include the use of bound field log books in which all information on sample collection will be entered in indelible ink. Appropriate information will be entered to reconstruct the sampling event, including site name (top of each page), sample identification, brief description of sample, date and time of collection, sampling methodology, field measurements and observations, and sampler's initials (bottom of each page, and dated).

A rigorous data control program will insure that all documents for the investigations are accounted for when they are completed. Accountable documents include items such as log books, field data records, correspondence, chain-of-custody records, analytical reports, data packages, photographs, computer disks, and reports. The project manager will be responsible for maintaining a project file in which all accountable documents will be inventoried. The project records will be retained for a period of three years after project close-out; then the files will be forwarded to the Navy.

All the field data, such as those generated during field measurements, observations and field instrument calibrations, will be entered directly into a bound field notebook. Each project team member will be responsible for proofing all data transfers made, and the Project Manager or his designee will proof at least ten percent of all data transfers.

9.2 Laboratory Data Procedures

The following procedures summarize the practices routinely used by laboratory staff for data reduction, validation, and reporting. Numerical analyses, including manual calculations, will be documented and subjected to quality control review. Records of numerical analyses must be legible and complete enough to permit reconstruction of the work by a qualified individual other than the originator.

9.2.1 Laboratory Data Validation

Data validation begins with data reduction and continues through to the reporting of data.

Data processing will be checked by an individual other than the analyst who performed the data processing. The checker will review the data for the following:

- Utilization of the proper equations
- Correctness of numerical input
- Correctness of computations
- Correct interpretation of raw data (chromatographs, strip charts, etc.)

The checking process will be sufficient thorough enough to verify the results.

All entries made in benchbooks, data sheets, computation sheets, input sheets, etc. will be made in ink. No entry will be rendered unreadable.

9.2.2 Analytical Reports

The items listed below will be required of analytical reports.

- Data will be presented in a tabular format.
- Analytical reports will be approved by appropriate laboratory personnel.
- The following information will be included on the report: client name and address, report date, sample date, analysis dates, number of samples, purchase order number, project number, and project type. All pages must be numbered.
- The sample numbers and corresponding laboratory numbers will be identified.
- The parameters analyzed, report units, and values will be identified.
- Method, trip, and field blank results will be reported.
- Matrix spike, matrix spike duplicate, and replicate recoveries will be reported.
- Calibration summaries will be reported.
- Surrogate recoveries will be reported.
- Holding times and sample analysis dates will be reported.
- The detection limit of the procedure will be identified.
- Consistent significant figures will be used.
- Referenced footnotes will be used when applicable.
- A letter of transmittal will accompany the report if any anomalies are associated with the data.

9.3 Independent (Third Party) Data Validation

Review of all pertinent analytical data will be performed by Baker personnel and an independent third party data validater.

A preliminary review will be performed by the Project Manager or designee to verify that all necessary paperwork (e.g., chain-of-custodies, traffic reports, analytical reports, and laboratory personnel signatures) and deliverables are present. A detailed and independent data validation will be performed by a data validation subcontractor to verify the qualitative and quantitative reliability of the data presented and adherence to stated analytical protocols. This review will include a detailed review and interpretation of all data generated by the laboratory for Level III or IV deliverables. The primary tools which will be used by experienced data validation personnel will be analytical method operating practices, statements of work (for CLP), guidance documents, established criteria, and professional judgment.

During the data review, a data support documentation package will be prepared which will provide the back-up information that will accompany all qualifying statements present in the quality assurance review.

10.0 INTERNAL QUALITY CONTROL CHECKS

The following section describes internal quality control checks.

10.1 Field Quality Control Checks

Four types of field quality assurance/quality control samples will be submitted to the laboratory: trip blanks, equipment rinsates, field blanks, and field duplicates. The results from the field quality control samples will be used by the data validator to determine the overall quality of the data. A breakdown by type of sample with which the QA/QC samples will be submitted to the laboratories is given in Table 10-1. A summary of the number of environmental and QA/QC samples to be submitted for analysis will be given in the FSAP.

Field Blanks

Field blanks consist of the source water used in decontamination, steam cleaning, and drilling. At a minimum, one field blank from each vent and each source of water must be collected and analyzed for the same parameters as the related samples. Organic-free deionized water is taken to the field in sealed containers and poured into the appropriate sample containers at predesignated locations. This will be done to determine if any contaminants present in the area may have an affect on the sample integrity.

Trip Blank

Analysis of trip blanks will be performed to monitor possible contamination during shipment and collection of samples. Trip blanks are initiated in the laboratory prior to the shipping of sample packs. A corresponding trip blank will be prepared for each set of samples to be analyzed for volatile organic compounds.

Trip blank samples will be prepared by adding four drops of concentrated hydrochloric acid and then filling the container with organic-free deionized water (ASTM Type II). The trip blanks accompany the samples through shipment to the sample site, sample collection, shipment to the laboratory, and storage of the samples.

If the analyses indicate contamination of the trip blank, the sample sources may be resampled. If the extent and nature of the contamination does not warrant such actions, the data will be accepted as valid.

