

N00639.AR.000926
NSA MID SOUTH
5090.3a

FINAL WORK PLAN FOR FIELD APPLICATION TO ENHANCE IN SITU BIOREMEDIATION
OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT SITE N-6 MILLINGTON
SUPPACT TN
6/1/2000
PARSONS ENVIRONMENTAL SCIENCE

FINAL

Work Plan for Field Application to Enhance *In-Situ* Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site N-6, Former Naval Support Activity Mid-South, Millington, Tennessee



Naval Support Activity Mid-South
Millington, Tennessee

Prepared For

Naval Facilities Engineering Command
Port Hueneme, California

Naval Facilities Engineering Command
Southern Division
North Charleston, South Carolina

and

Naval Support Activity Mid-South
Millington, Tennessee

June 2000

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado 80290

FINAL
WORK PLAN FOR FIELD APPLICATION TO ENHANCE *IN-SITU*
BIOREMEDIATION OF CHLORINATED SOLVENTS
VIA VEGETABLE OIL INJECTION AT SITE N-6,
FORMER NAVAL SUPPORT ACTIVITY MID-SOUTH,
MILLINGTON, TENNESSEE

June 2000

Prepared for:

NAVAL FACILITIES ENGINEERING COMMAND
PORT HUENEME, CALIFORNIA

NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
NORTH CHARLESTON, SOUTH CAROLINA

and

NAVAL SUPPORT ACTIVITY MID-SOUTH
MILLINGTON, TENNESSEE

Prepared by:

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

TABLE OF CONTENTS

	Page
ACRONYMS AND ABBREVIATIONS	iv
SECTION 1 - INTRODUCTION	1-1
1.1 Scope of Work	1-1
1.2 Background	1-2
SECTION 2 - SITE-SPECIFIC DATA REVIEW	2-1
2.1 Geology	2-1
2.2 Hydrogeology	2-5
2.3 Nature and Extent of Contamination	2-7
2.3.1 Soil Analytical Results	2-7
2.3.2 Groundwater Quality	2-8
2.4 Groundwater Use and Potential Receptors	2-8
SECTION 3 - ENHANCED BIOREMEDIATION OF CHLORINATED SOLVENTS USING VEGETABLE OIL	3-1
3.1 Biodegradation of Chlorinated Solvents	3-1
3.2 Biodegradation at Site N-6	3-4
SECTION 4 - SYSTEM INSTALLATION AND ADDITIONAL DATA COLLECTION	4-1
4.1 Field Application Activities	4-1
4.2 Site Management	4-4
4.2.1 NSA Mid-South Support	4-4
4.2.2 City of Millington Municipal Airport Authority Support	4-4
4.2.3 Contingency Plans	4-4
4.2.3.1 Access and Coordination Contingencies	4-5
4.2.3.2 Equipment Contingencies	4-5
4.2.3.3 Sampling Location Contingencies	4-5
4.2.3.4 Monitoring and Injection Well Permit Delays	4-5
4.2.3.5 Project Health and Safety Plan	4-6
4.2.4 Waste Handling	4-6
4.3 Initial System Installation	4-6
4.3.1 Injection and Groundwater Monitoring Locations	4-7
4.3.2 Drilling and Soil Sampling Procedures	4-7
4.3.3 Injection and Groundwater Monitoring Well Installation	4-7
4.3.3.1 Pre-Installation Activities	4-11
4.3.3.2 Materials Decontamination	4-11
4.3.3.3 Screen and Casing	4-11
4.3.3.4 Injection and Monitoring Well Completion	4-11

TABLE OF CONTENTS (Continued)

	Page
4.3.3.5	Injection and Monitoring Well Development 4-12
4.3.3.6	Equipment Decontamination Procedures 4-12
4.3.3.7	Datum Survey..... 4-13
4.4	Measurement of Baseline Geochemical Conditions and Contaminant Profiles 4-13
4.4.1	Groundwater Sampling 4-13
4.4.2	Preparation for Sampling 4-15
4.4.2.1	Equipment Cleaning 4-15
4.4.2.2	Equipment Calibration 4-15
4.4.3	Groundwater Sampling Procedures 4-15
4.4.3.1	Preparation of Location..... 4-16
4.4.3.2	Water Level and Total Depth Measurements..... 4-16
4.4.3.3	Purging Before Sampling..... 4-16
4.4.3.4	Sample Extraction 4-16
4.4.4	Onsite Groundwater Parameter Measurement 4-17
4.4.4.1	Dissolved Oxygen Measurements..... 4-17
4.4.4.2	pH, Temperature, and Specific Conductance..... 4-17
4.4.4.3	Carbon Dioxide Measurements..... 4-17
4.4.4.4	Alkalinity Measurements 4-18
4.4.4.5	Nitrate + Nitrite (as Nitrogen) Measurements..... 4-18
4.4.4.6	Sulfate and Hydrogen Sulfide Measurements..... 4-18
4.4.4.7	Ferrous Iron Measurements..... 4-18
4.4.4.8	Manganese Measurements 4-18
4.4.4.9	Oxidation/Reduction Potential..... 4-19
4.4.5	Handling of Samples for Laboratory Analysis 4-19
4.4.5.1	Sample Preservation..... 4-19
4.4.5.2	Sample Container and Labels..... 4-19
4.4.5.3	Sample Shipment 4-20
4.4.5.4	Chain-of-Custody Control..... 4-20
4.4.5.5	Sampling Records 4-20
4.4.5.6	Laboratory Analyses 4-21
4.5	Pre- Oil Injection Aquifer Testing 4-21
4.5.1	Definitions..... 4-21
4.5.2	Equipment..... 4-22
4.5.3	General Test Methods 4-22
4.5.4	Falling Head Test 4-23
4.5.5	Rising Head Test..... 4-24
4.5.6	Slug Test Data Analysis..... 4-24
4.6	Oil Injection and Radius of Influence Testing 4-24
4.6.1	Oil Injection 4-24
4.6.2	Radius of Influence Testing 4-24
4.7	Process Monitoring 4-25
SECTION 5 - QUALITY ASSURANCE/QUALITY CONTROL 5-1	

TABLE OF CONTENTS

	Page
SECTION 6 - DATA ANALYSIS AND REPORT	6-1
SECTION 7 - REFERENCES	7-1
APPENDICES	
A - Project Health and Safety Plan	
B - Analytical Sample Requirements	
C - Selected Data from Previous Site Investigations	
D - Responses to Comments	

LIST OF TABLES

No.	Title	Page
2.1	Summary of Volatile Organic Compounds Detected in Groundwater	2-9
4.1	Summary of Proposed Initial Site Activities	4-2
4.2	Summary of Proposed Monitoring Activities	4-3
4.3	Proposed Monitoring Well Construction Summary	4-9
4.4	Analytical Protocols for Groundwater Samples.....	4-14
5.1	QA/QC Sampling Program.....	5-2

LIST OF FIGURES

No.	Title	Page
1.1	Naval Support Activity Mid-South Location and Topographic Map	1-3
1.2	Site N-6 Features and Potential Source Areas	1-5
2.1	Cross Section and Sampling Location Map.....	2-2
2.2	Hydrogeologic Cross Section A-A'.....	2-3
2.3	Hydrogeologic Cross Section B-B'.....	2-4
2.4	Fluvial Deposits Groundwater Potentiometric Surface Map	2-6
2.5	TCE in Fluvial Groundwater Maximum Historical Concentrations - 1994 to 1998	2-11
2.6	TCE in Fluvial Groundwater - 1994 to 1998.....	2-12
2.7	TCE in Fluvial Groundwater - 1994 to 1998.....	2-13
3.1	Anaerobic Reductive Dehalogenation	3-3
4.1	Proposed Injection and Monitoring Well Locations	4-8
4.2	Injection Well Layout	4-10

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
µg/L	micrograms per liter
AOC A	Area of Concern A
BCT	BRAC Cleanup Team
BEHP	bis(2-ethylhexyl)phthalate
Bgs	below ground surface
BRAC	Base Closure and Realignment Act
CAHs	chlorinated aliphatic hydrocarbons
COCs	contaminants of concern
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
DOT	Department of Transportation
DPT	direct-push technology
EnSafe	EnSafe, Inc.
ft ² /day	square feet per day
ft/day	feet per day
ft/ft	foot per foot
ft/year	feet per year
gpm	gallons per minute
HSWA	Hazardous and Solid Waste Amendments
ID	inside-diameter
IDW	investigation-derived waste
IRP	Installation Restoration Program
K	hydraulic conductivity
lb/in ²	pounds per square inch
LCSs	laboratory control samples
LMBs	laboratory method blanks
LTM	long-term monitoring
MCLs	maximum contaminant levels
mg/L	milligrams per liter
MSDS	Material Safety Data Sheet
N	nitrogen
NAPL	non-aqueous phase liquid

NAS	Naval Air Station
NAVFAC	Naval Facility Engineering Command
NSA	Naval Support Activity
ORP	oxidation-reduction potential
Parsons ES	Parsons Engineering Science, Inc.
PCE	tetrachloroethene
POC	point of contact
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAP	Quality Assurance Plan
RBCs	risk-based concentrations
RCRA	Resource Conservation and Recovery Act
redox	reduction-oxidation
RFI	RCRA Facility Investigation
SSL	soil screening levels
SWMU	Solid Waste Management Unit
SVOCs	semi-volatile organic compounds
T	transmissivity
TCA	trichloroethane
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TOC	total organic carbon
TPH-DRO	total petroleum hydrocarbons – diesel range organics
UIC	underground injection control
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOCs	volatile organic compounds

SECTION 1

INTRODUCTION

This work plan presents the scope of work required to conduct a field application for enhanced *in-situ* bioremediation of chlorinated solvents via vegetable oil injection at Site N-6, Former Naval Support Activity (NSA) Mid-South Northside, Millington, Tennessee. This work plan has been prepared for the Naval Facilities Engineering Command (NAVFAC) and NSA Mid-South by Parsons Engineering Science, Inc. (Parsons ES).

This work plan was developed based on review of the February 2000 *RCRA Facility Investigation Report, Naval Support Activity Memphis, AOC A, Northside Fluvial Groundwater* (EnSafe, Inc. [EnSafe], 2000b). All field work will follow health and safety procedures presented in the *Project Health and Safety Plan for Field Application for Enhanced In Situ Remediation of Chlorinated Solvents via Vegetable Oil Injection at Site N-6, Naval Support Activity Mid-South, Tennessee* (Appendix A).

1.1 SCOPE OF WORK

This project is being conducted by NAVFAC in conjunction with Parsons ES and NSA Mid-South to document the enhanced bioremediation of chlorinated solvents dissolved in groundwater and sorbed to the aquifer matrix by injecting vegetable oil into the subsurface below the water table. Specifically, the objective of this field application is to determine if vegetable oil injection is a viable treatment option for volatile organic compounds (VOCs) in groundwater at Site N-6. Site-specific activities at Site N-6 in support of the enhanced bioremediation field application will include:

- Installation of eight (8) vegetable oil injection wells and sixteen (16) groundwater monitoring wells using Rotasonic drilling technology;
- Baseline (i.e., pre-injection) sampling of groundwater at the newly installed monitoring wells and existing monitoring wells 007G15UF (shallow) and 007G15LF (deep), in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (U.S. Environmental Protection Agency [USEPA], 1998);
- Pre-injection aquifer testing (hydraulic conductivity) of four injection wells and four monitoring wells;
- Plumbing of the injection wells and injection of up to 10,000 gallons of food-grade vegetable oil;
- Injection of bromide (aqueous phase) for determining zones of influence;

- Post-injection aquifer testing (hydraulic conductivity) of the previously-tested four injection wells;
- Surveying of the newly installed injection and monitoring wells;
- Post-injection sampling of groundwater and vegetable oil (if present) at the newly installed monitoring and injection wells and existing monitoring wells 007G15UF and 007G15LF, in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998) at two (2), six (6), 12, and 18 months after injection; and
- Preparation of a report detailing the results of the field application.

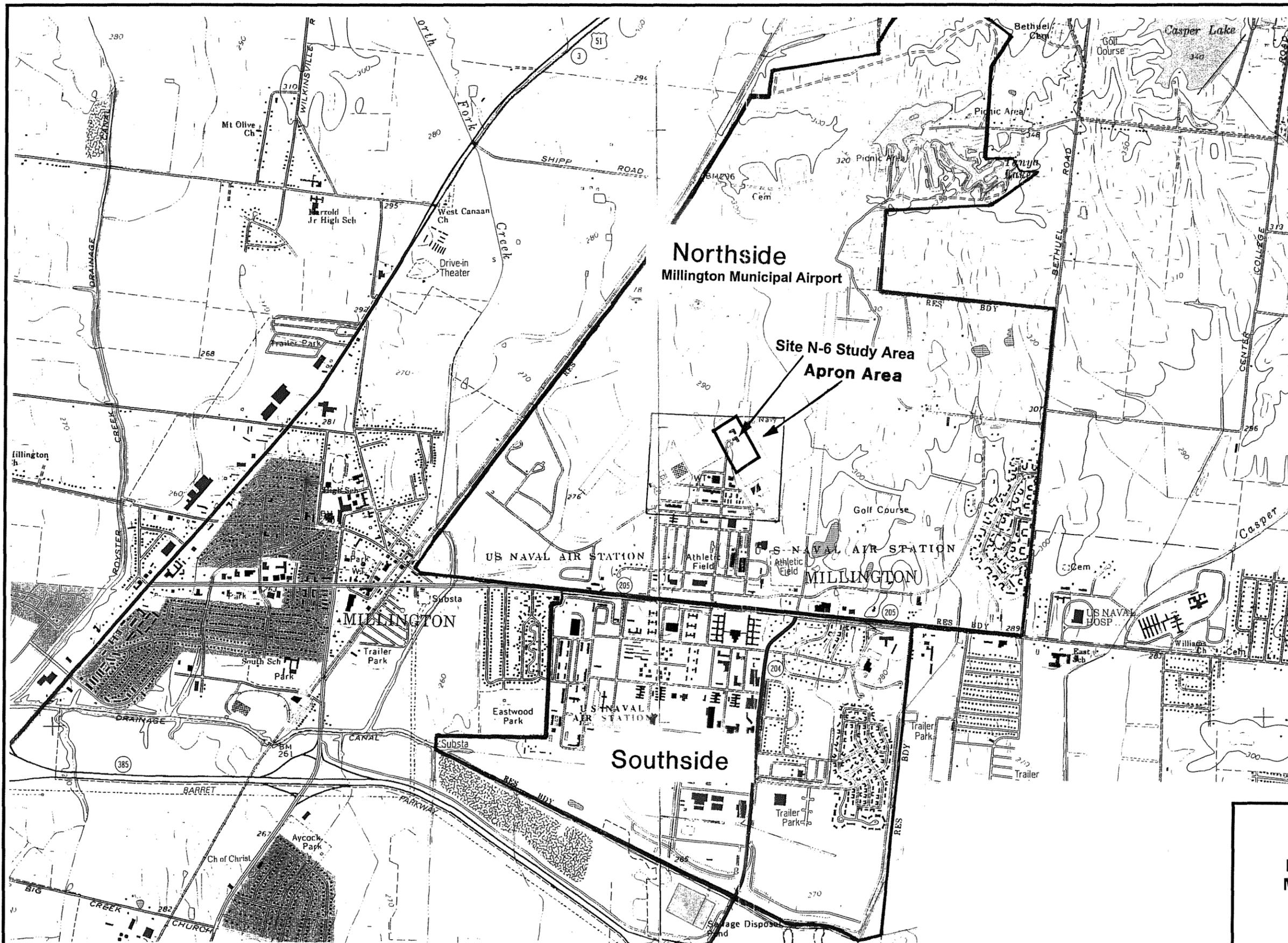
The materials and methodologies to accomplish these activities are described in Section 4.

This work plan consists of seven sections, including this introduction, and three appendices. Section 2 presents a review and analysis of available, previously reported, site-specific data. Section 3 provides an overview of biodegradation of chlorinated solvents. Section 4 describes system installation and the procedures to be followed for data collection. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 describes the final report, and Section 7 contains the references used in preparing this document. Appendix A contains the Project Health and Safety Plan. Appendix B contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater analytical samples. Appendix C contains pertinent historical data, including summary tables, figures, and borehole logs. Appendix D contains responses to comments received on the Draft Work Plan.

1.2 BACKGROUND

NSA Mid-South is located in Millington, Tennessee (Figure 1.1). As a result of the Base Closure and Realignment Act (BRAC) of 1990, a portion of NSA Mid-South (the Northside) has been closed and transferred to the City of Millington (December, 1999). Navy airfield operations ceased in 1995, at which time the mission of this Navy facility changed from Naval Air Station (NAS) Memphis to NSA Memphis. In 1998, the facility officially became NSA Mid-South. The City of Millington now owns and operates the Northside as a municipal airport.

To expedite the transfer of the Northside to the City of Millington, the BRAC Cleanup Team (BCT) designated the NSA Northside fluvial deposits groundwater as Area of Concern A (AOC A). A Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for Solid Waste Management Unit (SWMU) 7, the Building N-126 Plating Shop Dry Well, identified multiple areas in which groundwater was contaminated with chlorinated solvents. One particular site near former Hanger N-6 is the focus of this field application. The RCRA RFI was performed pursuant to the Navy's Installation Restoration Program (IRP) and the Hazardous and Solid Waste Amendments (HSWA) section of the RCRA Permit (TNHW-094), issued to NSA Memphis in 1996 by the Tennessee Department of Environment and Conservation (TDEC).



2000 0 2000
SCALE FEET

FIGURE 1.1

**NAVAL SUPPORT ACTIVITY
MID-SOUTH LOCATION AND
TOPOGRAPHIC MAP**

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

Site N-6 is located in the Northside portion of NSA Mid-South, now City of Millington Property. Figure 1.2 shows the site features and potential sources of solvents. The N-6 Site is centered around a former aircraft hanger (former Building N-6), and includes the surrounding flightline apron. The Building N-6 area was previously used for maintenance of military aircraft. Suspected releases of solvents at the site include the reported use of unspecified solvents as weed killer east of former Building N-6. Other suspected sources of solvents include a small aircraft parts stripping and painting area west of former Building N-6 and an underground waste tank present within former Building N-6 (EnSafe, 2000b). Actual dates or quantities of contaminant releases are unknown.

Solvents reportedly used at NSA Mid-South include 1,1,1-tetrachlorethane (TCA) and trichloroethene (TCE). Chemicals of concern (COCs) identified for Site N-6 include TCE; the dichloroethene (DCE) isomers 1,1-DCE, *cis*-1,2-DCE, and *trans*-1,2-DCE; 1,1-dichloroethane (DCA) and 1,2-DCA; and carbon tetrachloride. The work under this project will focus on the bioremediation of these chlorinated compounds.

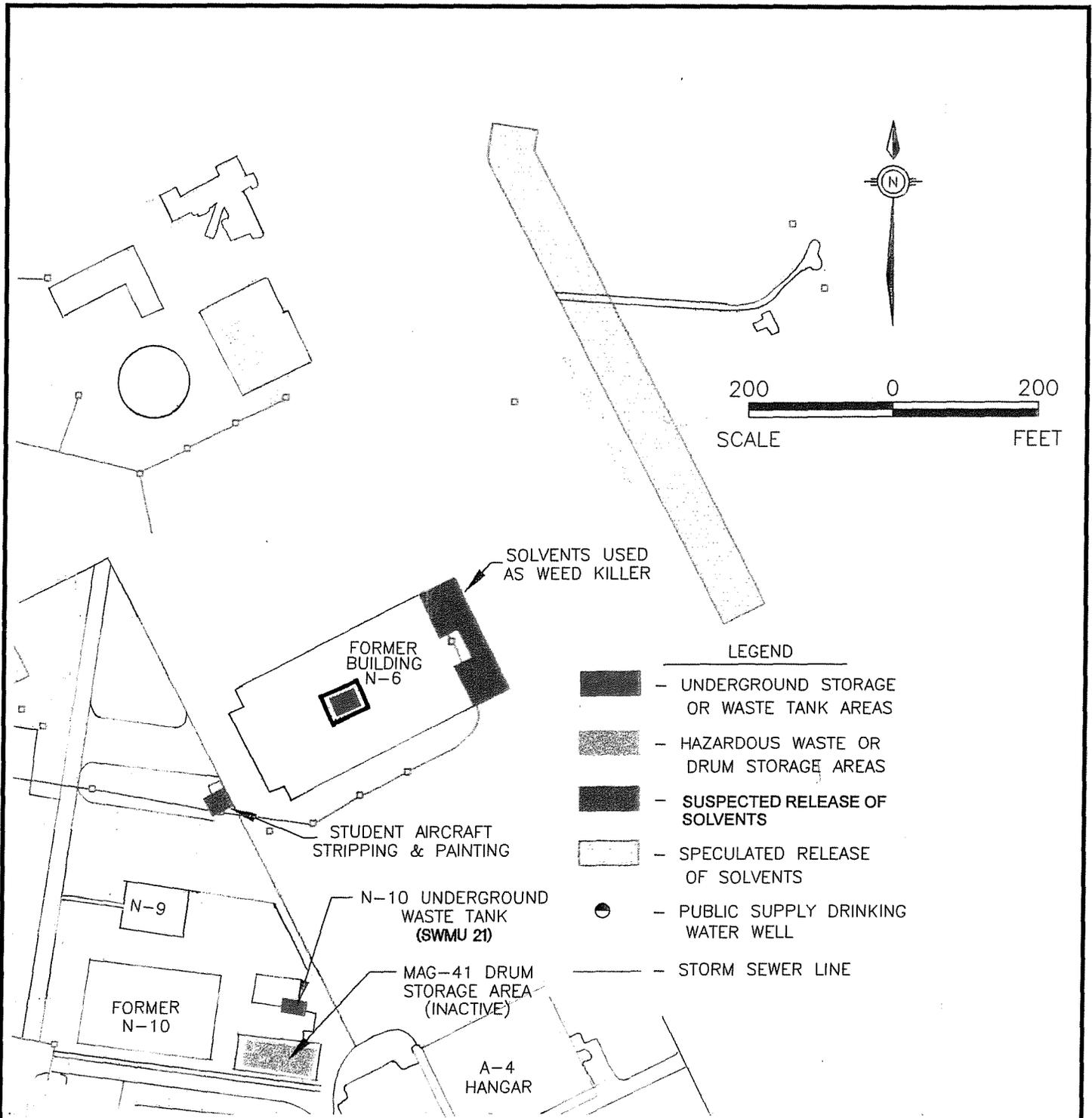


FIGURE 1.2

SITE N-6 FEATURES AND POTENTIAL SOURCE AREAS

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

Source: EnSafe, Inc., 1998.
 draw18511V.cdr pup aee 0300

SECTION 2

SITE-SPECIFIC DATA REVIEW

Site-specific data were reviewed to evaluate groundwater flow and contaminant transport and to determine locations for installation of injection and groundwater monitoring wells. Section 2.1 presents a synopsis of site characterization data made available to Parsons ES. Section 2.2 presents an interpretation of the data from the standpoint of biodegradation of chlorinated ethenes, ethanes, and methanes present at the site. Because chlorinated ethenes comprise the bulk of dissolved chlorinated solvents at Site N-6, they are the focus of this discussion.

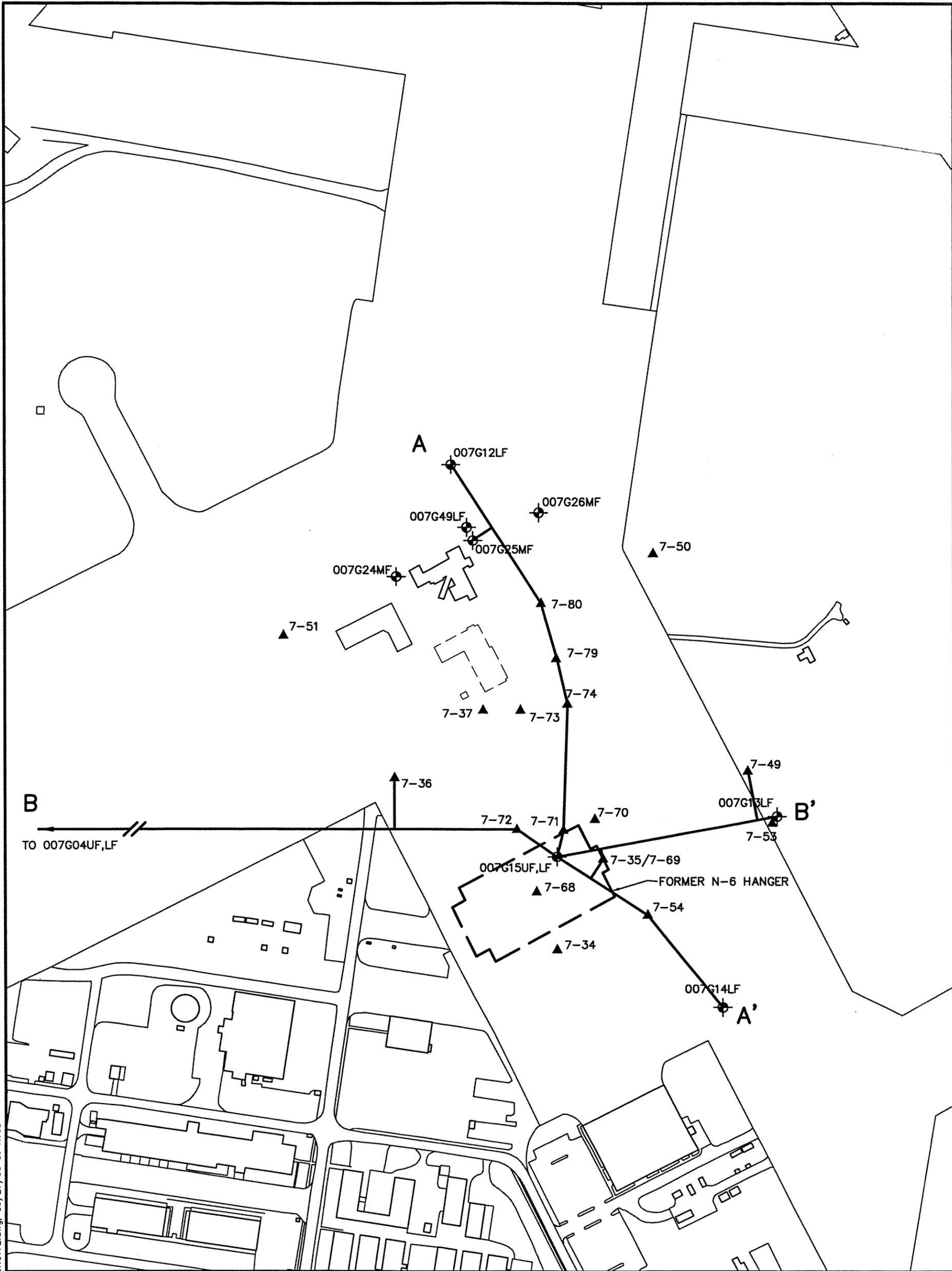
The following sections are based upon review and summary of data from the following sources:

- *Aquifer Characterization Test Report, Area of Concern A, Naval Support Activity Mid-South, Millington, Tennessee* (EnSafe, 2000a);
- *RCRA Facility Investigation Report, Naval Support Activity Memphis, AOC A, Northside Fluvial Groundwater* (EnSafe, 2000b);
- *RCRA Facility Investigation Report Addendum, Naval Support Activity Memphis, AOC A, Northside Fluvial Groundwater* (EnSafe, 2000c);
- *Hydrogeology and Groundwater Quality of Naval Support Activity Memphis, Millington, Tennessee* (Carmichael, *et al.*, 1997).

The reader is referred to these documents for a more detailed review of site-specific data. Additional sources are referenced within the text.

2.1 GEOLOGY

The stratigraphic units beneath Site N-6 identified for this and previous studies in descending order are: Pleistocene age loess; Pleistocene to possibly Pliocene age fluvial deposits; and upper units of the Claiborne Group, specifically the Cockfield and Cook Mountain Formations of Eocene age. The Cockfield and Cook Mountain Formations are overlying confining units to the Memphis Sand, which comprises the regional Memphis aquifer. Alluvium is locally present beneath the alluvial plain of North Fork Creek and its tributaries (Figure 1.1), but is generally absent in the apron area (i.e., Site N-6). Figure 2.1 shows the locations of hydrogeologic Cross Sections A-A' (Figure 2.2) and B-B' (Figure 2.3) across Site N-6. The following lithologic descriptions and stratigraphic relationships are summarized from the AOC A RFI (EnSafe, 2000b and 2000c).



LEGEND

7-54 ▲ - DPT SAMPLE AND LOCATION NUMBER

007G14LF ⊕ - WELL SAMPLE AND WELL NUMBER

UF - UPPER FLUVIAL DEPOSITS WELL

LF - LOWER FLUVIAL DEPOSITS WELL

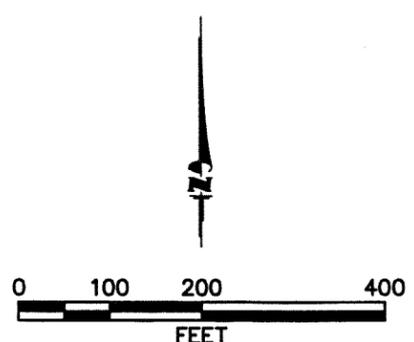


FIGURE 2.1
CROSS SECTION AND
SAMPLING LOCATION MAP

NSA Mid-South Site N-6
 Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

S:\ES\Remed\737490\02000\WORKPLAN\00DN0172.dwg, 06/27/00 at 11:00

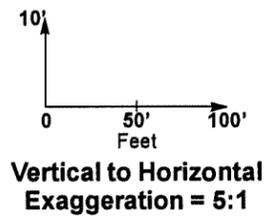
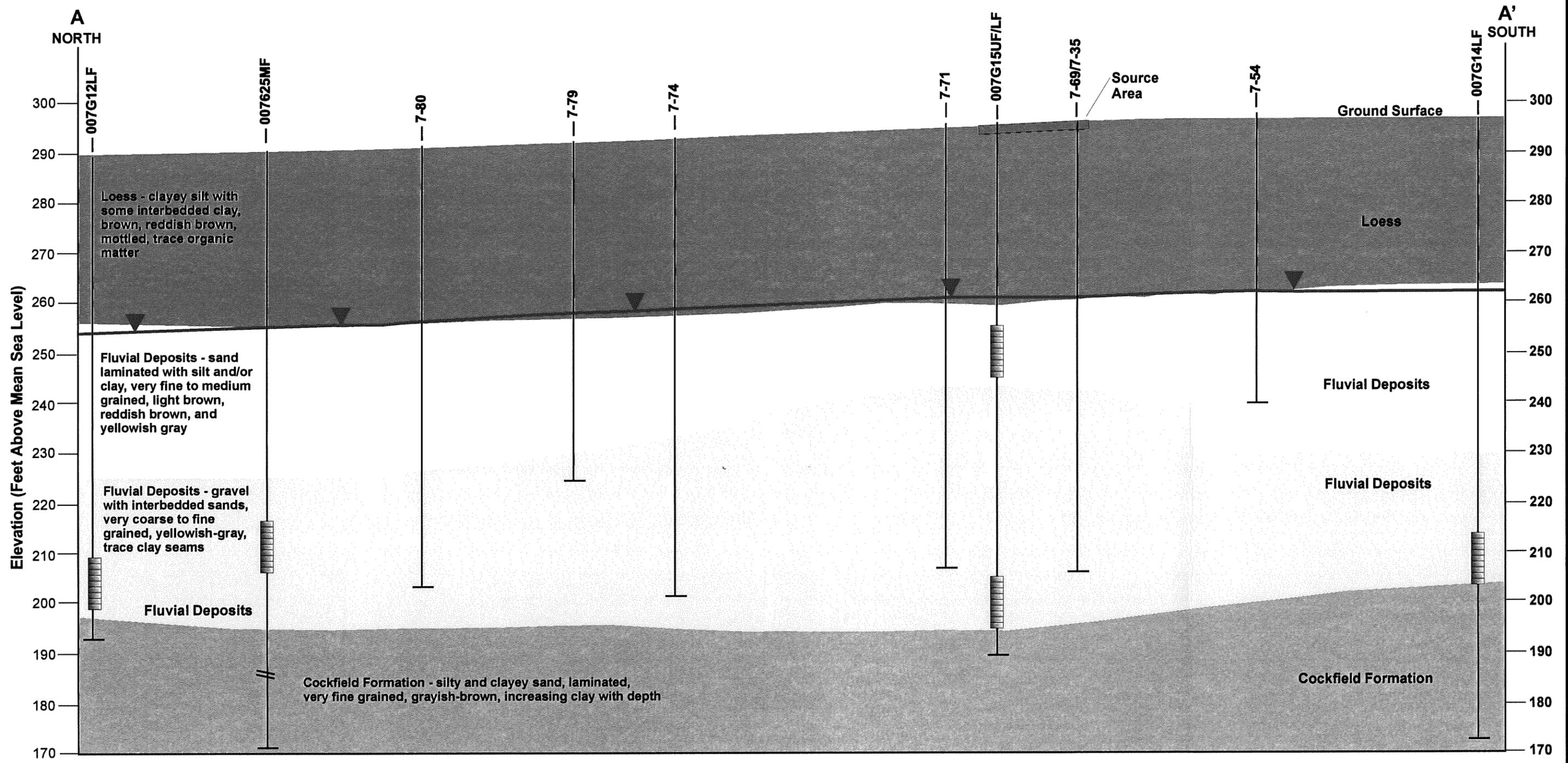


FIGURE 2.2

HYDROGEOLOGICAL CROSS SECTION A-A'

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

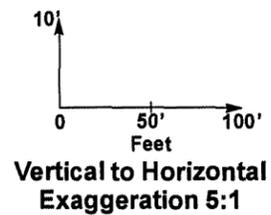
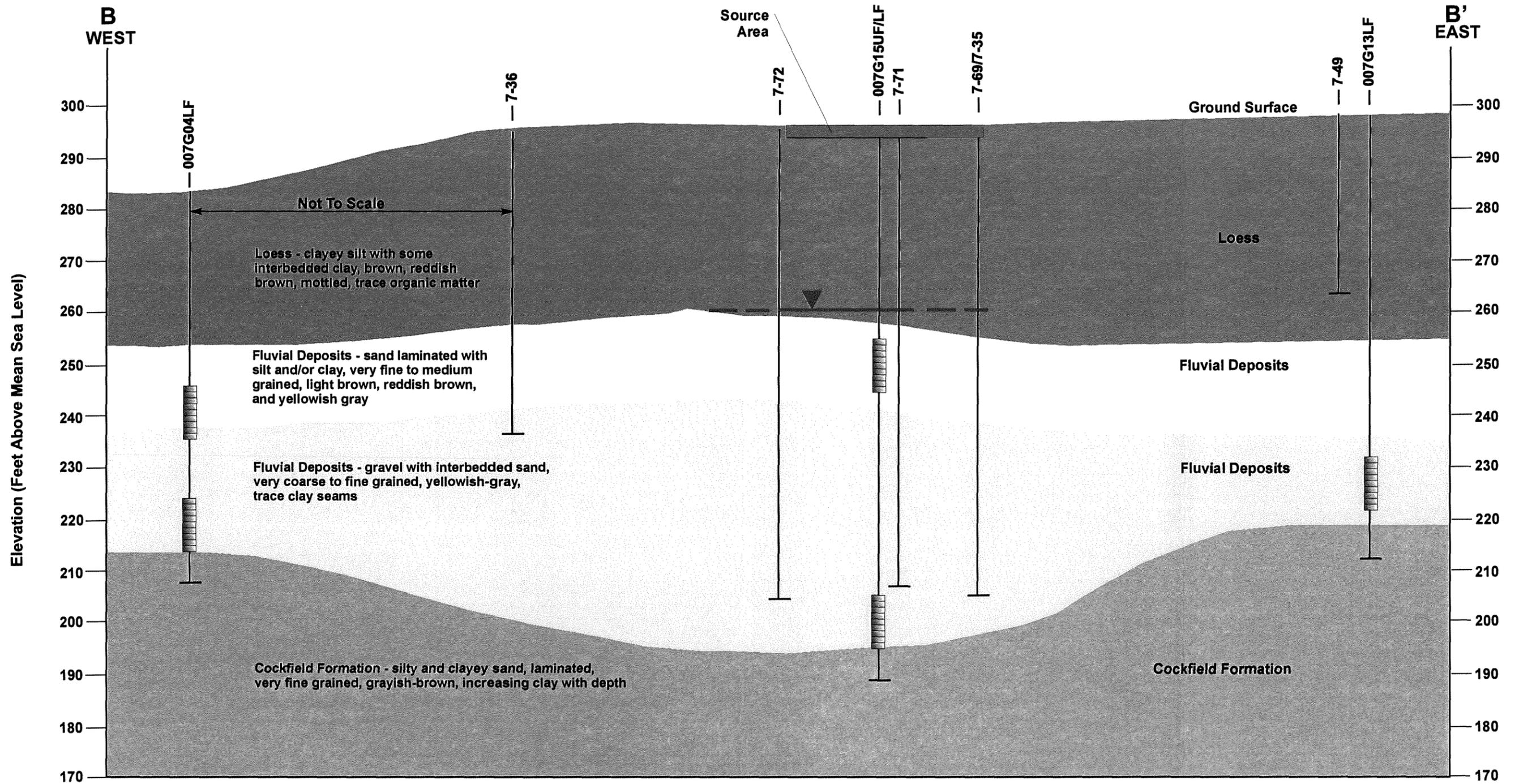


FIGURE 2.3
HYDROGEOLOGICAL
CROSS SECTION
B-B'

NSA Mid-South Site N-6
 Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

Loess deposits underlying the Northside consist of silt, silty clay, and minor amounts of sand and clay. Loess deposits range in thickness from 25 to 45 feet across the apron area, and average approximately 35 feet thick at Site N-6. The color of the loess varies from differing shades of brown, yellow, orange, red, and olive-gray. It is often mottled in color and may contain trace amounts of organic matter. The loess typically becomes stiffer, less moist, and contains a greater clay content with depth. In areas not covered by the concrete apron, the loess yields water and is the shallowest water-bearing zone at NSA Mid-South.

A relatively thin layer of reworked fluvial deposits is locally present between the loess and underlying fluvial deposits. Where present, this transition zone consists of sandy silt and silty and clayey fine- to medium-grained sand.

Fluvial deposits lie unconformably beneath the loess/fluvial deposits transition zone and may be recognized by the uppermost presence of very fine grained sand. Previous investigations at the site have divided the fluvial deposits into an upper sand-dominated zone and a lower gravel-dominated zone (Cross Sections A-A' and B-B'). The upper sand-dominated fluvial sediments consist of very-fine- to coarse-grained sand, coarsening downward in the sequence. These sands locally contain lenses of silt and/or clay and the sand may be finely micaceous. Scattered gravel also is present intertonguing or interbedded with the fluvial sands. Sand-dominated fluvial deposits are commonly light brown to reddish-brown, and are locally mottled yellowish-gray to orange.

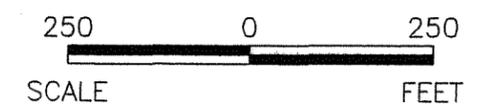
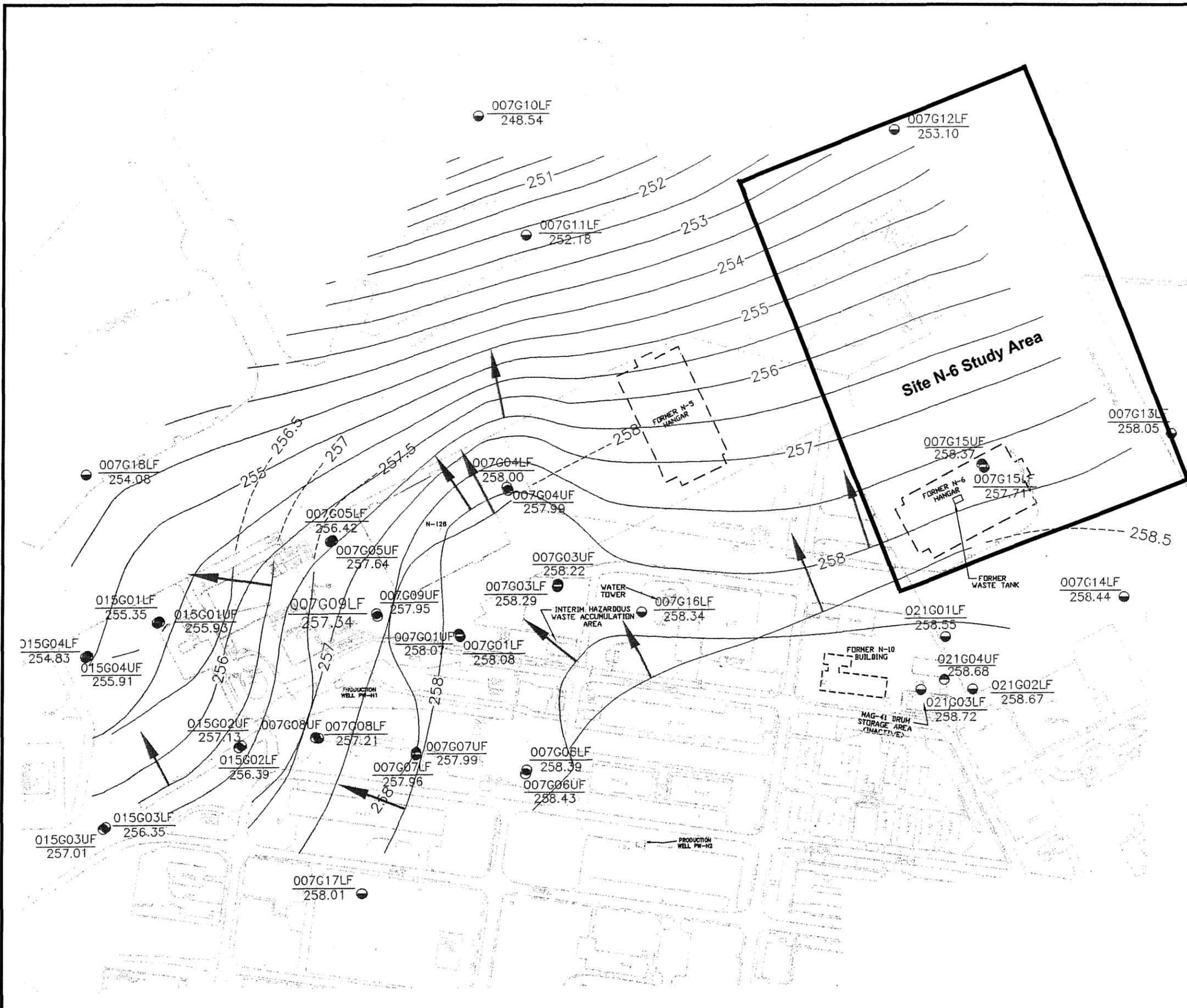
The lower gravel-dominated fluvial deposits are characterized by mixtures of poorly to moderately sorted gravels (up to 3-inch diameter) and fine- to very coarse-grained sand, in a generally coarsening downward sequence. The gravel and sand mixtures contain intertonguing fine- to coarse-grained sand stringers with some silt and clay. The gravel-dominated fluvial deposits are generally dusky yellow to dark yellowish-orange and yellowish-gray.

The fluvial deposits beneath Site N-6 range from 35 feet to 64 feet thick, with the thickest deposits directly beneath the former N-6 hanger (source area identified on Cross Sections A-A' and B-B').

The Cockfield Formation lies unconformably below the fluvial deposits at depths of 80-100 feet below Site N-6 (Cross Sections A-A' and B-B'). The upper contact of the Cockfield Formation is typically distinguished by a marked change from the overlying gravel-dominated fluvial deposits to a heterogeneous mixture of sand, silt, clayey sand, clay, and lignite. The uppermost part of the Cockfield Formation is generally comprised of very fine- to fine-grained sand with interlamination of silt and/or clay, and is generally dusky brown to brownish-gray.

2.2 HYDROGEOLOGY

The Northside fluvial groundwater flow pattern can be seen in Figure 2.4, which illustrates upper and lower fluvial deposits groundwater flow across the Northside AOC A for April 1996 (EnSafe, 2000b). Groundwater is not locally present within the loess at



- LEGEND
- - LOWER FLUVIAL DEPOSITS MONITORING WELL
 - - UPPER FLUVIAL DEPOSITS MONITORING WELL
 - 258.67 - FEET ABOVE MEAN SEA LEVEL
 - ⇨ - GROUNDWATER FLOW DIRECTION

FIGURE 2.4
**FLUVIAL DEPOSITS GROUNDWATER
 POTENTIOMETRIC SURFACE MAP**

NSA Mid-South Site N-6
 Millington, Tennessee

PARSONS
 PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

Site N-6. As shown, the local flow direction near Site N-6 is toward the northwest with a horizontal gradient of approximately 0.004 foot per foot (ft/ft), based on elevations from wells 007G12LF and 007G13LF. The fluvial deposits potentiometric surface occurs within the loess deposits (Cross Sections A-A' and B-B'), indicating confined or semi-confined conditions. Groundwater elevations for wells screened in the upper and lower fluvial deposits indicate that groundwater flow for these horizons are similar across the apron area. Groundwater elevation data from well pair 007G15UF/LF indicate a vertical gradient of -0.013 ft/ft in a downward direction.

Aquifer characterization during the RFI (EnSafe, 2000b) indicated horizontal hydraulic conductivity of the fluvial deposits across the Northside of 5.3 feet per day (ft/day) from an aquifer test; horizontal hydraulic conductivity ranging from 10 to 38 ft/day by monitoring well specific capacity testing; and horizontal hydraulic conductivity ranging from 0.004 to 1.98 ft/day using Hydrocone testing within the upper fluvial deposits/loess transitional interval. Further aquifer characterization by EnSafe (2000a) using a short-term, specific-capacity test, a step-drawdown test, and a longer-term constant-rate aquifer test yielded a hydraulic conductivity for the fluvial deposits ranging from 44.6 ft/day to 68.3 ft/day, with a geometric mean of 59.1 ft/day.