Field Duplicates

Duplicates for soil samples are collected, homogenized, and split. All samples except VOCs are homogenized, and split. Volatiles are not mixed, but select segments of the soil are taken from the length of the core and placed in 4-ounce glass jars. Cores may be sealed and shipped to the laboratory for subsampling if the project deems this appropriate. The duplicate for water samples should be collected simultaneously. Field duplicates should be collected at a frequency of 10% per sample matrix for Levels III and IV. All the duplicates should be sent to the primary laboratory responsible for analysis. The same samples used for field duplicates shall be split by the laboratory and used by the laboratory as the laboratory duplicate or matrix spike. This means that for the duplicate sample, there will be analyses of the normal sample, the field duplicate, and the laboratory matrix spike/duplicate.

TABLE 10-1

QA/QC SAMPLE FREQUENCY

Type of Sample	Metal	Organic
Trip Blank (for volatiles only)	NA[(1)]	One per cooler or one per shipping day
Equipment Rinsate[(2)]	One per day	One per day
Field Blank	One per source per event[(3)]	
Field Duplicate[(4)]	10%	10%

(1) Not Applicable

(2) Samples are collected daily; however, only samples from every other day are analyzed. Other samples are held and analyzed only if evidence of contamination exists.

(3) Source water includes water used in decontamination, steam cleaning, and drilling.

(4) The duplicate must be taken from the sample which will become the laboratory matrix spike/matrix spike duplicate for organics or for the sample used as a duplicate in inorganic analysis.

Equipment Rinsates

Equipment rinsates are the final organic-free deionized water rinse from equipment cleaning collected daily during a sampling event to determine if deioning procedures were adequate. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsate, the remaining samples must be analyzed. The results of the blanks will be used to flag or assess levels of analytes in the samples. This comparison is made during validation. The rinsates are analyzed for the same parameters as the related samples.

10.2 Laboratory Quality Control Checks

This section provides descriptions of the laboratory quality control checks.

Method Blank

Analysis of method blanks will be performed to verify that method interferences caused by contamination in reagents, glassware, solvents, etc. are minimized and known.

Method blanks will be initiated by the analyst prior to the preparation and/or analysis of the sample set. A method blank consists of a volume of organic-free deionized water equal to the sample volume which is carried through the entire analytical procedure. For solid samples to be analyzed by GC/MS, the method blank consists of a purified solid matrix approximately equal to the sample weight. A method blank will be analyzed with each set of samples or at the very least, daily. If the analytical data of the method blank indicates excessive contamination, the source of contaminant will be determined. The samples may be re-analyzed or the data may be processed "as is" depending upon the nature and extent of the contamination.

Replicate Sample Analysis

Replicate sample analysis will be performed to demonstrate the precision of an analysis. An interlaboratory replicate sample is initiated by the analyst prior to sample preparation and carried through the entire analytical procedure. The frequency of interlaboratory replicate analysis for each analyte is summarized in Table 10-2.

Spike Analysis

Spike analysis will be performed to demonstrate the accuracy of an analysis. The analyst initiates the spike prior to sample preparation and analysis by adding a known amount of analyte(s) to a sample. The spike sample is carried through the entire analytical procedure. The frequency of spike analysis for each analyte(s) is summarized in Table 10-2.

Surrogate Standards

Surrogate standard analysis will be performed to monitor the preparation and analyses of samples. All samples and blanks analyzed by GC/MS and GC are fortified with a surrogate spiking solution prior to extraction or purging.

Internal Standards

Internal standard analyses will be performed to monitor system stability. Prior to injection or purging, internal standards are added to all blanks and samples analyzed by GC/MS (refer to Section 5.1.1.).

TABLE 10-2

QC ANALYSIS FREQUENCY

Parameter	Replicate	Spike
Organic		
All analyses by GC/MS	5%	5%
All analyses by GC	5%	5%
Metals		
Liquids by flame AA or ICP	5%	5%
Solids by flame AA or ICP	5%	10%
All analyses by furnace AA	5%	10%

Matrix Spikes and Matrix Spike Duplicates

A matrix spike is an aliquot of a matrix (water or soil) fortified (spiked) with known quantities of specific compounds and subjected to the entire analytical procedure in order to indicate the appropriateness of the method for the matrix by measuring recovery. A matrix spike duplicate is a second aliquot of the same matrix as the matrix spike that is spiked in order to determine the precision of the method. A matrix spike and matrix spike duplicate will be performed at a frequency of 1 per 20 samples for organics.

10.3 Laboratory Control Limits

Control limits will be established for QC checks (spikes, duplicates, blanks, etc.). CLP control limits for surrogate standards spikes, and duplicates associated with GC/MS analyses and pesticides/PCB analyses. Control limits for spikes, duplicates, and reference samples will be determined internally through statistical analysis.

Whenever an out-of-control situation occurs, the cause is determined. Any needed corrective actions must be taken.

Method Blanks

For metals analyses, the criteria below are used for method blank analysis.

- If the concentration of the method blank is less than or equal to the detection level, no correction of sample results is performed.

- If the concentration of the blank is above the detection level for any group of samples associated with a particular blank, the concentration of the sample with the least concentrated analyte must be ten times the blank concentration. Otherwise, all samples associated with the blank and less than ten times the blank concentration must be redigested (reprepared) and reanalyzed, if possible. If the affected samples cannot be reprepared and reanalyzed within method holding times, the flagged sample result and the blank result are both to be reported. The sample value is not corrected for the blank value.

For GC/MS, GC analyses, the criteria below are used for method blank analysis:

- A method blank for volatiles analysis must contain no greater than five times the detection limit of common laboratory solvents (common laboratory solvents are: methylene chloride, acetone, toluene, 2-butanone, and chloroform).

- A method blank for semivolatiles analysis must contain no greater than five times the detection limit of common phthalate esters.

- For all other compounds not listed above, the method blank must contain less than the detection limit of any single compound. If a method blank exceeds the criteria, the analytical system is considered to be out of control. The source of the contamination is investigated and appropriate corrective measures are taken and documented before sample analysis proceeds. All samples processed with a method blank that is out of control (i.e., contaminated), are reextracted/repurged and reanalyzed, when possible. If the affected samples cannot be reextracted/repurged and reanalyzed within method holding times, the flagged sample result and the blank result are both to be reported. The sample value is not corrected for the blank value.

- No positive result for pesticides/PCBs should be reported unless the concentration of the compound exceeds five times the amount in the blank.

- A method blank for pesticides/PCBs must contain no greater than five times the detection limit for any pesticides/PCBs.

Surrogate Standards

For method blank surrogate standard analysis, corrective action will be taken if any one of the conditions below exist.

- Recovery of any one surrogate compound in the volatile fraction is outside the required surrogate standard recovery limit.

- Recovery of any one surrogate compound in the semivolatile fraction is outside surrogate standard recovery limits.

Corrective action will include steps listed below:

- A check of: the calculations for errors; the internal standard and surrogate spiking solutions for degradation, contamination, etc.; and instrument performance.

- Recalculation or reinjection/repurging of the blank or extract if the above corrective actions fail to solve the problem.

- Reextraction and reanalysis of the blank. For sample surrogate standard analysis, corrective action will be taken if any one of the following conditions exist:

  - Recovery of any one surrogate compounds in the volatile fraction is outside the surrogate spike recovery limits;

  - Recovery of any one surrogate compound in either semivolatile fraction is below ten percent; or

  - Recoveries of two or more surrogate compounds in either semivolatile fraction are outside surrogate spike recovery limits.

Corrective action will include the steps listed below.

- A check of: the calculations for errors; of the internal standard and surrogate spiking solutions for degradation, contamination, etc.; and of instrument performance.

- Recalculating or reanalysis the sample or extract if the above corrective action fails to solve the problem.

- Reextraction and reanalysis of the sample if none of the above are a problem.

11.0 PERFORMANCE AND SYSTEM AUDITS

A field audit will be conducted during the field investigation to verify that sampling is being performed according to the plan. A report will be submitted within 30 calendar days of completion of the audit. Serious deficiencies will be reported within 24 hours of the time of discovery of the deficiency, including actions taken or to be taken to correct such deficiencies.

The following table (Table 11-1) is used for audits. At the appropriate time, the Project Manager or Program QA/QC designee will conduct field audits. Additionally, personnel adhere to Baker's Standard Operating Procedures which cover procedures, reporting and quality.

FIELD SITE AUDIT INSPECTION FORM

LEGEND
X = YES
O = NO
NA = NOT APPLICABLE

1. SITE NAME ______________________ CTO# ______________________
2. LOCATION ______________________ INSPECTOR ______________________
3. AUDIT NO. ______________________ DATE ______________________
EIC ______________________

CERTIFICATION OF PERSONNEL

1. ALL BEI, RFW AND FW PERSONNEL ON SITE ARE CURRENTLY ACTIVE ON CERTIFICATION LIST? ____
2. SITE SAFETY OFFICER AND SITE SUPERVISOR ARE QUALIFIED? ____

COMMENTS: ______________________

MEDICAL AND FIRST AID

1. FIRST AID KITS ACCESSIBLE AND IDENTIFIED? ____
2. EMERGENCY EYE/SAFETY WASHES AVAILABLE? ____
3. AT LEAST TWO FIRST AID AND CPR TRAINED PERSONS ON SITE AT ALL TIMES WHEN WORKING? ____

COMMENTS: ______________________

SITE SAFETY/EMERGENCY PLANS

1. SAFETY PLAN POSTED ON SITE AND AVAILABLE FOR REVIEW BY EACH PERSON? ____
2. INITIAL SITE SAFETY MEETING HELD AND DOCUMENTED BEFORE WORK BEGINS? ____
3. HAZARDOUS MATERIALS INFORMATION AVAILABLE FOR ALL SITE HAZARDS? ____
4. EMERGENCY TELEPHONE NUMBERS POSTED? ____
5. EMERGENCY ROUTES DESIGNATED? ____
6. EMERGENCY CONTINGENCY PLAN AND SIGNAL REVIEWED WITH ALL PERSONS. ____
7. DIRECTIONS TO THE HOSPITAL CLEARLY DEFINED AND POSTED? ____
8. DIRECTIONS AND MILEAGE TO HOSPITAL VERIFIED AND DOCUMENTED? ____