Given an estimated effective porosity of 27 percent, a hydraulic gradient of 0.004 ft/ft, and a hydraulic conductivity of 5.3 ft/day, EnSafe (2000b) calculated an advective groundwater velocity of 30 feet per year (ft/yr) for an area incorporating Site N-6. Similarly, a hydraulic conductivity of 59.1 ft/day can be used to calculate an advective groundwater velocity of 320 ft/yr. Based on the observed variation in lithology and hydraulic conductivity within the fluvial deposits, groundwater velocities may range over an order of magnitude or greater. This suggests the potential for preferential flowpaths or horizons.

2.3 NATURE AND EXTENT OF CONTAMINATION

Delineation of contaminants in soil and groundwater at Site N-6 has occurred over a number of sampling events involving both permanent monitoring wells and single-point sampling with direct-push technology (DPT) sampling techniques. The extent and nature of soil and groundwater contamination based on historical analytical results are discussed in the following sections.

2.3.1 Soil Analytical Results

Soil samples were collected near the Site N-6 source area from a single borehole (007SMW15) drilled for monitoring well location 007G15LF/UF (Figure 2.1). No constituent in any soil sample from this location exceeded soil screening levels (SSLs) for contaminant transport from soil to groundwater, or residential soil risk-based concentrations (RBCs) established for AOC A (EnSafe, 2000b). This soil borehole location is within the footprint of former Hanger N-6, and may not be optimally located to characterize source-area soils. Suspected source areas at Site N-6 include a former grassy area to the east of former Hanger N-6 and a former subsurface waste tank located below grade and within the footprint of the former Hanger (Figure 1.2).

2.3.2 Groundwater Quality

Eight permanent monitoring wells (007G12LF, 007G13LF, 007G14LF, 007G15LF, 007G15UF, 007G24MF, 007G25MF, and 007G26MF), and 37 single-point samples from 19 temporary DPT borehole locations have been sampled from 1994 to 1998 as part of the RFI and long-term monitoring (LTM) at Site N-6. Historical analytical results for VOCs in groundwater are summarized in Table 2.1

Table 2.1 indicates that TCE, 1,1-DCE, 1,2-DCA, and carbon tetrachloride have been detected consistently over time in samples from wells 007G15UF and 007G15LF. To a lesser extent, the common degradation products 1,2-DCE and chloroform also have been detected in site groundwater. Concentrations of TCE range up to 1,160 micrograms per liter ($\mu\text{g/L}$) at a depth of 60 feet at DPT location 7-69, located just to the east of the former hanger.

The maximum concentrations of 1,2-DCE (29.2 $\mu\text{g/L}$), carbon tetrachloride (199 $\mu\text{g/L}$), and chloroform (180 $\mu\text{g/L}$) also were detected at the same depth interval at 7-69. The maximum concentrations of 1,1-DCE (380D [diluted] $\mu\text{g/L}$), 1,1-DCA (67 $\mu\text{g/L}$), and benzene (6.6 $\mu\text{g/L}$) were detected in well 007G15UF in April 1997. Other VOC compounds detected at Site N-6 include tetrachloroethene (PCE), 1,2-DCA, bromochloromethane, dichlorofluoromethane, and acetone. Semi-volatile organic compounds (SVOCs) detected were bis(2-ethylhexyl)phthalate (BEHP) and total petroleum hydrocarbons - diesel range organics (TPH-DRO). The limited presence of benzene and TPH-DRO indicates some release of fuel hydrocarbons in addition to chlorinated solvents.

Maximum historical concentrations of TCE from 1994 to 1998 at each sampling location for fluvial deposits groundwater are contoured on Figure 2.5. The maximum identified concentrations of TCE are in groundwater at the eastern end of former Hanger N-6, coinciding with a former grassy area where solvents reportedly were spread to kill weeds (Figures 1.2 and 2.5). The TCE plume extends approximately 900 feet downgradient towards the northwest in the direction of groundwater flow (Figures 2.5 and 2.6).

Figure 2.6 and 2.7 show the vertical profiles of TCE in groundwater along Cross Sections A-A' and B-B' (see Figure 2.1 for cross section locations). While TCE is present from the potentiometric surface to the base of the fluvial deposits, the maximum TCE concentrations are inferred to occur within the middle to lower portions of the aquifer. However, this cannot be demonstrated conclusively because of a lack of groundwater sampling points in the upper fluvial deposits downgradient of the source area (Figure 2.6).

2.4 GROUNDWATER USE AND POTENTIAL RECEPTORS

Fluvial deposits groundwater is not used for beneficial use at former NSA Mid-South Northside. The nearest potential receptor on the Northside is public supply well PW-N1, located approximately 450 feet southwest of the Building N-126 dry well (approximately 1,500 feet cross gradient from Site N-6). PW-N1 is screened in the Memphis Aquifer and hydraulically separated from the shallower fluvial aquifer by the upper Claiborne

confining unit (EnSafe, 2000b). This well has been placed on emergency standby as a precautionary measure since 1994.

Potential receptors within the fluvial deposits groundwater consist of shallow private domestic wells outside the Northside (City of Millington) property. The nearest domestic supply well screened in the fluvial deposits is approximately 6,000 feet north-northwest of the apron area and is inactive (EnSafe, 2000b).

Because contaminated groundwater at Site N-6 has the potential to migrate off the Northside property, the objective of this field application is to determine if vegetable oil injection is a viable treatment option for chlorinated solvents in groundwater at Site N-6. The downgradient property boundary is located approximately 4,000 feet northwest from the Site N-6 source area (Figure 1.1).

SECTION 3

ENHANCED BIOREMEDIATION OF CHLORINATED SOLVENTS USING VEGETABLE OIL

3.1 BIODEGRADATION OF CHLORINATED SOLVENTS

Chlorinated solvents can be transformed, directly or indirectly, by biological processes (e.g., Bouwer *et al.*, 1981; Miller and Guengerich, 1982; Reineke and Knackmuss, 1984; Wilson and Wilson, 1985; de Bont *et al.*, 1986; Nelson *et al.*, 1986; Spain and Nishino, 1987; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gossett, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; Sander *et al.*, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; Chapelle, 1993; McCarty and Semprini, 1994; Vogel, 1994; Suflita and Townsend, 1995; Bradley and Chapelle, 1996; Bradley and Chapelle, 1998; Spain, 1996). Biodegradation of chlorinated solvents, also termed chlorinated aliphatic hydrocarbons (CAHs), and chlorinated benzenes results from the same general processes that bring about biodegradation of fuel hydrocarbons. However, a more complex series of processes often is involved, as CAHs and chlorinated benzenes may act either as substrates (electron donors) or electron acceptors depending upon the prevailing geochemical conditions.

Chlorinated solvents may undergo biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated process. At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most likely.

In a pristine aquifer, native organic carbon is utilized as an electron donor and dissolved oxygen (DO) is utilized first as the prime electron acceptor. Where anthropogenic carbon (e.g., vegetable oil, fuel hydrocarbons, landfill leachate, less-chlorinated CAHs, or chlorinated benzenes with four or fewer chlorines) is present, it also may be utilized as an electron donor. Most chlorinated solvents that can act as electron donors have thus far only been demonstrated to do so under aerobic conditions, with the notable exception of vinyl chloride (VC) (Bradley and Chapelle, 1996 and 1998). After the DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, manganese oxide, ferric iron oxyhydroxide, sulfate, and finally carbon dioxide. Evaluation of the distribution of these electron acceptors can provide evidence of where and how biodegradation of chlorinated solvents is occurring.

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. This is the only biological reaction known to degrade PCE, TCE, TCA, carbon tetrachloride, and chlorinated benzenes with more than four chlorines. During reductive dehalogenation, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. Figure 3.1 illustrates the transformation of chlorinated ethenes via reductive dehalogenation. In general, reductive dehalogenation occurs by sequential dechlorination. For the chlorinated ethenes, dechlorination progresses from PCE to TCE to DCE to VC to ethene.

Likewise, for the chlorinated methanes, dechlorination progresses from carbon tetrachloride to chloroform to methylene chloride to chloromethane to methane. Depending upon environmental conditions, these dechlorination sequences may be interrupted, with other processes then acting upon the products. During reductive dehalogenation of TCE, all three isomers of DCE theoretically can be produced; however, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated solvents differently. PCE, TCE, and carbon tetrachloride are the most susceptible of these compounds to reductive dehalogenation because they are the most oxidized. Conversely, VC and chloromethane are the least susceptible to reductive dehalogenation because they are the least oxidized of these compounds. Reductive dehalogenation has been demonstrated under nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994).

Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur. Potential carbon sources include vegetable oil, fuel hydrocarbons, low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter or less-chlorinated compounds such as VC, DCE, chloroethane, or DCA. An evaluation of chlorinated ethene groundwater data suggests that the natural biodegradation of chlorinated ethenes at Site N-6 is electron-donor limited. Innocuous, food-grade vegetable oil will be used to remediate the solvent plume at Site N-6 by overcoming the observed electron donor limitation.

The most common approach utilized to date to stimulate reductive dehalogenation has been addition of a carbon source dissolved in groundwater. This approach may prove effective in some applications, but in many cases may have difficulty competing with pump-and-treat remedial systems because the carbon source must be continuously injected. Other approaches involving the emplacement of solid materials that release carbon are promising, but the cost of the solid carbon addition will be high. The separate phase nature of vegetable oil allows for slow dissolution into groundwater, thus making it a slow-release carbon source. Thus, the carbon substrate will only be injected one time, which will significantly reduce overall costs. Vegetable oil is an inexpensive, innocuous, food-or feed-grade carbon source that is not regulated as a contaminant by the USEPA. Because vegetable oil is a non-aqueous phase liquid (NAPL), the potential exists that a

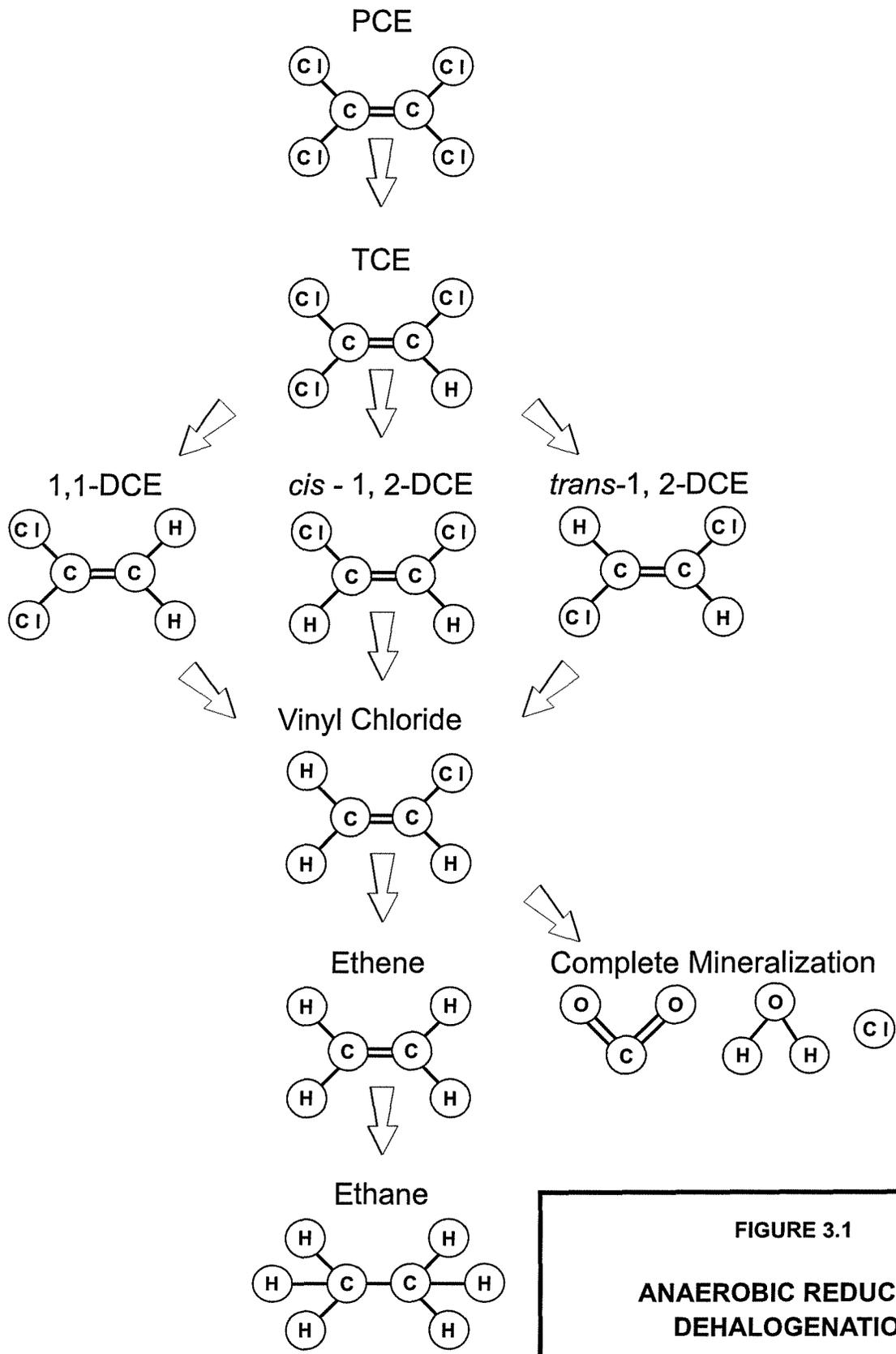


FIGURE 3.1

**ANAEROBIC REDUCTIVE
DEHALOGENATION**

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

single, low-cost injection could provide sufficient carbon to drive reductive dechlorination for many years.

Vegetable oil will be injected to create the reduction-oxidation (redox) and electron donor conditions necessary to promote the microbial reductive dehalogenation of the chlorinated solvents found as Site N-6. A secondary benefit is partitioning of the dissolved chlorinated solvents into the vegetable oil NAPL. This is beneficial because aqueous-phase chlorinated solvent concentrations will be lowered until steady-state (equilibrium) conditions are reached.

3.2 BIODEGRADATION AT SITE N-6

Compounds detected at the N-6 site assumed to be parent compounds include PCE, TCE, and carbon tetrachloride. 1,1,1-TCA was not detected in groundwater at the site, but also is considered a parent compound that may be present in source area soils. Degradation daughter products detected in groundwater at the site that are not considered to have been released but are a product of biodegradation include 1,2-DCE, 1,1-DCE, 1,1-DCA, 1,2-DCA, and chloroform.

The presence of 1,2-DCE suggests reductive dehalogenation of TCE under reducing conditions. However, the concentrations of 1,2-DCE generally are an order of magnitude less than TCE, and the extent of 1,2-DCE is limited to the immediate source area (i.e., wells 007G15UF and 007G15LF, and DPT location 7-69 [Table 2.1]). This suggests that the reducing conditions necessary for TCE degradation are very limited. A lack of VC indicates that further degradation of DCE is not occurring at Site N-6.

1,1-DCE also may be a degradation product of TCE, but more likely the higher concentrations and extent of 1,1-DCE (relative to 1,2-DCE) is a result of degradation of 1,1,1-TCA by hydrolysis. Low levels of DCA are present at the site, indicating that limited degradation of 1,1,1-TCA under reducing conditions also may occur.

With a single exception (DPT sample 7-35), chloroform was detected along with carbon tetrachloride in groundwater samples. This suggests that degradation of carbon tetrachloride is occurring throughout the plume. Concentrations of carbon tetrachloride at well locations 007G15UF and 007G15LF have consistently declined from March 1996 to November 1997 (Table 2.1).

In summary, the limited occurrence of daughter products at Site N-6 suggests that under sufficiently reducing conditions, degradation of chlorinated solvents can occur. The presence of low levels of benzene and TPH-DRO (Section 2.3.2) indicate that a source of organic substrate may have been present at one time in sufficient quantities to induce limited reductive dehalogenation of the chlorinated compounds. However, there currently is not sufficient organic substrate (electron donor) present to cause significant loss (degradation) of contaminant mass at the site.

SECTION 4

SYSTEM INSTALLATION AND ADDITIONAL DATA COLLECTION

4.1 FIELD APPLICATION ACTIVITIES

Field activities at Site N-6 include the initial system installation, baseline sampling, vegetable oil injection, and groundwater monitoring. Subsequent system monitoring will be performed at two (2), six (6), 12, and 18 months after injection. Site-specific activities for the initial field event are summarized in Table 4.1, and will include:

- Installation of eight (8) vegetable oil injection wells and sixteen (16) groundwater monitoring wells using Rotasonic drilling technology;
- Background (i.e., pre-injection) sampling of groundwater at the newly installed monitoring wells and existing monitoring wells 007G15UF (shallow) and 007G15LF (deep), in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998);
- Pre-injection aquifer testing (hydraulic conductivity) of four injection wells and four monitoring wells;
- Plumbing of the injection wells and injection of up to 10,000 gallons of food-grade vegetable oil;
- Injection of bromide (aqueous phase) for determining zones of influence;
- Post-injection aquifer testing (hydraulic conductivity) of the previously-tested four injection wells; and
- Surveying of the newly installed injection and monitoring wells.

System monitoring activities are summarized in Table 4.2, and involve post-injection sampling of groundwater and vegetable oil (if present) at the newly installed monitoring and injection wells and existing monitoring wells 007G15UF (shallow) and 007G15LF (deep), in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998) at two (2), six (6), 12, and 18 months after injection.

TABLE 4.1
SUMMARY OF PROPOSED INITIAL SITE ACTIVITIES
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

Location	Monitoring Well Installation	Slug Test Analysis	Water Level Measurement	Soil Analyses		Oil Analyses	Groundwater Analyses							
				VOCs ^{a/} SW8260B	Total Organic Carbon (SW9060)	VOCs SW8260B	VOCs SW8260B	Methane, Ethane, Ethene	Nitrate + Nitrite (E300.1)	Bromide (E320.1)	Total Organic Carbon (SW9060M)	Well Head Analyses ^{b/}	Mobile Lab Analyses ^{c/}	
Monitoring Wells														
PES-MW-1D	X	X	X		1		1	1	1			1	1	
PES-MW-1S	X	X	X		1		1	1	1			1	1	
PES-MW-2D	X		X				1	1	1		1	1	1	
PES-MW-2S	X		X				1	1	1		1	1	1	
PES-MW-3D	X		X				1	1	1		1	1	1	
PES-MW-3S	X		X				1	1	1		1	1	1	
PES-MW-4D	X		X				1	1	1		1	1	1	
PES-MW-4S	X		X				1	1	1		1	1	1	
PES-MW-5D	X		X				1	1	1		1	1	1	
PES-MW-5S	X		X				1	1	1		1	1	1	
PES-MW-6D	X		X				1	1	1		1	1	1	
PES-MW-6S	X		X				1	1	1		1	1	1	
PES-MW-7D	X		X				1	1	1		1	1	1	
PES-MW-7S	X		X				1	1	1		1	1	1	
PES-MW-8D	X	X	X		1		1	1	1		1	1	1	
PES-MW-8S	X	X	X		1		1	1	1		1	1	1	
007GL15UF			X				1	1	1			1	1	
007GL15LF			X				1	1	1			1	1	
Injection Wells														
PES-INJ-1D	X		X		2		1	1	1		1	1	1	
PES-INJ-1S	X		X				1	1	1		1	1	1	
PES-INJ-2D	X	2X	X		2		1	1	1		1	1	1	
PES-INJ-2S	X	2X	X				1	1	1		1	1	1	
PES-INJ-3D	X	2X	X		2		1	1	1		1	1	1	
PES-INJ-3S	X	2X	X				1	1	1		1	1	1	
PES-INJ-4D	X		X		2		1	1	1		1	1	1	
PES-INJ-4S	X		X				1	1	1		1	1	1	
SUBTOTALS		12			8	4	4	26	26	26	10	22	26	26
QA/QC														
Duplicates					1		1	3	3	3	1	3		3
MS/MSD					1		1	2						
Trip Blanks								3						
Rinseates								1						
TASK TOTAL:					10	4	6	35	29	29	11	25	26	29

^{a/} VOCs to include aromatic and chlorinated aliphatic hydrocarbons.
^{b/} Well head analyses include dissolved oxygen, oxidation-reduction potential, pH, temperature, and conductivity.
^{c/} Mobile lab analyses include chloride, carbon dioxide, alkalinity, ammonia, sulfate, ferrous iron, sulfate, hydrogen sulfide, and manganese.

TABLE 4.2
SUMMARY OF PROPOSED MONITORING ACTIVITIES
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

Location	Water Level Measurement	Oil Analyses		Groundwater Analyses					
		VOCs ^{a/} SW8260B	VOCs SW8260B	Methane, Ethane, Ethene	Nitrate + Nitrite (E300.1)	Bromide (E320.1)	Total Organic Carbon (SW9060M)	Well Head Analyses ^{b/}	Mobile Lab Analyses ^{c/}
Monitoring Wells									
PES-MW-1D	X		1	1	1			1	1
PES-MW-1S	X		1	1	1			1	1
PES-MW-2D	X		1	1	1	1	1	1	1
PES-MW-2S	X		1	1	1	1	1	1	1
PES-MW-3D	X		1	1	1	1	1	1	1
PES-MW-3S	X		1	1	1	1	1	1	1
PES-MW-4D	X		1	1	1	1	1	1	1
PES-MW-4S	X		1	1	1	1	1	1	1
PES-MW-5D	X		1	1	1	1	1	1	1
PES-MW-5S	X		1	1	1	1	1	1	1
PES-MW-6D	X		1	1	1	1	1	1	1
PES-MW-6S	X		1	1	1	1	1	1	1
PES-MW-7D	X		1	1	1	1	1	1	1
PES-MW-7S	X		1	1	1	1	1	1	1
PES-MW-8D	X		1	1	1	1	1	1	1
PES-MW-8S	X		1	1	1	1	1	1	1
007GL15UF	X		1	1	1			1	1
007GL15LF	X		1	1	1			1	1
Injection Wells									
PES-INJ-1D	X		1	1	1	1	1	1	1
PES-INJ-1S	X		1	1	1	1	1	1	1
PES-INJ-2D	X	2	1	1	1	1	1	1	1
PES-INJ-2S	X	2	1	1	1	1	1	1	1
PES-INJ-3D	X	2	1	1	1	1	1	1	1
PES-INJ-3S	X	2	1	1	1	1	1	1	1
PES-INJ-4D	X		1	1	1	1	1	1	1
PES-INJ-4S	X		1	1	1	1	1	1	1
SUBTOTALS		8	26	26	26	22	22	26	26
QA/QC									
Duplicates		1	3	3	3	3	3		3
MS/MSD		1	2						
Trip Blanks			2						
Rinseates			1						
SUBTOTAL PER EVENT:		10	34	29	29	25	25	26	29
TASK TOTAL:		10	136	116	116	100	100	104	116

^{a/} VOCs to include aromatic and chlorinated aliphatic hydrocarbons.

^{b/} Well head analyses include dissolved oxygen, oxidation-reduction potential, pH, temperature, and conductivity.

^{c/} Mobile lab analyses include chloride, carbon dioxide, alkalinity, sulfate, ferrous iron, hydrogen sulfide, and manganese.

4.2 SITE MANAGEMENT

The following paragraphs outline site management issues pertaining to the field activities to be conducted at Site N-6, including NSA Mid-South and City of Millington Municipal Airport Authority support.

4.2.1 NSA Mid-South Support

NSA Mid-South will provide the following support during field activities:

- **Assign Accumulation Points.** Any purge fluids and decontamination rinsate or excavated soils generated during site work that are suspected of being hazardous will be properly contained. The NSA Mid-South point of contact (POC) will specify the location for the storage of containerized waste. Waste handling procedures are outlined in Section 4.2.4.
- **Underground Utility Clearances.** Before any work, each proposed intrusive sampling location at Site N-6 will be checked for underground utilities by Parsons ES and NSA Mid-South engineering personnel. The NSA Mid-South POC will provide utility drawings to Parsons ES. A copy of all utility maps will be kept at the site where drilling work will be conducted.

4.2.2 City of Millington Municipal Airport Authority Support

The City of Millington Municipal Airport Authority will provide the following support during field activities:

- **Provide Site Access to Field Team Members.** The Airport Authority POC will ensure daily access to the site. Parsons ES will be responsible for keeping secured access areas locked at all times.
- **Badge and Vehicle Passes.** The issue of personnel badges and vehicle passes will not be necessary for this site.
- **Provide Scheduling Information.** The Airport Authority POC will notify Parsons ES of any airfield activities that may adversely affect field activities and/or impact the sampling schedule.

4.2.3 Contingency Plans

This subsection describes steps that will be taken by Parsons ES to minimize delays during the investigations. Potential problems that could be encountered during the field effort include:

- Access and coordination difficulties;
- Equipment breakdowns;
- Conflicts with planned sampling locations;

- Abnormal site conditions (e.g., severe weather, unexpected airfield operations); and/or
- Monitoring or injection well permit delays.

4.2.3.1 Access and Coordination Contingencies

Anticipated support needs are outlined in Sections 4.2.1 and 4.2.2. In the event that site access difficulties arise, the Airport Authority and NSA Mid-South POCs will be contacted to resolve the problem. The Parsons ES site manager and field team leader will be responsible for notifying the Airport Authority and NSA Mid-South POCs of access or coordination difficulties.

4.2.3.2 Equipment Contingencies

In the event of operation problems with field equipment or testing instruments, the following actions will be taken:

- Contact the field team leader;
- Refer to the instrument's instruction book for troubleshooting procedures; and
- Contact the manufacturer and/or supplier.

If necessary, backup instruments will be obtained. However, any such decisions will be made by the Parsons ES site manager after consideration of other potential solutions. Equipment will be maintained and extra batteries and other standard replacement parts will be carried in order to avoid downtime due to minor problems.

4.2.3.3 Sampling Location Contingencies

During the field effort, certain chosen sampling locations may be inaccessible due to site conditions. When the conditions can be adjusted (e.g., unlocking a gate or moving a vehicle), the Parsons ES site manager and/or field team leader will contact the Airport Authority POC to arrange for access to the sampling location.

4.2.3.4 Monitoring and Injection Well Permit Delays

Drilling locations will be cleared for underground utilities by Parsons ES and NSA Mid-South engineering personnel prior to intrusive activities at Site N-6. NSA Mid-South will furnish copies of all existing utility drawings prior to field mobilization.

Well construction and underground injection control (UIC) permits will be obtained by Parsons ES from the Memphis and Shelby County Health Department and the TDEC Division of Water Supply. Drilling operations will not begin until these permits are approved. The well and UIC permits will be effective only for the time period indicated by the final signature authority. Reauthorization from all organizations and the technical representative shall be required for any additional time required after expiration of the original permitting period.

4.2.3.5 Project Health and Safety Plan

A site-specific Project Health and Safety Plan (Appendix A) has been prepared for field activities to be conducted at Site N-6. The Plan includes the following information:

- An index of all hazardous materials to be used at the site;
- Plan for protecting personnel and property during the transport, storage, and use of the materials;
- Procedures for spill response and disposal;
- Material Safety Data Sheets (MSDSs) for materials listed in the index of the Plan; and
- Approved labeling system to identify contents of all containers on site.

4.2.4 Waste Handling

Investigation-derived waste (IDW) will include soil from drilling, groundwater removed from monitoring and injection wells during development or purging, and water used for decontamination. Parsons ES will be responsible for containerizing and arranging for disposal of all soil and water IDW generated during the field application.

Soil IDW generated by the Rotasonic drilling method is anticipated to be minimal, and will be containerized in Department of Transportation (DOT) approved 55-gallon drums. The drums will be properly labeled according to NSA Mid-South protocol (contents, source, date generated, and date sampled); and transported to a central staging area near Building 1694 (NSA Mid-South hazardous waste facility). Soil analytical results (including soil composite samples) will be used to determine final disposal. If soil wastes are non-hazardous, then Parsons ES will arrange for disposal to a local landfill facility. If the soil wastes are characterized as hazardous wastes, then NSA Mid-South will arrange for final disposal. Approval for final disposition of soil IDW will be obtained from TDEC Division of Solid Waste.

All water collected during decontamination, development, and purging of monitoring wells will be containerized in a portable tank(s) and transported to a central staging area near Building 1694. Upon confirmation of analytical results, water will be disposed of at a waste disposal site provided by NSA Mid-South. It is anticipated that water IDW will be disposed to an onsite oil/water separator.

4.3 INITIAL SYSTEM INSTALLATION

Installation of eight (8) vegetable oil injection wells and sixteen (16) groundwater monitoring wells will be performed using Rotasonic drilling technology. Rotasonic drilling has been used successfully at NSA Mid-South and is the drilling technology of choice.

4.3.1 Injection and Groundwater Monitoring Locations

The proposed locations for the 8 injection wells and the 16 groundwater monitoring wells are shown in Figure 4.1. These locations were determined from a review of available site data as described in Section 2. The sampling and injection well locations were selected to provide the distribution of oil in the portion of the plume with the highest contaminant concentrations (i.e., greater than 1,000 µg/L TCE).

The proposed monitoring well construction and screened intervals are listed in Table 4.3. The four injection well pairs will be located 15 feet apart, across the area with the highest groundwater TCE concentration (1,160 µg/L at DPT location 7-69). The vertical layout of the injection wells is shown in Figure 4.2. It is anticipated that the radius of influence of the injected vegetable oil will be up to approximately 10 to 12 feet (horizontally).

Monitoring well pairs are located at distances of 10, 20, 30, 50 and 100 feet downgradient of the injection wells. Monitoring well locations are intended to monitor the groundwater system immediately downgradient of the injection zone over a period of 18 months, based on groundwater advective velocities ranging from 30 to 320 ft/yr (Section 2.2). One upgradient well pair (MW-1S,D) is located to monitor background groundwater geochemistry.

4.3.2 Drilling and Soil Sampling Procedures

Drilling in unconsolidated soils will be accomplished using the Rotasonic drilling method. Boreholes will be drilled and sampled to the proposed total depth for the injection or monitoring well (Table 4.3). A Parsons ES field scientist will be responsible for collecting soil samples, maintaining a detailed descriptive log of all subsurface materials recovered during drilling, and properly labeling and storing samples. During borehole advancement, soil samples for visual description will be collected at a frequency sufficient to identify the depths of significant stratigraphic contacts or other soil properties. Soil samples will be collected from drilling cores obtained by the Rotasonic drilling method. Procedures will be modified, if necessary, to ensure good sample recovery.

Soil samples will be collected in each of the boreholes at approximately 5-foot intervals from ground surface to total depth and a portion of the sample will be used to measure the total ionizable VOC concentration in soil headspace using a photoionization detector (PID). If headspace readings significantly above background readings are obtained, indicating the presence of vadose zone contamination, then the sample will be submitted to a laboratory for analysis of VOCs using the method specified in Table 4.4. Soil samples for total organic carbon (TOC) analysis also will be collected from selected drilling locations in uncontaminated or minimally contaminated areas upgradient or downgradient of the groundwater contaminant plume.

4.3.3 Injection and Groundwater Monitoring Well Installation

This section describes the procedures to be used for installation of the 8 injection and 16 groundwater monitoring wells. Newly installed wells will be constructed of 2-inch

confining unit (EnSafe, 2000b). This well has been placed on emergency standby as a precautionary measure since 1994.

Potential receptors within the fluvial deposits groundwater consist of shallow private domestic wells outside the Northside (City of Millington) property. The nearest domestic supply well screened in the fluvial deposits is approximately 6,000 feet north-northwest of the apron area and is inactive (EnSafe, 2000b).

Because contaminated groundwater at Site N-6 has the potential to migrate off the Northside property, the objective of this field application is to determine if vegetable oil injection is a viable treatment option for chlorinated solvents in groundwater at Site N-6. The downgradient property boundary is located approximately 4,000 feet northwest from the Site N-6 source area (Figure 1.1).

SECTION 3

ENHANCED BIOREMEDIATION OF CHLORINATED SOLVENTS USING VEGETABLE OIL

3.1 BIODEGRADATION OF CHLORINATED SOLVENTS

Chlorinated solvents can be transformed, directly or indirectly, by biological processes (e.g., Bouwer *et al.*, 1981; Miller and Guengerich, 1982; Reineke and Knackmuss, 1984; Wilson and Wilson, 1985; de Bont *et al.*, 1986; Nelson *et al.*, 1986; Spain and Nishino, 1987; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gossett, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; Sander *et al.*, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; Chapelle, 1993; McCarty and Semprini, 1994; Vogel, 1994; Suflita and Townsend, 1995; Bradley and Chapelle, 1996; Bradley and Chapelle, 1998; Spain, 1996). Biodegradation of chlorinated solvents, also termed chlorinated aliphatic hydrocarbons (CAHs), and chlorinated benzenes results from the same general processes that bring about biodegradation of fuel hydrocarbons. However, a more complex series of processes often is involved, as CAHs and chlorinated benzenes may act either as substrates (electron donors) or electron acceptors depending upon the prevailing geochemical conditions.

Chlorinated solvents may undergo biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated process. At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most likely.

In a pristine aquifer, native organic carbon is utilized as an electron donor and dissolved oxygen (DO) is utilized first as the prime electron acceptor. Where anthropogenic carbon (e.g., vegetable oil, fuel hydrocarbons, landfill leachate, less-chlorinated CAHs, or chlorinated benzenes with four or fewer chlorines) is present, it also may be utilized as an electron donor. Most chlorinated solvents that can act as electron donors have thus far only been demonstrated to do so under aerobic conditions, with the notable exception of vinyl chloride (VC) (Bradley and Chapelle, 1996 and 1998). After the DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, manganese oxide, ferric iron oxyhydroxide, sulfate, and finally carbon dioxide. Evaluation of the distribution of these electron acceptors can provide evidence of where and how biodegradation of chlorinated solvents is occurring.

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. This is the only biological reaction known to degrade PCE, TCE, TCA, carbon tetrachloride, and chlorinated benzenes with more than four chlorines. During reductive dehalogenation, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. Figure 3.1 illustrates the transformation of chlorinated ethenes via reductive dehalogenation. In general, reductive dehalogenation occurs by sequential dechlorination. For the chlorinated ethenes, dechlorination progresses from PCE to TCE to DCE to VC to ethene.

Likewise, for the chlorinated methanes, dechlorination progresses from carbon tetrachloride to chloroform to methylene chloride to chloromethane to methane. Depending upon environmental conditions, these dechlorination sequences may be interrupted, with other processes then acting upon the products. During reductive dehalogenation of TCE, all three isomers of DCE theoretically can be produced; however, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated solvents differently. PCE, TCE, and carbon tetrachloride are the most susceptible of these compounds to reductive dehalogenation because they are the most oxidized. Conversely, VC and chloromethane are the least susceptible to reductive dehalogenation because they are the least oxidized of these compounds. Reductive dehalogenation has been demonstrated under nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994).

Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur. Potential carbon sources include vegetable oil, fuel hydrocarbons, low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter or less-chlorinated compounds such as VC, DCE, chloroethane, or DCA. An evaluation of chlorinated ethene groundwater data suggests that the natural biodegradation of chlorinated ethenes at Site N-6 is electron-donor limited. Innocuous, food-grade vegetable oil will be used to remediate the solvent plume at Site N-6 by overcoming the observed electron donor limitation.

The most common approach utilized to date to stimulate reductive dehalogenation has been addition of a carbon source dissolved in groundwater. This approach may prove effective in some applications, but in many cases may have difficulty competing with pump-and-treat remedial systems because the carbon source must be continuously injected. Other approaches involving the emplacement of solid materials that release carbon are promising, but the cost of the solid carbon addition will be high. The separate phase nature of vegetable oil allows for slow dissolution into groundwater, thus making it a slow-release carbon source. Thus, the carbon substrate will only be injected one time, which will significantly reduce overall costs. Vegetable oil is an inexpensive, innocuous, food-or feed-grade carbon source that is not regulated as a contaminant by the USEPA. Because vegetable oil is a non-aqueous phase liquid (NAPL), the potential exists that a

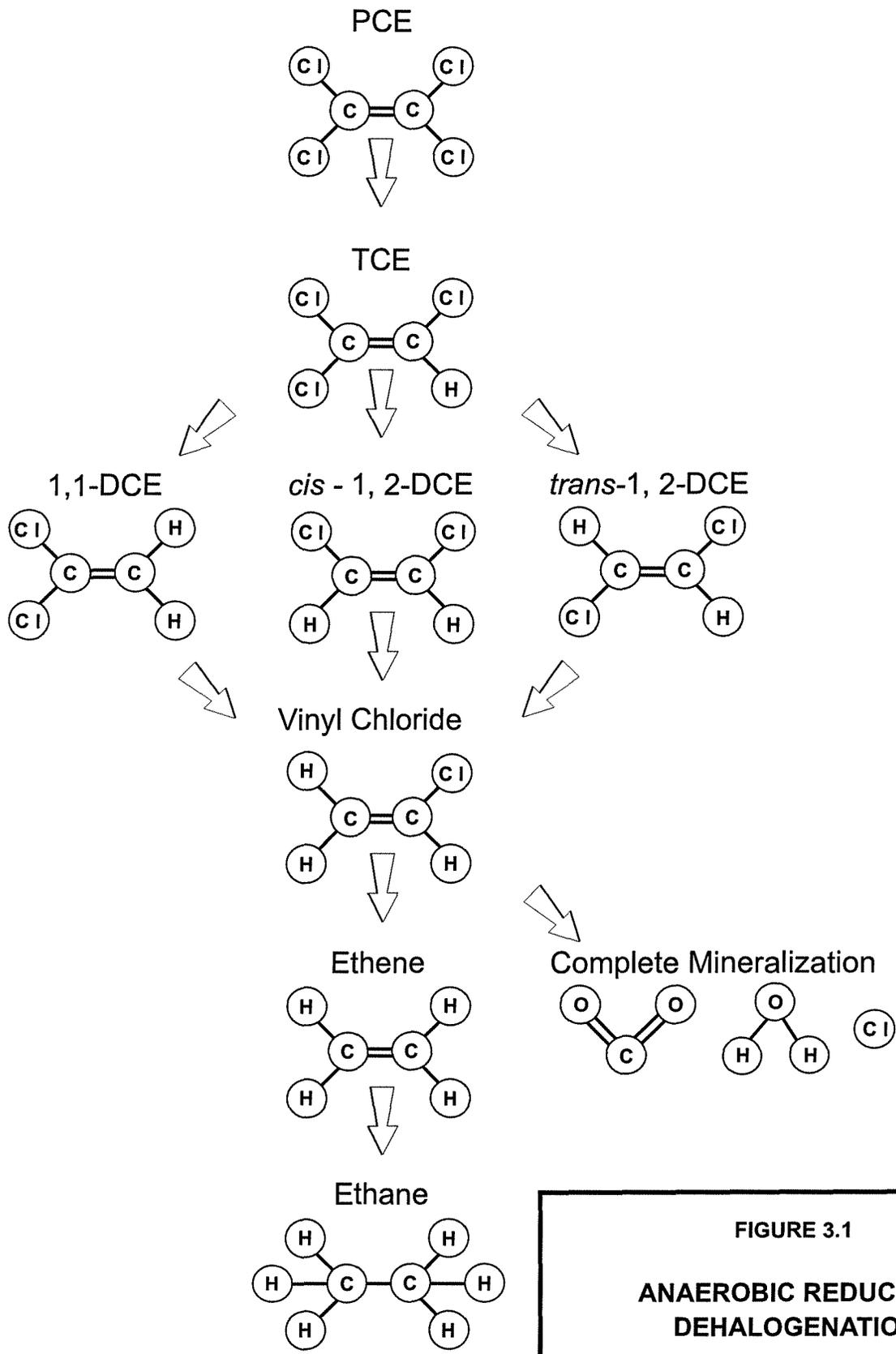


FIGURE 3.1

**ANAEROBIC REDUCTIVE
DEHALOGENATION**

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

single, low-cost injection could provide sufficient carbon to drive reductive dechlorination for many years.

Vegetable oil will be injected to create the reduction-oxidation (redox) and electron donor conditions necessary to promote the microbial reductive dehalogenation of the chlorinated solvents found as Site N-6. A secondary benefit is partitioning of the dissolved chlorinated solvents into the vegetable oil NAPL. This is beneficial because aqueous-phase chlorinated solvent concentrations will be lowered until steady-state (equilibrium) conditions are reached.

3.2 BIODEGRADATION AT SITE N-6

Compounds detected at the N-6 site assumed to be parent compounds include PCE, TCE, and carbon tetrachloride. 1,1,1-TCA was not detected in groundwater at the site, but also is considered a parent compound that may be present in source area soils. Degradation daughter products detected in groundwater at the site that are not considered to have been released but are a product of biodegradation include 1,2-DCE, 1,1-DCE, 1,1-DCA, 1,2-DCA, and chloroform.

The presence of 1,2-DCE suggests reductive dehalogenation of TCE under reducing conditions. However, the concentrations of 1,2-DCE generally are an order of magnitude less than TCE, and the extent of 1,2-DCE is limited to the immediate source area (i.e., wells 007G15UF and 007G15LF, and DPT location 7-69 [Table 2.1]). This suggests that the reducing conditions necessary for TCE degradation are very limited. A lack of VC indicates that further degradation of DCE is not occurring at Site N-6.

1,1-DCE also may be a degradation product of TCE, but more likely the higher concentrations and extent of 1,1-DCE (relative to 1,2-DCE) is a result of degradation of 1,1,1-TCA by hydrolysis. Low levels of DCA are present at the site, indicating that limited degradation of 1,1,1-TCA under reducing conditions also may occur.

With a single exception (DPT sample 7-35), chloroform was detected along with carbon tetrachloride in groundwater samples. This suggests that degradation of carbon tetrachloride is occurring throughout the plume. Concentrations of carbon tetrachloride at well locations 007G15UF and 007G15LF have consistently declined from March 1996 to November 1997 (Table 2.1).

In summary, the limited occurrence of daughter products at Site N-6 suggests that under sufficiently reducing conditions, degradation of chlorinated solvents can occur. The presence of low levels of benzene and TPH-DRO (Section 2.3.2) indicate that a source of organic substrate may have been present at one time in sufficient quantities to induce limited reductive dehalogenation of the chlorinated compounds. However, there currently is not sufficient organic substrate (electron donor) present to cause significant loss (degradation) of contaminant mass at the site.

SECTION 4

SYSTEM INSTALLATION AND ADDITIONAL DATA COLLECTION

4.1 FIELD APPLICATION ACTIVITIES

Field activities at Site N-6 include the initial system installation, baseline sampling, vegetable oil injection, and groundwater monitoring. Subsequent system monitoring will be performed at two (2), six (6), 12, and 18 months after injection. Site-specific activities for the initial field event are summarized in Table 4.1, and will include:

- Installation of eight (8) vegetable oil injection wells and sixteen (16) groundwater monitoring wells using Rotasonic drilling technology;
- Background (i.e., pre-injection) sampling of groundwater at the newly installed monitoring wells and existing monitoring wells 007G15UF (shallow) and 007G15LF (deep), in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998);
- Pre-injection aquifer testing (hydraulic conductivity) of four injection wells and four monitoring wells;
- Plumbing of the injection wells and injection of up to 10,000 gallons of food-grade vegetable oil;
- Injection of bromide (aqueous phase) for determining zones of influence;
- Post-injection aquifer testing (hydraulic conductivity) of the previously-tested four injection wells; and
- Surveying of the newly installed injection and monitoring wells.

System monitoring activities are summarized in Table 4.2, and involve post-injection sampling of groundwater and vegetable oil (if present) at the newly installed monitoring and injection wells and existing monitoring wells 007G15UF (shallow) and 007G15LF (deep), in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998) at two (2), six (6), 12, and 18 months after injection.

TABLE 4.1
SUMMARY OF PROPOSED INITIAL SITE ACTIVITIES
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

Location	Monitoring Well Installation	Slug Test Analysis	Water Level Measurement	Soil Analyses		Oil Analyses	Groundwater Analyses							
				VOCs ^{a/} SW8260B	Total Organic Carbon (SW9060)	VOCs SW8260B	VOCs SW8260B	Methane, Ethane, Ethene	Nitrate + Nitrite (E300.1)	Bromide (E320.1)	Total Organic Carbon (SW9060M)	Well Head Analyses ^{b/}	Mobile Lab Analyses ^{c/}	
Monitoring Wells														
PES-MW-1D	X	X	X		1		1	1	1			1	1	
PES-MW-1S	X	X	X		1		1	1	1			1	1	
PES-MW-2D	X		X				1	1	1		1	1	1	
PES-MW-2S	X		X				1	1	1		1	1	1	
PES-MW-3D	X		X				1	1	1		1	1	1	
PES-MW-3S	X		X				1	1	1		1	1	1	
PES-MW-4D	X		X				1	1	1		1	1	1	
PES-MW-4S	X		X				1	1	1		1	1	1	
PES-MW-5D	X		X				1	1	1		1	1	1	
PES-MW-5S	X		X				1	1	1		1	1	1	
PES-MW-6D	X		X				1	1	1		1	1	1	
PES-MW-6S	X		X				1	1	1		1	1	1	
PES-MW-7D	X		X				1	1	1		1	1	1	
PES-MW-7S	X		X				1	1	1		1	1	1	
PES-MW-8D	X	X	X		1		1	1	1		1	1	1	
PES-MW-8S	X	X	X		1		1	1	1		1	1	1	
007GL15UF			X				1	1	1			1	1	
007GL15LF			X				1	1	1			1	1	
Injection Wells														
PES-INJ-1D	X		X		2		1	1	1		1	1	1	
PES-INJ-1S	X		X				1	1	1		1	1	1	
PES-INJ-2D	X	2X	X		2		1	1	1		1	1	1	
PES-INJ-2S	X	2X	X				1	1	1		1	1	1	
PES-INJ-3D	X	2X	X		2		1	1	1		1	1	1	
PES-INJ-3S	X	2X	X				1	1	1		1	1	1	
PES-INJ-4D	X		X		2		1	1	1		1	1	1	
PES-INJ-4S	X		X				1	1	1		1	1	1	
SUBTOTALS		12			8	4	4	26	26	26	10	22	26	26
QA/QC														
Duplicates					1		1	3	3	3	1	3		3
MS/MSD					1		1	2						
Trip Blanks								3						
Rinseates								1						
TASK TOTAL:					10	4	6	35	29	29	11	25	26	29

^{a/} VOCs to include aromatic and chlorinated aliphatic hydrocarbons.
^{b/} Well head analyses include dissolved oxygen, oxidation-reduction potential, pH, temperature, and conductivity.
^{c/} Mobile lab analyses include chloride, carbon dioxide, alkalinity, ammonia, sulfate, ferrous iron, sulfate, hydrogen sulfide, and manganese.