COMMENTS: ______________________

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

TRAINING

1. NEW PERSONNEL TO SITE RECEIVE:
   - COPY OF SITE SAFETY PLAN? ______
   - SITE ORIENTATION? ______
   - DISCUSSION ON LEVEL OF PROTECTION? ______
   - DISCUSSION ON DECON PROCEDURES? ______
   - DISCUSSION ON WORK ZONES? ______
   - BRIEFING ON SITE SPECIFIC HAZARDS? ______
2. ALL EMPLOYEES INSTRUCTED IN HAZARDOUS MATERIALS HANDLING PRACTICES? ______

COMMENTS: ______

PERSONAL PROTECTION/EQUIPMENT

1. ALL EQUIPMENT MEETS ANSI/OSHA/EPA CRITERIA? ______
2. LEVELS OF PROTECTION ESTABLISHED? ______
3. SITE CONTROL ZONES CLEARLY DESIGNATED? ______
4. PERSONNEL FAMILIAR WITH PPE PROTOCOLS? ______
5. EMPLOYEES FIT TESTED FOR RESPIRATORS? ______
6. BREATHING AIR GRADE "D" CERTIFIED? ______
7. SUFFICIENT QUANTITIES OF EQUIPMENT? ______
8. INSTRUMENTS PROPERLY CALIBRATED? ______
9. CALIBRATION LOGS UP TO DATE? ______
10. DEFECTIVE EQUIPMENT TAGGED OUT? ______

COMMENTS: ______

DECONTAMINATION

1. DECON SYSTEM SET UP ON SITE? ______
2. DECON SYSTEM UTILIZED? ______
3. CONTAMINATION ZONE CLEARLY DELINEATED? ______
4. APPROPRIATE WASTE RECEPTICALS AVAILABLE FOR ALL WASTES? ______
5. RECEPTICALS PROPERLY CLOSED AT THE END OF EACH DAY? ______
6. ALL DECON LIQUIDS PROPERLY CONTAINED AND DISPOSED OF? ______
7. ALL WASTE DISPOSED OF ACCORDING TO APPROVED PLAN? ______
8. ALL REUSABLE PPE DECONNED AND DISINFECTED DAILY? ______

COMMENTS: ______

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

FIRE PREVENTION/PROTECTION

1. HOT WORK PERMITS REQUIRED? ____
2. SMOKING RESTRICTED TO DESIGNATED AREA? ____
3. FLAMMABLE/COMBUSTIBLE LIQUID DISPENSING TRANSFER SYSTEMS GROUNDED AND BONDED? ____
4. PROPER FLAMMABLE MATERIALS STORAGE? ____
5. LOCATION AND USE OF FIRE EXTINGUISHERS KNOWN BY ALL PERSONNEL? ____
6. FIRE EXTINGUISHERS APPROPRIATE FOR FIRE HAZARD POTENTIAL? ____
7. COMBUSTIBLE MATERIALS SEGREGATED FROM IGNITION SOURCES? ____

COMMENTS: ______________________________

WALKING AND WORKING SURFACES

1. ACCESS WAYS, STAIRS AND RAMPS FREE OF DEBRIS, MUD, SNOW AND/OR ICE? ____
2. STAIRWAYS, FLOOR AND WALL OPENINGS GUARDED? ____
3. ELEVATED WORK AREAS GUARDRAILED OR SAFETY CHAINED? ____
4. FLOTATION DEVICES WORN WHEN WORKING ON OR OVER DANGEROUS WATERS? ____
5. TOE BOARDS ON OVERHEAD WORK SURFACES? ____
6. MOBILE OFFICES HAVE FIXED STAIRS AND HANDRAILS? ____
7. WORK AREAS KEPT FREE OF DEBRIS AND EQUIPMENT NOT BEING USED? ____
8. LADDERS APPROPRIATE FOR TYPE OF WORK (I.E., DO NOT EXCEED MAXIMUM LENGTH) BEING PERFORMED? ____
9. SAFETY FEET ON STRAIGHT AND EXTENSION LADDERS? ____
10. METAL LADDERS PROHIBITED IN ELECTRICAL SERVICE? ____

COMMENTS: ______________________________

EXCAVATIONS AND CONFINED SPACES

1. UTILITY CHECK PERFORMED AND DOCUMENTED PRIOR TO DRILLING OR EXCAVATION? ____
2. EXCAVATIONS SLOPED OR SHORED TO PREVENT CAVE-INS? ____
3. SHORING APPROVED BY AN ENGINEER? ____
4. GUARDRAILS OR FENCES PLACED AROUND EXCAVATIONS NEAR WALKWAYS OR ROADS? ____
5. EXCAVATION LOCATIONS VISIBLE AT NIGHT? ____
6. LADDERS AVAILABLE IN TRENCHES MORE THAN