TABLE 4.2
SUMMARY OF PROPOSED MONITORING ACTIVITIES
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

Location	Water Level Measurement	Oil Analyses	Groundwater Analyses						
		VOCs ^{a/} SW8260B	VOCs SW8260B	Methane, Ethane, Ethene	Nitrate + Nitrite (E300.1)	Bromide (E320.1)	Total Organic Carbon (SW9060M)	Well Head Analyses ^{b/}	Mobile Lab Analyses ^{c/}
Monitoring Wells									
PES-MW-1D	X		1	1	1			1	1
PES-MW-1S	X		1	1	1			1	1
PES-MW-2D	X		1	1	1	1	1	1	1
PES-MW-2S	X		1	1	1	1	1	1	1
PES-MW-3D	X		1	1	1	1	1	1	1
PES-MW-3S	X		1	1	1	1	1	1	1
PES-MW-4D	X		1	1	1	1	1	1	1
PES-MW-4S	X		1	1	1	1	1	1	1
PES-MW-5D	X		1	1	1	1	1	1	1
PES-MW-5S	X		1	1	1	1	1	1	1
PES-MW-6D	X		1	1	1	1	1	1	1
PES-MW-6S	X		1	1	1	1	1	1	1
PES-MW-7D	X		1	1	1	1	1	1	1
PES-MW-7S	X		1	1	1	1	1	1	1
PES-MW-8D	X		1	1	1	1	1	1	1
PES-MW-8S	X		1	1	1	1	1	1	1
007GL15UF	X		1	1	1			1	1
007GL15LF	X		1	1	1			1	1
Injection Wells									
PES-INJ-1D	X		1	1	1	1	1	1	1
PES-INJ-1S	X		1	1	1	1	1	1	1
PES-INJ-2D	X	2	1	1	1	1	1	1	1
PES-INJ-2S	X	2	1	1	1	1	1	1	1
PES-INJ-3D	X	2	1	1	1	1	1	1	1
PES-INJ-3S	X	2	1	1	1	1	1	1	1
PES-INJ-4D	X		1	1	1	1	1	1	1
PES-INJ-4S	X		1	1	1	1	1	1	1
SUBTOTALS		8	26	26	26	22	22	26	26
QA/QC									
Duplicates		1	3	3	3	3	3		3
MS/MSD		1	2						
Trip Blanks			2						
Rinseates			1						
SUBTOTAL PER EVENT:		10	34	29	29	25	25	26	29
TASK TOTAL:		10	136	116	116	100	100	104	116

^{a/} VOCs to include aromatic and chlorinated aliphatic hydrocarbons.

^{b/} Well head analyses include dissolved oxygen, oxidation-reduction potential, pH, temperature, and conductivity.

^{c/} Mobile lab analyses include chloride, carbon dioxide, alkalinity, sulfate, ferrous iron, hydrogen sulfide, and manganese.

4.2 SITE MANAGEMENT

The following paragraphs outline site management issues pertaining to the field activities to be conducted at Site N-6, including NSA Mid-South and City of Millington Municipal Airport Authority support.

4.2.1 NSA Mid-South Support

NSA Mid-South will provide the following support during field activities:

- **Assign Accumulation Points.** Any purge fluids and decontamination rinsate or excavated soils generated during site work that are suspected of being hazardous will be properly contained. The NSA Mid-South point of contact (POC) will specify the location for the storage of containerized waste. Waste handling procedures are outlined in Section 4.2.4.
- **Underground Utility Clearances.** Before any work, each proposed intrusive sampling location at Site N-6 will be checked for underground utilities by Parsons ES and NSA Mid-South engineering personnel. The NSA Mid-South POC will provide utility drawings to Parsons ES. A copy of all utility maps will be kept at the site where drilling work will be conducted.

4.2.2 City of Millington Municipal Airport Authority Support

The City of Millington Municipal Airport Authority will provide the following support during field activities:

- **Provide Site Access to Field Team Members.** The Airport Authority POC will ensure daily access to the site. Parsons ES will be responsible for keeping secured access areas locked at all times.
- **Badge and Vehicle Passes.** The issue of personnel badges and vehicle passes will not be necessary for this site.
- **Provide Scheduling Information.** The Airport Authority POC will notify Parsons ES of any airfield activities that may adversely affect field activities and/or impact the sampling schedule.

4.2.3 Contingency Plans

This subsection describes steps that will be taken by Parsons ES to minimize delays during the investigations. Potential problems that could be encountered during the field effort include:

- Access and coordination difficulties;
- Equipment breakdowns;
- Conflicts with planned sampling locations;

- Abnormal site conditions (e.g., severe weather, unexpected airfield operations); and/or
- Monitoring or injection well permit delays.

4.2.3.1 Access and Coordination Contingencies

Anticipated support needs are outlined in Sections 4.2.1 and 4.2.2. In the event that site access difficulties arise, the Airport Authority and NSA Mid-South POCs will be contacted to resolve the problem. The Parsons ES site manager and field team leader will be responsible for notifying the Airport Authority and NSA Mid-South POCs of access or coordination difficulties.

4.2.3.2 Equipment Contingencies

In the event of operation problems with field equipment or testing instruments, the following actions will be taken:

- Contact the field team leader;
- Refer to the instrument's instruction book for troubleshooting procedures; and
- Contact the manufacturer and/or supplier.

If necessary, backup instruments will be obtained. However, any such decisions will be made by the Parsons ES site manager after consideration of other potential solutions. Equipment will be maintained and extra batteries and other standard replacement parts will be carried in order to avoid downtime due to minor problems.

4.2.3.3 Sampling Location Contingencies

During the field effort, certain chosen sampling locations may be inaccessible due to site conditions. When the conditions can be adjusted (e.g., unlocking a gate or moving a vehicle), the Parsons ES site manager and/or field team leader will contact the Airport Authority POC to arrange for access to the sampling location.

4.2.3.4 Monitoring and Injection Well Permit Delays

Drilling locations will be cleared for underground utilities by Parsons ES and NSA Mid-South engineering personnel prior to intrusive activities at Site N-6. NSA Mid-South will furnish copies of all existing utility drawings prior to field mobilization.

Well construction and underground injection control (UIC) permits will be obtained by Parsons ES from the Memphis and Shelby County Health Department and the TDEC Division of Water Supply. Drilling operations will not begin until these permits are approved. The well and UIC permits will be effective only for the time period indicated by the final signature authority. Reauthorization from all organizations and the technical representative shall be required for any additional time required after expiration of the original permitting period.

4.2.3.5 Project Health and Safety Plan

A site-specific Project Health and Safety Plan (Appendix A) has been prepared for field activities to be conducted at Site N-6. The Plan includes the following information:

- An index of all hazardous materials to be used at the site;
- Plan for protecting personnel and property during the transport, storage, and use of the materials;
- Procedures for spill response and disposal;
- Material Safety Data Sheets (MSDSs) for materials listed in the index of the Plan; and
- Approved labeling system to identify contents of all containers on site.

4.2.4 Waste Handling

Investigation-derived waste (IDW) will include soil from drilling, groundwater removed from monitoring and injection wells during development or purging, and water used for decontamination. Parsons ES will be responsible for containerizing and arranging for disposal of all soil and water IDW generated during the field application.

Soil IDW generated by the Rotasonic drilling method is anticipated to be minimal, and will be containerized in Department of Transportation (DOT) approved 55-gallon drums. The drums will be properly labeled according to NSA Mid-South protocol (contents, source, date generated, and date sampled); and transported to a central staging area near Building 1694 (NSA Mid-South hazardous waste facility). Soil analytical results (including soil composite samples) will be used to determine final disposal. If soil wastes are non-hazardous, then Parsons ES will arrange for disposal to a local landfill facility. If the soil wastes are characterized as hazardous wastes, then NSA Mid-South will arrange for final disposal. Approval for final disposition of soil IDW will be obtained from TDEC Division of Solid Waste.

All water collected during decontamination, development, and purging of monitoring wells will be containerized in a portable tank(s) and transported to a central staging area near Building 1694. Upon confirmation of analytical results, water will be disposed of at a waste disposal site provided by NSA Mid-South. It is anticipated that water IDW will be disposed to an onsite oil/water separator.

4.3 INITIAL SYSTEM INSTALLATION

Installation of eight (8) vegetable oil injection wells and sixteen (16) groundwater monitoring wells will be performed using Rotasonic drilling technology. Rotasonic drilling has been used successfully at NSA Mid-South and is the drilling technology of choice.

4.3.1 Injection and Groundwater Monitoring Locations

The proposed locations for the 8 injection wells and the 16 groundwater monitoring wells are shown in Figure 4.1. These locations were determined from a review of available site data as described in Section 2. The sampling and injection well locations were selected to provide the distribution of oil in the portion of the plume with the highest contaminant concentrations (i.e., greater than 1,000 µg/L TCE).

The proposed monitoring well construction and screened intervals are listed in Table 4.3. The four injection well pairs will be located 15 feet apart, across the area with the highest groundwater TCE concentration (1,160 µg/L at DPT location 7-69). The vertical layout of the injection wells is shown in Figure 4.2. It is anticipated that the radius of influence of the injected vegetable oil will be up to approximately 10 to 12 feet (horizontally).

Monitoring well pairs are located at distances of 10, 20, 30, 50 and 100 feet downgradient of the injection wells. Monitoring well locations are intended to monitor the groundwater system immediately downgradient of the injection zone over a period of 18 months, based on groundwater advective velocities ranging from 30 to 320 ft/yr (Section 2.2). One upgradient well pair (MW-1S,D) is located to monitor background groundwater geochemistry.

4.3.2 Drilling and Soil Sampling Procedures

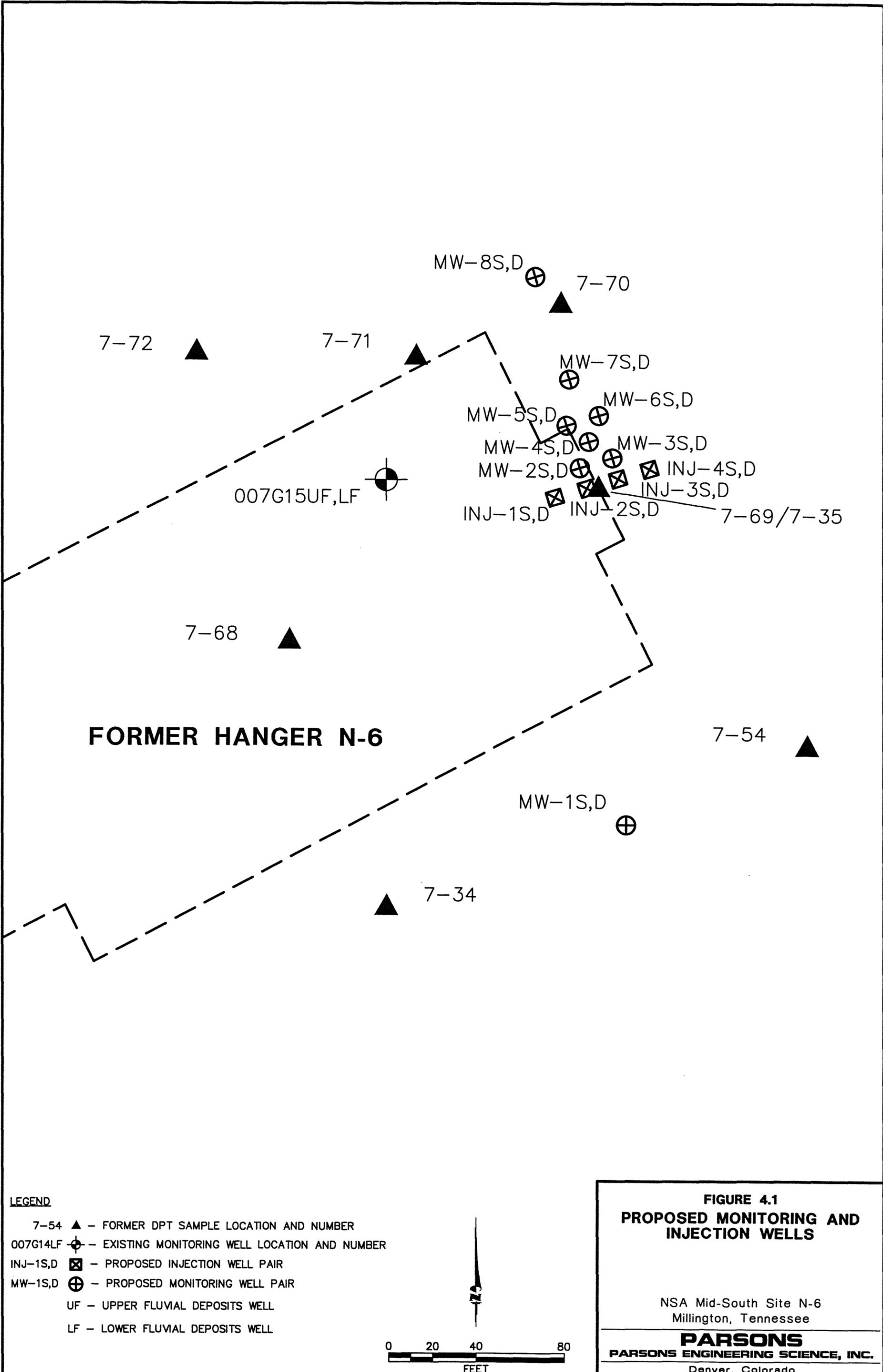
Drilling in unconsolidated soils will be accomplished using the Rotasonic drilling method. Boreholes will be drilled and sampled to the proposed total depth for the injection or monitoring well (Table 4.3). A Parsons ES field scientist will be responsible for collecting soil samples, maintaining a detailed descriptive log of all subsurface materials recovered during drilling, and properly labeling and storing samples. During borehole advancement, soil samples for visual description will be collected at a frequency sufficient to identify the depths of significant stratigraphic contacts or other soil properties. Soil samples will be collected from drilling cores obtained by the Rotasonic drilling method. Procedures will be modified, if necessary, to ensure good sample recovery.

Soil samples will be collected in each of the boreholes at approximately 5-foot intervals from ground surface to total depth and a portion of the sample will be used to measure the total ionizable VOC concentration in soil headspace using a photoionization detector (PID). If headspace readings significantly above background readings are obtained, indicating the presence of vadose zone contamination, then the sample will be submitted to a laboratory for analysis of VOCs using the method specified in Table 4.4. Soil samples for total organic carbon (TOC) analysis also will be collected from selected drilling locations in uncontaminated or minimally contaminated areas upgradient or downgradient of the groundwater contaminant plume.

4.3.3 Injection and Groundwater Monitoring Well Installation

This section describes the procedures to be used for installation of the 8 injection and 16 groundwater monitoring wells. Newly installed wells will be constructed of 2-inch

S:\ES\Remed\737490\02000\WORKPLAN\00DN0174.dwg, 06/27/00 at 11:30



LEGEND

- 7-54 ▲ - FORMER DPT SAMPLE LOCATION AND NUMBER
- 007G14LF ⊕ - EXISTING MONITORING WELL LOCATION AND NUMBER
- INJ-1S,D ⊠ - PROPOSED INJECTION WELL PAIR
- MW-1S,D ⊕ - PROPOSED MONITORING WELL PAIR
- UF - UPPER FLUVIAL DEPOSITS WELL
- LF - LOWER FLUVIAL DEPOSITS WELL

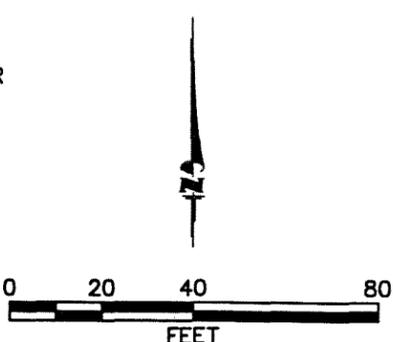


FIGURE 4.1
PROPOSED MONITORING AND INJECTION WELLS

NSA Mid-South Site N-6
 Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

TABLE 4.3
PROPOSED MONITORING WELL CONSTRUCTION SUMMARY
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

Identification	Well Diameter (inches)	Total Depth (feet bgs) ^{b/}	Screened Interval (feet bgs)	Feet of Riser (feet)	Feet of Screen (feet)	Interval
Injection Wells by Rotasonic Drilling						
PES-INJ-1D	2.0	85	75-85	75	10	Lower-Fluvial
PES-INJ-1S	2.0		55-65	55	10	Mid-Fuvial
PES-INJ-2D	2.0	75	65-75	65	10	Mid-Fluvial
PES-INJ-2S	2.0		45-55	45	10	Upper-Fuvial
PES-INJ-3D	2.0	85	75-85	75	10	Lower-Fluvial
PES-INJ-3S	2.0		55-65	55	10	Mid-Fuvial
PES-INJ-4D	2.0	75	65-75	65	10	Mid-Fluvial
PES-INJ-4S	2.0		45-55	45	10	Upper-Fuvial
Monitoring Wells by Rotasonic Drilling						
PES-MW-1D	2.0	80	70-80	70	10	Mid-Fluvial
PES-MW-1S	2.0		45-55	45	10	Mid-Fuvial
PES-MW-2D	2.0	85	75-85	75	10	Lower-Fluvial
PES-MW-2S	2.0		55-65	55	10	Mid-Fuvial
PES-MW-3D	2.0	75	65-75	65	10	Mid-Fluvial
PES-MW-3S	2.0		45-55	45	10	Upper-Fuvial
PES-MW-4D	2.0	85	75-85	75	10	Lower-Fluvial
PES-MW-4S	2.0		55-65	55	10	Mid-Fuvial
PES-MW-5D	2.0	75	65-75	65	10	Mid-Fluvial
PES-MW-5S	2.0		45-55	45	10	Upper-Fuvial
PES-MW-6D	2.0	85	75-85	75	10	Lower-Fluvial
PES-MW-6S	2.0		55-65	55	10	Mid-Fuvial
PES-MW-7D	2.0	75	65-75	65	10	Mid-Fluvial
PES-MW-7S	2.0		45-55	45	10	Upper-Fuvial
PES-MW-8D	2.0	85	75-85	75	10	Lower-Fluvial
PES-MW-8S	2.0		55-65	55	10	Mid-Fuvial

^{a/} feet bgs indicates depth in feet below ground surface.

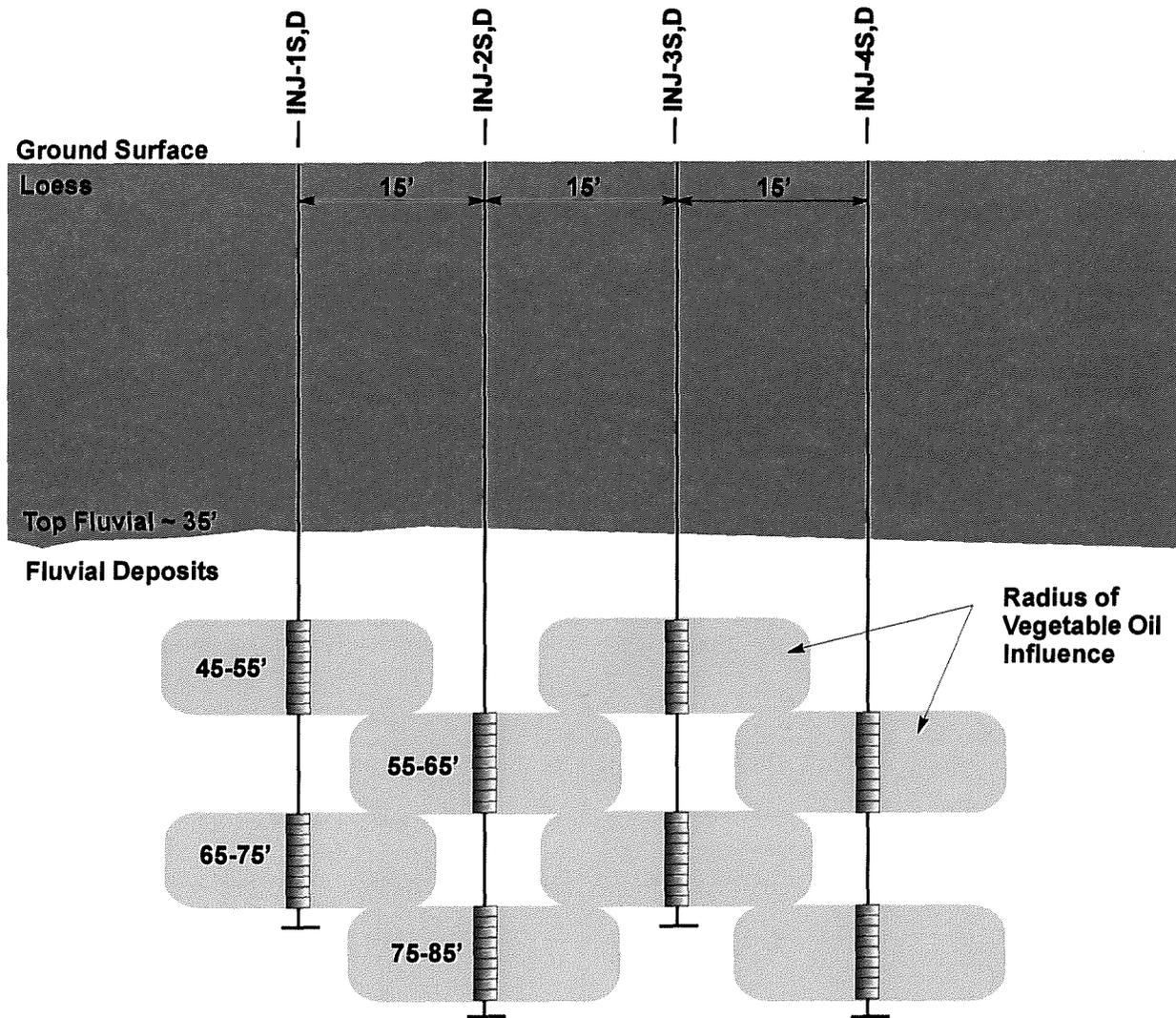


FIGURE 4.2

INJECTION WELL
LAYOUT

NSA Mid-South Site N-6
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

inside-diameter (ID) polyvinyl chloride (PVC) casing installed with the Rotasonic drilling rig equipment.

4.3.3.1 Pre-Installation Activities

All necessary monitoring and injection well permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 4.2.

Water to be used in well installation and equipment cleaning will be obtained from an onsite water supply. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

4.3.3.2 Materials Decontamination

All completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, end caps, and surface plugs will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

4.3.2.3 Screen and Casing

Injection and monitoring wells will be installed through the drill rig drive casing using 2-inch-diameter PVC casing and screen. Injection and monitoring well screens will be constructed of 10 feet of flush-threaded, Schedule 40 PVC with an ID of 2.0 inch. The screens will be factory slotted with 0.020-inch openings. Screens will be installed beneath the water table at the intervals listed on Table 4.3.

Blank casing will be constructed of Schedule 40 PVC with an ID of 2.0 inch. All casing sections will be flush-threaded; joints will not be glued. The casing at each well will be fitted with a PVC bottom cap and a locking top cap.

The field scientist will verify and record the total depth of the injection wells and monitoring wells, the lengths of all casing sections, and the depth to the top of all completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

4.3.3.4 Injection and Monitoring Well Completion

Two injection or monitoring wells with different screened intervals will be installed in each borehole. A graded sand filter pack will be installed around the lower screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand. A filter pack seal will be installed above the filter pack using sodium bentonite pellets. The pellet seal will be a minimum of 2 feet thick and will be hydrated in place with potable water. The pellet seal will be overlain by a bentonite grout that will extend from the top of the pellet seal to approximately 2 feet below the upper screened interval. A sand filter pack will be installed from approximately 2 feet below to 2 feet above the upper screened interval. A bentonite pellet seal will be set above the

upper screened interval sand pack as described above, and grout will be placed to within 3 feet of ground surface. The grout will be overlain by concrete that will extend to the ground surface. Each injection and groundwater monitoring well casing will be completed slightly below-grade, with an at-grade flush-mounted protective casing to protect the wells.

4.3.3.5 Injection and Monitoring Well Development

The injection wells and groundwater monitoring wells will be developed prior to sampling. Development removes sediment from inside the well casing and flushes fines from the portion of the formation adjacent to the screen. Development will be accomplished using a submersible pump provided by Parsons ES. The pump will be regularly lowered to the bottom of the well while development is underway so that fines which have accumulated in the bottom are agitated and removed from the well.

Development will be continued until a minimum 10 casing volumes of water have been removed from the well and until pH, temperature, specific conductance, DO, and water clarity (turbidity) stabilize. If the water remains turbid, development will continue until the turbidity of the water produced has been stable after the removal of several additional casing volumes.

Development water will be collected in portable poly-tanks provided by Parsons ES. The tanks will be staged to a designated hazardous-waste collection area. A development record will be maintained for each injection and monitoring well. The development record will be completed in the field by the field scientist. Development records will include:

- Injection or groundwater monitoring well number;
- Date and time of development;
- Development method;
- Predevelopment water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post development water level and well depth; and
- Field analytical measurements, including pH and specific conductance.

4.3.3.6 Equipment Decontamination Procedures

Prior to arriving at the site, and between each monitoring and injection well site, drill bits, drill pipe, drill casing, instrumented probes, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinsate will be collected in portable tanks or 55-gallon drums.

Potable water to be used in equipment cleaning, decontamination, or grouting will be obtained from an onsite water supply. Use of the onsite water supply will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

4.3.3.7 Datum Survey

The locations and elevations of the newly installed injection and groundwater monitoring wells will be surveyed by a registered surveyor. Horizontal locations will be measured relative to established NSA Mid-South coordinates. Horizontal coordinates will be measured in Tennessee State Plane Coordinates to the nearest 0.1 foot. The elevation of the ground surface adjacent to the well casing and the measurement datum (top of the casing) will be measured relative to an existing benchmark location. Vertical elevations will be measured with respect to the National Vertical Datum (NAVD) of 1998 to the nearest 0.01 foot.

4.4 MEASUREMENT OF BASELINE GEOCHEMICAL CONDITIONS AND CONTAMINANT PROFILES

After installation of the injection and groundwater monitoring wells, Parsons ES will characterize initial (baseline) site-specific geochemical and contaminant conditions in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998). Parsons ES shall evaluate geochemical, metabolic byproduct, and contaminant breakdown product data to evaluate the potential for existing reductive dehalogenation, future enhanced reductive dehalogenation, and any expected changes in the above profile as a result of substrate addition.

Groundwater samples collected from the monitoring locations will be analyzed for oxidation-reduction potential (ORP), DO, pH, specific conductance, temperature, ferrous iron, manganese, hydrogen sulfide, sulfate, alkalinity, carbon dioxide, nitrate + nitrite (as nitrogen [N]), chloride, methane, ethane, ethene, total organic carbon (TOC), and VOCs (Table 4.4).

4.4.1 Groundwater Sampling

Collection of groundwater quality samples will be conducted by qualified scientists and technicians from Parsons ES who are trained in the performance of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample collection and will have a copy of the work plan available onsite for reference. Groundwater samples will be collected from previously installed monitoring wells 007G15UF and 007G15LF and from all newly installed injection and groundwater monitoring wells. Locations to be sampled are shown on Figure 4.1. Prior to sampling, the injection and monitoring wells will be developed as described in Section 4.3.2.5. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the following sections will be followed.

TABLE 4.4
ANALYTICAL PROTOCOLS FOR
GROUNDWATER SAMPLES
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

MATRIX Analyte	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Redox Potential	Direct-reading meter	F
Dissolved Oxygen	Direct-reading meter	F
pH	Direct-reading meter	F
Specific Conductance	Direct-reading meter	F
Temperature	Direct-reading meter	F
Ferrous Iron	Colorimetric, Hach Method 8146 (or similar)	F
Manganese	Colorimetric, Hach Method 8034 (or similar)	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131 (or similar)	F
Sulfate	Colorimetric, Hach Method 8051 (or similar)	F
Alkalinity (Carbonate [CO ₃ ⁻²] and Bicarbonate [HCO ₃ ⁻¹])	Titrimetric, Hach Method 8221 (or similar)	F
Chloride	Titrimetric, Hach Kit 8P (or similar)	F
Carbon Dioxide	Titrimetric, CHEMetrics Method 4500 (or similar)	F
Nitrate + Nitrite [as Nitrogen (N)]	E300.1	L
Bromide	E320.1	L
Methane, Ethane, Ethene	RSKSOP-175mod ^{a/} or ASTM 3810	L
Total Organic Carbon	SW9060	L
VOCs ^{b/}	SW8260B	L
SOIL		
Total Organic Carbon	SW9060 modified	L
VOCs	SW8260B	L
VEGETABLE OIL		
VOCs	SW8260B	L

^{a/} RSKSOP = Robert S. Kerr Laboratory standard operating procedure.

^{b/} VOCs = volatile organic compounds.

4.4.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to mobilizing to the field.

4.4.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the water-level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (Alconox®);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use (to the extent practical).

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record.

Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the laboratory's permanent record of the sampling event.

4.4.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, pH, specific conductance, ORP, sulfate, ferrous iron, and other field parameters listed in Table 4.4.

4.4.3 Groundwater Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The primary way in which sample contamination can occur is through cross-contamination due to insufficient cleaning of equipment between wells. To prevent such contamination, the water-level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 4.4.2.1. A submersible pump and/or disposable bailers will be used for purging and sampling each groundwater sampling location.

A clean pair of new, disposable nitrile or latex gloves will be worn each time a different monitoring location is sampled. The following paragraphs present the

procedures to be followed for groundwater sample collection. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the sampler's field notebook and on the groundwater sampling form.

4.4.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing and new monitoring wells will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring location. In addition, the sampling location will be inspected for the integrity of the protective cover, lock, external surface seal, concrete pad, cap, datum reference, and internal surface seal.

4.4.3.2 Water Level and Total Depth Measurements

Prior to removing any water from the sampling well, the static water level will be measured. An electric water-level probe (or oil/water interface probe) will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water-level probe will be slowly lowered to the bottom of the well if the well depth is not known, and the depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the monitoring well will be calculated. Otherwise, previously recorded well depths will be used to calculate purge volumes.

4.4.3.3 Purging Before Sampling

The volume of water contained within the monitoring well casing at the time of sampling will be calculated, and a minimum of three times the calculated volume will be removed from the monitoring well. Purge waters will be handled in accordance with the procedures outlined in Section 4.2.3.

4.4.3.4 Sample Extraction

A submersible pump or disposable bailer will be used to extract groundwater samples from the injection and monitoring wells. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be handled according to the procedures outlined in Section 4.2.3.

If a monitoring well is evacuated to a dry state during purging, the monitoring well will be allowed to recharge, and the sample will be collected as soon as sufficient water is present to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

4.4.4 Onsite Groundwater Parameter Measurement

As indicated on Table 4.4, many of the groundwater chemical parameters will be measured onsite by Parsons ES personnel. Some of the measurements will be made with direct-reading meters, while others will be made using a Hach® or CHEMetrics® portable colorimeter or titration kit in accordance with manufacturer-specified procedures. These procedures are described in the following subsections.

Samples will be collected after stable conditions have been obtained. Stability will be determined between successive purge volumes equal to one calculated saturated casing volume. Stability is obtained when the temperature, specific conductance, and pH fall within the following acceptable ranges: ± 0.2 degrees Celsius ($^{\circ}\text{C}$), ± 100 microsiemens per centimeter ($\mu\text{s}/\text{cm}$), and ± 0.2 pH units, respectively.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox® and water, and rinsing with distilled water and isopropyl alcohol to prevent interference or cross contamination between measurements. If concentrations of an analyte are greater than the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinsate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer to the approved disposal facility.

4.4.4.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a sensor in a flow-through cell or a downhole oxygen sensor. Multiple measurements will be taken before groundwater sample acquisition during well purging, with the final measurement made immediately prior to completion of the well purge. When DO measurements are taken in monitoring wells that have not yet been sampled, the existing monitoring wells will be purged until DO levels stabilize. DO measurements will be recorded on the groundwater sampling record.

4.4.4.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in a flow-through cell during the purging process as described for DO in Section 4.4.4.1. The measured values will be recorded in the groundwater sampling record.

4.4.4.3 Carbon Dioxide Measurements

Carbon dioxide is a byproduct of biological reactions and can be used to evaluate the bioactivity of the groundwater system. Carbon dioxide concentrations in groundwater will be measured in the field by experienced Parsons ES scientists via titrimetric analysis using CHEMetrics® Method 4500 [0 to 250 mg/L], or equivalent.

4.4.4.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced Parsons ES scientists via titrimetric analysis using USEPA-approved Hach® Method 8221 (0 to 5,000 mg/L as calcium carbonate), or equivalent.

4.4.4.5 Nitrate + Nitrite (as Nitrogen) Measurements

Nitrate + nitrite (as N) concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate is also a potential nitrogen source for hydrocarbon-degrading bacteria biomass formation. Nitrite is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate + nitrite (as N) concentrations in groundwater will be measured in the laboratory (Table 4.4). In addition, nitrate and nitrite may be measured in the field by experienced Parsons ES scientists via colorimetric analysis using a Hach® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with Hach® Method 8039 (0 to 30.0 mg/L nitrate), or equivalent. Nitrite concentrations in groundwater samples will be analyzed after preparation with USEPA-approved Hach® Method 8507 (0 to 0.35 mg/L nitrite), or equivalent.

4.4.4.6 Sulfate and Hydrogen Sulfide Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is produced during sulfate reduction. Sulfate will be measured in the laboratory (Table 4.4), or Parsons ES scientists may measure sulfate and hydrogen sulfide concentrations via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. USEPA-approved Hach® Methods 8051 (0 to 70.0 mg/L sulfate) and 8131 (0.60 mg/L hydrogen sulfide) or equivalent will be used to prepare samples and analyze sulfate and hydrogen sulfide concentrations, respectively.

4.4.4.7 Ferrous Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the ORP of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Ferrous iron concentrations will be measured in the field via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. Hach® Method 8146, or equivalent, for ferrous iron (0 to 3.0 mg/L) will be used to prepare and quantitate the samples.

4.4.4.8 Manganese Measurements

Manganese is a potential electron acceptor in anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a Hach® DR/700 Portable Colorimeter. USEPA-approved Hach® Method 8034 (0 to 20.0 mg/L),

or equivalent, will be used to prepare the samples for quantitation of manganese concentrations.

4.4.4.9 Oxidation/Reduction Potential

The ORP of groundwater is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. ORPs can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The ORP of a groundwater sample taken inside the contaminant plume should be somewhat lower than that of a sample taken in an upgradient location.

The ORP of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. Therefore, this parameter will be measured in a flow-through cell as described for DO in Section 4.4.4.1.

4.4.5 Handling of Samples for Laboratory Analysis

This section describes the handling of samples from the time of sampling until the samples are delivered to the laboratory.

4.4.5.1 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the sample containers to the field. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 °C or lower.

4.4.5.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory (Appendix B). The sample containers will be filled as described in Section 4.4.3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample station identification;
- Sample type (e.g., groundwater, soil, surface water, sediment);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and

- Analyses requested.

4.4.5.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the laboratory. The packaged samples will be delivered to the laboratory as soon as possible (within holding limits) after sample collection.

The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

4.4.5.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the field to the laboratory will be completed.

4.4.5.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample station identification;
- Date and time of sampling;
- Sampling method;
- Field observations of sample appearance and odor;
- Weather conditions;
- Water level prior to purging (groundwater samples only);
- Total monitoring well/well depth (groundwater samples only);
- Purge volume (groundwater samples only);
- Monitoring well/well condition (groundwater samples only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, ORP, and specific conductance (groundwater samples only); and

- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form.

4.4.5.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 4. The analytical methods for these sampling events are listed in Table 4.4. Prior to sampling, the laboratory will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those listed in Appendix B of this plan.

Laboratory personnel will specify the necessary QC samples and prepare appropriate QC sample containers. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers and ice chests with adequate padding will be provided by laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

4.5 PRE- OIL INJECTION AQUIFER TESTING

Slug tests will be conducted before and after oil injection on four of the newly installed injection wells to estimate the hydraulic conductivity of unconsolidated deposits at the site and to estimate the impact of oil injection. In addition, slug tests will be conducted prior to oil injection on four monitoring wells. Slug testing will be performed after the baseline geochemical and contaminant sampling.

A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of screened interval of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft²/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

4.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness of the water-bearing zone.
- **Slug Test.** Two types of tests are possible: rising head and falling head. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation adjacent to the screened interval by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation adjacent to the screened interval by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

4.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water-level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE3000, or equivalent).

4.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water-level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water-level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping, may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The Parsons ES field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 4.4.2.1.

4.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with water-tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Static water level, and
 - Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water-level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

4.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure:

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

4.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using the computer code AQTESOLV™ (Geraghty & Miller, 1994) or similar, and the method of Cooper *et al.* (1967) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

4.6 OIL INJECTION AND RADIUS OF INFLUENCE TESTING

4.6.1 Oil Injection

After the background geochemical and contaminant sampling and slug testing have been completed, an estimated 8,000 to 10,000 gallons (total) of soybean oil will be injected into the eight new injection wells using an Ingersol-Rand ARO air operated diaphragm pump model 66605J.388 or similar. This pump has a ½ inch inlet and a ½ inch outlet. The maximum flow rate is 13 gallons per minute (gpm) and the maximum operating pressure is 100 pounds per square inch (lb/in²).

4.6.2 Radius of Influence Testing

In order to trace groundwater migrating from the immediate vicinity of the injection wells (i.e., zone of influence), a water "push" containing bromide at a concentration of approximately 100 mg/L will be injected immediately after oil injection. The volume of the water push will be sufficient to clear the well annulus and filter pack of oil so the well can later be purged and used for process monitoring (Section 4.7).

Bromide has a low adsorptive potential and migrates at approximately the rate of advective groundwater flow, and will be tracked in groundwater after injection to estimate advective groundwater flow in the study area. The migration of total organic carbon in groundwater (from dissolution of the vegetable oil) also will be tracked, although it is anticipated to be retarded relative to migration of the bromide due to its higher adsorptive potential.

4.7 PROCESS MONITORING

In order to monitor system performance over time, Parsons ES will sample the 8 injection wells, the 16 newly installed groundwater monitoring wells, and wells 007G15UF and 007G15LF for the parameters listed in Table 4.4 at two (2), six (6), 12, and 18 months after oil injection. Based upon the results of the field application, continued monitoring and further injection of vegetable oil will be evaluated. The procedures listed in Section 4.4 will be used for all sampling events.

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates/replicates and rinsate, field, and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4 degrees Celsius (°C) or less.

All field sampling activities will be recorded in a bound, sequentially-paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater samples, rinsate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC procedures will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Duplicate groundwater samples will be collected at a frequency of one for every 10 or fewer samples of similar matrix. Each duplicate water sample will be collected concurrently with, and by the same method as, the primary sample. Duplicate water samples will be analyzed for VOCs and geochemical parameters.

One rinsate sample will be collected for every 20 or fewer groundwater samples collected. The rinsate sample will consist of a sample of distilled water poured into or through the sampling device and subsequently transferred into a sample container provided by the laboratory. If dedicated sampling equipment is used, then only one rinsate sample will be collected per sampling device type to document the cleanliness of the dedicated equipment. Rinsate samples will be analyzed for VOCs only.

One field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container at the well while sampling activities are underway. The field blank will be analyzed for VOCs only.

TABLE 5.1
QA/QC SAMPLING PROGRAM
NSA MID-SOUTH SITE N-6
MILLINGTON, TENNESSEE

QA/QC Sample Type	Minimum Frequency to be Collected and Analyzed ^{a/}	Analytes
Duplicates/Replicates	10 percent of groundwater and soil samples	VOCs, methane, ethane, ethene, geochemical
Rinseate Blanks	5 percent of groundwater and soil samples	VOCs
Trip Blanks	One per sample shipment containing VOC samples	VOCs
Matrix Spike Samples	5 percent of groundwater and soil samples	VOCs
Laboratory Control Sample	One per method per medium per analytical batch	Laboratory control charts (Method Specific)
Laboratory Method Blanks	One per method per medium per analytical batch	Laboratory control charts (Method Specific)

^{a/} Actual frequency of QA/QC samples may be altered by the Parsons ES field scientist, but will not be less than minimum QA/QC sampling frequency.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory, and will be transported inside each sample shipment containing samples for VOC analysis. Trip blanks will be analyzed for VOCs only.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs. Sufficient extra sample volume will be submitted to the laboratory to allow matrix spike preparation and analysis. LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the sites are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used (Table 4.4).

SECTION 6

DATA ANALYSIS AND REPORT

Parsons ES will compile, analyze, and interpret field test data in a Field Application Results Report. Parsons ES will provide defensible conclusions regarding, but not limited to: the efficiency of electron donor utilization for reductive dehalogenation as compared to metabolic (e.g. methane production) and anabolic (i.e. biomass) processes; contributions or effects of any reagent added to the system (e.g. vegetable oil); extent and uniformity of reagent distribution (e.g. vegetable oil); loss of electron donor and tracer compounds; effective radii of influence; apparent electron donor requirements; observed changes in site-geochemistry; actual/significant changes in contaminant concentrations and mass (considering volatilization, dilution, degradation, and daughter product formation and persistence); reaction kinetics and contact time; feasibility and relative cost-effectiveness of expanded-scale implementation. Based upon the results of the field application, continued monitoring and further injection of vegetable oil will be evaluated.

SECTION 7

REFERENCES

- Alvarez-Cohen, L.M. and McCarty, P.L., 1991a, Effects of toxicity, aeration, and reductant supply on trichloroethylene transformation by a mixed methanotrophic culture: *Appl. Environ. Microbiol.*, vol. 57, no. 1, p. 228-235.
- Alvarez-Cohen, L.M., and McCarty, P.L., 1991b, Product toxicity and cometabolic competitive inhibition modeling of chloroform and trichloroethylene transformation by methanotrophic resting cells: *Appl. Environ. Microbiol.*, vol. 57, no. 4, p. 1031-1037.
- Arciero, D., Vannelli, T., Logan, M., and Hooper, A.B., 1989, Degradation of trichloroethylene by the ammonia-oxidizing bacterium *Nitrosomonas europaea*: *Biochem. Biophys. Res. Commun.*, vol. 159, p. 640-643.
- Bouwer, H., and Rice, R.C., 1976, A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells: *Water Resources Research*, v. 12, no. 3, p.423-428.
- Bouwer, H., 1989, The Bouwer and Rice slug test - an update: *Groundwater*, v. 27, no. 3, p.304-309.
- Bouwer, E.J., Rittman, B.E., and McCarty, P.L., 1981, Anaerobic degradation of halogenated 1- and 2-carbon organic compounds: *Environ. Sci. Technol.*, vol. 15, no. 5, p. 596-599.
- Bouwer, E.J. and Wright, J.P., 1988, Transformations of trace halogenated aliphatics in anoxic biofilm columns: *J. Contam. Hydrol.*, vol. 2, p. 155-169.
- Bouwer, E.J., 1994, Bioremediation of chlorinated solvents using alternate electron acceptors. In: *Handbook of Bioremediation*. CRC Press, Boca Raton, FL.
- Bradley, P.M., and Chapelle, F.H., 1996, Anaerobic mineralization of vinyl chloride in Fe(III)-reducing aquifer sediments: Accepted for publication in *Environmental Science and Technology*, 1996.
- Bradley, P.M., and Chapelle, F.H., 1998, Effect of Contaminant Concentration on Aerobic Microbial Mineralization of DCE and VC in Stream-Bed Sediments, *Environmental Science and Technology*, v. 32, no. 5, p. 553-557.
- Carmichael, J.K., Parks, W.S., Kingsbury, J.A., and D.E. Ladd, 1997, Hydrogeology and Groundwater Quality of Naval Support Activity Memphis, Millington, Tennessee. *Water Resources Investigations Report 97-4158*. U.S. Geological Survey: Nashville, Tennessee.

- Chapelle, F.H., 1993. Ground-Water Microbiology and Geochemistry: John Wiley & Sons, Inc., New York, 424 p.
- Cline, P.V., and Delfino, J.J., 1989, Transformation kinetics of 1,1,1-trichloroethane to the stable product 1,1-dichloroethene, In: Biohazards of Drinking Water Treatment. Lewis Publishers, Inc. Chelsea, MI. p. 47-56.
- Cooper, H.H., J.D. Bredehoeft and S.S. Papadopoulos, 1967, Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263-269.
- de Bont, J.A.M., Vorage, M.J.W., Hartmans, S., and van den Tweel, W.J.J., 1986, Microbial Degradation of 1,3-Dichlorobenzene: Appl. And Environ. Microbiol., 52:677-680.
- DeStefano, T.D., Gossett, J.M., and Zinder, S.H., 1991, Reductive dehalogenation of high concentrations of tetrachloroethene to ethene by an anaerobic enrichment culture in the absence of methanogenesis: Appl. Environ. Microbiol., vol. 57, no. 8, p. 2287-2292.
- EnSafe, Inc. (EnSafe), 2000a, Aquifer Characterization Test Report, Area of Concern A, Naval Support Activity Mid-South, Millington, Tennessee. Revision 01. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina. February 25.
- EnSafe, 2000b, RCRA Facility Investigation Report, Naval Support Activity Memphis, AOC A, Northside Fluvial Groundwater. Revision 02. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina. February 17.
- EnSafe, 2000c, RCRA Facility Investigation Report Addendum, Naval Support Activity Memphis, AOC A, Northside Fluvial Groundwater. Revision 0. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina. February 17.
- Folsom, B.R., Chapman, P.J., and Pritchard, P.H., 1990, Phenol and trichloroethylene degradation by *Pseudomonas cepacia* G4: Kinetics and interactions between substrates: Appl. Environ. Microbiol., vol. 56, no. 5, p. 1279-1285.
- Freedman, D.L., and Gossett, J.M., 1989, Biological reductive dehalogenation of tetrachloroethylene and trichloroethylene to ethylene under methanogenic conditions: Appl. Environ. Microbiol., vol. 55, no. 4, p. 1009-1014.
- Geraghty & Miller, Inc., 1994, AQTESOLV® Aquifer Test Solver, Version 2.0. Millersville, Maryland. October.
- Harker, A.R., and Kim, Y., 1990, Trichloroethylene degradation by two independent aromatic-degrading pathways in *Alcaligenes eutrophus* JMP134: Appl. Environ. Microbiol., vol. 56, no. 4, p. 1179-1181.
- Hartmans, S., and de Bont, J.A.M., 1992, Aerobic vinyl chloride metabolism in *Mycobacterium aurum* Li: Appl. Environ. Microbiol., vol. 58, no. 4, p. 1220-1226.

- Henry, S.M., 1991, Transformation of Trichloroethylene by Methanotrophs from a Groundwater Aquifer. Ph.D. Thesis. Stanford University. Palo Alto, California.
- Little, C.D., Palumbo, A.V., Herbes, S.E., Lidstrom, M.E., Tyndall, R.L., and Gilmer, P.J., 1988, Trichloroethylene biodegradation by a methane-oxidizing bacterium: Appl. Environ. Microbiol., vol. 54, no. 4, p. 951-956.
- Mayer, K.P., Grbic-Galic, D., Semprini, L., and McCarty, P.L., 1988, Degradation of trichloroethylene by methanotrophic bacteria in a laboratory column of saturated aquifer material: Wat. Sci. Tech. (Great Britain), vol. 20, no. 11/12, p. 175-178.
- McCarty, P.L., Roberts, P.V., Reinhard, M., and Hopkins, G., 1992, Movement and transformations of halogenated aliphatic compounds in natural systems, In: Fate of Pesticides and Chemicals in the Environment. Ed., J.L. Schnoor. John Wiley & Sons, Inc. New York, New York. p. 191-209.
- McCarty, P.L., and Semprini, L., 1994, Ground-Water Treatment for Chlorinated Solvents, In: Handbook of Bioremediation. Lewis Publishers, Boca Raton, FL. 1994.
- Miller, R.E., and Guengerich, F.P., 1982, Oxidation of trichloroethylene by liver microsomal cytochrome P-450: Evidence for chlorine migration in a transition state not involving trichloroethylene oxide: Biochemistry, vol. 21, p. 1090-1097.
- Nelson, M.J.K., Montgomery, S.O., O'Neille, E.J., and Pritchard, P.H., 1986, Aerobic metabolism of trichloroethylene by a bacterial isolate: Appl. Environ. Microbiol., vol. 52, no. 2, p. 949-954.
- Parsons Engineering Science, Inc. (Parsons ES), 2000, Project Health and Safety Plan for Field Application to Enhance *In Situ* Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site N-6, Naval Support Activity Mid-South, Tennessee. April.
- Reineke, W., and Knackmuss, H.J., 1984, Microbial Metabolism of Haloaromatics: Isolation and Properties of a Chlorobenzene-Degrading Bacterium: European J. Appl. Microbiol. Biotechnol., 47:395-402.
- Sander, P., Wittach, R.M., Fortnagel, P., Wilkes, H., and Francke, W., 1991, Degradation of 1,2,4-trichloro and 1,2,4,5-tetrachlorobenzene by *Pseudomonas* Strains: Appl. Environ. Microbiol., 57:1430-1440.
- Spain, J.C., and Nishino, S.F., 1987, Degradation of 1,4-Dichlorobenzene by a *Pseudomonas sp.*: Appl. Environ. Microbiol., 53:1010-1019.
- Spain, J.C., 1996, Future Vision: Compounds with Potential for Natural Attenuation. In *Proceedings of the Symposium on Natural Attenuation of Chlorinated Organics in Groundwater; Dallas TX. September 11-13, 1996*: EPA/540/R-96/509.
- Sulfito, J.M., and Townsend, G.T., 1995, The Microbial Ecology and Physiology of Aryl Dehalogenation Reactions and Implications for Bioremediation, In *Microbial transformation and Degradation of Toxic Organic Chemicals*: (Young, L.Y., and Cerniglia, C.E., Eds.), Wiley-Liss, New York, 654 p.

US Environmental Protection Agency (USEPA), 1998, Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater: EPA/600/R-98/128, September 1998; <http://www.epa.gov/ada/reports.html>.

Vogel, T.M., 1994, Natural Bioremediation of Chlorinated Solvents, In: Handbook of Bioremediation. Lewis Publishers, Boca Raton, FL. 1994.

Wilson, J.T., and Wilson, B.H., 1985, Biotransformation of trichloroethylene in soil: Appl. Environ. Microbiol., vol. 49, no. 1, p. 242-243.

APPENDIX A
PROJECT HEALTH AND SAFETY PLAN

PROJECT HEALTH AND SAFETY PLAN
FOR FIELD APPLICATION TO ENHANCE *IN-SITU*
BIOREMEDIATION OF CHLORINATED SOLVENTS VIA
VEGETABLE OIL INJECTION AT SITE N-6, NAVAL SUPPORT
ACTIVITY MID-SOUTH, TENNESSEE

Prepared for:

NAVAL FACILITIES ENGINEERING COMMAND
PORT HUENEME, CALIFORNIA

NAVAL FACILITIES ENGINEERING COMMAND
SOUTH DIVISION
NORTH CHARLESTON, SOUTH CAROLINA

and

NAVAL SUPPORT ACTIVITY MID-SOUTH
MILLINGTON, TENNESSEE

US NAVY CONTRACT: N47408-00-C-7112

April 2000

Prepared by:

PARSONS ENGINEERING SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290

Reviewed and Approved By:

	Name	Date
Project Manager	<u>Bruce M Henry</u>	<u>4/24/00</u>
Program H & S Manager	<u>Timothy S Mustard</u>	<u>4/24/00</u>

TABLE OF CONTENTS

	<u>Page</u>
SECTION 1 - PURPOSE AND POLICY.....	1-1
SECTION 2 - PROJECT DESCRIPTION AND SCOPE OF WORK.....	2-1
2.1 Project Description.....	2-1
2.2 Scope of Work	2-1
SECTION 3 - PROGRAM TEAM ORGANIZATION.....	3-1
SECTION 4 - SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS.....	4-1
4.1 Additional Safety Training Requirements	4-2
4.1.1 Site-Specific Safety Training	4-2
4.1.2 Daily Safety Briefings.....	4-3
4.2 Medical Monitoring Requirements	4-3
SECTION 5 - SAFETY AND HEALTH RISK ANALYSIS AND HAZARD MITIGATION	5-1
5.1 Chemical Hazards	5-1
5.2 Physical Hazards	5-1
5.2.1 Heavy Equipment and Drilling Rigs.....	5-5
5.2.3 Support Vehicles.....	5-7
5.2.4 Subsurface Hazards.....	5-7
5.2.5 Electrical Hazards	5-7
5.2.6 Slip, Trip, and Fall Hazards	5-9
5.2.7 Noise-Induced Hearing Loss.....	5-10
5.2.8 Fire or Explosion Hazards	5-10
5.2.9 Electric Power Line Clearance and Thunderstorms.....	5-11
5.2.10 Effects and Prevention of Heat Stress.....	5-11
5.2.10.1 Heat-Related Problems.....	5-13
5.2.10.2 Heat-Stress Monitoring	5-13
5.2.11 Cold Exposure.....	5-15
5.2.11.1 Evaluation and Control	5-17

TABLE OF CONTENTS (Continued)

	<u>Page</u>
5.2.11.2 Work-Warming Regimen.....	5-19
5.3 Biological Hazards.....	5-20
SECTION 6 - EMERGENCY RESPONSE PLAN.....	6-1
6.1 Guidelines for Pre-Emergency Planning and Training	6-1
6.2 Emergency Recognition and Prevention.....	6-1
6.3 Personnel Roles, Lines of Authority, and Communication Procedures During an Emergency	6-4
6.4 Evacuation Routes and Procedures, Safe Distances, and Places of Refuge.....	6-4
6.5 Decontamination of Personnel During an Emergency.....	6-5
6.6 Emergency Site Security and Control.....	6-5
6.7 Procedures for Emergency Medical Treatment and First Aid	6-6
6.7.1 Chemical Exposure	6-6
6.7.2 Personal Injury	6-7
6.7.3 Fire or Explosion.....	6-7
SECTION 7 - LEVELS OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT REQUIRED FOR SITE ACTIVITIES.....	7-1
7.1 Personal Protective Equipment	7-1
7.2 Equipment Needs	7-5
7.3 Equipment Disposal	7-6
SECTION 8 - FREQUENCY AND TYPES OF AIR MONITORING.....	8-1
SECTION 9 - SITE CONTROL MEASURES.....	9-1
9.1 Site Organization-Operation Zones	9-1
9.1.1 Exclusion Zone (Contamination Zone).....	9-1
9.1.2 Contamination Reduction Zone	9-2
9.1.3 Support Zone.....	9-2
9.2 Site Security	9-2
9.3 Site Communication	9-3
9.4 Safe Work Practices	9-3

TABLE OF CONTENTS (Continued)

	<u>Page</u>
SECTION 10 - DECONTAMINATION PROCEDURES	10-1
10.1 Personnel Decontamination Procedures.....	10-1
10.2 Decontamination of Equipment	10-3
SECTION 11 - AIR MONITORING EQUIPMENT USE AND CALIBRATION PROCEDURES	11-1
11.1 Photovac Microtip® Air Analyzer.....	11-1
11.2 HNU® Photoionization Detector.....	11-2
11.3 Explosivity Meter.....	11-2
11.4 Sensidyne® or Dräger® Colorimetric Gas Analysis Tubes	11-5
SECTION 12 - EMERGENCY CONTACTS AND ROUTE TO HOSPITAL	
APPENDIX A - PROJECT HEALTH AND SAFETY FORMS	
APPENDIX B - JOB SAFETY ANALYSES	

LIST OF TABLES

No.	Title	Page
5.1	Health Hazard Qualities of Hazardous Substances of Concern	5-2
5.2	Suggested Frequency of Physiological Monitoring For Fit and Acclimatized Workers.....	5-14
5.3	Threshold Limit Values Work/Warm-up Schedule for Four-Hour Shift.....	5-18
11.1	MicroTip® Relative Response Factors (10.6 eV Lamp)	11-3
11.2	MicroTip® Response Factors (10.6 eV Lamp)	11-4

LIST OF FIGURES

No.	Title	Page
7.1	Flowchart for Selection of Respiratory Protection	7-2
10.1	Decontamination Station Layout Level B and C Protection.....	10-2
12.1	Directions to Hospital	12-2

SECTION 1

PURPOSE AND POLICY

The purpose of this project health and safety plan is to establish protection standards and mandatory safety practices for all Parsons Engineering Science, Inc. (Parsons ES) and subcontractor personnel involved in the enhanced bioremediation field application at Site N-6, Naval Support Activity (NSA) Mid-South, Millington, Tennessee. The goal of this safety program is to conduct the entire project with **zero accidents**. All task activities shall be designed for zero accidents. This plan provides guidance for safe operations on the enhanced bioremediation test site and provides for contingencies that may arise during field operations. All Parsons ES field team members and subcontractors are responsible for reading and conforming to this plan and the associated addenda. All personnel will be required to sign the Plan Acceptance Form located in Appendix A. No employee will perform a project activity that he or she believes may endanger his or her health and safety or the health and safety of others.

All personnel must share responsibility in performing all work in such a manner and under such conditions to preclude or minimize the possibility of damage to property or injury to themselves or others. Carelessness or disregard of accepted safety, health, and fire protection standards will not be tolerated. Any field team member who does not comply with established safety procedures will be subject to immediate dismissal from the site.

A project description and scope of work summary for the project are provided in Section 2. Section 3 presents the project team organization, personnel responsibilities, and lines of authority. Training and medical monitoring requirements are contained in Section 4. Section 5 presents a safety and health risk analysis. Section 6 contains the

program emergency response plan. Program requirements for levels of protection are included in Section 7, and air monitoring procedures are provided in Section 8. Site control measures, including designation of site work zones, are contained in Section 9, and Section 10 provides decontamination procedures. Section 11 contains information on the use and calibration of air monitoring equipment. Section 12 contains an Emergency Contacts Form. Appendix A contains a Plan Acceptance Form, Site-Specific Training Record Form, Field Experience Documentation Form, Air Monitoring Data Forms, Accident Report Form, Near-Miss Incident Form, Shipping Paper, Daily Vehicle Inspection Report, and Respirator Use Forms. Appendix B contains job analyses for project activities.

SECTION 2

PROJECT DESCRIPTION AND SCOPE OF WORK

2.1 PROJECT DESCRIPTION

Under this project, Parsons ES will provide services to the U.S. Navy Facilities Engineering Command (NAVFAC) and Naval Support Activity (NSA) Mid-South through the contract Parsons ES has with NAVFAC to demonstrate the use of enhanced bioremediation via vegetable oil injection to reduce concentrations of solvents (chlorinated aliphatic hydrocarbons) in the groundwater and soil at NSA Mid-South Site N-6.

2.2 SCOPE OF WORK

Site activities will include use of Rotasonic drilling technology for monitoring and injection point installation; vegetable oil injection; soil, oil, and groundwater sampling; and aquifer testing. Field work is expected to begin in June 2000 and will be completed in December 2001.



SECTION 3

PROGRAM TEAM ORGANIZATION

The Parsons ES team assigned to the bioremediation treatability studies project, their responsibilities, and lines of authority are outlined below.

<u>Name</u>	<u>Task Assigned</u>
Mr. Robert Hinchee, P.E.	Technical Director
Mr. Todd Wiedemeier, P.G.	Technical Manager
Mr. Bruce Henry, P.G.	Project/Site Manager
Mr. Timothy Mustard, C.I.H.	Program Health and Safety Manager
Mr. Jim Reed	Project Manager NAVFAC
Mr. Rob Williamson	Project Manager NSA Mid-South
Jason Bidgood	Site Health and Safety Officer
Tom Drago	Alternate Health and Safety Officer

The technical director and manager, Mr. Robert Hinchee and Mr. Todd Wiedemeier, are responsible for conduct and review of all technical work on this project to ensure technical accuracy and adequacy. They will provide advice to the project manager and project personnel on technical issues.

The project manager, Mr. Bruce Henry, is directly responsible for the execution of all phases of this project. He is responsible for planning, staffing, assuring adequate planning for health and safety and quality assurance/quality control (QA/QC), execution of each phase, coordination with NAVFAC and NSA Mid-South, and interpretation of data and reporting. The project manager will also coordinate with NSA Mid-South to obtain permission for site access, coordination of activities with appropriate officials, and

The program health and safety manager, Mr. Timothy Mustard, will ensure that all field activities are performed with strict adherence to OSHA requirements and this program health and safety plan. He will be responsible for updating and revising the program health and safety plan, as needed, and for ensuring that all field team members meet health and safety training and medical monitoring requirements.

The site health and safety officer (SHSO) along with the project manager is responsible for ensuring that day-to-day project activities are performed in strict conformance with the program health and safety plan. Through action and example, the SHSO will instill a sincere attitude toward the zero accident philosophy for this program, and will help field personnel develop a better understanding of accident prevention and loss control. The SHSO, project manager, and program health and safety manager have the authority to stop work if actions or conditions are judged to be unsafe or not in conformance with the program health and safety plan.

The site manager will support the project manager for the specific work the team will accomplish at each site and will be responsible for scheduling and coordinating the testing activities at the respective sites. The site manager will assist the project manager in the day-to-day organization and execution of the various project tasks. The site manager will also apply the zero accident philosophy in designing field tasks. He will use any downtime in the field for safety training and educational purposes, to the extent possible.

SECTION 4

**SITE-SPECIFIC EMPLOYEE TRAINING
AND MEDICAL MONITORING REQUIREMENTS**

The Parsons ES corporate health and safety manual, incorporated by reference, presents general requirements for Parsons ES employee training and medical monitoring. All field team members will have completed the 40-hour basic health and safety training as specified by the Occupational Safety and Health Administration (OSHA) in Title 29, Code of Federal Regulations, Part 1910.120, paragraph (e) (29 CFR 1910.120[e]) and the 8-hour annual refresher training thereafter. All supervisory personnel onsite will be required to have completed an 8-hour supervisor course as required in 29 CFR 1910.120(e).

In addition to the 40-hour course, all field employees will be required to have completed a minimum of 3 days onsite training under the supervision of a trained and experienced supervisor, not necessarily at one of the current investigation sites. If this training is received during a current bioremediation treatability study, the training will be documented on the Field Experience Documentation Form provided in Appendix A. Employees will not participate in field activities until they have been trained to the level required by their job function and responsibility. In addition, at least one person on every Parsons ES field crew will have current certification in Red Cross or equivalent first-aid and cardiopulmonary resuscitation (CPR). All training documentation for Parsons ES personnel will be verified by the SHSO and maintained by the health and safety manager.

All Parsons ES field team members will be on current medical monitoring programs in accordance with federal OSHA requirements (29 CFR 1910.120) and Parsons ES

corporate policies. Listed below are additional health and safety training and medical monitoring requirements for this project.

4.1 ADDITIONAL SAFETY TRAINING REQUIREMENTS

If Level B (self-contained breathing apparatus [SCBA]) respiratory protection is used, additional training may be required for those personnel involved. This training will be conducted onsite as necessary by a qualified, Level B-experienced supervisor. Employees will also be trained in use, care, maintenance, limitations, and disposal of personal protective equipment (PPE) in accordance with 29 CFR 1910.132. All field team members must have site-specific training as discussed in the following subsection.

4.1.1 Site-Specific Safety Training

Site-specific safety and health training will be conducted by the Parsons ES SHSO for all personnel who will engage in any field work under this contract. Site-specific safety training will address the activities, procedures, monitoring, and equipment applicable to the site operations, as well as site or facility layout, potential hazards, and emergency response services at the site. Additional topics that will be addressed at the safety briefings will include:

- Names of responsible health and safety personnel;
- Zero accident performance philosophy
- Identification of site hazards and measures for eliminating or reducing hazard risk;
- Site contingencies and emergency procedures;
- Exposure risk;
- Symptoms of exposure and exposure treatment for chemical contaminants;
- Use, care, maintenance, and limitations of PPE;
- Decontamination procedures to be followed;

- Location of safety equipment;
- Review of planned activities and specialized training necessary for personnel to perform their work with zero accidents;
- Defined safety procedures to be followed during field activities; and
- Emergency and evacuation procedures.

4.1.2 Daily Safety Briefings

Daily safety briefings will also be conducted prior to commencement of field activities. Discussion and coordination of field team activities, discussion of hazards faced that day, and discussion of hazard mitigation procedures will be held with all field team members. Documentation of training and briefings, including agenda and signatures of attending personnel, will be maintained onsite. Site-specific training forms are provided in Appendix A.

4.2 MEDICAL MONITORING REQUIREMENTS

Prior to being assigned to the field activities, each Parsons ES employee will receive a preassignment or baseline physical examination. Preassignment screening has two major functions: 1) determination of an individual's fitness for duty, including the ability to perform work while wearing PPE; and 2) provision of baseline data for comparison with future medical data. Medical qualification/certification documentation will be maintained by the program health and safety manager. All medical examinations and procedures will be performed by or under the supervision of a licensed physician, preferably an occupational physician. The examination content will be determined by the examining physician in accordance with 29 CFR 1910.120(f).



SECTION 5

SAFETY AND HEALTH RISK ANALYSIS AND HAZARD MITIGATION

5.1 CHEMICAL HAZARDS

The chemicals of primary concern occurring at the bioremediation sites include chlorinated solvents. In particular, the chlorinated solvents tetrachloroethene (PCE), trichloroethene (TCE), isomers of dichloroethene (DCE), and vinyl chloride. In addition, petroleum fuels and the associated petroleum hydrocarbon constituents benzene, toluene, ethylbenzene, and xylenes (BTEX) also may be encountered.

Table 5.1 summarizes the health hazards and properties of the aforementioned compounds. If other compounds are discovered at these sites, the pertinent information about these compounds will be provided in Table 5.1 of the site-specific addenda. The health hazards or other physical/chemical hazards (e.g., corrosiveness, flammability) of the compounds will then be communicated to the onsite employees.

Hazardous substances of primary concern identified are those potentially occurring in contaminated groundwater, soils, or air.

5.2 PHYSICAL HAZARDS

In addition to the hazardous substances potentially present at the sites, other physical hazards or hazardous conditions may be expected at the sites during the course of performing investigation or remediation activities. These hazards include possible risks from injury while working around motor vehicles including the Rotasonic drilling rig, stationary or moving equipment, fire or explosion hazards, slip, trip, and fall hazards; electrical hazards; and excessive noise conditions. Additional physical hazards include heat stress and cold-related exposures.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL ^{a/} (ppm)	TLV ^{b/} (ppm)	IDLH ^{c/} (ppm)	Odor Threshold ^{d/} (ppm)	Ionization Potential ^{e/} (eV)	Physical Description/Health Effects/Symptoms
Benzene	1 (29 CFR 1910.1028) ^{f/}	0.5 (skin) ^{g/}	500	4.7	9.24	Colorless to light-yellow liquid (solid < 42°F) with an aromatic odor. Eye, nose, skin, and respiratory system irritant. Causes giddiness, headaches, nausea, staggered gait, fatigue, anorexia, exhaustion, dermatitis, bone marrow depression, and leukemia. Mutagen, experimental teratogen, and carcinogen.
1,1-Dichloroethene (DCE) (Vinylidene Chloride)	1	5	NA ^{h/}	NA	10.00	Colorless liquid or gas (> 89°F) with a mild, sweet, chloroform-like odor. Irritates eyes, skin, and throat. Causes dizziness, headaches, nausea, shortness of breath, liver and kidney dysfunctions, and lung inflammation. Mutagen and carcinogen.
1,2-Dichloroethene (DCE) (cis- and trans-isomers)	200	200	1,000	0.085-500	9.65	Colorless liquid (usually a mixture of cis- and trans- isomers), with a slightly acid, chloroform-like odor. Irritates eyes and respiratory system. CNS depressant. Cis- isomer is a mutagen.
Diesel Fuel	400 ^{i/}	400 ^{i/}	1,100 ^{i/}	0.08	NA	Colorless to brown, slightly viscous liquid with a gasoline- or kerosene like odor. Irritates eyes, nose, and throat. Causes dizziness, drowsiness, headaches, nausea, dry cracked skin, and chemical pneumonia.
Ethylbenzene	100	100	800 (10% LEL) ^{j/}	0.25-200	8.76	Colorless liquid with an aromatic odor. Irritates eyes, skin, and mucous membranes. Causes dermatitis, headaches, narcosis, and coma. Mutagen and experimental teratogen.
Gasoline	300	300	NA	0.005-10	NA	Clear/amber flammable, volatile liquid with a characteristic odor. Irritates eyes, skin, and mucous membranes. Causes dermatitis, headaches, fatigue, blurred vision, dizziness, slurred speech, confusion, convulsions, chemical pneumonia, and possible liver and kidney damage. In animals, causes liver and kidney cancer. Monitor for BTEX constituents. Carcinogen.
Jet Fuel	400 ^{i/}	400 ^{i/}	1,100 ^{i/}	0.08-1	NA	Colorless to light-brown liquid with a fuel-like odor. Long-term effects include liver, kidney, and CNS damage. JP-4 is a questionable carcinogen.
2-Methylnaphthalene	NA	NA	NA	0.003-0.04	7.96	Colorless gas or solid with a disagreeable garlic or rotten cabbage odor.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL ^{a/} (ppm)	TLV ^{b/} (ppm)	IDLH ^{c/} (ppm)	Odor Threshold ^{d/} (ppm)	Ionization Potential ^{e/} (eV)	Physical Description/Health Effects/Symptoms
						Irritates eyes, skin, nose, and throat.
Naphthalene	10	10	250	0.3	8.12	Colorless to brown solid (shipped as a molten liquid) with a mothball-like odor. Irritates eyes, skin, and bladder. Causes headaches, confusion, excitement, convulsions, coma, vague discomfort, nausea, vomiting, abdominal pain, profuse sweating, jaundice, hematoma, hemoglobin in the urine, renal shutdown, dermatitis, optic nerve disorders, and corneal and liver damage. Experimental teratogen and questionable carcinogen.
Perchloroethylene (Tetrachloroethene or PCE)	25 ^{k/}	25	150	5-50	9.32	Colorless liquid with a mild chloroform odor. Eye, nose, skin and throat irritant. Causes nausea, flushed face and neck, vertigo, dizziness, headaches, hallucinations, incoordination, drowsiness, coma, pulmonary changes, and skin redness. Cumulative liver, kidney, and CNS damage. In animals, causes liver tumors. Mutagen, experimental teratogen, and carcinogen.
Toluene	100	50 (skin)	500	0.2-40 ^{l/}	8.82	Colorless liquid with sweet, pungent, benzene-like odor. Irritates eyes and nose. Causes fatigue, weakness, dizziness, headaches, hallucinations or distorted perceptions, confusion, euphoria, dilated pupils, nervousness, tearing, muscle fatigue, insomnia, skin tingling, dermatitis, bone marrow changes, and liver and kidney damage. Mutagen and experimental teratogen.
1,1,1-Trichloroethane (TCA (Methyl Chloroform)	350	350	700	20-500	11.00	Colorless liquid with a mild chloroform-like odor. Irritates eyes and skin. Causes headaches, exhaustion, CNS depression, poor equilibrium, dermatitis, liver damage, cardiac arrhythmia, hallucinations or distorted perceptions, motor activity changes, aggression, diarrhea, and nausea or vomiting. Mutagen, experimental teratogen, and questionable carcinogen.
Trichloroethene (TCE)	50	50	1,000	21.4-400	9.45	Clear, colorless or blue liquid with chloroform-like odor. Irritates skin and eyes. Causes fatigue, giddiness, headaches, vertigo, visual disturbances, tremors, nausea, vomiting, drowsiness, dermatitis, skin tingling, cardiac arrhythmia, and liver injury. In animals, causes liver and kidney cancer. Mutagen, experimental teratogen, and carcinogen.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL ^{a/} (ppm)	TLV ^{b/} (ppm)	IDLH ^{c/} (ppm)	Odor Threshold ^{d/} (ppm)	Ionization Potential ^{e/} (eV)	Physical Description/Health Effects/Symptoms
Vinyl Chloride	1 (29 CFR 1910.1017) ^{f/}	1	NA	260	9.99	Colorless gas (liquid < 7°F) with a pleasant odor at high concentrations. Severe irritant to skin, eyes, and mucous membranes. Causes weakness, abdominal pain, gastrointestinal bleeding, enlarged liver, pallor or blue skin on the extremities, liver cancer, and frostbite (liquid). Also attacks lymphatic system. Mutagen, experimental teratogen, and carcinogen.
Xylene (o-, m-, and p-isomers)	100	100	900	0.05-200 ^{k/}	8.56 8.44 (p)	Colorless liquid with aromatic odor. P-isomer is a solid < 56°F. Irritates eyes, skin, nose, and throat. Causes dizziness, drowsiness, staggered gait, incoordination, irritability, excitement, corneal irregularities, conjunctivitis, dermatitis, anorexia, nausea, vomiting, abdominal pain, and olfactory and pulmonary changes. Also targets blood, liver, and kidneys. Mutagen and experimental teratogen.

- a/ PEL = Permissible Exposure Limit. OSHA-enforced average air concentration to which a worker may be exposed for an 8-hour workday without harm. Expressed as parts per million (ppm) unless noted otherwise. PELs are published in the *NIOSH Pocket Guide to Chemical Hazards*, current edition. Some states (such as California) may have more restrictive PELs. Check state regulations.
- b/ TLV = Threshold Limit Value - Time-Weighted Average. Average air concentration (same definition as PEL, above) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), *TLVs® and BEIs®* current edition.
- c/ IDLH = Immediately Dangerous to Life or Health. Air concentration at which an unprotected worker can escape without debilitating injury or health effects. Expressed as ppm unless noted otherwise. IDLH values are published in the *NIOSH Pocket Guide to Chemical Hazards*, current edition.
- d/ When a range is given, use the highest concentration.
- e/ Ionization Potential, measured in electron volts (eV), used to determine if field air monitoring equipment can detect substance. Values are published in the *NIOSH Pocket Guide to Chemical Hazards*, current edition.
- f/ Refer to expanded rules for this compound.
- g/ (skin) = Refers to the potential contribution to the overall exposure by the cutaneous route.
- h/ NA = Not available.
- i/ Based on exposure limits for petroleum distillates (petroleum naphtha).
- j/ Indicates that the IDLH value was based on 10% of the lower explosive limit for safety considerations, even though relevant toxicological data indicated that irreversible health effects or impairment of escape existed only at higher concentrations (*NIOSH Pocket Guide to Chemical Hazards*, current edition).
- k/ NIOSH recommends reducing exposure to the lowest feasible concentration, and limiting the number of workers exposed.
- l/ Olfactory fatigue has been reported for the compound and odor may not serve as an adequate warning property.



The guidelines presented in this section are applicable to all types of equipment that may be used during field activities at NSA Mid-South. Individual equipment types or certain specialized equipment may require additional safety considerations or specialized training prior to its use. Should any specialized equipment be required during the performance of a task, the program health and safety manager will ensure that operators receive appropriate training. The program health and safety manager is also responsible for ensuring that all equipment is routinely inspected and that any piece of equipment considered unsafe is not used until the unsafe conditions are corrected or repaired.

5.2.1 Heavy Equipment and Drilling Rigs

Working with large motor vehicles and drilling rigs could be a major hazard at this site. Injuries can result from equipment dislodging and striking unsuspecting personnel, and impacts from flying objects or overturning of vehicles. Vehicles and heavy equipment design and operation will be in accordance with 29 CFR, Subpart O, 1926.600 through 1926.602. In particular, the following precautions will be used to help prevent injuries and accidents:

- Daily vehicle and drill rig inspections will be conducted and documented.
- Do not back up large motor vehicles unless the vehicle has backup warning lights and a reverse signal alarm audible above the surrounding noise level, or an observer signals it is safe to do so.
- No riders other than the driver are permitted on heavy equipment.
- Motor vehicle cabs will be kept free of all nonessential items and all loose items will be secured.
- Drilling rig masts will be lowered to the ground and parking brakes will be set before shutting off the vehicle.

- Drilling rig brakes, cables, kill switches, hydraulic lines, light signals, fire extinguishers, fluid levels, steering, tires, horn, and other safety devices will be inspected daily.
- All personnel working at and around the drilling rig must be informed of the locations of the kill switches.
- Only qualified operators will be allowed to operate heavy equipment.
- When heavy equipment is left unattended, loads must be lowered, controls neutralized, power shut off, and brakes set. Wheels must be chocked if a vehicle is parked on an incline.

When working near a backhoe or excavator, field personnel will maintain sight contact with the operator. Field personnel shall not work within the swing radius of the backhoe boom while the equipment is operating. The swing radius will be defined by fully extending the boom and defining the radius with traffic cones, barrier tape, or other suitable means, such as inscribing the radius on the soil surface using the bucket. Personnel will not cross the demarcated line without first establishing eye contact with the operator. The operator will lower the bucket to the ground on either side of the trench and remove his hands and feet from the controls and/or turn the backhoe off, before allowing personnel access to the area within the swing radius of the backhoe arm. Backhoe operations will resume only after all personnel have left the area within the swing radius.

When working near a drill rig, personnel shall be aware of snag hazards from rotating tools and pinch and crush hazards from suspended tools. No loose, dangling clothing will be allowed. Personnel will also be aware of falling object hazards and wear hard hats at all times. Personnel will be aware of slip, trip, and fall hazards from drilling equipment, tools, and well construction materials that may be lying on the ground in the vicinity of the drill rig. To reduce the threat of slip, trip, and fall hazards, the area immediately around the drill rig will be kept clear of equipment and supplies. Use of a downhole

hammer will require the use of an air compressor. The compressor air hoses will be checked daily prior to startup for cracks or other defects that could result in injuries. Refer to Section 5.2.7 for noise associated with drill rig and air compressor.

5.2.2 Support Vehicles

Contractor/subcontractor personnel shall wear seat belts and obey posted speed limits. Personnel shall comply with applicable state, local, and installation traffic regulations. Current or anticipated hazardous road conditions (i.e., ice, construction) will be addressed at the daily safety briefings. No personnel shall ride in the bed of pickup trucks or standing on the side or riding on the fenders of heavy equipment.

Personnel will conduct a "walk-around" inspection of the vehicle before moving it to ensure they do not drive over personnel or equipment.

No personally-owned vehicles (POVs) will be driven into contaminated areas, nor will contaminated equipment, personnel, or material be transported in POVs. POVs must be left in support zones on-site. Stunt driving, racing, and horseplay are prohibited and will be subject to disciplinary action, including dismissal.

5.2.3 Subsurface Hazards

Before intrusive field activities are performed, efforts must be made to determine if underground installations (i.e., sewers, and telephone, water, fuel, and electrical lines) will be encountered and if so, where such underground installations are located. The site manager will ensure that all underground installations have been identified prior to any intrusive operations.

5.2.4 Electrical Hazards

Some of the equipment used during bioremediation is powered by electricity. Maintenance and daily activities require personnel to use, handle, and control this equipment. Safe work practices must be strictly observed to avoid serious injury and death.

According to 29 CFR 1910.269(l), only qualified employees may work on or with exposed energized lines or parts of equipment, or in areas containing unguarded, uninsulated, energized lines or parts of equipment operating at 50 volts (V) or more. Qualified employees must be trained in accordance with 29 CFR 1910.269(a) and certified as such by the employer.

Ordinary 120 V electricity may be fatal. Extensive studies have shown that currents as low as 10 to 15 milliamps (mA) can cause loss of muscle control and that 12 V may, on good contact, cause injury. Therefore, all voltages should be considered dangerous.

Electricity can paralyze the nervous system and stop muscular action. Frequently, electricity may affect the breathing center at the base of the brain and interrupt the transmission of the nerve impulses to the muscles responsible for breathing. In other cases, the electrical current directly affects the heart, causing it to cease pumping blood. Death follows due to a lack of oxygen in the body. Therefore, a victim must be freed from the live conductor promptly by use of a nonconducting implement, such as a piece of wood, or by turning off the electricity to at least this point of contact. Bare hands should never be used to remove a live wire from a victim or a victim from an electrical source. Artificial respiration or CPR should be applied immediately and continuously until breathing is restored, or until a physician or emergency medical technician arrives.

General rules for recognizing electrical safety are provided below.

- Only authorized and qualified personnel will perform electrical installations or repairs.
- All electrical wires and circuits will be assumed to be "live," unless it can be positively determined they are not.
- Appropriate protective clothing will be worn by personnel performing electrical work.

- All electrical equipment will be properly grounded and class-approved for the location.
- Ground fault circuit interrupter receptacles and circuit breakers will be installed where required by the National Electric Code and 29 CFR 1926.404.
- Electrical control panels will not be opened unless necessary.
- No safety device will be made inoperative by removing guards, using oversized fuses, or by blocking or bypassing protective devices, unless it is absolutely essential to the repair or maintenance activity, and then only after alerting operating personnel and the maintenance supervisor.
- All power tools will have insulated handles, be electrically grounded, or be double insulated.
- Fuse pullers will be used to change fuses.
- Metal ladders, metal tape measures, and other metal tools will not be used around electrical equipment or overhead electrical lines.
- Wires and extension cords will be placed or arranged so as to not pose a tripping hazard.

5.2.5 Slip, Trip, and Fall Hazards

Existing site conditions may pose a number of slip, trip, and fall hazards, such as:

- Open excavations, pits, or trenches;
- Slippery surfaces;
- Steep or uneven grades;
- Surface obstructions; and
- Construction materials or debris.

The extension cords connecting pumps to power supplies also provide a trip and fall hazard. Caution must be exercised and unnecessary personnel should avoid the area of the cord.

All field team members will be instructed to be cognizant of potential safety hazards and immediately inform the SHSO or the site manager about any new hazards. If the hazard cannot be immediately removed, actions must be taken to warn site workers about the hazard. The site will be kept in a neat, organized, and orderly fashion. Rubbish, trash, or debris generated by the project team shall be picked up and properly disposed of on a daily basis. Items such as tools, equipment, and hoses will be properly stored when not in use.

5.2.6 Noise-Induced Hearing Loss

Work onsite may involve the use of equipment such as drilling rigs, downhole hammers, pumps, compressors, and generators. The exposure of unprotected site workers to this noise or to aircraft noise during site activities can result in noise-induced hearing loss. Heavy equipment can emit noise levels exceeding the federal OSHA time-weighted average (TWA) limit of 85 decibels (dB). Noise levels in the area of the drilling rig and Geoprobe® unit will be presumed in exceedance of the OSHA TWA, and hearing protection will be required. Foam ear plugs will generally provide adequate protection. The SHSO will ensure that either ear muffs or disposable foam earplugs are made available to, and are used by, all personnel in the vicinity of the operation of equipment, aircraft noise or other sources of high intensity noise.

5.2.7 Fire or Explosion Hazards

Fuels and solvents may have been released into the soils at the site and vapors from these fuels may be flammable or explosive. Therefore, precautions will be taken when performing investigation and remediation activities to ensure that combustible or explosive vapors have not accumulated, or that an ignition source is not introduced into a flammable atmosphere.

OSHA standards for fire protection and prevention are included in 29 CFR Subpart F, 1926.150 through 1926.154. Of particular concern on these sites are:

- Proper storage of flammables;
- Adequate numbers of 20 lb. A:B:C type fire extinguishers;
- Use of intrinsically safe (explosion-proof) equipment where appropriate; and
- Monitoring for development of an explosive atmosphere.

5.2.8 Electric Power Line Clearance and Thunderstorms

Above- and below-ground utility lines may pose a safety hazard to workers during excavation or drilling. Extra precautions will be exercised when drilling near electrical lines. The minimum clearance between overhead electrical lines of 50 kilovolts (kV) or less and the drill rig mast is 20 feet. The location of underground utilities must be determined prior to excavation or drilling. No drilling will take place without the identification of underground utility lines by a representative of the utility company(ies) or by the appropriate installation personnel. All permits, licenses, and/or rights-of-entry required by state, local, and/or installation authorities will be the responsibility of the contractor. Drilling operations and other tasks performed outdoors must cease during thunderstorms.

The SHSO will provide onsite surveillance of the drilling subcontractor to ensure that personnel meet these requirements. If deficiencies are noted, work will be stopped and corrective actions implemented. Reports of health and safety deficiencies and the corrective actions taken will be forwarded to the installation manager by the SHSO.

5.2.9 Effects and Prevention of Heat Stress

Adverse weather conditions are important considerations in planning and conducting site operations. Hot or cold weather can cause physical discomfort, loss of efficiency, and personal injury. These conditions are discussed further below.

If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur. They can range from mild symptoms such as fatigue; irritability; anxiety; and decreased concentration, dexterity, or movement; to death. Medical help must be obtained for the more serious cases of heat stress. One or more of the following actions will help reduce heat stress:

- Provide plenty of liquids. To replace body fluids (water and electrolytes) lost due to perspiration, each employee must drink 1 to 1.5 gallons of water or commercial electrolyte mix per day. Workers are encouraged to frequently drink small amounts, i.e. one cup every 15-20 minutes.
- Field personnel are cautioned to minimize alcohol intake during off-duty hours.
- Provide cooling devices (e.g., water jackets or ice vests) to aid natural body ventilation. These devices, however, add weight, and their use should be balanced against worker mobility.
- Wear long cotton underwear, which acts as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.
- Install portable emergency showers and/or hose-down facilities to reduce body temperature and to cool protective clothing.
- In extremely hot weather, conduct nonemergency response operations in the early morning or evening.
- Ensure that adequate shelter is available to protect personnel against sun, heat, or other adverse weather conditions which decrease physical efficiency and increase the probability of accidents.
- In hot weather, rotate workers wearing protective clothing.

- Maintain good hygienic standards by frequent changing of clothing and daily showering. Clothing should be permitted to dry during rest periods. Workers who notice skin problems should immediately consult the SHSO.

5.2.9.1 Heat-Related Problems

- Heat rash: Caused by continuous exposure to heat and humid air, and aggravated by chafing clothes. Decreases ability to tolerate heat and is a nuisance.
- Heat cramps: Caused by profuse perspiration with inadequate fluid intake and chemical replacement, especially salts. Signs include muscle spasms and pain in the extremities and abdomen.
- Heat exhaustion: Caused by increased stress on various organs to meet increased demands to cool the body. Signs include shortness of breath; increased pulse rate (120-200 beats per minute); pale, cool, moist skin; profuse sweating; and dizziness and exhaustion.
- Heat stroke: The most severe form of heat stress. Body must be cooled immediately to prevent severe injury and/or death. Signs include red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; and possibly coma. Medical help must be obtained immediately.

5.2.9.2 Heat-Stress Monitoring

Monitoring of personnel wearing impermeable clothing will begin when the ambient temperature is 70°F (21°C) or above. Table 5.2 presents the suggested frequency for such monitoring. Monitoring frequency will increase as the ambient temperature increases or as slow recovery rates are observed. Heat-stress monitoring will be performed by a person with current first-aid certification who is trained to recognize heat-stress symptoms. For monitoring the body's recuperative capabilities in response to excess heat, one or more of the techniques listed below will be used. Other methods of heat-stress monitoring may also be used, such as the wet-bulb globe temperature index from



TABLE 5.2
SUGGESTED FREQUENCY OF PHYSIOLOGICAL MONITORING FOR FIT
AND ACCLIMATIZED WORKERS^{a/}

Adjusted Temperature ^{b/}	Normal Work Ensemble ^{c/}	Impermeable Ensemble ^{d/}
90°F (32.2°C) or above	After each 45 minutes of work	After each 15 minutes of work
87.5° - 90°F (30.8°-32.2° C)	After each 60 minutes of work	After each 30 minutes of work
82.5° -87.5° F (28.1°-30.8°C)	After each 90 minutes of work	After each 60 minutes of work
77.5°-82.5° F (25.3°-28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5°-77.5°F (22.5°-25.3°C)	After each 150 minutes of work	After each 120 minutes of work

^{a/} For work levels of 250 kilocalories/per hour.

^{b/} Calculate the adjusted air temperature (ta adj) by using this equation: $ta\ adj = ta\ ^\circ F + (13 \times \text{sunshine multiplier})$ [i.e., 50 percent sunshine equals a .5 multiplier]. Measure air temperature (ta) with a standard mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate the sunshine multiplier by judging what percent of time the sun is not covered by clouds that are thick enough to produce a shadow (100 percent sunshine - no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows).

^{c/} A normal work ensemble consists of cotton coveralls or other cotton clothing with long sleeves and trousers.

^{d/} Saranex[®], Poly-Coated Tyvek[®], Etc.



the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) Booklet.

To monitor the worker, measure:

- Heart rate: Count the radial pulse during a 30-second period as early as possible during the rest period.
 - If the heart rate exceeds 110 beats per minute at the beginning of the rest period, the next work cycle will be shortened by one-third and the rest period will remain the same.
 - If the heart rate still exceeds 110 beats per minute at the next rest period, the following work cycle will be reduced by one-third.
- Oral temperature: Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking).
 - If oral temperature exceeds 99.6° (37.6°C), the next work cycle will be reduced by one-third without changing the rest period.
 - If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, the following work cycle will be reduced by one-third.
 - No worker will be permitted to wear a semipermeable or impermeable garment when oral temperature exceeds 100.6°F (38.1°C).

5.2.10 Cold Exposure

It is possible that work on this project may be conducted during the winter months; therefore, injury due to cold exposure may become a problem for field personnel. Cold exposure symptoms, including hypothermia and frostbite, will be monitored when personnel are exposed to low temperatures for extended periods of time.

Persons working outdoors in temperatures at or below freezing may suffer from cold exposure. During prolonged outdoor periods with inadequate clothing, effects of cold

exposure may even occur at temperatures well above freezing. Cold exposure may cause severe injury by freezing exposed body surfaces (frostbite), or may result in profound generalized cooling (hypothermia), possibly causing death. Areas of the body which have high surface area-to-volume ratios such as fingers, toes, and ears are the most susceptible to frostbite.

Two factors influence the development of a cold injury: ambient temperature and wind velocity. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. For example, 14°F with a wind speed of 15 miles per hour (mph) is equivalent in chilling effect to still air at -18°F. Cold exposure is particularly a threat to site workers if the body cools suddenly when chemical-protective equipment is removed, and the clothing underneath is perspiration-soaked. The presence of wind greatly increases the rate of cooling.

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage. Frostbite of the extremities can be categorized into:

- Frost nip or incipient frostbite: characterized by sudden blanching or whitening of skin.
- Superficial frostbite: skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.
- Deep frostbite: tissues are cold, pale, and solid; an extremely serious injury.

Systemic hypothermia, or lowering of the core body temperature, is caused by exposure to freezing or rapidly dropping temperatures. Symptoms are usually exhibited in five stages:

- Shivering and uncoordination;
- Apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F (35°C);

- Unconsciousness, glassy stare, slow pulse, and slow respiratory rate;
- Freezing of the extremities; and
- Death.

5.2.10.1 Evaluation and Control

TLVs recommended for properly clothed workers for periods of work at temperatures below freezing are shown in Table 5.3. For exposed skin, continuous exposure should not be permitted when the air speed and temperature results in an equivalent chill temperature of -32°C (-25.6°F). Superficial or deep local tissue freezing will occur only at temperatures below -1°C (30.3°F) regardless of wind speed.