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

FOUR FEET DEEP AND AT A MINIMUM, TWENTY-FIVE FOOT INTERVALS ALONG A FENCE? _____

7. EXCAVATED MATERIAL IS AT LEAST TWENTY-FOUR INCHES FROM THE EDGE OF ALL TRENCHES? _____
8. CONFINED SPACE ENTRY PERMIT PROCEDURE IN PLACE AND COMMUNICATED TO ALL PERSONNEL? _____
9. EMPLOYEE TRAINING INCLUDES CONFINED SPACE ENTRY HAZARDS? _____
10. CONFINED SPACES TESTED AND DOCUMENTED FOR: _____
    - OXYGEN _____
    - CARBON MONOXIDE _____
    - COMBUSTIBLE GASES _____
    - TOXICITY (HCN- OR H_2S) _____
11. CONTINUOUS MONITORING FOR OXYGEN, CARBON MONOXIDE AND COMBUSTIBLE GASES? _____
12. PERSONNEL ENTERING CONFINED SPACE ARE AT A MINIMUM IN LEVEL "B" OR CONSTANT VENTILATION AND MONITORING IS PROVIDED? _____
13. SAFETY WATCH ASSISTING CONFINED SPACE ENTRY PERSONNEL? _____
14. SAFETY WATCH PROTECTED SAME AS FIELD TEAM? _____
15. COMMUNICATION AVAILABLE FROM INSIDE TO OUTSIDE PERSONNEL? _____
16. WORK IS NOT CONDUCTED IN ANY TANK, VESSEL OR OTHER CONTAINER UNTIL THERE IS NO POSSIBILITY THAT LINES OR ELECTRICAL EQUIPMENT CAN BE ACTIVATED? _____

COMMENTS: ____

MINOR VEHICLES/HEAVY EQUIPMENT

1. INSPECTED BEFORE EACH USE? _____
2. OPERATORS LICENSE FOR EQUIPMENT USED? _____
3. UNSAFE EQUIPMENT TAGGED OUT AND REPORTED? _____
4. EQUIPMENT SHUTDOWN FOR FUELING? _____
5. EQUIPPED WITH BACKUP ALARMS OR SPOTTER USED IF 360° VISIBILITY IS RESTRICTED? _____
6. LOADS ARE SECURE BEFORE TRANSPORT? _____

COMMENTS: ____

SLINGS AND CHAINS

1. SLINGS, CHAINS AND RIGGING INSPECTED PER OSHA? _____
2. DAMAGED SLINGS, CHAINS AND RIGGING TAGGED OUT AND REPORTED? _____
3. EMPLOYEES ARE INSTRUCTED AND KEEP CLEAR OF SUSPENDED LOADS? _____

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

COMMENTS: ____

ELECTRICAL
1. WARNING SIGNS INDICATE HIGH VOLTAGE (250 V OR GREATER) PRESENT AND LOCATION? ____
2. ELECTRICAL EQUIPMENT AND WIRING PROPERLY GUARDED? ____
3. ELECTRICAL LINES, EXTENSION CORDS AND CABLES GUARDED AND PROPERLY MAINTAINED? ____
4. EXTENSION CORDS ARE KEPT AWAY FROM DAMP AREAS? ____
5. DAMAGED EQUIPMENT TAGGED OUT? ____
6. UNDERGROUND ELECTRICAL LINES LOCATED AND INDICATED? ____
7. OVERHEAD ELECTRICAL LINES DE-ENERGIZED OR ELEVATED WORK PLATFORMS, WORK AREAS, BOOMS OR LADDERS ERECTED SO NO CONTACT CAN OCCUR WITH ELECTRICAL LINES? ____
8. A POSITIVE ELECTRICAL LOCK-OUT SYSTEM IS USED WHENEVER WORK IS PERFORMED ON OR IN ELECTRIC EQUIPMENT OR ELECTRICALLY ACTIVATED EQUIPMENT? ____

COMMENTS: ____

HAND AND POWER TOOLS
1. GUARDS AND SAFETY DEVICES IN PLACE AND USED? ____
2. TOOLS ARE INSPECTED BEFORE EACH USE? ____
3. EYE PROTECTION AREAS IDENTIFIED AND PROTECTION WORN? ____
4. NON-SPARKING TOOLS AVAILABLE? ____
5. EQUIPMENT TAGGED OUT IF DEFECTIVE? ____

COMMENTS: ____

COMPRESSED GAS CYLINDERS/PRESSURIZED LINES
1. BREATHING AIR CYLINDERS CHARGED ONLY TO PRESCRIBED PRESSURE? ____
2. NO OTHER GAS SYSTEM CAN BE MISTAKEN FOR BREATHING AIR? ____
3. FITTINGS PROHIBIT CROSS CONNECTION? ____
4. CYLINDERS SEGREGATED APPROPRIATELY IN CONTROLLED, PROTECTED BUT WELL VENTILATED AREAS? ____
5. CYLINDERS STORED UPRIGHT AND SECURED? ____