Special protection of the hands is required to maintain manual dexterity for the prevention of accidents. If fine work is to be performed with bare hands for more than 10 to 20 minutes in an environment below 16°C (60.8°F), special provisions should be established for keeping the workers' hands warm. For this purpose, warm air jets, radiant heaters (fuel burner or electric radiator), or contact warm plates may be used. At temperatures below -1°C (30.2°F), metal handles of tools and control bars should be covered by thermal insulating material.

To prevent contact frostbite, workers should wear gloves. When cold surfaces below -7°C (19.4°F) are within reach, a warning will be given to the workers by the supervisor or SHSO to prevent inadvertent contact with bare skin. If the air temperature is -17.5°C (0°F) or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

Provisions for additional total body protection are required if work is performed in an environment at or below 4°C (39.2°F). The workers will wear cold protective clothing appropriate for the level of cold and physical activity. If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind should be reduced by shielding the work area or by wearing an easily removable



TABLE 5.3
THRESHOLD LIMIT VALUES WORK/
WARM-UP SCHEDULE FOR FOUR-HOUR SHIFT

Air Temperature - Sunny Sky		No Noticeable Wind		5 mph Wind		10 mph Wind		15 mph Wind		20 mph Wind	
°C (approx.)	°F (approx.)	Max. Work Period	No. of Breaks								
-26° to -28°	-15° to -19°	(Norm. Breaks)	1	(Norm. Breaks)	1	75 min	2	55 min	3	40 min	4
-29° to -31°	-20° to -24°	(Norm. Breaks)	1	75 min	2	55 min	3	40 min	4	30 min	5
-32° to -34°	-25° to -29°	75 min	2	55 min	3	40 min	4	30 min	5	Non-emergency work should cease	
-35° to -37°	-30° to -34°	55 min	3	40 min	4	30 min	5	Non-emergency work should cease			
-38° to -39°	-35° to -39°	40 min	4	30 min	5	Non-emergency work should cease		Non-emergency work should cease			
-40° to -42°	-40° to -44°	30 min	5	Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease			
-43° & below	-45° & below	Non-emergency work should cease									

Notes for Table 5.3

- Schedule applies to any 4-hour work period with moderate to heavy work activity, with warm-up periods in a warm location and with an extended break (e.g., lunch) at the end of the 4-hour work period in a warm location. For light-to-moderate work (limited physical movement): apply the schedule one step lower. For example, at -35°C (-30°F) with no noticeable wind (Step 4), a worker at a job with little physical movement should have a maximum work period of 40 minutes with 4 breaks in a 4 hour period (Step 5).
- The following is suggested as a guide for estimating wind velocity if accurate information is not available: 5 mph; light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.
- In general the warm-up schedule provided above slightly under-compensates for the wind at the warmer temperatures, assuming acclimatization and clothing appropriate for winter work. On the other hand, the chart slightly over-compensates for the actual temperatures in the colder ranges, since windy conditions rarely prevail at extremely low temperatures.
- TLVs apply only for workers in dry clothing.



windbreak garment. If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work will be modified or suspended until adequate clothing is made available or until weather conditions improve.

5.2.10.2 Work-Warming Regimen

If work is performed continuously in the cold at an equivalent chill temperature (ECT) below -7°C (19.4°F), heated warming shelters (tents, cabins, rest rooms) will be made available nearby. The workers will be encouraged to use these shelters at regular intervals, the frequency depending on the severity of the environmental exposure. The onset of heavy shivering, frostnip, the feeling of excessive fatigue, drowsiness, irritability, or euphoria are indications for immediate return to the shelter. When entering the heated shelter, the outer layer of clothing should be removed and the remainder of the clothing loosened to permit sweat evaporation, or a change of dry work clothing should be provided. A change of dry work clothing may be necessary to prevent workers from returning to work with wet clothing. Dehydration, or the loss of body fluids, occurs insidiously in the cold environment and may increase the susceptibility of the worker to cold injury due to a significant change in blood flow to the extremities. Warm sweet drinks and soups should be provided at the work site to provide caloric intake and fluid volume. The intake of coffee should be limited because of the diuretic and circulatory effects.

For work practices at or below -12°C (10.4°F) ECT, the following should apply:

- The workers will be under constant protective observation (buddy system or supervision).
- The work rate should not be so high as to cause heavy sweating that will result in wet clothing; if heavy work must be done, rest periods will be taken in unheated shelters, and the opportunity for changing into dry clothing should be provided.

- New employees should not be required to work full-time in the cold during the first days of employment until they become accustomed to the working conditions and required protective clothing.
- The weight and bulkiness of clothing should be included in estimating the required work performances and weights to be lifted by the worker.
- The work should be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected metal chair seats will not be used. The worker should be protected from drafts to the greatest extent possible.
- The workers will be instructed in safety and health procedures relative to cold exposures.

5.3 BIOLOGICAL HAZARDS

Various biological hazards may be encountered at the site. These hazards include pathogenic organisms or diseases such as Equine Encephalitis and Lyme Disease. Other biological hazards include insects, snakes, spiders, and cactuses or other harmful plants (such as poison ivy).

Equine encephalitis, an inflammation of the brain, can be carried by mosquitoes. Field personnel must wear long-sleeved clothing and/or use insect repellents if they are working in areas of mosquito infestations.

Bites from wood ticks may result in the transmission of Lyme disease - a serious and often fatal bacterial disease. The *Borrelia burgdorferi* bacteria infects wood ticks, which can bite humans and transfer the bacteria into the bloodstream. Transmission of Lyme disease is most likely in late spring, summer, and early fall.

There are three stages of Lyme disease, although not everyone will proceed through all the stages or experience all the symptoms. The initial symptoms may include a red rash that is circular and blotchy and expands around the tick bite, and flu-like symptoms such

as fatigue, headaches, fever, swollen glands, and stiffness and pain in muscles and joints. The next stage can occur from a few days to a few weeks after the initial stage. Symptoms of this phase may include irregular heartbeat, facial paralysis, joint pain, irritability, headaches, dizziness, poor coordination, weakness, severe fatigue, and memory loss. The third stage may occur weeks to years after the second stage. Arthritis, often in the knees, is the most common symptom of this stage. The arthritis may disappear and recur many times, and chronic arthritis may develop.

Prompt medical treatment with antibiotics is usually successful in preventing further complications from this disease. Lyme disease becomes more difficult to treat the longer treatment is delayed. Long-sleeved shirts with snug collar and cuffs, pants tucked into socks, and personal protective equipment will offer some protection. However, the use of tick repellent may also be warranted. Personnel should perform self-checks for ticks at the end of each work day.

The potential exists for contact with snakes or insects which may cause injury or disease when performing investigation or remediation activities at the installations. There are plants which may be injurious (i.e., thorns) as well. Sturdy work clothes and shoes will be worn by field personnel to help prevent injuries. Personnel should be aware that rattlesnakes, water moccasins or alligators may be present in an area and should therefore exercise caution, especially when working in previously undisturbed areas and locations around animal dens and wetland habitats.

Poison ivy, poison oak, and poison sumac can be encountered at many installations. Poison ivy is a woody vine leaves are divided into three leaflets. Poison oak is a low branching shrub with leaflets also in threes. Poison sumac is a shrub or small tree occurring in swamps. Poison sumac have 7 to 13 leaflets which resemble those of green ash trees. All of these species are poisonous and can cause contact dermatitis. Personnel must wear Tyvek® suits or other protective clothing when working in areas containing these plant species.

Black widow spiders may also be present onsite. The black widow spider has a shiny black body about the size of a pea, with a red or yellow hourglass-shaped mark on its abdomen. It weaves shapeless diffuse webs in undisturbed areas. A bite may result in severe pain, illness, and possible death from complications, but usually not from the bite itself. There are several types of scorpions native to the United States. In addition to spiders, bees and wasps may be nuisances to field personnel. Properly trained personnel will administer first aid should a bee or wasp sting occur.

SECTION 6

EMERGENCY RESPONSE PLAN

All hazardous waste site activities will present a degree of risk to onsite personnel. During routine operations, risk is minimized by establishing good work practices, staying alert, and using proper PPE. Unpredictable events such as physical injury, chemical exposure, or fire may occur and must be anticipated. The sections below establish procedures and guidelines for emergencies.

6.1 GUIDELINES FOR PRE-EMERGENCY PLANNING AND TRAINING

Employees must read this program health and safety plan and the appropriate site-specific addendum to this plan, and familiarize themselves with the information provided. Prior to project initiation, the SHSO will conduct a meeting with the field team members to review the provisions of this program health and safety plan and the addendum, and to review the emergency response plan. Employees are required to have a copy of the emergency contacts and telephone numbers immediately accessible onsite and know the route to the nearest emergency medical services. The emergency contacts, telephone numbers, and routes to the hospital are provided in Section 12.

6.2 EMERGENCY RECOGNITION AND PREVENTION

Emergency conditions are considered to exist if:

- Any member of the field crew is involved in an accident or experiences any adverse effects or symptoms of exposure while onsite.
- A condition is discovered that suggests the existence of a situation more hazardous than anticipated (e.g. flammable atmospheres).

- Concentrations of combustible vapors reach or exceed 10 percent of the lower explosive limit (LEL).
- A fire or explosion hazard exists.
- Concentrations of organic vapors measured in the worker breathing zone by a photoionization detector (PID) are above background air concentrations greater than an amount equal to the lowest permissible exposure limit (PEL) of a contaminant of concern onsite.
- A vehicle accident occurs.

Preventive measures are listed below.

- Site workers must maintain visual contact and should remain close together to assist each other during emergencies. (Use the buddy system.)
- During continual operations, onsite workers act as safety backup to each other. Offsite personnel provide emergency assistance.
- All field crew members should make use of all of their senses to alert themselves to potentially dangerous situations to avoid (e.g., presence of strong and irritating or nauseating odors).
- Personnel will practice unfamiliar operations prior to performing them in the field.
- Field crew members will be familiar with the physical characteristics of investigations and field demonstrations, including:
 - Wind direction in relation to contamination zones;
 - Accessibility to co-workers, equipment, vehicles and communication devices;
 - Communication signals and devices;
 - Hot zone locations (areas of known or suspected contamination);

- Site access; and
- Nearest water sources.
- Personnel and equipment in the designated work area should be minimized, consistent with effective site operations.

The discovery of any condition that would suggest the existence of a situation more hazardous than anticipated, will result in the reevaluation of the hazard and the level of protection required, and may result in a temporary evacuation of the field team from the immediate work area. Such conditions may include an adverse effect or symptom of exposure experienced by a field team member, or the exceedance of the action levels for organic vapors and/or combustible vapors. If the action levels for organic vapors and/or combustibles are exceeded, procedures will be followed as stated in Section 7 of this health and safety plan.

In the event of an accident, the SHSO or site manager will complete the Accident Report Form provided in Appendix A. Copies of the completed forms will be maintained by the program health and safety manager in the health and safety file of the affected employee. Follow-up action should be taken to correct the situation that caused the accident.

Near-miss incidents will also be documented using the form provided in Appendix A, and filed with the onsite health and safety records, as well as with the program health and safety manager. Near-miss incidents are defined as any incident which could have led to injury or property damage, but for whatever reason, did not. The assessment of near-miss incidents provides a better measure of safety program effectiveness than simply tracking accidents, since near-misses tend to occur at much higher frequencies than actual accidents.

6.3 PERSONNEL ROLES, LINES OF AUTHORITY, AND COMMUNICATION PROCEDURES DURING AN EMERGENCY

When an emergency occurs, decisive action is required. Rapidly made choices may have far-reaching, long-term consequences. Delays of minutes can create or exacerbate life-threatening situations. Personnel must be ready to respond to emergency situations immediately. All personnel will know their own responsibilities during an emergency, know who is in charge during an emergency, and the extent of that person's authority. This section outlines personnel roles, lines of authority, and communication procedures during emergencies.

In the event of an emergency situation at the site, the site manager will assume total control and will be responsible for onsite decision-making. The designated alternate for the site manager will be the SHSO. These individuals have the authority to resolve all disputes about health and safety requirements and precautions. They will also be responsible for coordinating all activities until emergency response teams (ambulance, fire department, etc.) arrive onsite.

The site manager and/or SHSO will ensure that the necessary Navy personnel, Parsons ES personnel, and agencies are contacted as soon as possible after the emergency occurs. All onsite personnel must know the location of the nearest phone and the location of the emergency phone number list.

6.4 EVACUATION ROUTES AND PROCEDURES, SAFE DISTANCES, AND PLACES OF REFUGE

In the event of emergency conditions, decontaminated employees will evacuate the area as instructed, transport decontaminated injured personnel, or take other measures to ameliorate the situation. Evacuation routes and safe distances will be decided upon and posted by the field team prior to initiating work. Evacuation routes will be oriented upwind of the exclusion zone. Wind direction will be monitored through the use of wind socks, surveyors flagging or other appropriate measures.

6.5 DECONTAMINATION OF PERSONNEL DURING AN EMERGENCY

Procedures for leaving a contaminated area must be planned and implemented prior to going onsite. Decontamination areas and procedures will be established based on anticipated site conditions. If a member of the field crew is exposed to chemicals, the emergency procedures outlined below will be followed:

- Another team member (buddy) will assist or remove the individual from the immediate area of contamination to an upwind location.
- Precautions will be taken to avoid exposure of other individuals to the chemical.
- If the chemical is on the individual's clothing, the clothing will be removed if it is safe to do so.
- Administer first aid and transport the victim to the nearest medical facility, if necessary.

If uninjured employees are required to evacuate a contaminated area in an emergency situation, emergency decontamination procedures will be followed. At a minimum, these would involve moving into a safe area and removing protective equipment. Care will be taken to minimize contamination of the safe area and personnel. Contaminated clothing will be placed in plastic garbage bags or other suitable containers. Employees will wash or shower as soon as possible.

6.6 EMERGENCY SITE SECURITY AND CONTROL

For this project, the site manager (or designated representative) must know who is onsite and who is in the work area. Personnel access into the work area will be controlled. In an emergency situation, only necessary rescue and response personnel will be allowed into the exclusion zone.

6.7 PROCEDURES FOR EMERGENCY MEDICAL TREATMENT AND FIRST AID

The following general procedures will be implemented in the event of an emergency. Emergency contact names and telephone numbers and a map detailing the route to the local hospital are included in Section 12.

6.7.1 Chemical Exposure

In the event of chemical exposure (skin contact, inhalation, ingestion) the following procedures will be implemented:

- Another team member (buddy) will assist or remove the individual from the immediate area of contamination to an upwind location.
- Precautions will be taken to avoid exposure of other individuals to the chemical.
- If the chemical is on the individual's clothing, the clothing will be removed if it is safe to do so.
- If the chemical has contacted the skin, the skin will be washed with copious amounts of water, preferably under a shower.
- In case of eye contact, an emergency eyewash will be used. Eyes will be washed for at least 15 minutes. Emergency eyewashes will comply with ANSI Z-358.1 and filled with tempered water maintained no cooler than 60°F and no warmer than 95°F. Eyewashes will be capable of delivering 0.4 to 0.8 gallons of water to both eyes for a minimum of 15 minutes. Each jobsite will have at least one emergency eyewash station. Each crew will have, at a minimum, an ANSI-approved personal eyewash suitable for initial eye flushing while the injured person is moved to an emergency eyewash station or medical facility.
- If necessary, the victim will be transported to the nearest hospital or medical center. If necessary, an ambulance will be called to transport the victim.

6.7.2 Personal Injury

In the event of personal injury:

- Field team members trained in first aid can administer treatment to an injured worker.
- The victim will be transported to the nearest hospital or medical center. If necessary, an ambulance will be called to transport the victim.
- The SHSO or site manager is responsible for the completion of the appropriate accident report form.

6.7.3 Fire or Explosion

In the event of fire or explosion, personnel will evacuate the area immediately. Administer necessary first aid to injured employees. Personnel will proceed to a safe area and telephone the emergency support services designated in the appropriate sit-specific addendum. Upon contacting the emergency support services, state your name, nature of the hazard (fire, high combustible vapor levels), the location of the incident, and whether there were any physical injuries requiring an ambulance. Do not hang up until the emergency support services personnel have all of the additional information they may require.

SECTION 7

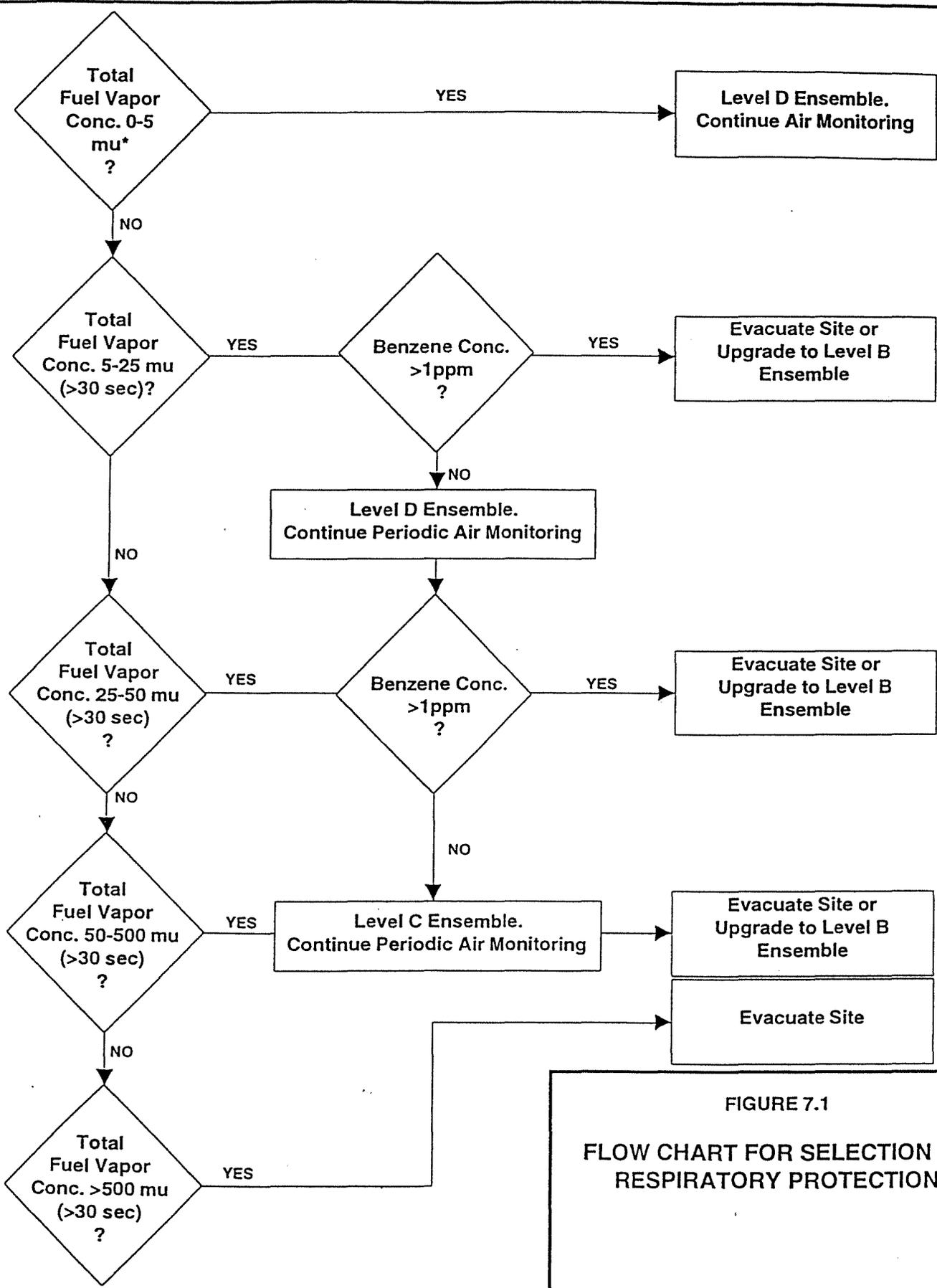
LEVELS OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT REQUIRED FOR SITE ACTIVITIES

7.1 PERSONAL PROTECTIVE EQUIPMENT

The personal protection level prescribed for the bioremediation treatability studies is OSHA Level D (no respiratory or chemical protective clothing), with a contingency for the use of OSHA Level C or B as site conditions require (Figure 7.1). Unless certain compounds are ruled out through use of appropriate air monitoring techniques such as Dräger® tubes, portable sampling pumps, or an onsite gas chromatograph (GC), Level C respiratory protection (air-purifying respirator [APR]) cannot be used. Level C protection may only be used on this project when vapors in air are adequately identified and quantified and Level C respirator-use criteria are met. Level B (supplied air) respiratory protection must be used on this project in the presence of unknown vapor constituents or if benzene or vinyl chloride is detected at or above 1 part per million, volume per volume (ppmv). This is based primarily on the toxicity and inadequate warning properties (high odor threshold) for benzene and vinyl chloride. In addition, the PEL for 1,1-DCE is also 1 ppmv. The presence of 1,1-DCE can only be confirmed by laboratory analysis. Air monitoring must be conducted in the worker breathing zone when the potential occurrence of these compounds exists.

Ambient air monitoring of organic gases/vapors (using photoionization detectors such as an HNU® or Photovac® MicroTIP®, or by colorimetric analysis with Dräger® tubes) will be used to select the appropriate level of personal protection. If there is the potential for vinyl chloride at the site, a reading of 1 ppmv or greater above background in the worker breathing zone as indicated by a PID will require the use of a Dräger® tube or the equivalent to determine if vinyl chloride is present at a concentration greater than or equal





* mu = Meter Units

FIGURE 7.1
 FLOW CHART FOR SELECTION OF
 RESPIRATORY PROTECTION

PARSONS
 ENGINEERING SCIENCE, INC.
 Denver, Colorado



to the PEL of 1 ppmv. Due to the inadequate warning properties of vinyl chloride, Level B protection must be used if concentrations of vinyl chloride exceed 1 ppmv above background in the worker breathing zone. If vinyl chloride is not present, continue to monitor the air in the worker breathing zone. If concentrations in the worker breathing zone persist above 1 ppmv as indicated by the PID, periodic use of the vinyl chloride Dräger® tubes must be used to confirm the absence of vinyl chloride.

If there exists the potential for 1,1-DCE at the site, the following will occur since there is no Dräger® tube for 1,1-DCE. If sustained air monitoring readings in the worker breathing zone indicate vapor concentrations greater than or equal to 1 ppm above background for 30 seconds or longer, the field crew will be forced to evacuate and ventilate the area until readings are less than 1 ppm in the worker breathing zone. If ventilation is inadequate, air samples will be taken to confirm or deny the existence of the contaminants of concern and/or the crew will upgrade to Level B respiratory protection. These samples will be sent to a lab to analyzed by Environmental Protection Agency (EPA) Compendium Method TO-14 or the equivalent.

If the aforementioned solvents are not present, the flow chart presented in Figure 7.1 will be used to select respiratory protection against volatile hydrocarbon constituents. If the portable air monitoring equipment indicates organic vapor concentrations of 0-5 meter units (mu), site workers will continue air monitoring in a Level D ensemble. If organic vapors reach 5-25 mu for more than 30 seconds, and benzene concentrations exceed 1 ppmv, site workers will evacuate the area or upgrade to Level B ensemble, if trained to do so. If benzene concentrations are less than 1 ppmv in the breathing zone, and vapors are in the range of 5-25 mu, the site crews may continue in Level D ensembles with periodic air monitoring. If organic vapor concentrations reach 25-50 mu for more than 30 seconds and benzene concentrations exceed 1 ppmv in the worker breathing zone, site crews will evacuate the area or upgrade to Level B ensembles. If benzene concentrations are less than 1 ppmv, and vapors are in the range of 25-50 mu, site workers will don full facepiece APRs equipped with organic vapor cartridges (National Institute for Occupational Safety and Health [NIOSH]-approved), and continue periodic

monitoring. If organic vapor concentrations reach 50-500 mu for more than 30 seconds, site crews will evacuate the site or upgrade to Level B ensembles. If organic vapor concentrations exceed 500 mu for more than 30 seconds, site crews will evacuate the site.

Before work can be performed in Level B respiratory protection, the project manager must be notified. He will initiate the change order process with the Navy or decide to halt activities at that site. (Level B operations also require approval from Parsons ES corporate health and safety.) The SHSO will determine whether it is safe to continue activities without respiratory protection or assign an upgrade to Level C protection.

The use of PPE will be required when handling contaminated samples and working with potentially contaminated materials. The SHSO must ensure that all field personnel are properly trained in use, maintenance, limitations (including breakthrough time), and disposal of PPE assigned to them, in accordance with federal OSHA regulations in 29 CFR 1910.132. Disposable PPE will be used whenever possible to simplify decontamination, to reduce generation of contaminated washwater, and to avoid potential problems with chemical permeation (breakthrough). Single-use PPE (such as Tyvek®) will be disposed of whenever personnel go through decontamination. At most, a single item of disposable PPE (including respirator cartridges) will be used for no more than one day and will then be disposed of. Double layers of gloves will be used when personnel are handling contaminated soil or water, or equipment to minimize breakthrough. If personnel note chemical odors on their hands, clothing or skin after wearing PPE, or develop skin irritation or rashes, consult with the SHSO and decide on alternate actions and/or seek medical attention.

Respirator and other PPE selection will be determined for each of the sites individually and variations from what is specified in this plan will be presented in the site-specific addenda. The criteria will be based on previously collected data indicating the contaminants of concern and their concentrations. Respiratory protection against chlorinated solvents will be discussed in the site-specific addenda. Hard hats will be worn in the vicinity of the Rotosonic drilling rig and in all other areas where a head

impact hazard exists. Steel-toed, steel-shank leather workboots will be worn by all field personnel.

The following personal protective ensemble is required only when handling contaminated samples or equipment.

Mandatory Equipment

- Vinyl or latex inner gloves
- 4H or SilverShield® outer gloves

Optional Equipment

- Air-purifying respirator (equipped with organic vapor/high-efficiency particulate air [HEPA] cartridges)
- Self-contained breathing apparatus or air-line respirator in pressure-demand mode
- Rubber safety boots
- Disposable Tyvek® coveralls
- Outer disposable boot covers
- Saranex® suits
- Chemical goggles

7.2 EQUIPMENT NEEDS

Each field team will have the following items readily available:

- Copy of this project health and safety plan and a separate list of emergency contacts;
- First aid kit which includes PPE for bloodborne pathogens;
- Eyewash station;
- Paper towels;
- Duct tape;

- Water (for drinking and washing);
- Plastic garbage bags;
- Fire extinguisher; and
- Earplugs.

7.3 EQUIPMENT DISPOSAL

All reusable PPE (such as hard hats and respirators), if contaminated, will be decontaminated in accordance with procedures specified in Section 10 of this health and safety plan. Contaminated single-use PPE (such as Tyvek® suits and protective gloves) will be properly disposed of according to installation requirements.

SECTION 8

FREQUENCY AND TYPES OF AIR MONITORING

Air monitoring will be used to identify and quantify airborne levels of hazardous substances. Periodic monitoring is required during on site activities. The types of monitoring and equipment to be used are as follows:

<u>Type of Equipment</u>	<u>Minimum Calibration Frequency</u>	<u>Parameter(s) to be Measured</u>	<u>Minimum Sampling Frequency</u>	<u>Sampling Locations</u>
Photoionization Detector	1/day	Benzene Organic Vapors	2/hour for general site activities	Breathing Zone
Explosivity Meter	1/day	Combustible Gases	2/hour as needed	Soil Borings Monitoring Wells
Sensidyne® or Drager® Tubes	None (check manufacturer's requirements)	Benzene Organic Vapors	When PID Exceeds lowest PEL of the contaminants of concern	Breathing Zone
Dosimeter Badges	None	Benzene Organic Vapors	As needed on workers with greatest exposure to contamination initially detected by Drager® tubes	Breathing Zone
Portable Air Sampling Pumps	Prior to and after each use	Benzene Organic Vapors	As needed on workers with greatest exposure to contamination initially detected by Drager® tubes	Breathing Zone

During bioremediation activities, a photoionization detector (such as an HNU® or MicroTIP®) equipped with an 11.7 electron-volt (eV) lamp will be used to measure ambient air concentrations in the worker breathing zone.

Evacuation may be necessary if the lowest PEL of a contaminant of concern is exceeded above background in the breathing zone of the site workers. This evacuation will be necessary until the area is well ventilated or the respiratory protection is upgraded, if possible. Any detectable concentration above background concentrations in the breathing zone will necessitate following the respiratory protection flowchart (Figure 7.1). The explosivity meter will be used at least twice per hour to measure combustible gas levels at the wellhead or borehole when a potential exists for combustible vapors. At 10 percent of the LEL, evacuate the area and allow the borehole to ventilate.

Worker exposure monitoring will be conducted to document any exposures of Parsons ES site personnel to organic vapors. Portable air sampling pumps or dosimeter badges will be used for personal exposure monitoring, if necessary. The following general protocols will be followed if badges or pumps are used.

Passive Dosimeter Badges

An organic vapor monitoring badge will be attached in the worker's breathing zone for an eight-hour period when the potential for exposure exists. The exposed badges and a blank will be sent to the laboratory for analysis. These personal dosimeter badges work by means of diffusion eliminating the need for a pump, calibration or batteries.

Portable Sampling Pumps

- The portable pump will be calibrated to the required flow rate (in liters per minute) following the manufacturer's calibration procedures.
- The pump will be equipped with the appropriate sorbent tube for the particular organic compounds to be monitored (e.g., charcoal for volatile organics).
- A personal air monitoring data sheet (provided in Appendix A) listing pump flow rates, start and stop times, sorbent tube used, etc. will be completed.
- The pump will undergo a post calibration to determine final flow rates.

- The laboratory analytical results will be disclosed to the employee(s) monitored.
- The analytical results will be placed in the employee's permanent medical file for documentation of any exposures received.



SECTION 9

SITE CONTROL MEASURES

The following site control measures will be followed to minimize potential contamination of workers, protect the public from potential site hazards, and control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. The first aspect, site organization, is discussed in this section. The second aspect, decontamination, is considered in the next section.

9.1 SITE ORGANIZATION-OPERATION ZONES

The following organization-operation zones will be established on the site or around a particular site feature (e.g., the drill rig).

- Exclusion Zone (Contamination Zone),
- Contamination Reduction Zone, and
- Support Zone.

The site manager and/or SHSO will be responsible for establishing the size and distance between zones at the site or around the site feature. Considerable judgment is required to ensure safe working distances for each zone are balanced against practical work considerations.

9.1.1 Exclusion Zone (Contamination Zone)

The exclusion zone includes the areas where active investigation or cleanup operations take place. Within the exclusion zone, prescribed levels of PPE must be worn by all personnel. The hotline, or exclusion zone boundary, is initially established based upon

the presence of actual wastes or apparent spilled material, or through air monitoring, and is placed around all physical indicators of hazardous substances. For drilling operations, the hotline will be located at a distance equal to the drilling rig boom height or 25 feet, whichever is greater, from the drill rig. The hotline generally consists of an easily identifiable physical boundary (e.g., bright orange or yellow flagging attached to stakes, and may be readjusted based upon subsequent observations and measurements. This boundary will be physically secured and posted or well-defined by physical and geographic boundaries.

Under some circumstances, the exclusion zone may be subdivided into zones based upon environmental measurements or expected onsite work conditions.

9.1.2 Contamination Reduction Zone

If decontamination is required, a contamination reduction zone will be established between the exclusion zone and the support zone. The contamination reduction zone will be located upwind of the exclusion zone. This zone provides an area to prevent or reduce the transfer of hazardous materials which may have been picked up by personnel or equipment leaving the exclusion area. All decontamination activities occur in this area. The organization of the contamination reduction zone, and the control of decontamination operations, are described in Section 10.

9.1.3 Support Zone

The support zone is the outermost area of the site and is considered a noncontaminated or clean area. The support zone contains the command post for field operations, first-aid stations, and other investigation and cleanup support. Normal work clothes are appropriate apparel within this zone; potentially contaminated personnel, clothing or equipment are not permitted.

9.2 SITE SECURITY

Site security is necessary to prevent exposure of unauthorized, unprotected individuals in the work area. The areas immediately surrounding the work area will be clearly

marked through use of warning signs, traffic cones, barrier tape, rope, or other suitable means.

Site security will be enforced by the SHSO or a designated alternate who will ensure that only authorized personnel are allowed in the work area and that entry personnel have the required level of PPE, are trained under the requirements of 29 CFR 1910.120, and are on a current medical monitoring program.

9.3 SITE COMMUNICATION

Internal site communication is necessary to alert field team members in the exclusion and contamination reduction zones to:

- Emergency conditions;
- To convey safety information; and
- Communicate changes or clarification in the work to be performed.

For internal site communication, the field team members will use prearranged hand signals (and responses). Radios and/or compressed air horns may also be used for communication.

External site communication is necessary to coordinate emergency response teams and to maintain contact with essential offsite personnel. A telephone will be available for use in external site communication. A list of emergency contact telephone numbers will be provided in subsequent addenda.

9.4 SAFE WORK PRACTICES

To ensure a strong safety-awareness program during field operations, field personnel will be adequately trained for their particular tasks. In addition, standing work orders will be developed and communicated to all field personnel, as will the provisions of this program health and safety plan and the appropriate addenda. Sample standing work

orders for personnel entering the contamination reduction zone and exclusion zone are as follows:

- No horseplay at any time;
- No smoking, eating, drinking or chewing of tobacco or gum;
- Alcoholic beverage intake and illegal drug use is prohibited during the work shift and will result in immediate dismissal from the site;
- No matches or lighters;
- No personal vehicles;
- Check in/check out at access control points;
- Use the buddy system;
- Wear appropriate PPE;
- Avoid walking through puddles or stained soil;
- Upon discovery of unusual or unexpected conditions, immediately evacuate and reassess the site conditions and health and safety practices;
- Conduct safety briefings prior to onsite work;
- Conduct daily safety meetings; and
- Take precautions to reduce injuries resulting from heavy equipment and other tools.

SECTION 10

DECONTAMINATION PROCEDURES

10.1 PERSONNEL DECONTAMINATION PROCEDURES

An exclusion zone, contamination reduction zone, and support zone will be established whenever field personnel are using PPE. Decontamination station layout will be made on a site-specific basis and will be based on the level of PPE used, the types of chemical hazards encountered, and the site conditions, including topography, wind direction, and traffic patterns. Defined site access and egress points will be established and personnel will enter and exit only through these points. As a general rule, persons assisting in the decontamination station may be in one level lower of respiratory protection than required in the work zone.

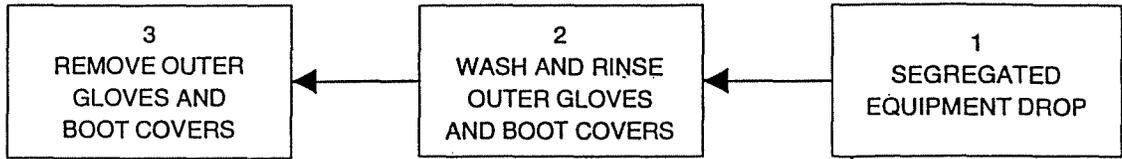
A guideline for personnel decontamination is presented in Figure 10.1. This procedure may be modified by the SHSO if necessary.

If personnel are in Level D-modified protection (no respirator but using protective gloves and/or suits and other equipment), a portable decontamination station will be set up at the site. The decontamination station will include provisions for collecting disposable PPE (e.g., garbage bags); washing boots, gloves, vinyl rain suits, field instruments and tools; and washing hands, face, and other exposed body parts. Onsite personnel will shower at the end of the work day. Refuse from decontamination will be properly disposed of in accordance with US Navy installation protocols.

Decontamination equipment will include:

- Plastic buckets and pails;
- Scrub brushes and long-handle brushes;

EXCLUSION ZONE



FILTER OR TANK CHANGE

4 WASH AND REMOVE SCBA BACKPACK (SKIP IF LEVEL C)

5 REMOVE DISPOSABLE TYVEK SUIT

6 WASH INNER GLOVES, REMOVE RESPIRATOR FACE PIECE

7 WASH/RINSE RESPIRATOR

8 REMOVE INNER GLOVES

9 FIELD WASH

EQUIPMENT DECONTAMINATION CORRIDOR

WIND DIRECTION ↑

CONTAMINATION REDUCTION ZONE

SUPPORT ZONE

FIGURE 10.1

DECONTAMINATION STATION LAYOUT
LEVEL B AND C PROTECTION

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

- Detergent;
- Containers of water;
- Paper towels;
- Plastic garbage bags;
- Plastic or steel 55-gallon barrels;
- Distilled water; and
- An eyewash station.

10.2 DECONTAMINATION OF EQUIPMENT

Decontamination of drilling rigs will be conducted at a designated location. High-pressure steam-cleaning of the rig will be necessary prior to the beginning of the drilling operation, between borehole locations, and before the drilling rig leaves the project site. All sampling equipment will be decontaminated prior to use, between samples, and between sampling locations. PPE will consist of splash protective clothing, eye protection, gloves, and boot covers, as necessary.

SECTION 11

AIR MONITORING EQUIPMENT USE AND CALIBRATION PROCEDURES

11.1 PHOTOVAC MICROTIP® AIR ANALYZER

The MicroTIP® is a direct-reading instrument used in conjunction with the span gas kit. To calibrate the MicroTIP®, press the power switch. Allow the MicroTIP® to warm up; the display will read "Ready." Press the calibration switch; the display will read "Connect zero gas then press enter." Connect the bag of zero gas to the MicroTIP® inlet (or allow the MicroTIP® to sample clean air) and press enter; the display will read "Calibrating now please wait." The display will then read "Span Conc.?" Enter the span concentration (usually 100 ppmv isobutylene). Connect the bag of span gas to the tip inlet and press enter; the display will read "Connect span gas then press enter." The MicroTIP® will then calibrate. When the display reads "Ready," the MicroTIP® has completed the calibration and is ready for use. Repeat the calibration daily.

To use the MicroTIP®, press the power switch and wait for the instrument to display the date, time, event number, current detected concentrations, and instrument status "ready." The minimum, maximum, and average concentrations measured in each 15-second period are automatically recorded in memory. The keyboard also allows for direct numeric entry.

Since a calibration gas (i.e., isobutylene) is used which typically differs from the contaminants of concern, it may be necessary to combine the instrument reading with a response factor to more closely approximate the concentration of the contaminants of concern. MSDSs for all chemicals (including calibration gases such as isobutylene) used in the field will be maintained by the field team.

Relative response factors are found in Table 11.1 for MicroTIP® models MP-100 and HL-200 with a 10.6 eV lamp. For these instruments, a more accurate concentration may be obtained by dividing the instrument reading by the appropriate relative response factor from Table 11.1 for the contaminant of concern.

For MicroTIP® instrument models MP-1000, HL-2000, IS-3000, and EX-4000 with a 10.6 eV lamp, the instrument reading is multiplied by the appropriate response factor from Table 11.2 for the contaminant of concern.

11.2 HNU® PHOTOIONIZATION DETECTOR

To calibrate the HNU®, turn the function switch to the “standby” mode and use the zero control to zero the instrument. Connect a bag of span gas (usually 100 ppmv isobutylene). Turn the function switch to the 0-200 range position and adjust the span control setting to read the ppmv concentration of the standard. Recheck the zero setting as previously described. If readjustment is needed, repeat the calibration step. This provides a two-point calibration to zero and the gas-standard point. Repeat the calibration daily. If the span setting from calibration is 0.0 or if calibration cannot be achieved, then the lamp must be cleaned.

To use the HNU® connect the probe to the instrument by matching the alignment slot in the probe connector to the key in the 12-pin connector on the control panel. Twist the probe connector until a distinct snap and lock is felt. Turn the function switch to battery check position. The needle should read within or above the green battery arc on the scale plate. If the needle is in the lower position of the battery arc, the instrument should be recharged before use. If the red light comes on, the battery should be recharged. Next, turn the functions switch to the on position, and the instrument is ready to take direct air readings.

11.3 EXPLOSIVITY METER

An explosivity meter is used to measure oxygen and combustible gas levels. The instrument provides characteristic warning signals when deficient oxygen conditions or unacceptable levels of combustible gas are detected.

TABLE 11.2
MICROTIP[®] RESPONSE FACTORS (10.6 eV LAMP)
INSTRUMENT MODELS MP-1000, HL-2000, IS-3000 & EX-4000

Compound	Response Factor	Compound	Response Factor
Acetaldehyde	6.6	n-Hexane	5.6
Acetic Acid	18.9	Hydrogen Sulfide	3.7
Acetone	1.2	Isobutyl Acetate	2.3
Acetone Cyanohydrin	1.2	Isobutyraldehyde	1.1
Acrolein	3.7	Isopentane	7.8
Allyl Chloride	4.3	Isoprene	0.6
Ammonia	10.1	Isopropyl Acetate	2.4
Benzene	0.6	Isopropyl Alcohol	4.5
1,3-Butadiene	0.7	Methyl Bromide	2.3
n-Butanol	4.6	Methyl tert-Butyl Ether	0.8
see-Butanol	3.0	Methyl Ethyl Ketone	0.9
n-Butyl Acetate	2.9	Methyl Isobutyl Ketone	1.1
n-Butyl Acrylate	1.9	Methyl Mercaptan	0.6
n-Butyl Mercaptan	0.7	Methyl Methacrylate	1.5
n-Butylaldehyde	1.9	Monoethylamine	0.8
Carbon Disulfide	1.4	Monomethylamine	1.0
Chlorobenzene	0.4	n-Octane	2.6
Cyclohexane	1.9	n-Pentane	10.8
Cyclohexanone	0.9	Perchloroethylene	0.7
1,2-Dichlorobenzene (ortho)	0.4	n-Propyl Acetate	3.5
cis-1,2-Dichloroethylene	0.8	n-Propyl Alcohol	6.3
trans-1,2-Dichloroethylene	0.4	Propionaldehyde	1.9
Diisobutylene	0.6	Propylene Oxide	7.1
Dimethylamine	1.5	Styrene	0.5
Di-n-propylamine	0.5	Tetrahydrofuran	1.5
1,4-Dioxane	1.2	Toluene	0.5
Epichlorohydrin	10.3	Trichloroethylene	0.6
Ethanol	11.1	Trimethylamine	0.9
Ethyl Acetate	4.2	Vinyl Acetate	1.2
Ethyl Acrylate	3.3	Vinyl Bromide	0.4
Ethylene	10.0	Vinyl Chloride	2.0
Ethyl Mercaptan	0.6	Vinylidene Chloride (1,1-DCE)	0.9
n-Heptane	3.7		

Note: Concentration = Instrument Reading x Response Factor



To use the explosivity meter, turn the unit on and wait a few seconds for the readings to stabilize. Check the battery charge and the alarms before using the instrument. Set the LEL indicator to zero and the oxygen indicator to 20.9 percent.

To calibrate the instrument, attach a bag, bulb or balloon of span gas and wait for the readings to stabilize. Adjust the instrument to read the LEL percent of the calibration gas. Remove the span gas and allow the instrument to exhaust. The combustible sensor will read 000-percent LEL in clean air.

11.4 SENSIDYNE® OR DRÄGER® COLORIMETRIC GAS ANALYSIS TUBES

Colorimetric tubes can be used to give an instantaneous reading of various organic compounds. Their aim is to determine very small concentrations of a compound in the shortest amount of time. To sample with a colorimetric tube use the Dräger® or Sensidyne® bellows pump and select the appropriate tube (for example, a tube marked benzene to look for benzene). Break off both ends on the pump's break-off plate. Insert the tube into the pump head (the tube should be inserted with the arrow pointing towards the pump). There is a specific number of suction strokes for each tube/compound. Each box of tubes will have instructions for how many suction strokes are required for that compound



SECTION 12

EMERGENCY CONTACTS

In the event of any situation or unplanned occurrence requiring assistance, the appropriate contact(s) should be made from a list similar to this which will be prepared in the health and safety plan addenda. For emergency situations, telephone or radio contact should be made with the site point of contact or site emergency personnel who will then contact the appropriate response teams.

<u>Contingency Contacts</u>	<u>Firm or Agency</u>	<u>Telephone Number</u>
Police	Tennessee State Police	911 (901) 873-2624
	NSA Mid-South Security	911 (901) 874-5522
Fire	Emergency Fire	911
Hospital	Methodist Hospital North	(901) 384-5200
Ambulance	Methodist Hospital North	911
HAZMAT Response	USEPA Environmental Response	(404) 347-4062
	USCG Environmental Response	(800) 424-8802
	Assoc. of Amer. Railroads Resp.	(800) 424-9300
Poison Control Center		(800) 523-2222
Rob Williamson	NSA Mid-South Site Contact	(901) 874-5399
Jim Reed	NAVFAC Project Manager	(843) 820-5543
 <u>Medical Emergency</u>		
Ambulance	Methodist Hospital North	911
Hospital Name	Methodist Hospital North	(901) 384-5200
Hospital Address	3960 New Covington Pike Memphis, TN 38128	
Emergency Room		911

Directions to the Hospital

From the site, turn left (south) on 5th Avenue and proceed approximately 0.5 mile past Navy Road to G Street. Turn left (east) on G Street and continue two blocks (approximately 0.25 mile) to 7th Avenue. Turn right (south) on 7th Avenue and proceed south, 7th Avenue becomes Singleton Parkway in approximately 0.5 mile. Turn slight right onto Singleton Parkway/TN-204 South. Proceed 6.4 miles south on Singleton Parkway/TN-204 South where Singleton Parkway/TN-204 South becomes New Covington Pike at Austin Peay Highway. Cross the Austin Peay Highway and proceed 0.1 mile on New Covington Pike. The hospital is on the left (northeast) side of New Covington Pike. The route to the hospital is shown on Figure 12.1.