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

COMMENTS: ____

MISCELLANEOUS

1. TOOLS AND OTHER EQUIPMENT (PORTABLE) ARE STORED AWAY FROM WALKWAYS, ROADS OR DRIVEWAYS WHERE THEY CANNOT FALL ON OR BE FALLEN OVER BY SITE PERSONNEL? ____
2. OVERHEAD HAZARDS ARE NOTED, COMMUNICATED TO ALL EMPLOYEES AND LABELED AS NEEDED? ____
3. HARD HAT, EYE AND HEARING PROTECTION AREAS ARE DEFINED AND/OR SIGNS IN PLACE? ____
4. HARD HATS, EYE AND HEAD PROTECTION IS USED WHERE APPROPRIATE? ____
5. COPIES OF CONTRACTS WITH CLIENT AND SUBCONTRACTORS ARE ON SITE? ____
6. BAKER'S ROLE REGARDING SITE HEALTH AND SAFETY RESPONSIBILITIES HAS BEEN ESTABLISHED IN SITE PLANS? ____
7. SITE MANAGER(S) UNDERSTANDS RESPONSIBILITIES? ____
8. SUBCONTRACTORS HAVE RECEIVED APPROVED COPIES OF THEIR SAFETY PLANS OR HAVE SIGNIFIED THEIR INTENT TO CONFORM WITH BAKER'S SAFETY PLAN? ____
9. THIS INTENT HAS BEEN SIGNED BY ALL SITE PERSONNEL AND A SUBCONTRACTOR MANAGER? ____
10. SITE MANAGERS UNDERSTAND THEIR RESPONSIBILITIES FOR SUBCONTRACTORS' CONFORMANCE WITH ALL OSHA AND OTHER HEALTH AND SAFETY REQUIREMENTS? ____

COMMENTS: ____

PROJECT LOG BOOKS

1. ALL ENTRIES IN SITE LOG MADE IN INK? ____
2. DATES AND MILITARY TIMES RECORDED FOR ALL OBSERVATIONS? ____
3. ENTRIES SIGNED AT THE END OF THE DAY OR BEFORE A NEW AUTHOR MAKES AN ENTRY? ____
4. BLANK SPACES ARE CROSSED OUT AND INITIALED? ____
5. CORRECTIONS ARE CROSSED OUT WITH A SINGLE LINE AND INITIALED? ____
6. LOG BOOK ENTRIES ARE LEGIBLE? ____
7. ENTRIES ARE OBJECTIVE AND NOT SUBJECTIVE? ____
8. ENTRIES INCLUDE DETAIL OR PROVIDE A CLEAR SEQUENCE OF EVENTS? ____
9. UNUSUAL OCCURRENCES ARE RECORDED (E.G., BREAKDOWNS, MEETINGS, TASKING)? ____

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

10. DIRECTIVES FROM MANAGEMENT ARE RECORDED? ____
11. SITE ENTRY AND EXIT TIMES ARE RECORDED? ____
12. WEATHER CONDITIONS ARE RECORDED? ____
13. REFERENCE TO INDIVIDUAL LOG BOOKS IS PROVIDED? ____

COMMENTS: ____

FIELD LOGS

1. BOREHOLE LOG COMPLETED FOR EACH WELL CONSTRUCTED? ____
2. SKETCHES OF WELL CONSTRUCTION AND WELL CONSTRUCTION LOGS COMPLETED? ____
3. INFORMATION ON WELL DEVELOPMENT RECORDED? ____
4. CHAIN OF CUSTODY FORMS COMPLETED AND PROPERLY FILED? ____
5. PROJECT LOG BOOK UP-TO-DATE? ____
6. SAMPLE IDENTIFICATION DOCUMENTS AVAILABLE AND ARE BEING UTILIZED? ____

COMMENTS: ____

SITE FILE SYSTEM (TECHNICAL)

1. CHAIN-OF-CUSTODY FORMS COMPLETED AND PROPERLY FILED? ____
2. DRUM INVENTORY FORMS COMPLETED AND UP-TO-DATE? ____
3. MANIFESTS AND DISPOSAL REPORTS COMPLETED AND FILED? ____
4. PRODUCT DATA SHEETS AVAILABLE (MSDS)? ____
5. SAMPLING LOGS COMPLETED AND UP-TO-DATE? ____
6. AIR MONITORING LOGS COMPLETED AND UP-TO-DATE? ____

COMMENTS: ____

SITE FILE SYSTEM (OPERATIONAL)

1. ALL SITE FILES ARE IN A CENTRAL LOCATION AND EASILY ACCESSIBLE? ____
2. THE SITE FILE SYSTEM IS WELL ORGANIZED? ____
3. AN INVENTORY SHEET INDICATES THE ORDER OF WHICH THE FILES ARE PLACED? ____
4. BUSINESS CARDS FILED OR POSTED (I.E., VENDORS, EPA, STATE PERSONNEL

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

WHO HAVE BEEN ON SITE)? _____
5. CHRONOLOGY OR NARRATIVE OF EVENTS COMPILED OF SITE ACTIVITIES TO DATE? _____
6. INVENTORY OF EQUIPMENT COMPILED AND AVAILABLE FOR REVIEW? _____
7. SITE ENTRY/EXIT LOGS COMPLETED AND UP-TO-DATE? _____
8. HOT ZONE ENTRY/EXIT LOGS COMPLETED AND UP-TO-DATE? _____
9. OPERATIONAL REPORTS AVAILABLE FOR REVIEW AND ARE BEING ADHERED TO? _____
10. ORGANIZATIONAL CHART AVAILABLE IDENTIFYING KEY PERSONNEL? _____

COMMENTS: ____

SITE FILE SYSTEM (FINANCIAL)
1. DELIVERY ORDERS COMPLETED AND PROPERLY FILED? _____
2. SHIPPING INVOICES ARE PROPERLY FILED (I.E., EQUIPMENT, SAMPLES, ETC.)? _____
3. ESTIMATED DISPOSAL COSTS AVAILABLE? _____
4. JOB COST SUMMARY FILED AND AVAILABLE? _____
5. MODIFICATIONS ARE COMPLETE AND FILED? _____
6. RECEIPTS ARE BEING TRACKED AND DOCUMENTED? _____