Parsons ES Contacts

Bruce Henry Project Manager	(303) 831-8100 (w) (303) 422-4019 (h)
Timothy Mustard, CIH (Denver) Program Health and Safety Manager	(303) 831-8100 (w) (303) 450-9778 (h)
Edward Grunwald, CIH (Atlanta) Corporate Health and Safety Manager	(678) 969-2394 (w) (404) 299-9970 (h)
Judy Blakemore (Denver) Assistant Program Health and Safety Manager	(303) 831-8100 (w) (303) 828-4028 (h) (303) 817-9734 (m)

US Navy Contacts

Jim Reed, NAVFAC Project Manager	(843) 820-5543(w)
Rob Williamson, NSA Mid-South Project Manager	(901) 874-5399(w)

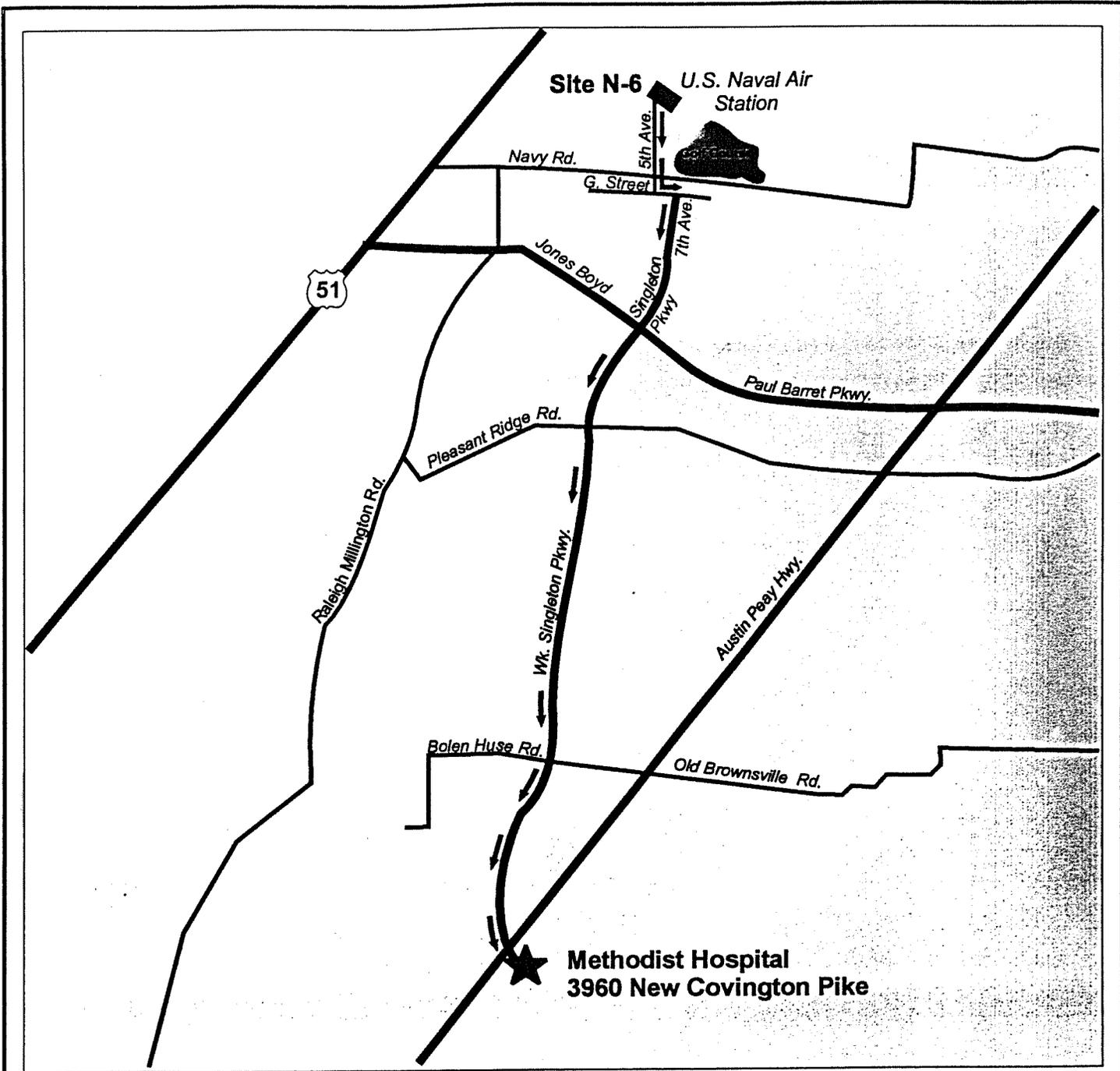


FIGURE 12.1

**DIRECTIONS TO
METHODIST HOSPITAL**

Site N-6 NSA Mid-South
Millington, Tennessee

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

APPENDIX A

PROJECT HEALTH AND SAFETY FORMS

PLAN ACCEPTANCE FORM

PROJECT HEALTH AND SAFETY PLAN

Instructions: This form is to be completed by each person to work on the subject project work site and returned to the safety manager.

I have read and agree to abide by the contents of the Health and Safety Plan for the following project:

Signed

Date

RETURN TO:

Office Health and
Safety Representative
Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290

SITE SPECIFIC TRAINING RECORD

Project: _____
Project No.: _____
Date: _____
Trainer: _____

On this date, the following individuals were provided site-specific training in accordance with OSHA regulations contained in 29CFR1910.120(e):

<u>Name (Print)</u>	<u>Employee No.</u>	<u>Employee Signature</u>
---------------------	---------------------	---------------------------

Forward this form to:

Office Health and Safety Representative
Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

PARSONS ENGINEERING SCIENCE, INC.

FIELD EXPERIENCE

DOCUMENTATION FORM

OSHA requires (29CFR1910.120(e)) that personnel involved in hazardous waste operations have 40-hours of initial training and a minimum of three days field experience working under the direction of a trained and experienced supervisor. This form serves to document the three days of additional field training/experience.

Employee Name: _____

Employee Number (or Social Security No.): _____

Project Name(s): _____

Project Number(s): _____

Dates of Field Training: _____

Summary of Activities Performed: _____

Levels of Respiratory Protection Used: _____

Comments:

Field Supervisor Signature: _____

Date: _____

Return this form to the Office Health and Safety Representative

**PARSONS ENGINEERING SCIENCE, INC.
PERSONAL AIR MONITORING DATA FORM**

PROJECT NAME _____

PROJECT NUMBER: _____

Person Sampling	Person(s) Sampled/Location	Date	Time	PID/BG** (PPM)	Dräger (PPM)	LEL/BG (%)	O ₂ /BG (%)	Other	Notes

PID

Explosimeter

Other

Model _____

Model _____

Model _____

Serial # _____

Serial # _____

Serial # _____

Cal. * Gas _____

Cal Gas _____

Cal Gas _____

Cal. Reading _____

Cal. Reading _____

Cal. Reading _____

BG Reading _____

BG Reading _____

BG Reading _____

* Cal = Calibration

**BG = Background

Project: _____

EMPLOYER

1. Name: _____

2. Mail Address: _____
(No. and Street) (City or Town) (State and Zip)

3. Location (if different from mail address): _____

INJURED OR ILL EMPLOYEE

4. Name: _____ Social Security No.: _____
(first) (middle) (last)

5. Home Address: _____
(No. and Street) (City or Town) (State and Zip)

6. Age: _____ 7. Sex: male () female ()

8. Occupation: _____
(specific job title, not the specific activity employee was performing at time of injury)

9. Department: _____
(enter name of department in which injured person is employed, even though they may have been temporarily working in another department at the time of injury)

THE ACCIDENT OR EXPOSURE TO OCCUPATIONAL ILLNESS

10. Place of accident or exposure: _____
(No. and Street) (City or Town) (State and Zip)

11. Was place of accident or exposure on employer's premises? Yes () No ()

12. What was the employee doing when injured? _____
(be specific--was employee using tools or equipment
_____ or handling material?)

13. How did the accident occur? _____
(describe fully the events that resulted in the injury or occupational illness.

Tell what happened and how. Name objects and substances involved. Give details on all factors that led to

_____ accident. Use separate sheet for additional space).

14. Time of accident: _____

15. ES WITNESS TO ACCIDENT
- | | | |
|--------|---------------|-------------|
| _____ | _____ | _____ |
| (Name) | (Affiliation) | (Phone No.) |
| _____ | _____ | _____ |
| (Name) | (Affiliation) | (Phone No.) |
| _____ | _____ | _____ |
| (Name) | (Affiliation) | (Phone No.) |

OCCUPATIONAL INJURY OR OCCUPATIONAL ILLNESS

16. Describe injury or illness in detail; indicate part of body affected:

17. Name the object or substance that directly injured the employee. (for example, object that struck employee; the vapor or poison inhaled or swallowed; the chemical or radiation that irritated the skin; or in cases of strains, hernias, etc., the object the employee was lifting, pulling, etc.).

18. Date of injury or initial diagnosis of occupational illness: _____
(date)

19. Did the accident result in employee fatality? Yes () No ()

20. Number of lost days ____/restricted workdays ____ resulting from injury or illness?

OTHER

21. Name and address of physician: _____
(No. and Street) (City or Town) (State and Zip)

22. If hospitalized, name and address: _____
(No. and Street) (City or Town) (State and Zip)

Date of report: _____ Prepared by: _____

Official position: _____

"NEAR MISS" INCIDENT INVESTIGATION REPORT FORM

1) Project name and number: _____

2) "Near miss" location: _____

3) Incident date and time: _____

4) Personnel present (optional): _____

5) Describe incident: _____

6) What action or condition contributed to incident? _____

7) What action was taken or suggested to prevent reoccurrence? _____

8) Comments _____

9) Date of report _____ Prepared by _____

10) Office health and safety representative review:

Signature

Date

APPENDIX B
JOB SAFETY ANALYSIS

**PARSONS ENGINEERING SCIENCE, INC.
JOB SAFETY ANALYSIS**

ACTIVITY: General Health and Safety

Potential Hazards	Recommended Controls
Slip, Trip, Fall, Loss of Balance	<ul style="list-style-type: none"> Site safety briefing Stay alert Maintain firm footing Use "buddy" system Watch for obstacles
Heat/Cold Stress	<ul style="list-style-type: none"> Wear appropriate clothing Monitor for heat/cold stress as recommended in the HASP Provide adequate drinking water (minimum 1.5 gallons/person) Carry communication equipment
Fire Hazards	<ul style="list-style-type: none"> Have approved fire protection devices available (see HASP) Equipment will be shut down prior to fueling Use good housekeeping procedures
Noise/Eye Hazards	<ul style="list-style-type: none"> Use hearing protection when appropriate Use approved safety glasses
Sharp Objects	<ul style="list-style-type: none"> Wear boots with steel toes and shanks Have a current tetanus booster as recommended by occupational physician Be extra cautious in areas containing medical "sharps"
Biohazard	<ul style="list-style-type: none"> Biohazard training Stay alert for snakes, insects, and animals Wear high-top safety boots
Physical Exertion	<ul style="list-style-type: none"> Follow work/rest regime Use "buddy" system Use proper lifting technique, size up the load, never twist or turn when lifting
Construction Hazards	<ul style="list-style-type: none"> Wear hard-hat, safety glasses, steel-toe/shank boots, and hearing protection when working near heavy equipment Never enter excavations Stay alert Maintain eye contact/communication with equipment operator when working in vicinity

**PARSONS ENGINEERING SCIENCE, INC.
JOB SAFETY ANALYSIS**

ACTIVITY: Drill Rig Operations

Potential Hazards	Recommended Controls
Operations Hazards Faulty/Damaged Equipment Hand/Power tools Falling Objects Pinch/Contact Points Fire Hazards	Wear hardhat and steel-toe/shank boots and proper PPE (see HASP) Stay alert, watch for pinch/contact points (sliding platforms, rotary equipment, etc.) Maintain eye contact/communication with equipment operator when working in vicinity Equipment will be operated by trained/experienced personnel only Equipment will be inspected upon arrival and at the beginning of each shift (e.g., frayed cables, worn fittings, etc.) Equipment found to be unsafe will be tagged and locked out Keep feet and hands clear of moving/suspended materials and equipment Machine guards shall remain in place Use long-handled shovels to remove auger cuttings Carry fire extinguisher on board vehicle Be aware of locations of kill switches
Chemical Hazards	Conduct daily site safety briefing Conduct air monitoring as described in Section 8 of the HASP and use the appropriate PPE level Avoid contact with contaminated soil and groundwater Avoid breathing dust by using dust suppression, if necessary Be aware of possible exposure symptoms (e.g., headache, nausea, dizziness, sleepiness, etc.) Immediately report any exposure symptoms to the Site Health and Safety Officer
Physical Exertion	Follow work/rest regime Use "buddy" system Use proper lifting technique, size up the load, never twist or turn when lifting
Noise/Eye Protection	Use hearing protection when appropriate Use approved safety glasses
Slip, Trip, Fall, Loss of Balance	Site safety briefing Stay alert Maintain firm footing Watch for obstacles

**PARSONS ENGINEERING SCIENCE, INC.
JOB SAFETY ANALYSIS**

ACTIVITY: Drill Rig Operations

Potential Hazards	Recommended Controls
Biohazard	Biohazard training Stay alert for snakes, insects, and animals Wear high-top safety boots
Heat/Cold Stress	Wear appropriate clothing Monitor for heat/cold stress as recommended in the HASP Carry drinking water (minimum 1.5 gallons per person) Carry communication equipment
Fire Hazards	Have approved fire protection devices available (see HASP) Equipment will be shut down prior to fueling Use good housekeeping procedures
Sharps/Metal Fragments	Wear boots with steel toes and shanks Have a current tetanus booster as recommended by occupational physician

Equipment to be used	Inspection Requirements	Training Requirements
Communications Equipment Air Monitoring Instruments Drill Rig	Function Test: Communications Equipment Air Monitoring Instruments Inspect Drill Rig Daily	Site-specific training Biohazard training 40-hr OSHA hazardous waste operations training Read and comply with the HASP

**PARSONS ENGINEERING SCIENCE, INC.
JOB SAFETY ANALYSIS**

ACTIVITY: General Field Vehicle Operations

Potential Hazards	Recommended Controls
Speeding	Observe posted speed limits Keep vehicle under control Operate at lesser speeds consistent with conditions
Backing up	Visual check around and behind vehicle Backup alarm or use observer to guide you Notify bystanders that vehicle is backing up (verbally or sound horn)
Unsafe Equipment	Perform vehicle inspection prior to shift Repair or replace defective equipment
Unfamiliar Area	Obtain map and/or detailed directions Lock doors
Unfamiliar Vehicle (e.g., rental car)	Familiarize yourself with controls Adjust seat, mirrors, etc. prior to putting vehicle in motion Set radio stations prior to putting vehicle in motion

**PARSONS ENGINEERING SCIENCE, INC.
JOB SAFETY ANALYSIS**

ACTIVITY: Concrete Coring/Chip Sampling

Potential Hazards	Recommended Controls
Noise/Eye Hazards	Use hearing protection Use approved safety glasses
Electrical Hazards	Conduct utility clearance prior to coring to avoid electrical and other utilities Connect coring machine to ground-fault circuit interrupter (GFCI) Inspect power cords for defects; replace if necessary Wear rubber-soled boots
Physical Exertion	Follow work/rest regime Use "buddy" system Use proper lifting technique, size up the load, never turn or twist when lifting
Heat/Cold Stress	Wear appropriate clothing Monitor for heat/cold stress as recommended in the HASP Provide adequate drinking water (minimum 1.5 gallons/person)
Slip, Trip, Fall, Loss of Balance	Stay alert Keep electrical cords and water hoses out of way as much as possible Watch for obstacles Maintain firm footing Use "buddy" system
Pinch/Contact Points	Keep hands and feet clear of rotating machinery Wear steel-toed safety boots Wear leather gloves

APPENDIX B
ANALYTICAL SAMPLE REQUIREMENTS

APPENDIX B
ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR
GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe ²⁺)	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Each sampling round	Collect 100 ml of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Ferrous (Fe ²⁺)	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above.	Each sampling round	Collect 100 ml of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L, method 8221	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater.	Each sampling round	Collect 100mL of water in glass container	Field
Water	Alkalinity	A2320, titrimetric; E310.2 or E150.1, colorimetric	Handbook method	Same as above.	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO ₃ ⁻¹) and Nitrite (NO ₂ ⁻¹)	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO ₃ ⁻¹)	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO ₂ ⁻¹)	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO ₄ ⁻²)	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO ₄ ⁻²)	HACH method # 8051	Colorimetric	Same as above.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved sulfide (S ⁻²)	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis.	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field
Water	Carbon dioxide	HACH test kit model CA-23, method 8223 or CHEMetrics Method R-1910	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate biodegradation of BTEX.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Methane, Ethane, and Ethene	Kampbell <i>et al.</i> , 1989 or SW3810 modified.	Method published and used by the U.S. Environmental Protection Agency (EPA) Nation Risk Management Research Laboratory	The presence of methane suggests hydrocarbon degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis).	Each sampling round	Collect water samples in 50 ml glass serum bottles with butyl gray/Teflon-lined caps; add H ₂ SO ₄ to pH 2; cool to 4°C	Fixed-base

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic and chlorinated hydrocarbons (BTEX, chlorinated compounds)	SW8260B	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for chlorinated solvents and byproducts, which are the primary target analytes for monitoring natural attenuation; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add sulfuric acid to pH 2	Fixed-base
Matrix Water	Analysis Dissolved organic carbon (DOC) (optional)	Method/Reference A5310 C	Comments An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	Data Use An indirect index of microbial activity.	Recommended Frequency of Analysis Each sampling round	Sample Volume, Sample Container, Sample Preservation Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Field or Fixed-Base Laboratory Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive.	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development.	Each sampling round	N/A	Field

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

APPENDIX C
SELECTED DATA FROM PREVIOUS SITE INVESTIGATIONS

**RFI REPORT
NAVAL SUPPORT ACTIVITY MEMPHIS**

**AOC A
NORTHSIDE FLUVIAL GROUNDWATER**



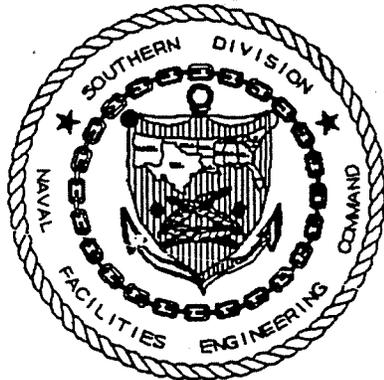
VOLUME I OF II

Revision: 01

CTO-094

Prepared for:

**Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina**



Prepared by:

**EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962**

June 10, 1998

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN, Building N-126</i>
Project No: <i>0094</i>	Surface Elevation: <i>283.76 feet msl</i>
Started at <i>0900 on 2-09-95</i>	TOC Elevation: <i>283.12 feet msl</i>
Completed at <i>0910 on 2-21-95</i>	Depth to Groundwater: <i>25.28 feet</i> Measured: <i>3/31/95</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>257.92 feet msl</i>
Drilling Company: <i>North Star Drilling</i>	Total Depth: <i>70.8 feet</i>
Geologist: <i>Jack Carmichael</i>	Well Screen: <i>60.3 to 70.3 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
5			1	62.5	BG		ML	Clayey silt, moderate brown, stiff.		
10			2	50	BG		ML			
15			3	60	BG		ML	Clayey silt, dark yellow brown, medium stiff, moist..		
20			4	80	BG		ML	Clayey silt, moderate yellow with reddish brown, hard.		
25			5	80	BG		ML	Clay, silty, trace sand, very fine, moderate reddish brown, stiff.		
25.8									25.8	
30							SC	Sand, clayey, silty, finely micaceous, moderate reddish orange to moderate reddish brown.		
							SC	Contact of Fluvial Deposits (30'-71') estimated at 30'.		
35			6	110	BG		SC	Sand, very fine to fine, silty, clayey, laminated, small clay casts, pale orange to moderate red.		
40										

Project: NSA Memphis	Location: <i>Millington, TN. Building N-126</i>
Project No.: 0094	Surface Elevation: 283.76 feet msl
Started at 0900 on 2-09-95	TOC Elevation: 283.12 feet msl
Completed at 0910 on 2-21-95	Depth to Groundwater: 252.8 feet Measured: 3/31/95
Drilling Method: Rotasonic	Groundwater Elevation: 257.92 feet msl
Drilling Company: North Star Drilling	Total Depth: 70.8 feet
Geologist: Jack Carmichael	Well Screen: 60.3 to 70.3 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
5			1	82.5	BG		ML	Clayey silt, moderate brown, stiff.		
10			2	50	BG		Clayey silt, dark yellow brown, medium stiff, moist..			
15			3	60	BG		Clayey silt, moderate yellow with reddish brown, hard.			
20			4	80	BG		Clay, silty, trace sand, very fine, moderate reddish brown, stiff.			
25			5	80	BG					
30							SC	Sand, clayey, silty, finely micaceous, moderate reddish orange to moderate reddish brown.	258.8	
35			6	110	BG		Contact of Fluvial Deposits (30'-71') estimated at 30'.			
40								Sand, very fine to fine, silty, clayey, laminated, small clay casts, pale orange to moderate red.		

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN, Building N-126</i>
Project No.: <i>0094</i>	Surface Elevation: <i>283.76 feet msl</i>
Started at <i>0900 on 2-09-95</i>	TOC Elevation: <i>283.12 feet msl</i>
Completed at <i>0910 on 2-21-95</i>	Depth to Groundwater: <i>25.28 feet</i> Measured: <i>3/31/95</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>257.92 feet msl</i>
Drilling Company: <i>North Star Drilling</i>	Total Depth: <i>70.8 feet</i>
Geologist: <i>Jack Carmichael</i>	Well Screen: <i>60.3 to 70.3 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
45			7	105	BG		SC	Sand, very fine to fine, silty, some clay, dark yellowish orange to grayish orange, wet.	238.8	<p>2" ID, Sch. 40 PVC and 8" steel casing</p> <p>0.01 slot, PVC screen</p>
50							Sand, gravelly, clay balls, grayish orange to moderate yellowish brown.			
55			8	100	BG		GP	Sand with gravel, fine to coarse, grayish orange to moderate yellowish brown, wet.		
60							Gravel, sandy, moderate yellowish brown to dark yellowish orange.			
65			9	100	BG					
70			10	100	BG			Log information taken from the boring for the Cockfield well at SWMU#7 Site 4.	213.8	
75										
80										

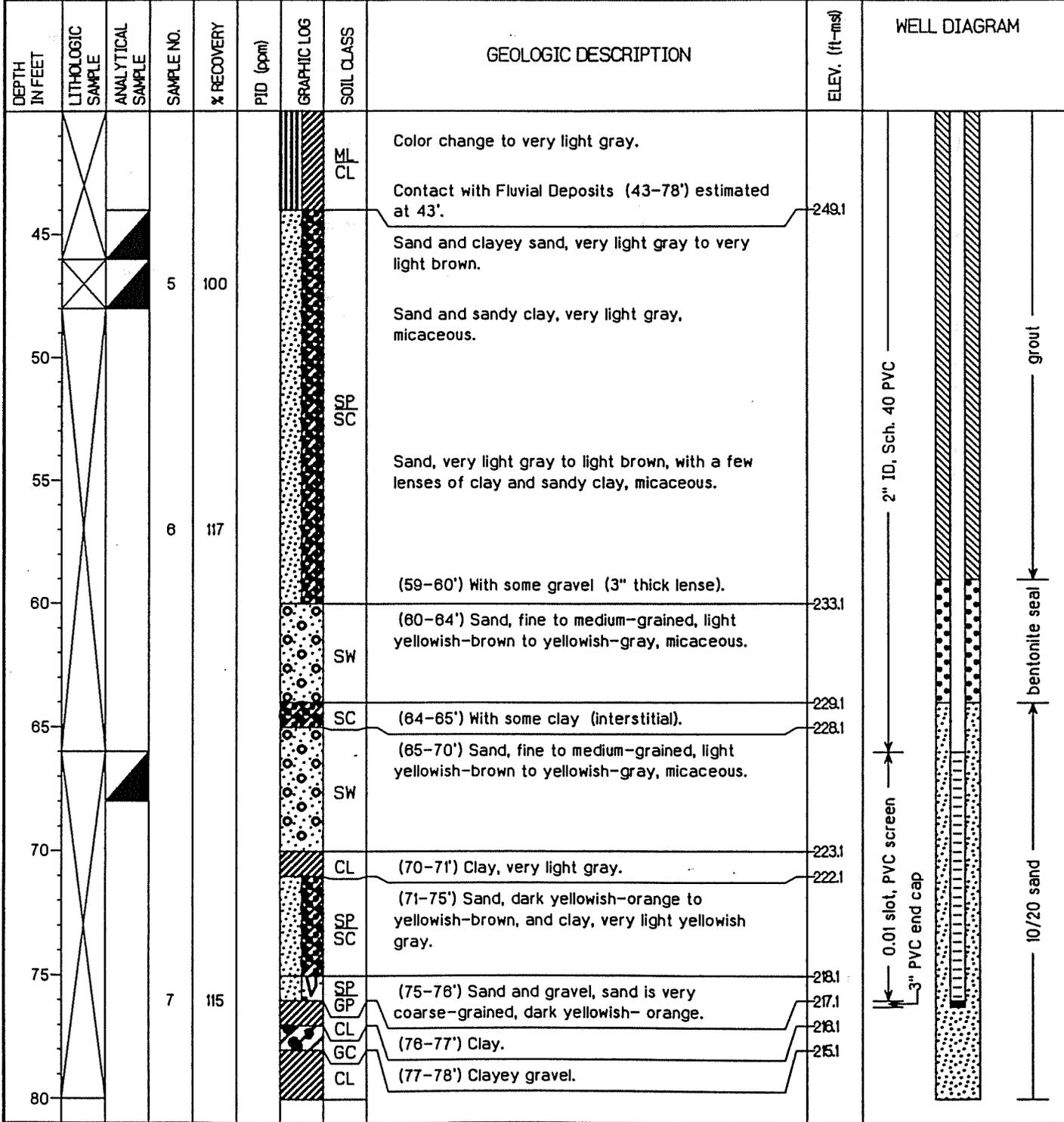
Project: <i>NSA Memphis</i>	Location: <i>Millington, TN SWMU 7 - Building N-126</i>
Project No: <i>0094-08420</i>	Surface Elevation: <i>289.10 feet msl</i>
Started at <i>0800 on 3-16-96</i>	TOC Elevation: <i>288.78 feet msl</i>
Completed at <i>1240 on 3-16-96</i>	Depth to Groundwater: <i>35.68 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>253.10 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>96.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>80 to 90 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85			8	120			SW	(81-82.5') Sand, fine to coarse-grained, dark yellowish-orange with clay lenses between 82' and 82.5', orangish-gray.	208.1	<p>0.01 slot, PVC screen 3" PVC end cap 10/20 sand bentonite plug</p>
						SC			206.6	
						SW			203.1	
90			9	110			SC GC	(86-90') Sand and gravel with some clay in matrix, dark yellowish-orange.	203.1	
95							CL	Cockfield Formation: Clay, dark brown, with thin interbeds of fine-grained sand.	199.1	
								Soil boring terminated at 96'.	193.1	
100										
105										
110										
115										
120										

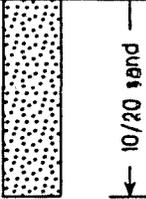
Project: <i>NSA Memphis</i>	Location: <i>Millington, TN SHMU 7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>293.14 feet msl</i>
Started at <i>1430 on 3-17-96</i>	TOC Elevation: <i>292.96 feet msl</i>
Completed at <i>1600 on 3-17-96</i>	Depth to Groundwater: <i>34.91 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.05 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>86.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>66 to 76 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0			1	100	.3			Silt, brown, with some gravel; fill 0' to 2', native material 2' to 4.		
5					.3			(4-15') Silt, light brown to reddish-brown, with some clay and organic material.		
10			2	50	.3					
15					.3		ML	(15-16') Silt, with some clay, moderate gray. (16-30') Silt, yellowish-brown and olive gray, with some clay, with some organic material and clay throughout, wet.		
20					.3					
25			3	70						
30							CL ML	(30-34') Silt and clay, greenish-gray to olive gray, moist to wet. (34-36') Increasing clay content.	283.1	
35										
40			4	150			ML CL	(38-44') Clay, silty and sandy, with scattered gravel, gray to light brown.	255.1	

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN. SHMU 7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>293.14 feet msl</i>
Started at <i>1430 on 3-17-96</i>	TOC Elevation: <i>292.96 feet msl</i>
Completed at <i>1600 on 3-17-96</i>	Depth to Groundwater: <i>34.91 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.05 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>86.0 feet</i>
Geologist: <i>J.Kingsbury</i>	Well Screen: <i>66 to 76 feet</i>



Project: <i>NSA Memphis</i>	Location: <i>Millington, TN SWMU 7 - Building N-126</i>
Project No: <i>0094-08420</i>	Surface Elevation: <i>293.14 feet msl</i>
Started at <i>1430 on 3-17-96</i>	TOC Elevation: <i>292.96 feet msl</i>
Completed at <i>1600 on 3-17-96</i>	Depth to Groundwater: <i>34.91 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.05 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>86.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>66 to 76 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85							CL	(78-86') Cockfield Formation (see descriptions below).	211.1	
							SC	(78-79') Clay and sandy clay, grayish-orange. (79-79.5') Dark brown, moderate brown to 80'. (82-86') Sand, fine to medium-grained, light olive gray to light yellowish-brown, with clay stringers, light gray to grayish-orange.	207.1	
90								Terminated soil boring at 86'.		
95										
100										
105										
110										
115										
120										

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN. SWMU 7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>296.65 feet msl</i>
Started at <i>1330 on 3-16-96</i>	TOC Elevation: <i>296.43 feet msl</i>
Completed at <i>1700 on 3-16-96</i>	Depth to Groundwater: <i>37.99 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.44 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>126.0 feet</i>
Geologist: <i>J. Kingsbury</i>	Well Screen: <i>84 to 94 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0								(0'-2') Concrete		
2								(2'-21') Silt, brown, with some clay	294.6	
5			1	71			ML	Moist at 10'		
10										
15										
20										
21			2	85			CL ML	(21'-30') Brown clay with some sand and silt. Sand is fine-grained and dark yellowish-orange.	275.6	
25										
30							ML	(30'-34') Silt with fine sand and minor clay, very light gray with some dark yellowish-orange mottling, dry	266.6	
34							SW SC	(34'-94') Fluvial Deposits (see descriptions below).	262.6	
36			3	100			CL	(34'-36') Fine to medium-grained sand, dark yellowish-orange to reddish-brown color, some clay present.	260.6	
38							SW	(36'-38') Clay, light brown.	258.6	

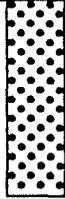
Project: NSA Memphis	Location: <i>Memphis, TN SHMJ 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 296.65 feet msl
Started at 1330 on 3-16-96	TOC Elevation: 296.43 feet msl
Completed at 1700 on 3-16-96	Depth to Groundwater: 37.99 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.44 feet msl
Drilling Company: Alliance Environmental	Total Depth: 126.0 feet
Geologist: J. Kingsbury	Well Screen: 84 to 94 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
45			4	88			SW	<p>(38'-71') Sand (see descriptions below).</p> <p>(38'-43') Sand, fine to medium-grained, dark yellowish-orange. Micaceous and wet at 40'</p> <p>(43'-45') Sand, fine to medium-grained, brownish-gray to medium gray, micaceous.</p> <p>(45'-48') Clay seam.</p> <p>(48'-54') Sand, fine to medium-grained, yellowish-gray and micaceous, with some minor clay.</p> <p>(54'-63') Sand, medium to very coarse-grained, dusky yellow, and minor gravel.</p> <p>(63'-66') Sand, fine to medium-grained, yellowish-gray to very light gray, with minor clay.</p> <p>(66'-71') Sand, fine to very coarse-grained, yellowish-gray to dark yellowish-orange, with minor gravel.</p>		<p>2" ID, Sch. 40 PVC</p> <p>grout</p>
75			5				SW CL	<p>(71'-84') Sand, sandy clay, and clay; alternating beds of sand and clay .5' to 1.0 feet thick; sand is fine to medium-grained, dark yellowish-orange to moderate yellowish-brown, clay is very light gray to yellowish-gray.</p>	225.6	
80										

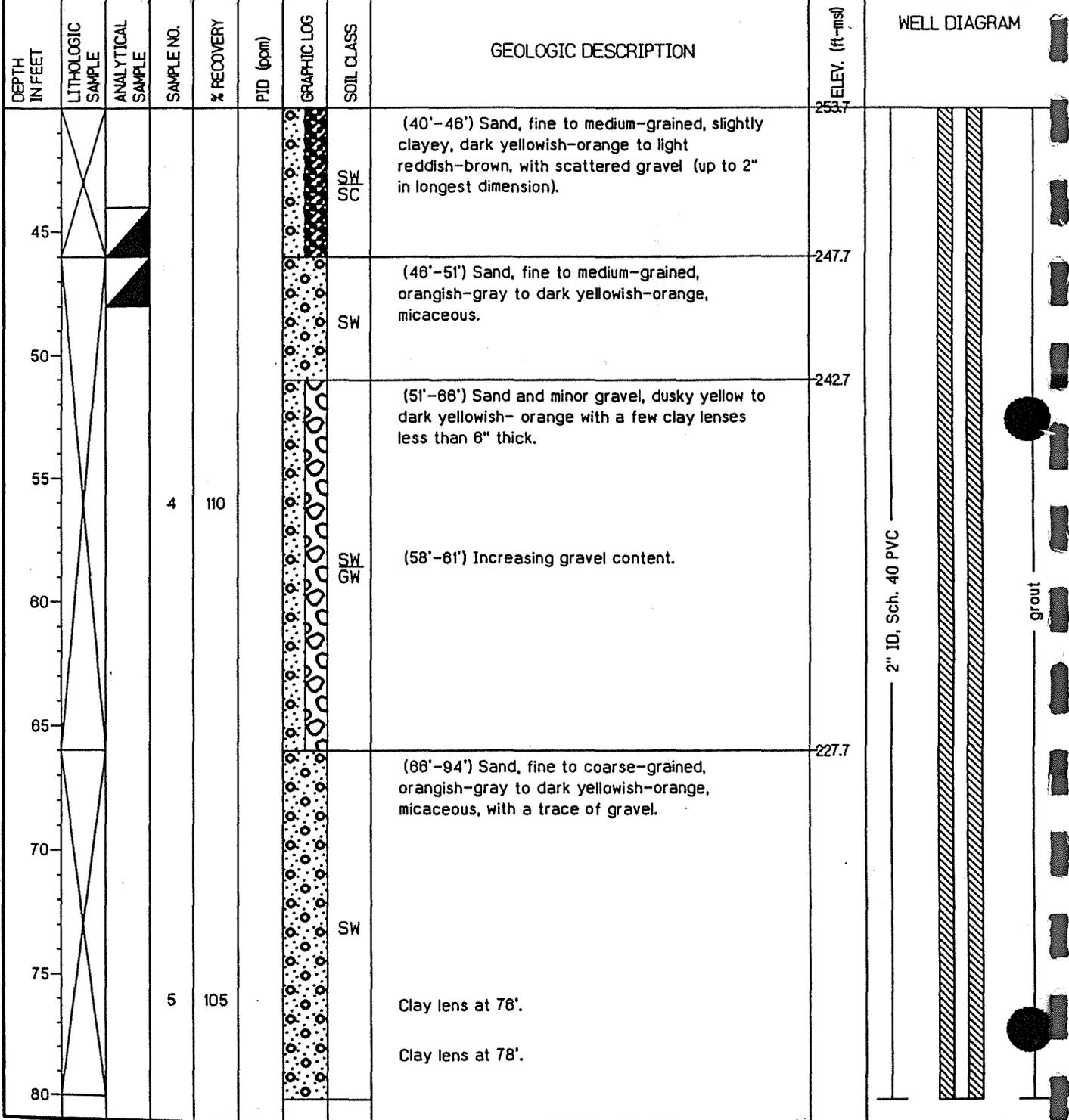
Project: NSA Memphis	Location: <i>Milington, TN SWMU 7 - Building N-126</i>
Project No: 0094-08420	Surface Elevation: 296.65 feet msl
Started at 1330 on 3-16-96	TOC Elevation: 296.43 feet msl
Completed at 1700 on 3-16-96	Depth to Groundwater: 37.99 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.44 feet msl
Drilling Company: Alliance Environmental	Total Depth: 126.0 feet
Geologist: J. Kingsbury	Well Screen: 84 to 94 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85							SW CL		212.6	<p>0.01 slot, PVC screen 3" PVC end cap</p> <p>10/20 sand</p> <p>bentonite seal</p>
							SW	(84'-86') Sand, fine to coarse-grained, dusky yellow to dark yellowish-orange.	210.8	
90			6	100			SW GW	(86'-94') Sand, fine to very coarse-grained, dusky yellow to yellowish-brown and gravel (up to 1.5" in longest dimension).		
95							SW	(94'-126') Cockfield Formation (see descriptions below). Fine to medium-grained sand, yellowish-brown to very light gray color, with a small amount of gravel near 96'. (96'-104') Sand, fine to medium-grained, medium yellowish-gray to dark yellowish-orange.	202.8	
100			7	95			SW	With a few thin stringers of clay at 104'		
105							SW	(106'-116') Sand, fine to medium-grained, yellowish-brown to yellowish-gray, with some dark yellowish-orange mottling, a few clay stringers throughout, and some sparse scattered gravel (up to 1" in longest dimension).		bentonite seal
110			8	120			SC	(118'-126') Sand, fine to medium-grained, grayish-orange to dark, yellowish-orange with streaks of clay throughout	180.8	
120							SC			

Project: <i>NSA Memphis</i>	Location: <i>Murkington, TN SWMU 7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>296.65 feet msl</i>
Started at <i>1330 on 3-16-96</i>	TOC Elevation: <i>296.43 feet msl</i>
Completed at <i>1700 on 3-16-96</i>	Depth to Groundwater: <i>37.99 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.44 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>126.0 feet</i>
Geologist: <i>J. Kingsbury</i>	Well Screen: <i>84 to 94 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
125			9	120			SC			
								Soil boring terminated at 126'.	170.6	▼ bentonite seal
130										
135										
140										
145										
150										
155										
160										

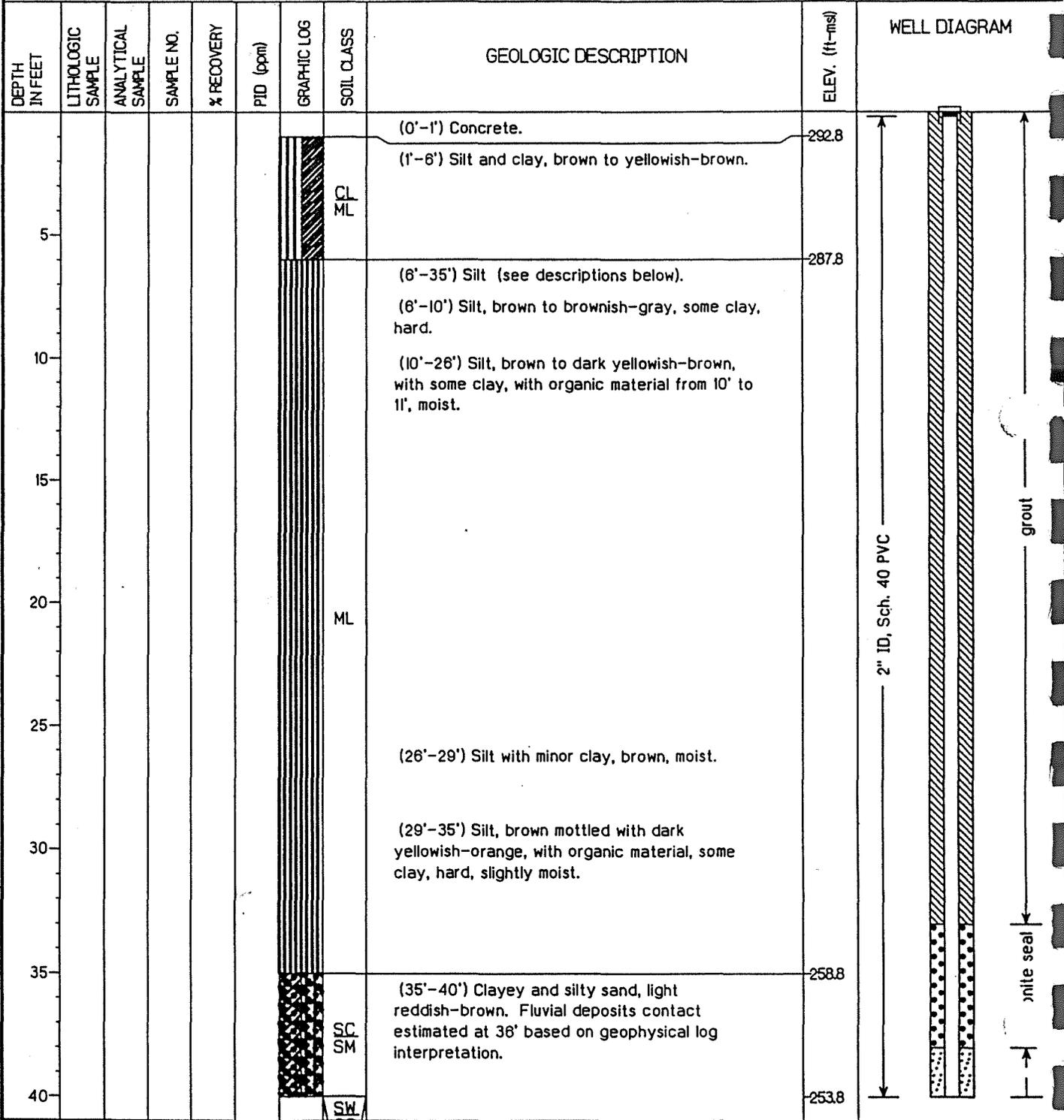
Project: NSA Memphis	Location: <i>Memington, TN SWMU 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 293.66 feet msl
Started at 1315 on 3-19-96	TOC Elevation: 293.36 feet msl
Completed at 1530 on 3-19-96	Depth to Groundwater: 35.65 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 257.71 feet msl
Drilling Company: Alliance Environmental	Total Depth: 106 feet
Geologist: JKingsbury	Well Screen: 90 to 100 feet



Project: NSA Memphis	Location: <i>Milington, TN. SWMU 7 - Building N-126</i>
Project No: 0094-09420	Surface Elevation: 293.66 feet msl
Started at 1315 on 3-19-96	TOC Elevation: 293.36 feet msl
Completed at 1530 on 3-19-96	Depth to Groundwater: 35.65 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 257.71 feet msl
Drilling Company: Alliance Environmental	Total Depth: 106 feet
Geologist: JKingsbury	Well Screen: 90 to 100 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85							SW			<p>2" ID, Sch. 40 PVC 0.01 slot, PVC screen 3" PVC end cap 10/20 sand bentonite seal grout</p>
90						SW				
95			6	95		SW GW	(94'-100') Sand and gravel, dark yellowish-orange to dusky yellow; sand is fine to very coarse-grained, gravel is (up to 1.5" in longest dimension).	199.7		
100						SP SC	Cockfield Formation: Sand, fine grained, with thin lenses of clay, yellowish-gray to light gray	193.7		
105								Soil boring terminated at 106'.	187.7	
110										
115										
120										

Project: NSA Memphis	Location: <i>Millington, TN. SHMU 7 - Building N-126</i>
Project No: 0094-08420	Surface Elevation: 293.79 feet msl
Started at 1600 on 3-19-96	TOC Elevation: 292.91 feet msl
Completed at 1730 on 3-19-96	Depth to Groundwater: 34.54 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.37 feet msl
Drilling Company: Alliance Environmental	Total Depth: 50 feet
Geologist: JKingsbury	Well Screen: 40 to 50 feet





Monitoring Well 007G15UF

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN. SHMU7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>293.79 feet msl</i>
Started at <i>1600 on 3-19-96</i>	TOC Elevation: <i>292.91 feet msl</i>
Completed at <i>1730 on 3-19-96</i>	Depth to Groundwater: <i>34.54 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.37 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>50 feet</i>
Geologist: <i>J.Kingsbury</i>	Well Screen: <i>40 to 50 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
45							SW/SC	(40'-46') Sand, fine to medium-grained, slightly clayey, dark yellowish-orange to light reddish-brown, with scattered gravel (up to 2" in longest dimension).	253.8	
50						SW	(46'-50') Sand, fine to medium-grained, orangish-gray to dark yellowish-orange, micaceous.	247.8		
55							Terminated soil boring at 50'. Note: No samples were collected for lithologic description. These descriptions were transferred from the log of adjacent monitoring well 007G15LF.	243.8		
60										
65										
70										
75										
80										



Environmental & Safety Designs, Inc.

Log of Monitoring Well 007G24MF

Project: <i>NAS Memphis Millington, TN</i>	Location: <i>SMU 7/AOC A</i>
Project No: <i>0094</i>	Surface Elevation: <i>feet msl</i>
Started at <i>0920 on 7-30-98</i>	TOC Elevation: <i>feet msl</i>
Completed at <i>1515 on 7-30-98</i>	Depth to Groundwater: <i>Measured</i>
Drilling Method: <i>Rotasonic; 4" core barrel through 6" casing</i>	Groundwater Elevation:
Drilling Company: <i>Alliance</i>	Total Depth: <i>95 feet</i>
Geologist: <i>David E. Ladd</i>	Well Screen: <i>60 to 70 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PTD (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0-2.5'							Ccr	(0-2.5') Surface conditions: Asphalt and concrete (Ccr)		<p>2" diam., Sch. 40 PVC</p> <p>grout</p>
2.5-5'			s-1	120	0.2		ML	(2.5-5') Silt, moderate yellowish brown mottled with some olive gray near top. Contains some asphalt at top. Hard, dry.		
5-9'			s-2	35	1.0		ML	(5-9') Same as above.		
9-15'							ML	(9-15') NO RECOVERY; lost returns. Driller said material was very soft.		
15-20'							ML	(15-20') NO RECOVERY; lost returns.		
20-25'							ML	(20-25') Silt, dark yellowish orange mottled with olive gray. Contains organic nodules. Micaceous.		
25-35'			s-3	25	0.2		ML	(25-35') Silt and clay, olive gray to greenish gray. Contains abundant iron-manganese nodules. Mottled with dark yellowish orange near very top. Moist.		
35-35.5'			s-4	95	0.2		ML	(35-35.5') Same as above.		
35.5-41'							ML	(35.5-41') Silt and clay, moderate yellowish brown to dark yellowish orange mottled with olive gray to greenish gray. Contains organic material. Contains abundant lignite near 41'. Moist.		