COMMENTS: ____

SITE FILE SYSTEM (COMMUNITY RELATIONS)
1. COMMUNITY RELATIONS PLAN IS COMPLETE AND AVAILABLE FOR REVIEW? _____
2. ALL SITE PERSONNEL ARE AWARE OF PLAN AND ARE FAMILIAR WITH PROTOCOLS? _____

COMMENTS: ____

PHOTO LOG
1. PHOTOGRAPHS SUPPLEMENT SITE LOG BOOKS AND ILLUSTRATE:
   - SPILL OR EMISSION SOURCES _____
   - PATHWAYS AND IMPACTS _____
   - CONTAINER TYPES _____
   - ON SITE ACTIVITIES _____
   - EQUIPMENT USAGE _____
2. THE PHOTOGRAPH IS PROPERLY LABELED WITH THE FOLLOWING:

FIELD SITE AUDIT INSPECTION FORM

X = YES
O = NO
NA = NOT APPLICABLE

NAME OF THE PHOTOGRAPHER	
TIME/DATE	____
PROJECT NUMBER	____
SITE LOCATION	____
SITE DESCRIPTION	____
3. SPECIAL LENSES, FILMS, FILTERS OR OTHER IMAGE ENHANCEMENT TECHNIQUES HAVE BEEN RECORDED IN THE SITE LOG BOOK?	____

COMMENTS: ____________________

8/28/92

12.0 PREVENTIVE MAINTENANCE

The following section outlines preventative maintenance.

12.1 Field Maintenance

The O_2/LEL meter and the HNu PI-101 are to be used in site characterization and will be maintained as described by the manufacturer's instructions. The pH and specific conductance meters to be used during sampling will be maintained according to Baker's Standard Operating Procedure (SOP) F201. A full set of SOPs will be maintained in the field trailer.

12.2 Laboratory Maintenance

Preventive maintenance is an organized program of actions to prevent instruments and equipment from failing during use and to maintain proper performance of equipment and instruments. A comprehensive preventive maintenance program is implemented to increase the reliability of the measurement system. The preventive maintenance program will address the following:

- Schedules of important preventive maintenance tasks that are carried out to minimize downtime.
- Lists of critical spare parts that are available to minimize downtime.

The laboratory maintains histories, in instrument/equipment logs, of all major equipment. Trouble shooting, maintenance, and spare parts inventory will be recorded in the logs. Instruments and equipment will be maintained periodically in accordance with procedures described in individual analytical methods, manufacturer's recommendation, and/or service contracts.

The modern analytical laboratory depends heavily upon instrumentation and equipment; therefore, cleaning and preventive maintenance are primary considerations in the sustained production of satisfactory data. Specific requirements for proper care of laboratory instrumentation and equipment are contained in the manufacturer's instructions; however, some general guidelines are considered, and are listed below.

- Special precautions must be taken to avoid spillage of corrosive chemicals on or around equipment and instrumentation not only to extend the life of the item, but also to eliminate contamination.
- Where available, covers must be placed on instrumentation when not in use.
- Instrument parts must be cleaned as required (i.e., mirrors, probes, detector cells).

13.0 DATA MEASUREMENT ASSESSMENT PROCEDURES

The following section outlines data measurement assessment procedures.

13.1 Overall Project Assessment

Overall data quality will be assessed by a thorough understanding of the data quality objectives. By maintaining thorough documentation of all decisions made during each phase of sampling, performing field and laboratory audits, thoroughly reviewing the analytical data as they are generated by the laboratory, and providing appropriate feedback as problems arise in the field or at the laboratory, data accuracy, precision, and completeness will be closely monitored.

13.2 Field Quality Assessment

To assure that all field data are collected accurately and correctly, specific written instructions will be issued to all personnel involved in field data acquisition by the Project Manager. The Project Manager will perform field audit(s) during the investigation to document that the appropriate procedures are being followed with respect to sample (and blank) collection. These audits will include a thorough review of the field books used by the project personnel to insure that all tasks were performed as specified in the instructions. The field audits will necessarily enable the data quality to be assessed with regard to the field operations.

The evaluation (data review) of field blanks, and other field QC samples will provide definitive indications of the data quality. If a problem that can be isolated arises, corrective actions can be instituted for future field efforts.

13.3 Laboratory Data Quality Assessment

As part of the analytical QA/QC program, the laboratory applies precision and accuracy criteria for each parameter that is analyzed. When analysis of a sample set is completed, QC data generated will be reviewed and evaluated to ensure acceptance criteria are met. These criteria will be method and matrix specific.

QA/QC data review is based on the following criteria:

- Method Blank Evaluation - The method blank results will be evaluated for high readings characteristic of background contamination. If high blank values are observed, laboratory glassware and reagents are checked for contamination and the analysis of future samples halted until the system can be brought under control. A high background is defined as a background value sufficient to result in a difference in the sample values, if not corrected, greater than or equal to the smallest significant digit known to be valid. A method blank must contain no greater than two times the parameter detection limit for most parameters.