Monitoring Well 007G12LF

Project: NSA Memphis

Location: Millington, TN SHMU 7 - Building N-26

Project No.: 0094-08420

Surface Elevation: 289.10 feet msl

Started at 0800 on 3-16-96

TOC Elevation: 288.78 feet msl

Completed at 1240 on 3-16-96

Depth to Groundwater: 35.68 feet

Measured: 4/8/96

Drilling Method: Rotasonic

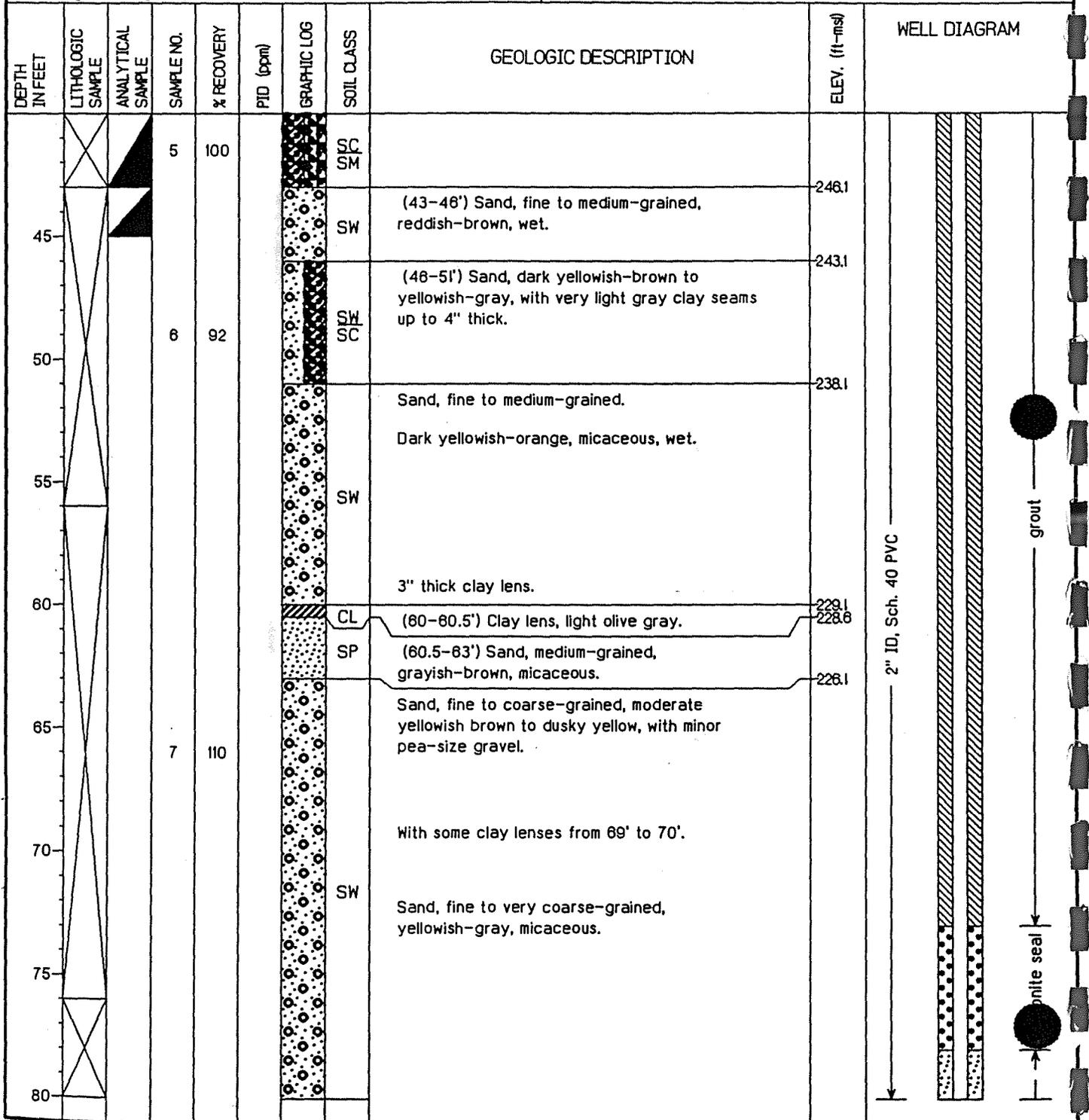
Groundwater Elevation: 253.10 feet msl

Drilling Company: Alliance Environmental

Total Depth: 96.0 feet

Geologist: JKingsbury

Well Screen: 80 to 90 feet E.S.





Monitoring Well 007G12LF

Project: NSA Memphis

Location: *Milington, TN. SWMU 7 - Building N-126*

Project No.: 0094-08420

Surface Elevation: 289.10 feet msl

Started at 0800 on 3-16-96

TOC Elevation: 288.78 feet msl

Completed at 1240 on 3-16-96

Depth to Groundwater: 35.68 feet Measured: 4/8/96

Drilling Method: Rotasonic

Groundwater Elevation: 253.10 feet msl

Drilling Company: Alliance Environmental

Total Depth: 96.0 feet

Geologist: JKingsbury

Well Screen: 80 to 90 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0-2'					.1			(0-2') Concrete.		<p>2" ID, Sch. 40 PVC</p> <p>grout</p>
2-22'			1		.1			(2-22') Silt, light brown to gray.	287.1	
5-10'			2	70	.1		ML	Silt, light brown to yellowish-brown, with some organic material, moist.		
14-16'					.1			(14-16') With dark yellowish-orange mottling.		
15-20'			3	100	.1			Silt, yellowish-brown to yellowish-gray, wet.		
20-25'								Clay and silt, brown, with some iron concretions.	267.1	
25-30'							CL ML	Silt and clay, yellowish-brown to light brown, with some dark yellowish-orange mottling.		
30-35'			4	86				Contact with Fluvial Deposits (34-90') estimated at 34'.		
35-40'							SC SM	(37-43') Sand, clay, and silt, reddish-brown to dark yellowish-orange, moist.	252.1	

Project: NAS Memphis Millington, TN

Location: SHMU 7/AOC A

Project No: 0094

Surface Elevation: feet msl

Started at 0920 on 7-30-98

TOC Elevation: feet msl

Completed at 1515 on 7-30-98

Depth to Groundwater: Measured:

Drilling Method: Rotasonic; 4" core barrel through 6" casing

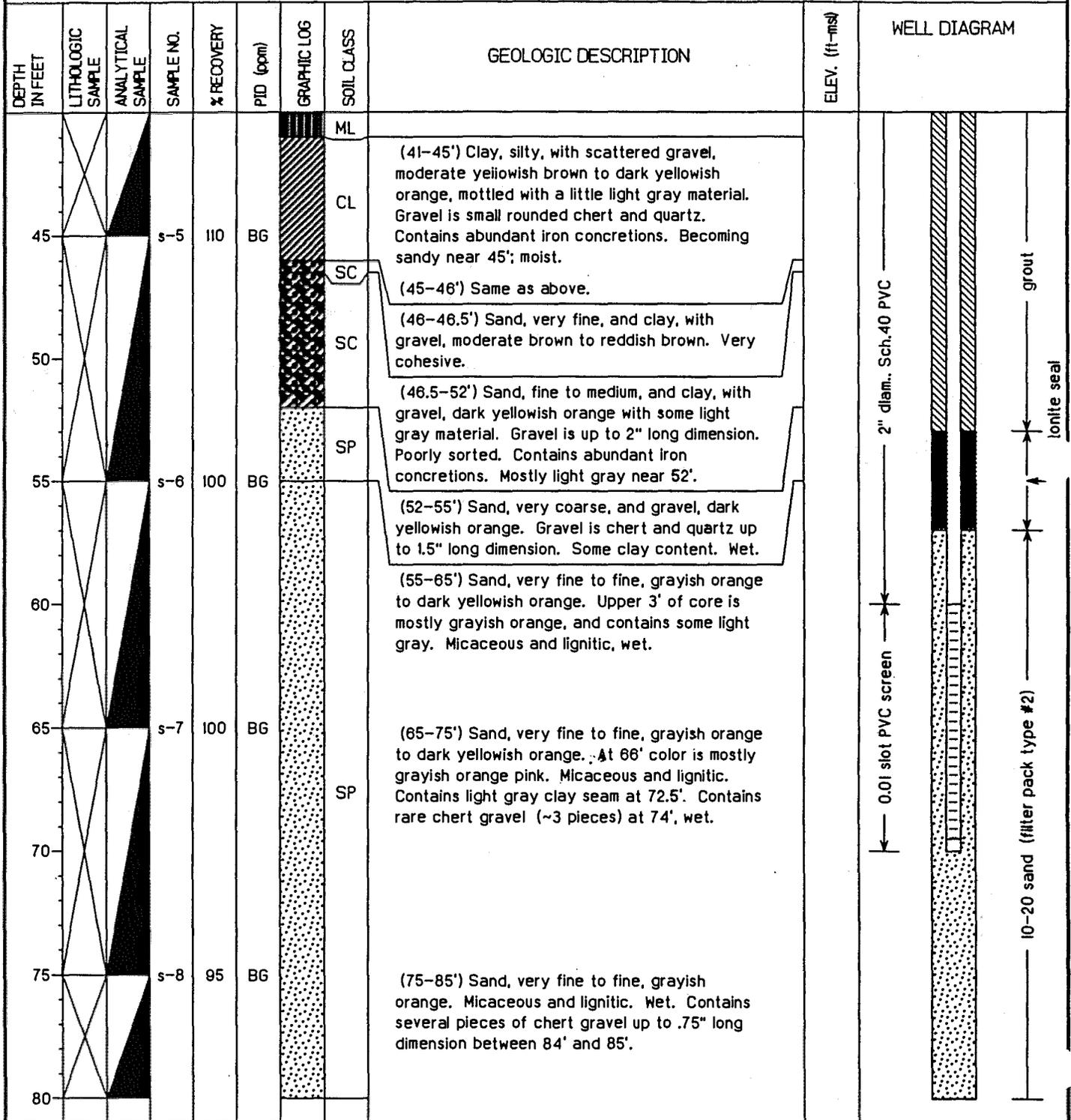
Groundwater Elevation:

Drilling Company: Alliance

Total Depth: 95 feet

Geologist: David E. Ladd

Well Screen: 60 to 70 feet





Environmental & Safety Designs, Inc.

Log of Monitoring Well 007G24MF

Project: <i>NAS Memphis Millington, TN</i>	Location: <i>SHMJ 7/AOC A</i>
Project No.: <i>0094</i>	Surface Elevation: <i>feet msl</i>
Started at <i>0920 on 7-30-98</i>	TOC Elevation: <i>feet msl</i>
Completed at <i>1515 on 7-30-98</i>	Depth to Groundwater: <i>Measured:</i>
Drilling Method: <i>Rotasonic; 4" core barrel through 6" casing</i>	Groundwater Elevation:
Drilling Company: <i>Alliance</i>	Total Depth: <i>95 feet</i>
Geologist: <i>David E. Ladd</i>	Well Screen: <i>60 to 70 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85			s-9	95	BG		SP			<p>bentonite plug</p> <p>10-20 sand (filler pack type #2)</p>
88.5							SP	(85-88.5') Sand, very coarse, and gravel, dark yellowish orange. Gravel is mostly angular to rounded chert up to 2.5" long dimension. Wet. Poorly sorted.		
90							CL	Tcf (88.5-95') Clay, sandy, dusky yellowish brown. Becomes mottled with light gray very fine sand seams below 92'. Micaceous and lignitic.		
95			s-10	100	BG			Bottom of boring at 95ft bgs.		
100										
105										
110										
115										
120										



Environmental & Safety Designs, Inc.

Log of Monitoring Well 007G25MF

Project: <i>NAS Memphis Millington, TN</i>	Location: <i>SMU 7/AOC A</i>
Project No: <i>0094</i>	Surface Elevation: <i>feet msl</i>
Started at <i>0945 on 8-3-98</i>	TOC Elevation: <i>feet msl</i>
Completed at <i>on 8-4-98</i>	Depth to Groundwater: <i>Measured:</i>
Drilling Method: <i>Rotasonic; 4" core barrel through 6" casing</i>	Groundwater Elevation:
Drilling Company: <i>Alliance</i>	Total Depth: <i>127 feet</i>
Geologist: <i>Ben Brantley</i>	Well Screen: <i>71.5 to 81.5 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PTD (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
							Ccr	Surface conditions: Concrete (~20").		
							ML	(1.2-3') Light olive gray silt, dry and hard from 2-3', mottled with greenish gray material.		
5			s-1	100	0.4		ML	(3-7.5') Dark yellowish brown to moderate yellowish brown silt, dry and hard.		
10								(7.5-9') Light olive gray and moderate yellowish brown silt, dry and hard. (8.5-9') Manganese concretions. NO RECOVERY from 9.5-15'.		
15			s-2	40	BG			(15-19') Dark yellowish orange with light olive gray and yellowish gray silt. Manganese and iron stains throughout; medium stiff and moist.		
20							ML	NO RECOVERY from 20-25'.		
25			s-3	40	BG			(25-29') Pale yellowish to dark yellowish brown silt with scattered manganese nodules and iron staining throughout.		
30								NO RECOVERY from 29-35'; Driller uncertain whether loss of recovery is at top or bottom of each run with loss. Loss has been assumed to be at the bottom of the runs with loss.		
35			s-4	40	0.2		ML	(35-42') Moderate yellowish brown clayey silt with dark yellowish orange and medium light gray clayey silt.		
40							CL	Light bluish gray clay lenses streaked in above matrix between 38.5' and 40'.		



Environmental & Safety Designs, Inc.

Log of Monitoring Well 007G25MF

Project: <i>NAS Memphis Millington, TN</i>	Location: <i>SMMU 7/AOC A</i>
Project No.: <i>0094</i>	Surface Elevation: <i>feet msl</i>
Started at <i>0945 on 8-3-98</i>	TOC Elevation: <i>feet msl</i>
Completed at <i>on 8-4-98</i>	Depth to Groundwater: <i>Measured:</i>
Drilling Method: <i>Rotasonic; 4" core barrel through 6" casing</i>	Groundwater Elevation:
Drilling Company: <i>Alliance</i>	Total Depth: <i>127 feet</i>
Geologist: <i>Ben Brantley</i>	Well Screen: <i>71.5 to 81.5 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PTD (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
45			s-5	105	BG	[Hatched pattern]	ML	Same lithology as 35-42' interval.		<p>2" diam., Sch.40 PVC</p> <p>0.01 slot PVC screen</p> <p>grout</p> <p>bentonite seal</p> <p>10-20 sand (filter pack type #2)</p>
45-50						[Diagonal hatching]	CL	Moderate yellowish brown sandy clay with light olive gray streaks and iron staining; hard and stiff, dry. Scattered chert gravels from 42-45'. Increasing fractions of sand and gravel to 47.5'.		
50-55						[Dotted pattern]	GC	(47.5-52.5') Light brown with abundant iron staining and clay, sand, gravel mixture --- cemented in portions to very indurated/hard.		
55			s-6	85	0.2	[Dotted pattern]	SM	(52.5-53.5') Dark yellowish orange silty fine sand.		
55						[Diagonal hatching]	SP	(53.5-55') Light gray fine sand with light gray clay lens (~4" thick).		
55-60						[Dotted pattern]	CL	Moderate red with yellowish gray clay lens (1ft thick), 55-56'. Same as above (53.5-55' interval) to 61' with 1" thick clay (light gray) seams at 58' and 58'.		
60						[Dotted pattern]	SP	Dark yellowish orange to grayish orange fine sand with light gray fine sand.		
65			s-7	85	0.2	[Diagonal hatching]	CL	Same as above to 69', with ~4" yellowish gray to grayish orange clay seam at 65-65.5'.		
70						[Dotted pattern]	SP	Grayish orange fine micaceous sand with scattered chert gravels (few from 69-75'); lignite grains within sand matrix.		
75			s-8	85	0.4	[Diagonal hatching]	CL	Same as above with yellowish gray to grayish orange clay seam from 76-77'.		
75-80						[Dotted pattern]	SP			



Monitoring Well 007G15UF

Project: NSA Memphis	Location: <i>Millington, TN SHMU 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 293.79 feet msl
Started at 1600 on 3-19-96	TOC Elevation: 292.91 feet msl
Completed at 1730 on 3-19-96	Depth to Groundwater: 34.54 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.37 feet msl
Drilling Company: Alliance Environmental	Total Depth: 50 feet
Geologist: JKingsbury	Well Screen: 40 to 50 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PTD (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								(0'-1') Concrete.	292.8	
5							MF	(1'-6') Silt and clay, brown to yellowish-brown.		
10							ML	(6'-35') Silt (see descriptions below). (6'-10') Silt, brown to brownish-gray, some clay, hard. (10'-26') Silt, brown to dark yellowish-brown, with some clay, with organic material from 10' to 11', moist.	287.8	
20								(26'-29') Silt with minor clay, brown, moist.		
25								(29'-35') Silt, brown mottled with dark yellowish-orange, with organic material, some clay, hard, slightly moist.		
35							SC SM	(35'-40') Clayey and silty sand, light reddish-brown. Fluvial deposits contact estimated at 36' based on geophysical log interpretation.	258.8	
40							SW SC		253.8	



Monitoring Well 007G15LF

Project: NSA Memphis	Location: Millington, TN SWMU 7 - Building N-126
Project No: 0094-08420	Surface Elevation: 293.66 feet msl
Started at 1315 on 3-19-96	TOC Elevation: 293.36 feet msl
Completed at 1530 on 3-19-96	Depth to Groundwater: 35.65 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 257.71 feet msl
Drilling Company: Alliance Environmental	Total Depth: 106 feet
Geologist: JKingsbury	Well Screen: 90 to 100 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85							SW			<p>2" ID, Sch. 40 PVC 0.01 slot, PVC screen 3" PVC end cap 10/20 sand bentonite seal grout</p>
90						SW				
95			6	95		SW GW	(94'-100') Sand and gravel, dark yellowish-orange to dusky yellow; sand is fine to very coarse-grained, gravel is (up to 1.5" in longest dimension).	89.7		
100						SP SC	Cockfield Formation: Sand, fine grained, with thin lenses of clay, yellowish-gray to light gray	83.7		
105								Soil boring terminated at 106'.	87.7	
110										
115										
120										



Monitoring Well 007G15LF

Project: NSA Memphis	Location: <i>M</i> ington, TN SHMU 7 - Building N-126
Project No.: 0094-08420	Surface Elevation: 293.66 feet msl
Started at 1315 on 3-19-96	TOC Elevation: 293.36 feet msl
Completed at 1530 on 3-19-96	Depth to Groundwater: 35.65 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 257.71 feet msl
Drilling Company: Alliance Environmental	Total Depth: 106 feet
Geologist: JKingsbury	Well Screen: 90 to 100 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft- <i>msl</i>)	WELL DIAGRAM
45							SW SC	(40'-46') Sand, fine to medium-grained, slightly clayey, dark yellowish-orange to light reddish-brown, with scattered gravel (up to 2" in longest dimension).	258.7	<p>2" ID, Sch. 40 PVC</p> <p>grout</p>
50							SW	(46'-51') Sand, fine to medium-grained, orangish-gray to dark yellowish-orange, micaceous.	247.7	
55			4	110			SW GW	(51'-66') Sand and minor gravel, dusky yellow to dark yellowish-orange with a few clay lenses less than 6" thick.	242.7	
60							SW GW	(58'-61') Increasing gravel content.		
65							SW	(66'-94') Sand, fine to coarse-grained, orangish-gray to dark yellowish-orange, micaceous, with a trace of gravel.	227.7	
70							SW	Clay lens at 78'.		
75			5	105			SW	Clay lens at 78'.		
80							SW			



Monitoring Well 007G15LF

Project: NSA Memphis	Location: <i>Millington, TN. SHMU7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 293.66 feet msl
Started at 1315 on 3-19-96	TOC Elevation: 293.36 feet msl
Completed at 1530 on 3-19-96	Depth to Groundwater: 35.65 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 257.71 feet msl
Drilling Company: Alliance Environmental	Total Depth: 106 feet
Geologist: JKingsbury	Well Screen: 90 to 100 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0					0			(0'-1') Concrete.	292.7	
0			1	83	0		CL	(1'-6') Silt and clay, brown to yellowish-brown.		
5					0		ML			
6					0			(6'-35') Silt, see descriptions below.	287.7	
10					0			(6'-10') Silt, brown to brownish-gray, some clay, hard.		
10					0			(10'-26') Silt, brown to dark yellowish-brown, with some clay, with organic material from 10' to 11', moist.		
15			2	85						
20							ML			
26								(26'-29') Silt with minor clay, brown, moist.		
29								(29'-35') Silt, brown mottled with dark yellowish-orange, with organic material, some clay, hard, slightly moist.		
35			3	100				(35'-40') Clayey and silty sand, light reddish-brown. Fluvial deposits contact estimated at 36' based on geophysical log interpretation.	258.7	
35							SC SM			
40							SW SC		253.7	



Monitoring Well 007G14LF

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN SHMU 7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>296.65 feet msl</i>
Started at <i>1330 on 3-16-96</i>	TOC Elevation: <i>296.43 feet msl</i>
Completed at <i>1700 on 3-16-96</i>	Depth to Groundwater: <i>37.99 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.44 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>126.0 feet</i>
Geologist: <i>J. Kingsbury</i>	Well Screen: <i>84 to 94 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM	
125			9	120			SC				
130								Soil boring terminated at 126'.	170.8		
135											
140											
145											
150											
155											
160											

Project: NSA Memphis	Location: <i>Millington, TN SWMU 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 296.65 feet msl
Started at 1330 on 3-16-96	TOC Elevation: 296.43 feet msl
Completed at 1700 on 3-16-96	Depth to Groundwater: 37.99 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.44 feet msl
Drilling Company: Alliance Environmental	Total Depth: 126.0 feet
Geologist: J. Kingsbury	Well Screen: 84 to 94 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85			6	100			SW CL		212.8	<p>0.01 slot, PVC screen 3" PVC end cap</p> <p>10/20 sand</p> <p>bentonite seal</p>
							SW	(84'-88') Sand, fine to coarse-grained, dusky yellow to dark yellowish-orange.	210.6	
90							SW GW	(88'-94') Sand, fine to very coarse-grained, dusky yellow to yellowish-brown and gravel (up to 1.5" in longest dimension).		
95							SW	(94'-126') Cockfield Formation (see descriptions below). Fine to medium-grained sand, yellowish-brown to very light gray color, with a small amount of gravel near 98'. (96'-104') Sand, fine to medium-grained, medium yellowish-gray to dark yellowish-orange.	202.6	
100			7	95			SW	With a few thin stringers of clay at 104'		
105							SW	(106'-116') Sand, fine to medium-grained, yellowish-brown to yellowish-gray, with some dark yellowish-orange mottling, a few clay stringers throughout, and some sparse scattered gravel (up to 1" in longest dimension).		
110			8	120			SW			
115							SC	(118'-126') Sand, fine to medium-grained, grayish-orange to dark, yellowish-orange with streaks of clay throughout	180.8	
120							SC			

Project: <i>NSA Memphis</i>	Location: <i>Memphis, TN SHMJ7 - Building N-126</i>
Project No.: <i>0094-08420</i>	Surface Elevation: <i>296.65 feet msl</i>
Started at <i>1330 on 3-16-96</i>	TOC Elevation: <i>296.43 feet msl</i>
Completed at <i>1700 on 3-16-96</i>	Depth to Groundwater: <i>37.99 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.44 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>126.0 feet</i>
Geologist: <i>J. Kingsbury</i>	Well Screen: <i>84 to 94 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
45			4	88			SW	<p>(38'-71') Sand (see descriptions below).</p> <p>(38'-43') Sand, fine to medium-grained, dark yellowish-orange. Micaceous and wet at 40'</p> <p>(43'-45') Sand, fine to medium-grained, brownish-gray to medium gray, micaceous.</p> <p>(45'-48') Clay seam.</p> <p>(48'-54') Sand, fine to medium-grained, yellowish-gray and micaceous, with some minor clay.</p> <p>(54'-63') Sand, medium to very coarse-grained, dusky yellow, and minor gravel.</p> <p>(63'-66') Sand, fine to medium-grained, yellowish-gray to very light gray, with minor clay.</p> <p>(66'-71') Sand, fine to very coarse-grained, yellowish-gray to dark yellowish-orange, with minor gravel.</p>		<p>2" ID, Sch. 40 PVC</p> <p>grout</p>
75			5				SW CL	<p>(71'-84') Sand, sandy clay, and clay; alternating beds of sand and clay .5' to 1.0 feet thick; sand is fine to medium-grained, dark yellowish-orange to moderate yellowish-brown, clay is very light gray to yellowish-gray.</p>	225.6	
80										



Monitoring Well 007G14LF

Project: NSA Memphis	Location: <i>Millington, TN SHMU 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 296.65 feet msl
Started at 1330 on 3-16-96	TOC Elevation: 296.43 feet msl
Completed at 1700 on 3-16-96	Depth to Groundwater: 37.99 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.44 feet msl
Drilling Company: Alliance Environmental	Total Depth: 126.0 feet
Geologist: J. Kingsbury	Well Screen: 84 to 94 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0								(0'-2') Concrete		
2								(2'-21') Silt, brown, with some clay	294.6	
5			1	71			ML	Molst at 10'		
10										
15										
20										
25			2	85			CL ML	(21'-30') Brown clay with some sand and silt. Sand is fine-grained and dark yellowish-orange.	275.6	
30							ML	(30'-34') Silt with fine sand and minor clay, very light gray with some dark yellowish-orange mottling, dry	266.6	
35							SW SC	(34'-94') Fluvial Deposits (see descriptions below).	262.6	
38			3	100			CL	(34'-38') Fine to medium-grained sand, dark yellowish-orange to reddish-brown color, some clay present.	260.6	
40							SW	(38'-38') Clay, light brown.	258.6	



Monitoring Well 007G13LF

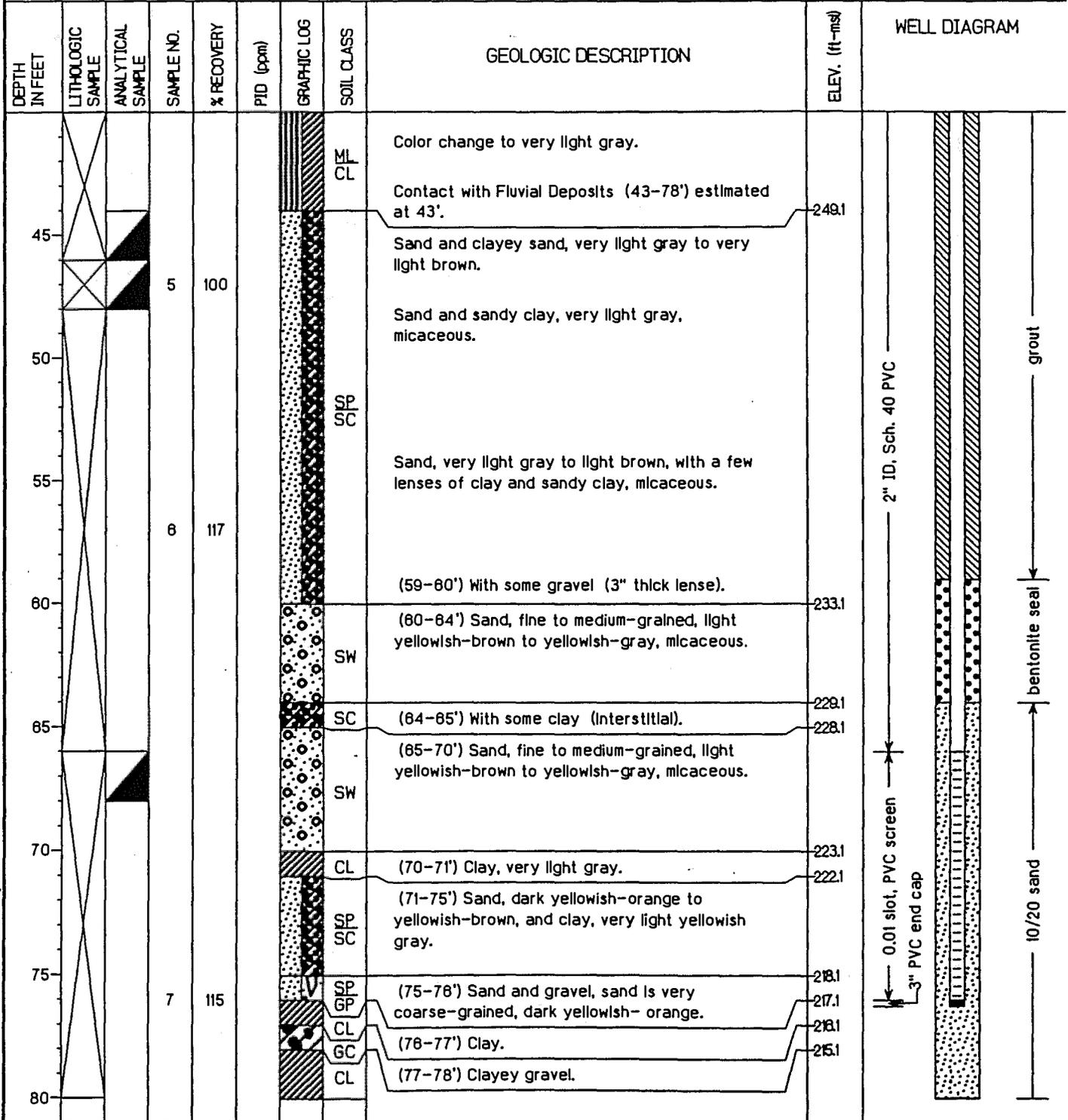
Project: <i>NSA Memphis</i>	Location: <i>Memington, TN. SIMJ7 - Building N-126</i>
Project No.: <i>0094-09420</i>	Surface Elevation: <i>293.14 feet msl</i>
Started at <i>1430 on 3-17-96</i>	TOC Elevation: <i>292.96 feet msl</i>
Completed at <i>1600 on 3-17-96</i>	Depth to Groundwater: <i>34.91 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>258.05 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>86.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>66 to 76 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85							CL	(78-86') Cockfield Formation (see descriptions below).	211.1	<p>10/20 sand</p>
							SC	(78-79') Clay and sandy clay, grayish-orange. (79-79.5') Dark brown, moderate brown to 80'.		
								(82-86') Sand, fine to medium-grained, light olive gray to light yellowish-brown, with clay stringers, light gray to grayish-orange.	207.1	
								Terminated soil boring at 86'.		
90										
95										
100										
105										
110										
115										
120										



Monitoring Well 007G13LF

Project: NSA Memphis	Location: <i>Millington, TN. SHMU 7 - Building N-126</i>
Project No.: 0094-08420	Surface Elevation: 293.14 feet msl
Started at 1430 on 3-17-96	TOC Elevation: 292.96 feet msl
Completed at 1600 on 3-17-96	Depth to Groundwater: 34.91 feet Measured: 4/8/96
Drilling Method: Rotasonic	Groundwater Elevation: 258.05 feet msl
Drilling Company: Alliance Environmental	Total Depth: 86.0 feet
Geologist: JKingsbury	Well Screen: 66 to 76 feet





Monitoring Well 007G13LF

Project: NSA Memphis

Location: *Millington, TN. SHMU 7 - Building N-126*

Project No: 0094-08420

Surface Elevation: 293.14 feet msl

Started at 1430 on 3-17-96

TOC Elevation: 292.96 feet msl

Completed at 1600 on 3-17-96

Depth to Groundwater: 34.91 feet Measured: 4/8/96

Drilling Method: Rotasonic

Groundwater Elevation: 258.05 feet msl

Drilling Company: Alliance Environmental

Total Depth: 86.0 feet

Geologist: JKingsbury

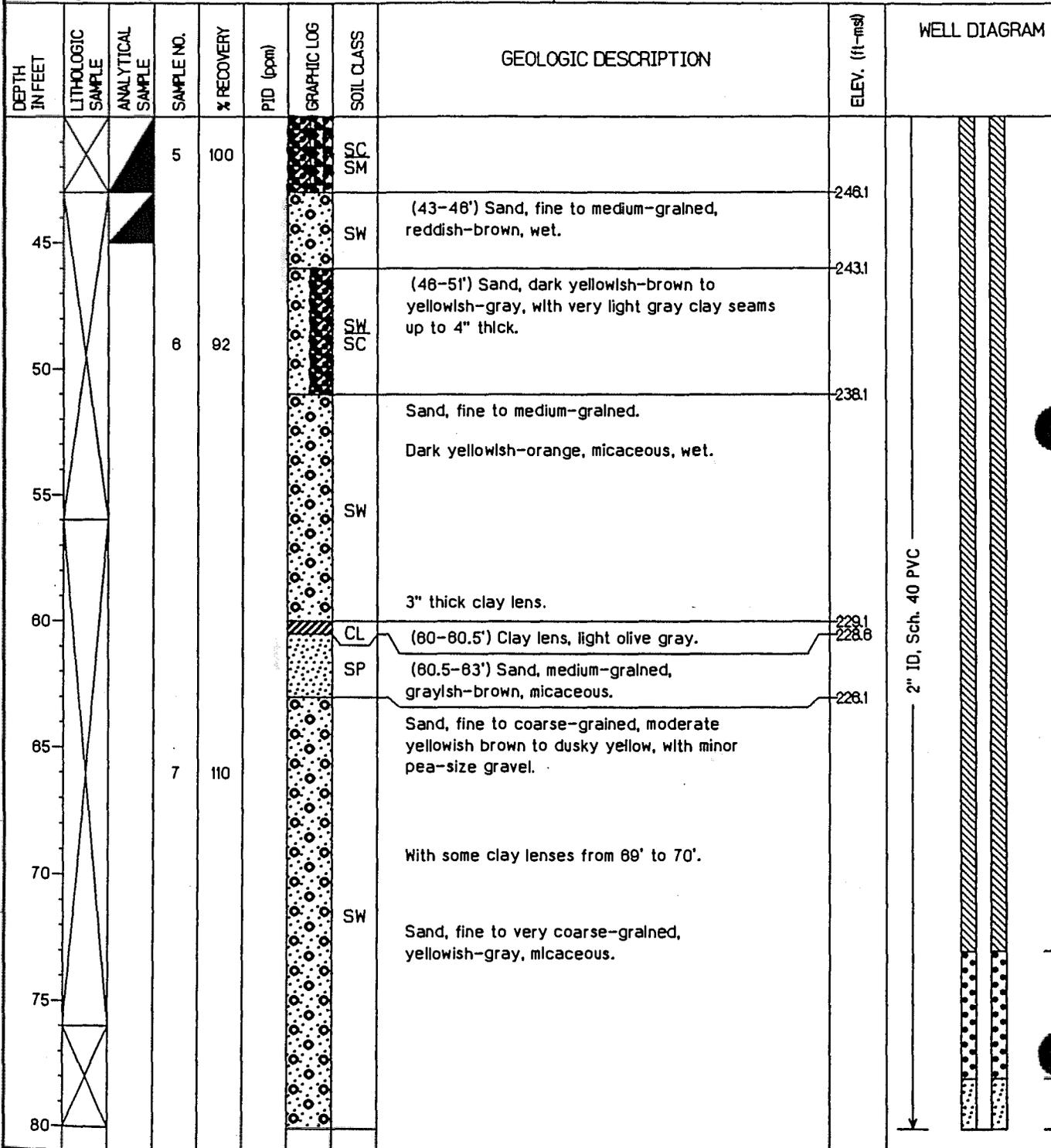
Well Screen: 66 to 76 feet 7.1'

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0			1	100	.3			Silt, brown, with some gravel; fill 0' to 2', native material 2' to 4.		
5					.3			(4-15') Silt, light brown to reddish-brown, with some clay and organic material.		
10			2	50	.3					
15					.3		ML	(15-16') Silt, with some clay, moderate gray.		
20					.3			(16-30') Silt, yellowish-brown and olive gray, with some clay, with some organic material and clay throughout, wet.		
25			3	70						
30								(30-34') Silt and clay, greenish-gray to olive gray, moist to wet.	263.1	
35							ML CL	(34-36') Increasing clay content.		
40			4	150			ML CL	(38-44') Clay, silty and sandy, with scattered gravel, gray to light brown.	255.1	

Project: <i>NSA Memphis</i>	Location: <i>Milington, TN SWMU 7 - Building N-126</i>
Project No: <i>0094-08420</i>	Surface Elevation: <i>289.10 feet msl</i>
Started at <i>0800 on 3-16-96</i>	TOC Elevation: <i>288.78 feet msl</i>
Completed at <i>1240 on 3-16-96</i>	Depth to Groundwater: <i>35.68 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>253.10 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>96.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>80 to 90 feet</i>

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
85			8	120			SW SC SW SC GC	(81-82.5') Sand, fine to coarse-grained, dark yellowish-orange with clay lenses between 82' and 82.5', orangish-gray.	208.1 208.6	<p>0.01 slot, PVC screen 3" PVC end cap 10/20 sand bentonite plug</p>
90			9	110			CL	(86-90') Sand and gravel with some clay in matrix, dark yellowish- orange.	203.1	
95							CL	Cockfield Formation: Clay, dark brown, with thin interbeds of fine- grained sand.	199.1	
96								Soil boring terminated at 96'.	193.1	
100										
105										
110										
115										
120										

Project: <i>NSA Memphis</i>	Location: <i>Millington, TN SHMU 7 - Building N-126</i>
Project No: <i>0094-08420</i>	Surface Elevation: <i>289.10 feet msl</i>
Started at <i>0800 on 3-16-96</i>	TOC Elevation: <i>288.78 feet msl</i>
Completed at <i>1240 on 3-16-96</i>	Depth to Groundwater: <i>35.68 feet</i> Measured: <i>4/8/96</i>
Drilling Method: <i>Rotasonic</i>	Groundwater Elevation: <i>253.10 feet msl</i>
Drilling Company: <i>Alliance Environmental</i>	Total Depth: <i>96.0 feet</i>
Geologist: <i>JKingsbury</i>	Well Screen: <i>80 to 90 feet 8.5'</i>





Monitoring Well 007G12LF

Project: NSA Memphis

Location: *Milington, TN. SHMU 7 - Building N-126*

Project No.: 0094-08420

Surface Elevation: 289.10 feet msl

Started at 0800 on 3-16-96

TOC Elevation: 288.78 feet msl

Completed at 1240 on 3-16-96

Depth to Groundwater: 35.68 feet

Measured: 4/8/96

Drilling Method: Rotasonic

Groundwater Elevation: 253.10 feet msl

Drilling Company: Alliance Environmental

Total Depth: 96.0 feet

Geologist: J.Kingsbury

Well Screen: 80 to 90 feet

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
0-2'					.1			(0-2') Concrete.		
2-22'			1		.1			(2-22') Silt, light brown to gray.	287.1	
5-10'			2	70	.1		ML	Silt, light brown to yellowish-brown, with some organic material, moist.		
14-18'					.1			(14-18') With dark yellowish-orange mottling.		
18-22'					.1			Silt, yellowish-brown to yellowish-gray, wet.		
22-25'			3	100				Clay and silt, brown, with some iron concretions.	267.1	
25-30'							CL ML	Silt and clay, yellowish-brown to light brown, with some dark yellowish-orange mottling.		
30-34'			4	88				Contact with Fluvial Deposits (34-90') estimated at 34'.		
34-37'										
37-43'							SC SM	(37-43') Sand, clay, and silt, reddish-brown to dark yellowish-orange, moist.	252.1	

NSA MID-SOUTH
Millington, TN.

Started : 0950 4/13/99
 Finished : 1421 4/13/99
 Drilling Method : Rotasonic
 Drilling Company : Alliance Drilling
 Geologist : C. Davis

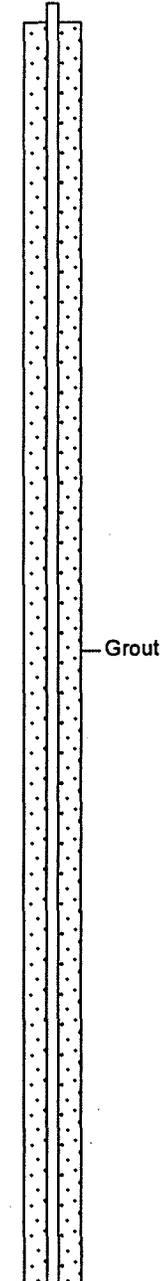
Northing : 392931.02
 Easting : 814783.22
 TOC Elevation : 289.68
 Total Depth : 98 feet
 Well Screen : 56.5 to 96.5 feet

Location: AOCA/SWMU 7

Project #: CTO 0094

Depth in Feet	Surf. Elev. 289.98	SAMPLES	% Recovery	PID (ppm)	GRAPHIC LOG	SOIL CLASS	DESCRIPTION
0							(0 - 5) Concrete and gravel
289						ML	(.5 - 4) Dark, orangish brown silt mottled w/ Lt. olive gray silt, some iron staining, moist
5		1	40				(4 - 8) No recovery
284							
10						ML	(8 - 16) Lt. olive gray silt and clayey silt, mottled w/ orangish brown silt and clayey silt w/ iron staining and nodules, moist
279		2	80				
15							(16 - 18) No recovery
274							
20							(18 - 24) Same as above, but little to no iron nodules, lots of iron staining and more clay content
269		3	100				
25						ML	(24 - 27) Pale orangish Lt. brown to gray clayey silt, moist
264							(27 - 28) Lt. olive gray silt and clayey silt, mottled w/ orangish brown silt and clayey silt w/ iron staining and nodules, moist
30		4	100				(28 - 35) Dusky orangish brown clayey to very clayey silt w/ iron staining, moist

Well: 007G49LF
 Elev.: 289.98
 Cover



NSA MID-SOUTH
Millington, TN.

Started : 0950 4/13/99
 Finished : 1421 4/13/99
 Drilling Method : Rotasonic
 Drilling Company : Alliance Drilling
 Geologist : C. Davis

Northing : 392931.02
 Easting : 814783.22
 TOC Elevation : 289.68
 Total Depth : 98 feet
 Well Screen : 56.5 to 96.5 feet

Location: AOCA/SWMU 7

Project #: CTO 0094

Depth in Feet	Surf. Elev. 289.98	SAMPLES	% Recovery	PID (ppm)	GRAPHIC LOG	SOIL CLASS	DESCRIPTION	Well: 007G49LF Elev.: 289.98
33	256	4	100				(35 - 45) Orangish brown and Lt. olive gray mottled clayey to very clayey silt w/ iron staining, moist	
38	251					ML		
43	246	5	100				(45 - 47) Orangish brown and Lt. olive gray mottled clayey to very clayey silt w/ iron staining and minor amounts of very fine sand, moist	Grout
48	241					SW	(47 - 48) same mottled colors w/ very fine to fine sand and subangular gravel (up to 1 1/2" dia.) (48 - 51) Same as above, very moist, sand grain to med.	
53	236	6	100			SC	(51 - 56.5) Alternating Lt. gray and bright orangish brown fine to med. clayey to clean sands, clay lense 2" thick at 54, 3" thick at 55.5, 6" thick from 56 to 56.5, very moist	Seal
58	231					SW	(56.5 - 58) Pale orangish to pale yellowish gray fine to med. sand, wet	
						SP	(58 - 62) Pale orangish brown fine sand, wet	Sand Pack
63		7	100			SC	(62 - 62.5) Red and gray banded to mottled clay, moist (62.5 - 68) Repeat pattern of sand and clay as follows: 62.5-63 is sand, 63-63.75 is clay, 63.75-64.5 is sand, 64.5-64.75 is clay, 64.75-66 is sand, 66-66.25 is clay, 66.25-66.5 is sand 66.5-67 is clay, 67-68 is sand	0.010 Slotted Screen

12-1b...09 N:WELL LOGS\NSAMIDSOUTH\007G49LF.BOR

NSA MID-SOUTH
Millington, TN.

Started : 0950 4/13/99
Finished : 1421 4/13/99
Drilling Method : Rotasonic
Drilling Company : Alliance Drilling
Geologist : C. Davis

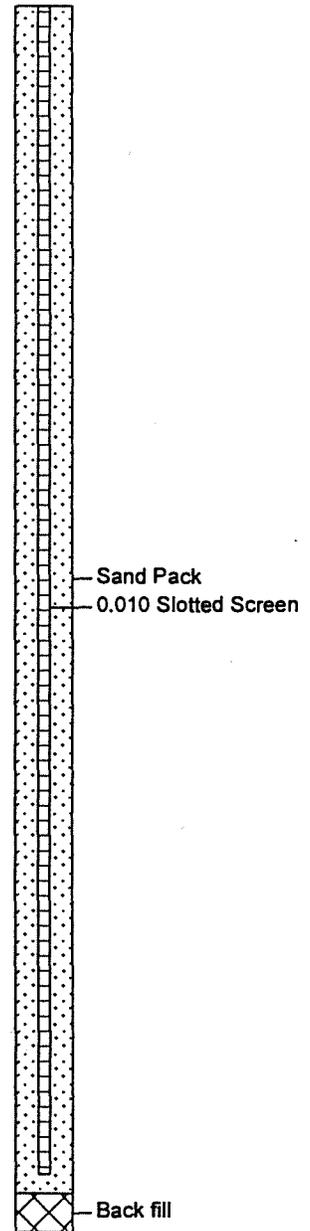
Northing : 392931.02
Easting : 814783.22
TOC Elevation : 289.68
Total Depth : 98 feet
Well Screen : 56.5 to 96.5 feet

Location: AOCA/SWMU 7

Project #: CTO 0094

Depth in Feet	Surf. Elev. 289.98	SAMPLES	% Rec-covery	PID (ppm)	GRAPHIC LOG	SOIL CLASS	DESCRIPTION
66	223	7	100			SC	
71	218	8	80			SW	(68 - 78) Yellowish gray to Lt. orangish brown fine to med sand w/ occasional very fine gravel, wet, Lt. gray clay, very moist
76	213						(78 - 86) Same, clay lense at 78.5 (2" thick)
81	208	9	100				
86	203						(86 - 88) No recovery
91	198	10	100			SP	(88 - 91) Pale orangish gray med. sand, wet (91 - 92) Pale orangish gray med. sand w/ gravel (up to 1 1/2")
96						SW	(92 - 93) Very pale orangish brown med. to very coarse sand w/ gravel
						SP	(93 - 94) Pale orangish gray med. sand w/ gravel (up to 1 1/2"), wet
						SW	(94 - 94.5) Orangish yellow brown med. to very coarse sand w/ gravel (up to 3")
						CL	(94.5 - 95) Gray to Lt. gray clay moist, some yellowish and orangish gray mottling (95 - 98) Very dark brown silty clay, w/ clayey silt bands, micaceous, moist

Well: 007G49LF
Elev.: 289.98



obtaining reliable, valid S values from pumping well data is not conducted due to potential storage and well loss effects during pumping from the well.