- Trip Blank Evaluation - Trip blank results will be evaluated for high readings similar to the method blanks described above. If high trip blank readings are encountered (i.e. a value sufficient to result in a difference in sample values, if not corrected, greater than or equal to the smallest significant digit known to be valid), procedures for sample collection, shipment, and laboratory analysis are reviewed. If both the method and the trip blanks exhibit significant background contamination, the source of contamination is probably within the laboratory. Ambient air in the laboratory and reagents will be checked as possible sources of contamination.

- Standard Calibration Curve Verification - The calibration curve or midpoint calibration standard (check standard) will be evaluated daily to determine curve linearity through its full range and that sample values are within the range defined by the low and high standards. If the curve is not linear, sample values are corrected. If average response factors are used to calculate sample concentrations, these factors are verified on a daily basis. Verification of calibration curves and response factors will be accomplished when the evaluated response for any parameter varies from the calibrated response by less than ranges specified in Section 7.0.

- Duplicate Sample Analyses - Duplicate sample analyses will be used to determine the precision of the analytical method for the sample matrix. Two types of duplicate samples will be analyzed for this project, field, and laboratory. Duplicate results will be used to calculate precision as defined by the relative percent difference (RPD). If laboratory duplicate values exceeds the control limit, the sample set may be reanalyzed for the parameter in question. Precision limits will be updated periodically following review of data.

- Reference Sample Analyses - The results of reference sample analysis will be compared with true values, and the percent recovery of the reference sample will be calculated. If correction is required (excessive or inadequate percent recovery), the reference sample must be reanalyzed to demonstrate that the corrective action has been successful.

- Surrogate Standard Analyses - Surrogate standard determinations will be performed on all samples and blanks for GC/MS analyses. All samples and blanks are fortified with surrogate spiking compounds before purging or extraction to monitor preparation and analysis of samples. Recoveries must meet specific criteria. If acceptance criteria are not met, corrective action must be taken to correct the problem and the affected sample must be reanalyzed.

- Matrix Spike Analyses - The observed recovery of spike versus theoretical spike recovery will be used to calculate accuracy as defined by the percent recovery. If the accuracy value exceeds the control limit for the given parameter, the appropriate laboratory personnel notified and corrective action will be taken before the sample set is reanalyzed for the parameter in question.

For completeness, it is expected that the methodology proposed for chemical characterization of the samples will meet QC acceptance criteria for at least 95 percent of all sample data. To ensure this completeness goal, data that does not meet the acceptance criteria will be recollected, reextracted, or reanalyzed, if necessary.

Data representativeness will be ensured through the use of appropriate analytical procedures, and analysis of samples performed within the allowed holding times.

Comparability is a qualitative characteristic of the data. By using standard methods for sampling and analyses, data generated in past or future investigations will be comparable with this investigation data.

14.0 CORRECTIVE ACTION

Corrective action will be taken whenever a nonconformance occurs. A nonconformance will be defined as an event which is beyond the limits established for a particular operation by the plan. Nonconformances can occur in a number of activities. Such activities include sampling procedures, sample receipt, sample storage, sample analysis, data reporting, and computations.

The following personnel will be responsible for detecting and reporting nonconformances:

- Project Staff - during testing and preparation and verification of numerical analyses.
- Laboratory Staff - during the preparation for analyses, performance of analytical procedures, calibration of equipment, and quality control activities.

14.1 Limits of Operation

The limits of operation that are used to identify nonconformances will be established by the contents of the Work Plan, QAPP, and FSAP. Interlaboratory control limits produced by statistical analyses will also be considered as limits of operation.

14.2 Corrective Action

Nonconformances will be identified and communicated to Baker to avoid delays with respect to project schedules and prevent the submission of non-valid data. Documentation will include the following:

- Personnel identifying the nonconformance(s) will be identified.
- The nonconformance(s) will be described and communicated to the Baker Project Manager.
- For serious nonconformances, the site supervisor will have the authority to initiate corrective action.
- For less serious nonconformances, corrective action will be decided upon and signatures will be obtained prior to implementation of corrective action.
- All nonconformances and corrective actions will be documented and reside with the Baker Activity Coordinator. This documentation will be available to LANTDIV.

The Baker Project Manager and Activity Coordinator will be notified of laboratory or field nonconformances and corrective actions taken if:

- A nonconformance causes a delay in work beyond the schedule completion date.
- A nonconformance affects information already reported.
- A nonconformance affects the validity of the data.

If the nonconformance(s) are serious and corrective action cannot resolve the problem(s), NEESA Contract Representatives (NCRs) and the LANTDIV NTR may be notified by Baker.

15.0 QUALITY ASSURANCE REPORTING PROCEDURES

The Project Manager will be responsible for assessing the performance of measurement systems and data quality related to the field investigation. A written record will be maintained of: the results of laboratory QC reports and other periodic assessments of measurement, data accuracy, precision, and completeness; performance and system audits; and any significant QA problems and recommended solutions. Each deliverable will contain a QA/QC assessment section. Also, a QA/QC assessment will be performed any time a significant problem is identified.

The Project Manager will keep in contact with the LANTDIV NTR through informal, verbal reports during the project as well as through monthly progress reports.