The hydraulic conductivity values shown for each well were calculated by dividing the geometric mean of the drawdown and recovery-derived T by the aquifer thickness at each well. As shown in the table, hydraulic conductivity values are calculated to range between 44.6 and 68.4 feet per day with a geometric mean of 59.1 feet per day.

Table 3
 Aquifer Characteristics

Observation Well	Transmissivity ft ² /day		Hydraulic Conductivity ^a (feet/day)	Storativity		Aquifer Model
	Based on Drawdown	Based on Recovery		Based on Drawdown	Based on Recovery	
<i>Fluvial Deposits Wells</i>						
007G34LF	3,024	2,880	68.4	1.4 E-4	1.8 E-4	Theis
007G35LF	2,448	3,024	60.8	2.3 E-4	1.4 E-5	Theis
007G36LF	2,304	2,880	61.0	1.3 E-4	1.2 E-4	Hantush-Jacob
007G37LF	2,304	2,736	63.8	2.1 E-8	7.8 E-11	Theis
007G37F1	2,592	2,304	62.6	7.8 E-4	8.7 E-4	Hantush-Jacob
007G38LF	2,016	2,592	54.6	1.2 E-4	8.6 E-5	Hantush-Jacob
007G39LF	4,320	4,032	68.3	4.4 E-4	4.8 E-4	Theis
007G40LF	1,872	1,872	66.0	1.6 E-4	2.2 E-4	Hantush-Jacob
007G41LF	2,448	1,296	44.6	1.6 E-4	1.5 E-3	Theis
007G42LF	2,880	2,592	56.7	1.4 E-4	1.3 E-4	Hantush-Jacob
007G43LF	1,584	2,016	45.0	1.2 E-4	1.3 E-4	Hantush-Jacob
007G46LF	2,016	2,448	62.5	7.5 E-5	8.4 E-5	Hantush-Jacob
<i>Geometric Mean</i>	2,448 ft ² /day (1.7 ft ² /min)		59.1 feet/day (0.041 ft ² /min)		1.8 E-4	

Note:

a = Based on the mean transmissivity value from the drawdown and recovery monitoring data divided by the aquifer thickness at each well.

total porosity, median grain size, specific gravity, and bulk density, while grab samples were analyzed for grain size and specific gravity. Analytical reports provided by the laboratory are provided in Appendix C. Table 2-2 summarizes the analytical results for samples collected from each stratigraphic unit. The sample collected from the loess was classified as a silt-clay. The fluvial deposits samples have been classified as poorly graded silty-clayey sand, poorly graded gravel, poorly graded sand/gravel and well graded gravel. Samples collected from the Cockfield Formation have been classified as either silt-clay or poorly graded silty-clayey sand.

Soil properties show distinctive trends corresponding to the stratigraphic units from which they were collected. The ranges of moisture contents, porosities, and coefficients of permeability for the loess, fluvial deposits, and Cockfield Formation are provided in Table 2-3. The loess and Cockfield Formation display similar properties (i.e., relatively low coefficients of permeability and high moisture contents) which contrast with the fluvial deposits (i.e., relatively high coefficients of permeability and low moisture contents).

Table 2-2
Geotechnical Samples Collected from AOC A Borings

Sample I.D.	*USCS Soil Classification	Coefficient of Permeability (cm/sec)	Moisture Content (%)	Total Porosity (%)	Median Grain Size (mm)	Specific Gravity
Loess Sample						
007S0009-22	silt-clay	9.5×10^{-7}	27.5	43.0	0.005	2.64
Fluvial Deposits Samples						
007SMW14-40	silty-clayey sand (PG)	—	—	—	0.18	2.65
007S0003-41	silty-clayey sand (PG)	—	—	—	0.30	—
007SMW16-43	silty-clayey sand (PG)	3.7×10^{-5}	14.8	38.0	0.29	2.63
007SMW12-43	silty-clayey sand (PG)	2.5×10^{-5}	19.2	36.0	0.19	2.72
007S0003-46	silty-clayey sand (PG)	—	—	—	0.18	—

Table 2-2
 Geotechnical Samples Collected from AOC A Borings

Sample I.D.	*USCS Soil Classification	Coefficient of Permeability (cm/sec)	Moisture Content (%)	Total Porosity (%)	Median Grain Size (mm)	Specific Gravity
007SMW15-48	silty-clayey sand (PG)	2.1×10^{-4}	22	34.6	0.27	2.60
007SMW13-49	silt-clay	1.1×10^{-6}	19.2	36.0	0.07	2.68
007SMW18-49	silty-clayey sand (PG)	1.5×10^{-6}	20.4	38.0	0.27	2.70
007SMW17-49	silty-clayey sand (PG)	2.2×10^{-4}	22.1	33.4	0.24	2.61
007SMW11-49	silty-clayey sand (PG)	8.3×10^{-5}	8.6	26.0	0.50	2.81
007SMW10-49	silty-clayey sand (PG)	3.3×10^{-6}	15.7	31.0	0.15	2.71
007SMW11-68	gravel (PG)	—	—	—	9.0	2.69
007SMW13-68	sand, gravelly sand (PG)	—	—	—	0.19	2.68
007SMW10-72	sand/gravel (PG)	—	—	—	19.0	2.71
007SMW17-72	sand/gravel (PG)	—	—	—	15.0	2.70
007S0002-75	silty-clayey sand (PG)	—	—	—	4.3	—
007SMW16-80	silty-clayey gravel (PG)	—	—	—	6.0	2.61
007SMW12-90	gravel (WG)	—	—	—	6.8	—
007SMW18-96	gravel (PG)	—	—	—	9.0	2.69
007SMW15-100	sand (PG)	—	—	—	3.4	2.68
Cockfield Formation Samples						
007S0001-77	silty-clayey sand (PG)	6.8×10^{-5}	17.4	39.7	0.1	—
007S0001-112	silt-clay	4.1×10^{-8}	31.7	50.6	0.0041	—
007S0003-117	silt-clay	1.6×10^{-8}	30.1	54.4	0.017	2.65
007S0008-127	silt-clayey sand (PG)	8.7×10^{-7}	29.3	49.7	0.097	—

Notes:

- PG — poorly graded
- WG — well graded
- mm — millimeters
- cm/sec — centimeters per second
- — Analysis not applicable to sample

Soil samples were not analyzed for Atterberg limits and thus the distinction between clay and silt was not made by the soil laboratory.

* Samples classified according to the Unified Soil Classification System (USCS).

Sample I.D.s 007S0003 and 007SMW18 correspond with well locations 007G03 and 007G18 depicted in the figures.

Table 2-3
Ranges of Select Soil Properties from AOC A Soil Borings

	Moisture Content (% dry weight)	Porosity (%)	Coefficient of Permeability (cm/sec)
<i>Loess</i>	27	43	9.5×10^{-7}
<i>Fluvial Deposits</i>	9 - 22	26 - 38	2.2×10^{-4} - 1.6×10^{-6}
<i>Cockfield Formation</i>	17 - 32	40 - 54	6.8×10^{-5} - 1.6×10^{-8}

Laboratory measured coefficients of permeability are shown in Figure 2-11 to vary by greater than four orders of magnitude and show two general groupings: those greater than 1.0×10^6 cm/sec correspond to samples collected from the fluvial deposits, while those less than 1.0×10^6 cm/sec correspond to those collected from the Cockfield Formation and the loess. It should be noted that Shelby tube samples were not collected from the lower section of the fluvial deposits due to difficulty retrieving samples in gravels. Therefore, the range of permeability coefficients for the fluvial deposits is representative only for the upper to middle sections of this unit.

Grain size analyses performed on the Shelby tube and grab samples have also been plotted graphically (Figure 2-12) to illustrate the median grain size³ for the different units. The Cockfield Formation contains a median grain size between silt, clay, and fine sand. Samples collected from the fluvial deposits fall into two general groupings: those collected from the upper and middle parts of the fluvial deposits contain median grain sizes ranging from fine to medium sand, while gravel is the predominant median grain size of the samples collected from the lower part of the fluvial deposits. The grain-size distribution curves for these samples are provided in Appendix C.

³The median grain size has been estimated from the grain-size distribution curves and represents the grain size corresponding to the 50th percentile coarser/finer by weight value (see Appendix C).

**Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area**

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
7-28	7S002812	S	12	ND/Dup ND	
7-29	7S002912	S	12	ND	
	7G002936	W	36	12.6/Dup 17 8/Dup 7	TCE PCE
7-30	7S003012	S	12	ND	
	7G003047	W	47	7.9 120	TCE PCE
7-31	7S003112	S	12	ND	
	7G003145	W	45	ND	
7-32	7S003212	S	12	ND	
	7G003245	W	45	4.9 8.5	m,p-Xylenes Trichlorofluorom
7-33	7S003312	S	12	ND	
	7G003336	W	36	9.4 8.2	1,1-DCE 1,1-DCA

Third DPT Sampling Results - 11/10/95 - 12/08/95

7-34	7G003445	G	45	ND	
7-35	7G003549	G	49	79.7 9.92 117 44.2 31.9 10.3	1,1-DCE c-1,2-DCE TCE 1,2-DCA Bromochloromet Carbon Tet.
7-36	7G003658	G	58	6.1/DUP ND ND/DUP - 28	Dichlorodifluoromethane 1,2-DCE
7-37	7G003760	G	60	ND	
7-38	7G003849	G	49	ND	
7-39	7G003934	G	34	6.5	TCE
7-40	7G004042	G	42	1.7 J/Dup 1 J	1,1-DCA

Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
7-41	7G004143	G	43	1.7 20	1,2-DCE TCE
7-42	7G004240	G	40	15/Dup ND 6.7/Dup ND 2.8/Dup ND 6.4/Dup 7.7	Dichlorofluorom. Methylene Chloride Chloroform Carbon Tet.
7-43	7G004346	G	46	ND	
7-44	7G004446	G	46	1.4	TCE
7-45	7G004545	G	45	ND/DUP 61	Acetone
7-46	7G004646	G	46	ND	
7-47	7G004746	G	46	5	TCE
7-48	7G004845	G	45	11.2	1,2-DCA
7-49	7G004934	G	34	8.1/Dup 7	TCE
7-50	7G005061	G	61	ND/Dup 16	MEK
7-51	7G005154	G	54	ND	
7-52	7G005265	G	52	ND	
Fourth DPT (Geoprobe) Sample Results 2/23/96-2/27/96 and 10/29/96					
7-53	007G005364	G	64	ND	
7-54	007G005458	G	58	ND	
7-55	007G005560	G	60	ND	
7-56	007G005650	G	50	ND	
7-57	007G005757	G	57	6.0/Dup 5.8 42.6/Dup 56.5 128/Dup 149	Choloroform PCE TCE
7-58	007G005872	G	58	7.4 3.3 16	Carbon Tet. Chloroform TCE

Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
7-59	007G005965	G	65	1.0 1.1 13.8 47.3	Carbon Tet. Chloroform TCE c-1,2-DCE
7-60	007G006079	G	79	ND	

**Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area**

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
7-67	007G006746 (UF)	G	46	ND/Dup ND	
	007G006751 (MF)	G	51	ND	
	007G006756 (MF)	G	56	ND	
	007G006760 (LF)	G	60	ND	
	007G006765 (LF)	G	65	ND	
	007G006772 (LF)	G	72	538 2.1 1.7 J	Acetone Chloroform TCE
7-68	007G006848(UF)	G	48	200 1.9 3.2 2.6	Acetone 1,1-DCA 1,1-DCE TCE
	007G006853 (UF)	G	53	50.9 J 2.7 5.1 3.7	Acetone 1,1-DCA 1,1-DCE TCE
	007G006858 (MF)	G	58	1380 2.4 4.3 1.6 J	Acetone 1,1-DCA 1,1-DCE TCE
	007G006864 (MF)	G	64	562 17.4 27.7 2.0 J	Acetone Carbon Tet. Chloroform 1,1-DCE
	007G006869 (MF)	G	69	23.2 22.4 2.3 J 1.2 J	Carbon Tet. Chloroform 1,1-DCE TCE
	007G006873 (LF)	G	73	15.2 23.3 8.2 5.6	Carbon Tet. Chloroform TCE cis-1,2-DCE
	007G006878 (LF)	G	78	6.5 8.1 6.4 5.12	Carbon Tet. Chloroform TCE cis-1,2-DCE
	007G006883 (LF)	G	83	594 1.3 J 4.1 J 1.3 J	Acetone Carbon Tet. Chloroform TCE
	007G006888 (LF)	G	88	1.4 J 3.9 J	Carbon Tet. Chloroform

Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
7-69	007G006960 (MF)	G	60	5.1/Dup 4.8 J 199/Dup 185 180/Dup 170 36.5/Dup 34.2 183/Dup 163 1160/Dup 1310 29.2/Dup 27.2	Benzene Carbon Tet. Chloroform 1,1-DCA 1,1-DCE TCE cis-1,2-DCE
	007G006990 (LF)	G	90	1.6 J	TCE
7-70	007G007046 (UF)	G	46	1.9 J 3.2 J 10.7 16.9	Chloroform 1,1-DCA 1,1-DCE TCE
	007G007068 (MF)	G	68	47.4 4.3 J 190	Chloroform 1,1-DCE TCE
	007G007088 (LF)	G	88	3.5 J 11.3 1.0 J 38.9	Carbon Tet. Chloroform 1,1-DCE TCE
7-71	007G007146 (UF)	G	46	1020 1.7 J	Acetone 1,1-DCA
	007G007168 (MF)	G	68	121 60.8 2.7 422	Carbon Tet. Chloroform 1,1-DCE TCE
	007G007188 (LF)	G	88	34.3 15.9 2.6 14	Carbon Tet. Chloroform 1,1-DCE TCE
7-72	007G007246 (UF)	G	46	4.1 8.7 16.1	1,1-DCA 1,1-DCE TCE
	007G007268 (MF)	G	68	10.3 30.6 1.6J 122	Carbon Tet. Chloroform 1,1-DCE TCE
	007G007290 (LF)	G	90	197 28.5 21.1 2.1 J 8.7	Acetone Carbon Tet. Chloroform 1,1-DCE TCE
7-73	007G007368 (MF)	G	68	164 2.1 J 15.3	Acetone Chloroform TCE

Table E-2
DPT Sampling Results for VOCs
SWMU 7/Apron Area

Sample Location	Sample ID	Soil or Water	Depth (ft. bls)	Concentration (ppb)	Compound
	007G007390 (LF)	G	90	44 J	Acetone
7-74	007G007468 (MF)	G	68	4.3 J 1.4 J 47.4	Chloroform 1,1-DCE TCE
	007G007491 (LF)	G	91	33 J 1.2 J	Acetone TCE
7-75	007G007559 (UF)	G	59	1.4 J 1.4 J	Benzene Toluene
7-76	007G007660 (UF)	G	60	ND	
	007G007680 (LF)	G	80	9.8	TCE
7-77	007G007768 (LF) ^a	G	68	4.3 J 9.7 J 22	Chloroform PCE TCE
7-78	007G007868 (LF)	G	68	11.5 2.3 J	Chloroform TCE
7-79	007G007967 (MF)	G	67	7.2 3.5 J 10.2 61.2	Chloroform 1,1-DCA 1,1-DCE TCE
7-80	007G008066 (MF)	G	66	3.3 J 14.2 26.2	Chloroform 1,1-DCE TCE
	007G008087 (LF)	G	87	ND	

Notes:

- a — Water sample very turbid and air bubbles reported in VOA vials.
- J — Compound was detected below the method reporting limit; value estimated.
- ND — Non detect
- ppb — parts per billion

Sample locations are shown on the figures presented in Sections 3 and 4 and Appendix A.

Table E-3
 SWMU 7/Apron Area
 Organics Detected in Groundwater by Well ($\mu\text{g/L}$)

Well ID	Constituent	RBC ^a	MCL ^b	Initial ^c	Intermediate ^d	Event 1 ^e	Event 2 ^f	Event 3 ^g
007G01LF	1,1-Dichloroethane	810	DNE	2 J	3 J	5 J	2 J	10 U
	1,1-Dichloroethene	0.044	7	3 J	4 J	9 J	3 J	10 U
	1,2-Dichloroethene (total)	55	70	2 J	2 J	2 J	2 J	10 U
	Carbon tetrachloride	0.16	5	4 J	10	10 U	6 J	10
	Chloroform	0.15	100	2 J	2 J	10 U	2 J	10 U
	Trichloroethene	1.6	5	6 J	8 J	4 J	8 J	10
	1,1-Dichloroethane	810	DNE	46	79	NS	NS	NS
007G01LS	1,1-Dichloroethene	0.044	7	1 J	4 J	NS	NS	NS
	1,2-Dichloroethane	0.12	5	3 J	4 J	NS	NS	NS
	1,2-Dichloroethene (total)	55	70	19	34	NS	NS	NS
	1,2-Dichloropropane	0.16	5	1 J	2 J	NS	NS	NS
	2-Hexanone	DNE	DNE	25 J	10 U	NS	NS	NS
	Benzene	0.36	5	7 J	8 J	NS	NS	NS
	Tetrachloroethene	1.1	5	10 U	2 J	NS	NS	NS
007G01UC	Trichloroethene	1.6	5	9 J	19	NS	NS	NS
	Acetone	3,700	DNE	10 U	10 U	84 J	NS	10 U
	1,1-Dichloroethane	810	DNE	18	26	75	45	30
	1,1-Dichloroethene	0.044	7	3 J	4 J	19	9 J	6 J
	1,2-Dichloroethene (total)	55	70	5 J	6 J	14	10	6 J
	1,2-Dichloropropane	0.16	5	10 U	10 U	2 J	2 J	10 U
	Tetrachloroethene	1.1	5	8 J	9 J	6 J	8 J	9 J
007G01UF	Trichloroethene	1.6	5	8 J	11	19	14	10
	4-Methyl-2-Pentanone (MIBK)	2,900	DNE	10 U	10 U	2 J	NS	10 U
	Carbon disulfide	1,000	DNE	10 U	10 U	1 J	NS	10 U
	1,2-Dichloroethane	0.12	5	10 U	10 U	10 U	1 J	10 U
	2-Butanone (MEK)	1,900	DNE	10 UJ	10 U	10 U	20 J	10 U
	Acetone	3,700	DNE	78	10 U	10 U	10 UJ	10 U
	Carbon tetrachloride	0.16	5	12	16	19	20 J	19
007G02UC	Chloroform	0.15	100	8 J	8 J	10	11	10
	Tetrachloroethene	1.1	5	1 J	2 J	2 J	4 J	3 J
	Trichloroethene	1.6	5	63	73	98	97	78
	Acetone	3,700	DNE	120	10 U	NS	NS	NS
	BEHP	4.8	DNE	2 J	NS	NS	NS	NS
	Acetone	3,700	DNE	22 U	16	29 U	NS	10 U
	Chloromethane	1.4	DNE	10 U	10 U	3 J	NS	10 U
007G03LF	Acetone	3,700	DNE	12	39	5 U	10 UJ	10 U
	Carbon disulfide	1,000	DNE	10 U	3 J	10 U	10 U	10 U

Table E-3
 SWMU 7/Apron Area
 Organics Detected in Groundwater by Well (µg/L)

Well ID	Constituent	RBC ^a	MCL ^b	Initial ^c	Intermediate ^d	Event 1 ^e	Event 2 ^f	Event 3 ^g
007G04LF	1,1-Dichloroethene	0.044	7	10 U	50 U	2 J	10 U	2 J
	1,2-Dichloroethene (total)	55	70	10 U	50 U	2 J	10 UJ	2 J
	Acetone	3,700	DNE	83	50 U	95 J	10 UJ	10 U
	Carbon tetrachloride	0.16	5	10 U	9 J	10 U	13 J	9 J
	Chloroform	0.15	100	10 U	50 U	10 U	3 J	2 J
	Methylene chloride	4.1	5	10 U	50 U	1 J	10 U	10 U
	Tetrachloroethene	1.1	5	10 U	26 J	61	6 J	31
	Trichloroethene	1.6	5	2 J	390	1,100 D	160	620 D
007G04UC	Acetone	3,700	DNE	10 U	10 J	NS	NS	10 U
	BEHP	4.8	DNE	3 J	NS	NS	NS	NS
007G04UF	Acetone	3,700	DNE	30	18 J	240	10 UJ	10 U
	Methylene chloride	4.1	5	10 U	10 U	2 J	10 U	10 U
	Trichloroethene	1.6	5	3 J	1 J	20 U	10 U	10 U
007G05LF	1,2-Dichloroethane	0.12	5	4 J	4 J	4 J	10 U	3 J
	Acetone	3,700	DNE	10 U	11 J	10 U	10 U	10 UJ
	Carbon tetrachloride	0.16	5	6 J	8 J	7 J	11	6 J
	Chloroform	0.15	100	4 J	5 J	10 U	5 J	5 J
	Tetrachloroethene	1.1	5	10 U	1 J	1 J	1 J	1 J
	Trichloroethene	1.6	5	22	28	31	38	27 J
007G05LS	Acetone	3,700	DNE	20	10 U	10 U	NS	NS
	Ethylbenzene	1,300	700	10 U	1 J	10 U	NS	NS
007G05UC	Acetone	3,700	DNE	49	10 UJ	10 U	NS	10 U
	Dimethyl phthalate	370,000	DNE	1 J	NS	NS	NS	NS
	Toluene	750	1,000	10 U	10 U	1 J	NS	10 U
007G05UF	2-Butanone (MEK)	1,900	DNE	10 U	10 U	1 J	10 UJ	10 U
	Acetone	3,700	DNE	10 U	98	39 U	10 UJ	10 U
007G06LF	Acetone	3,700	DNE	5 J	5 J	51 UJ	10 UJ	10 U
	Tetrachloroethene	1.1	5	1 J	1 J	2 J	2 J	3 J
	Trichloroethene	1.6	5	2 J	2 J	2 J	2 J	3 J
007G06LS	Acetone	3,700	DNE	11	10 U	10 U	NS	NS
	Phenol	22,000	DNE	10 U	NS	21	NS	NS
007G06UC	Acetone	3,700	DNE	10 U	10 U	24	NS	180 J
007G06UF	Acetone	3,700	DNE	59	320	10 U	10 U	10 U
007G07LF	1,1-Dichloroethane	810	DNE	2 J	1 J	NS	10 U	10 U
	1,1-Dichloroethene	0.044	7	1 J	1 J	NS	10 U	10 U
	Acetone	3,700	DNE	33	10 UJ	NS	10 U	10 U
	Carbon disulfide	1,000	DNE	1 J	10 U	NS	10 U	10 U
	Carbon tetrachloride	0.16	5	10 U	1 J	NS	10 U	10 U
	Tetrachloroethene	1.1	5	3 J	3 J	NS	8 J	6 J
	Trichloroethene	1.6	5	6 J	6 J	NS	7 J	6 J
007G07LS	Acetone	3,700	DNE	12	40 J	10 U	NS	NS
007G07UC	Acetone	3,700	DNE	10	21 J	150	NS	10 U

Table E-3
 SWMU 7/Apron Area
 Organics Detected in Groundwater by Well (µg/L)

Well ID	Constituent	RBC ^a	MCL ^b	Initial ^c	Intermediate ^d	Event 1 ^e	Event 2 ^f	Event 3 ^g
007G07UF	Acetone	3,700	DNE	10 U	25 J	10 U	10 U	10 U
	Vinyl chloride	0.019	2	2 J	2 J	10 U	10 U	10 U
	BEHP	4.8	DNE	1 J	NS	NS	NS	NS
007G08LF	1,1-Dichloroethane	810	DNE	4 J	4 J	100 U	5 J	10 U
	1,1-Dichloroethene	0.044	7	7 J	6 J	100 U	9 J	10
	1,2-Dichloroethene (total)	55	70	2 J	1 J	100 U	2 J	10 U
	Acetone	3,700	DNE	10 U	10 UJ	1,200	10 U	10 U
	Trichloroethene	1.6	5	7 J	8 J	100 U	9 J	9 J
	1,1-Dichloroethane	810	DNE	1 J	10 U	10 U	NS	10 U
007G08UC	1,2-Dichloroethane	0.12	5	1 J	10 U	10 U	NS	10 U
	1,2-Dichloroethene (total)	55	70	11	10 U	10 U	NS	10 U
	Acetone	3,700	DNE	18	10 UJ	10 U	NS	10 U
	Benzene	0.36	5	1 J	10 U	10 U	NS	10 U
	Bromomethane	8.7	DNE	1 J	10 U	10 U	NS	10 U
	Chloroform	0.15	100	2 J	10 U	10 U	NS	10 U
	Tetrachloroethene	1.1	5	5 J	10 U	10 U	NS	10 U
	Trichloroethene	1.6	5	4 J	10 U	10 U	NS	10 U
	1,2-Dichloroethane	0.12	5	3 J	3 J	2 J	10 U	10 U
007G08UF	Trichloroethene	1.6	5	1 J	1 J	10 U	2 J	10 U
007G09LF	1,1-Dichloroethane	810	DNE	10 U	10 U	2 J	10 U	2 J
	1,1-Dichloroethene	0.044	7	10 U	10 U	1 J	10 U	40
	1,2-Dichloroethane	0.12	5	10 U	2 J	10 U	10 U	10 U
	1,2-Dichloroethene (total)	55	70	10 U	10	34	16	10 U
	Benzene	0.36	5	10 U	10 U	2 J	10 U	10 U
	Chloroform	0.15	100	10 U	2 J	1 J	10 U	10 U
	Tetrachloroethene	1.1	5	10 U	6 J	15	12	33
	Trichloroethene	1.6	5	10 U	4 J	4 J	4 J	8 J
	Xylene (Total)	12,000	10,000	10 U	10 U	3 J	10 U	10 U
	Acetone	3,700	DNE	10 U	14	10 U	NS	NS
007G09LS	Chloroform	0.15	100	2 J	3 J	10 U	NS	NS
	Di-n-butylphthalate	3,700	DNE	10 U	NS	2 J	NS	NS
	TPH - DRO	100	DNE	NS	NS	120	NS	NS
007G09UC	Acetone	3,700	DNE	10 UJ	10 UJ	140 J	NS	10 U
	1,1-Dichloroethane	810	DNE	1 J	10 U	NS	10 UJ	10 U
007G09UF	Acetone	3,700	DNE	26	10 UJ	NS	10 UJ	10 U
	Bromomethane	8.7	DNE	1 J	10 U	NS	10 UJ	10 U
00MG09MF ^h	1,1-Dichloroethene	0.044	7	10 U	1 J	10 U	NS	NS
	2-Butanone (MEK)	1,900	DNE	10 U	10 U	19	NS	NS
	Benzene	0.36	5	1 J	10 U	10 U	NS	NS
	Toluene	750	1,000	1 J	10 U	10 U	NS	NS
	Trichloroethene	1.6	5	4 J	7 J	4 J	NS	NS

Table E-3
SWMU 7/Apron Area
Organics Detected in Groundwater by Well (µg/L)

Well ID	Constituent	RBC ^a	MCL ^b	Initial ^c	Intermediate ^d	Event 1 ^e	Event 2 ^f	Event 3 ^g
007G10LF ^h	4-Methyl-2-Pentanone (MIBK)	2,900	DNE	NS	NS	NS	2 J	10 U
	Carbon tetrachloride	0.16	5	NS	NS	NS	12	11
	Chloroform	0.15	100	NS	NS	NS	9 J	6 J
	Tetrachloroethene	1.1	5	NS	NS	NS	9 J	8 J
	Trichloroethene	1.6	5	NS	NS	NS	16	15
007G11LF ^h	1,2-Dichloroethene (total)	55	70	NS	NS	NS	3 J	10 U
	Carbon tetrachloride	0.16	5	NS	NS	NS	6 J	10 U
	Chloroform	0.15	100	NS	NS	NS	11	8 J
	TPH - DRO	100	DNE	NS	NS	NS	150	NS
	Tetrachloroethene	1.1	5	NS	NS	NS	120	27
Trichloroethene	1.6	5	NS	NS	NS	230 D	57	
007G13LF ^h	BEHP	4.8	DNE	NS	NS	NS	2 J	NS
007G14LF ^h	BEHP	4.8	DNE	NS	NS	NS	8 J	NS
007G15LF ^h	1,1-Dichloroethane	810	DNE	NS	NS	NS	10 U	2 J
	1,1-Dichloroethene	0.044	7	NS	NS	NS	10 U	6 J
	Carbon tetrachloride	0.16	5	NS	NS	NS	20	26
	Chloroform	0.15	100	NS	NS	NS	5 J	10
	TPH - DRO	100	DNE	NS	NS	NS	110	NS
	Trichloroethene	1.6	5	NS	NS	NS	10 U	13
	BEHP	4.8	DNE	NS	NS	NS	14	NS
007G15UF ^h	1,1-Dichloroethane	810	DNE	NS	NS	NS	48 J	43 J
	1,1-Dichloroethene	0.044	7	NS	NS	NS	280	290
	1,2-Dichloroethene (total)	55	70	NS	NS	NS	20 J	22 J
	Benzene	0.36	5	NS	NS	NS	7 J	6 J
	Carbon tetrachloride	0.16	5	NS	NS	NS	20 J	19 J
	Chloroform	0.15	100	NS	NS	NS	70	63
	TPH - DRO	100	DNE	NS	NS	NS	160	NS
Trichloroethene	1.6	5	NS	NS	NS	840	800	
007G16LF ^h	BEHP	4.8	DNE	NS	NS	NS	1 J	NS
	Carbon tetrachloride	0.16	5	NS	NS	NS	27	30
	Chloroform	0.15	100	NS	NS	NS	8 J	5 J
	Trichloroethene	1.6	5	NS	NS	NS	7 J	10
007G17LF ^h	BEHP	4.8	DNE	NS	NS	NS	1 J	NS
007G17LF ^h	Acetone	3,700	DNE	NS	NS	NS	7 J	10 U

Table E-3
SWMU 7/Apron Area
Organics Detected in Groundwater by Well ($\mu\text{g/L}$)

Well ID	Constituent	RBC ^a	MCL ^b	Initial ^c	Intermediate ^d	Event 1 ^e	Event 2 ^f	Event 3 ^g
007G18LF	4-Methyl-2-Pentanone (MIBK)	2,900	DNE	NS	NS	NS	10 U	1 J
	Carbon tetrachloride	0.16	5	NS	NS	NS	1 J	1 J
	Chloroform	0.15	100	NS	NS	NS	2 J	2 J
	Tetrachloroethene	1.1	5	NS	NS	NS	1 J	10 U
	Trichloroethene	1.6	5	NS	NS	NS	8 J	6 J
	BEHP	4.8	DNE	NS	NS	NS	1 J	NS

Notes:

- a — Tap water RBC from the 1997 Risk-Based Concentration Table (December 22, USEPA Region III RBC Memo).
- b — MCL from USEPA National Primary Drinking Water Standards (October 1996, USEPA Office of Water, Drinking Water Regulations and Health Advisories).
- c — Initial sampling event in March 1995, following monitoring well installation. All samples were submitted for FSA. Section 2 describes the parameters analyzed in FSA.
- d — Intermediate sampling event in May 1995, for SWMU 7 to confirm VOC contamination. Samples were submitted for VOC analysis only.
- e — First of three scheduled long-term monitoring events for Assembly A monitoring wells conducted in November/December 1995. Samples collected from loess wells were submitted for FSA. Samples from fluvial deposits and Cockfield Formation wells were submitted for VOC analysis only. (Wells 007G01LS, 007G03LS, 007G04UC, 007G07LF, 007G08LS, and 007G09UF were not sampled due to field oversight.)
- f — Second of three scheduled long-term monitoring events for Assembly A monitoring wells conducted in April 1996. Only fluvial deposits wells were sampled; samples were submitted for VOC analysis only. Ten newly installed (3/96) fluvial deposits wells were also sampled; samples were analyzed for FSA. (Well OGMG09MF was not sampled during this event due to sampling equipment malfunction.)
- g — Third of three scheduled long-term monitoring events for Assembly A monitoring wells conducted in August 1996. Only fluvial deposits and Cockfield wells were sampled.
- h — Existing well installed by Geraghty-Müller during a CS/VP in 1985.
- i — Monitoring well was installed in March 1996 and was initially sampled during the second scheduled monitoring event for Assembly A wells in April 1996. Samples were submitted for FSA.
- DNE — Does not exist.
- NS — Sample not submitted for analysis of this constituent this sampling event.
- U — Constituent analyzed but not detected.
- J — Compound was detected below the method reporting limit; value estimated.
- D — Value obtained during a secondary dilution.
- UJ — Undetected and estimated. The parameter was analyzed but not detected above the listed estimated quantitation limit; the quantitation limit is estimated because one or more laboratory quality control parameters were outside control limits.
- LS — "LS" indicates well is screened in loess.
- MF — "MF" indicates well is screened in middle portion of fluvial deposits.
- LF — "LF" indicates well is screened in lower portion of fluvial deposits.
- UF — "UF" indicates well is screened in upper portion of fluvial deposits.
- UC — "UC" indicates well is screened in the upper portion of the Cockfield Formation.

Monitoring well 007G08LS was sampled during the Initial Event and the Intermediate Event, and newly installed well 007G12LF was sampled during Event 2 and Event 3; however, no organic compounds were detected.



APPENDIX D
RESPONSES TO COMMENTS



PARSONS

Parsons Engineering Science, Inc.

1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208

05 June 2000

Mr. James Reed
Southern Division Naval Facilities Engineering Command
Mail Code 1888
2155 Eagle Drive
North Charleston, NC 29406

Subject: Response to technical review comments on the March 2000 Draft Work Plan for Field Application to Enhance *In Situ* Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site N-6, Naval Support Activity Mid-South, Tennessee

Dear Mr. Reed:

This letter provides responses to comments received on the Draft Work Plan for Field Application to Enhance *In Situ* Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site N-6, Naval Support Activity (NSA) Mid-South, Tennessee. The work plan was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Naval Facilities Engineering Command (NAVFAC) and NSA Mid-South.

The intent of the work plan is to detail the scope of work to be performed in support of enhanced bioremediation of groundwater contaminated with chlorinated solvents via vegetable oil injection at Site N-6. The draft work plan was submitted to NAVFAC and NSA Mid-South on 14 March 2000. Comments on the technical memorandum were received from NSA Mid-South as reviewed by Mr. Rob Williamson; from the US Environmental Protection Agency (USEPA) as reviewed by Mr. Brian Donaldson; from the State of Tennessee Division of Environment and Conservation (TDEC) as reviewed by Mr. Jim Morrison; from EnSafe, Inc. (EnSafe) as reviewed by Mr. John Stedman; and from the US Geological Survey (USGS) as reviewed by Mr. Jack Carmichael. NAVFAC did not comment on the draft work plan. Responses to these comments were prepared by Parsons ES and are presented herein.

NSA Mid-South Comments dated 04 May 2000

General Comments:

The only comments that we had concerning the work plan were from pages 4-4 and 4-5. Many of the issues addressed in paragraphs 4.2.1. will have to be coordinated with Mr. Russ Noble, who you met when you were down here before. His number is (901) 873-5792. You will need to coordinate with him about site access, since the City of Millington and the



Airport Authority now own that land. He may also have an airshow, at some point, but hopefully not in the near future. That could impact on your operations. Please let us know any adjustments in your schedule so that we can notify our people. You would need to do the same for Russ Noble. Please check with Jim Reed at SOUTHDIV concerning access to office equipment. That may be a responsibility for the contractor as well. I'm sure that we could arrange for short intermittent use of a copier or phone, but we do not have that available on a regular basis. Temporary storage of drums will probably be adjacent to building S-238. You will also need to coordinate with Russ Noble about a temporary storage site on the north side of the base. He said he could probably arrange it, but I didn't know if he would require a fee. Also, utilities would be something that you would need to arrange to locate, since we no longer own the land. However, our civil engineer could pull some utility drawings for you. He is Bob Sipowich (901) 874-5909.

Parsons ES Response: *Comment noted. The text in Section 4.2.1 will be changed to indicate the following:*

Site Access and Scheduling. *Parsons ES will coordinate with Mr. Russ Noble for site access. Personnel badges and vehicle passes will not be necessary. Parsons ES will inform Mr. Noble and NSA Mid-South of the field schedule as soon as work can proceed.*

Access to Office Equipment. *Parsons ES will have a cellular phone on location. The use of a copy machine would be convenient, but not necessary. Therefore, this item will be deleted from the final work plan.*

Accumulation Points. *Parsons ES will make use of a temporary storage site for drums containing soils wastes adjacent to Building S-238 (on the south side of the Base on Navy Property). Similarly, all development, purge, and decontamination fluids will be stored in portable tank(s) and staged on the south side of the Base near the NSA Mid-South water treatment (oil/water separator) facility. Parsons ES will arrange for classification and disposal of all investigation derived wastes (IDW); however, NSA Mid-South will assume responsibility for signing waste manifests required for transport and disposal. Parsons ES will coordinate with Mr. Russ Noble for temporary storage of drilling equipment and supplies on the north side of the Base (City of Millington property).*

Utility Clearances. *Parsons ES will request utility clearances from public utility companies. However, it is unlikely that public utility companies will have adequate records to provide*

clearances. Therefore, Parsons ES will obtain all available utility drawings or records from NSA Mid-South to locate utilities at the site. Parsons ES will in turn provide copies of the drawings to any public utility locators that request them for their records.

USEPA Comments dated 05 May 2000

Comment 1) Page 1-1 and Page 2-16 states that the objective of the field application is to improve groundwater quality so that groundwater meets MCLs at the downgradient property boundary for N-6. I believe the objective of this application is to determine if this application is a viable treatment option at NSA Mid-South. This information will then be used in the Corrective Measures Study.

Parsons ES Response: Comment noted. Although improving groundwater quality to meet regulatory guidelines is a goal of this field application, the text will be changed to indicate that the primary objective of the field application is to determine if vegetable oil injection is a viable treatment option for chlorinated solvents at Site N-6.

Comment 2) Section 4.2.3 states that it is anticipated that soils will not be hazardous and may be spread upon the ground surface. Where will this material be spread? It should be noted that this property has been transferred to the City. Any soil or any other material disposed on this property should only be done with the City's permission.

Parsons ES Response: Parsons ES will collect and temporarily stage any soils derived from the field application at a temporary storage site for drums adjacent to Building S-238 (on the south side of the Base on Navy Property). Parsons ES will collect up to two composite samples to characterize the waste, and then arrange for proper disposal. Soils will not be spread on the ground surface, but rather the soils will be transported to an appropriate landfill facility. Parsons ES will arrange for transport and disposal of the soil waste; however, a representative from NSA Mid-South will sign the waste manifest. Section 4.2.3 will be changed to indicate this change.

Comment 3) Section 6 - When will the report be submitted?

Parsons ES Response: An interim update presentation will be conducted by Parsons ES at NSA Mid-South after receiving laboratory analytical data for the second process monitoring event (6-month sampling event). Copies of the presentation will be made available. A draft

results report will be submitted within 45 days of receiving all final laboratory analytical data after the last process monitoring event (18-month sampling event).

State of Tennessee Comments dated 12 May 2000

Comment 1) Overall, this is a well thought out and organized work plan for this innovative remedial alternative. However, as was discussed over the phone, TDEC's concern with this pilot study is primarily with the adequacy of your monitoring well network. This concern is primarily due to the approach that was employed during our (NSA Mid-South BCT) BRAC investigation and that your monitoring network is built upon. Please be advised that the BCT's approach was to delineate the boundaries/perimeter of the contamination, it was never to locate and delineate/define the source area/term with any degree of certainty. It is because of this TDEC is not sure that the source term is defined sufficiently enough for your needs to adequately access the efficacy of the system. TDEC therefore suggests that additional monitoring wells and possibly source delineation wells may be necessary to assure the overall success of this project as data sets are acquired that yield non-projected/spurious data.

Parsons ES Response: *The location of the injection and monitoring wells are based on our interpretation of the best available data. This data suggests that elevated contaminant concentrations coincide with a former grassy area and storm water drain at the east end of former Hanger N-6 that are suspected source(s) of chlorinated solvents. Parsons ES concurs that source characterization is limited. Therefore, Parsons ES will evaluate all new data obtained during well installation and baseline sampling with regard to characterization of the source. Parsons ES will evaluate the need for additional monitoring wells concurrent with evaluation of enhanced bioremediation, and include those recommendations in the field test results report for consideration in the Corrective Measures Study.*

EnSafe Comments dated 26 April 2000

Comment 1) Page 1-1, 3rd Paragraph. In the past, USEPA has indicated that a remedial technology for this site was not acceptable if it allowed further degradation of the aquifer (i.e., can not use uncontaminated zone between the edge of N-6 plume and the base boundary as a "buffer zone").

Parsons ES Response: *The text will be changed to indicate that the primary objective of the field application is to determine if vegetable oil injection is a viable treatment option for chlorinated solvents at Site N-6 as noted in Parsons ES response to USEPA Comment 1 above. Thus, the use of the uncontaminated zone between the edge of the N-6 plume and the Base boundary as a buffer will not be implied.*

One benefit of the VegOil process is the stabilization of the solvent source or "hotspot" by preferential partitioning of the solvents into the injected oil until equilibrium between aqueous and non-aqueous phases is reached. This results in a rapid initial "apparent" attenuation of the dissolved phase contaminant plume. Therefore, further degradation of the aquifer is not anticipated and a buffer zone is not necessary.

Comment 2) Page 2-12, 2nd Paragraph. Locations and screened intervals for wells 007G25LF and 007G26LF are included in the AOC A RFI Addendum.

Parsons ES Response: *Parsons ES has received the AOC A RFI Addendum from EnSafe, Inc. and will update Cross Section A-A' (Figures 2.2 and 2.6).*

Comment 3) Page 2-16, 1st Paragraph. Same as Comment 1.

Parsons ES Response: *The text will be changed in accordance with the response to EnSafe Comment 1 above.*

Comment 4) Page 4-9, Figure 4.1. What is the basis for the injection well spacing?

Parsons ES Response: *The injection well spacing is based on an assumed radius of influence of 10 to 15 feet. Monitoring well spacing is based on an estimated groundwater advective velocity of 30 to as high as 320 feet per year (Section 2.2), and the 18-month duration of the field monitoring period. Parsons ES will evaluate the need for additional monitoring wells if observed groundwater and contaminant transport velocities are higher than anticipated.*

Comment 5) Page 4-32, 2nd Paragraph. What is the basis for the volume (10,000 gallons) of oil to be injected?

Parsons ES Response: *The estimated volume of oil to be injected is based on the following:*

- *number of injection wells (8);*
- *an estimated radius of influence of 10 to 15 feet, and averaging 12 feet;*

- *the volume a cylinder of 12 feet in diameter (estimated radius of influence) and 10 tall (well screen length);*
- *the estimated effective porosity of the aquifer matrix (30 percent); and*
- *an effective oil saturation of 10 percent of the effective porosity of the aquifer matrix.*

Calculating the volume of oil for the above parameters yields a volume of approximately 1,000 gallons per well, or 8,000 gallons total. Based on prior experience, Parsons ES believes that an additional 25 percent (2,000 gallons) may be injected under optimum conditions. Therefore, the text will be changed to indicate that approximately 8,000 to 10,000 gallons (total) will be injected.

Comment 6) Page 4-32, 3rd Paragraph. Is this paragraph suggesting that the distance bromide and vegetable oil travels within the subsurface would be the same? If so, what would be the basis?

Parsons ES Response: *The distance bromide and vegetable oil travels within the subsurface would not be the same. The text for Section 4.6.2 will be changed to:*

" In order to trace groundwater migrating from the immediate vicinity of the injection wells (i.e., zone of influence), a water "push" containing bromide at a concentration of approximately 100 mg/L will be injected immediately after oil injection. The volume of the water push will be sufficient to clear the well annulus and filter pack of oil so the well can later be purged and used for process monitoring (Section 4.7).

Bromide has a low adsorptive potential and migrates at approximately the rate of advective groundwater flow, and will be tracked in groundwater after injection to estimate advective groundwater flow in the study area. The migration of total organic carbon in groundwater (from dissolution of the vegetable oil) also will be tracked, although it is anticipated to be retarded relative to migration of the bromide due to its higher adsorptive potential."

Comment 7) Page 4-32, 4th Paragraph. In order to incorporate results of this study into the AOC A CMS, please provide a schedule that includes dates for installation, monitoring events, progress reports, completion date, and final report. This paragraph states that the last sampling event will be 18 months after oil

injection which indicates final results would not be available until after that time. Will there be a preliminary evaluation performed before that time? A preliminary evaluation performed after six or nine months may provide sufficient information for the CMS and consequently would not delay the CMS over a year.

Parsons ES Response: *Field work is scheduled for July 2000, pending approval of injection well permits. A draft results report will be submitted within 30 days of receiving all final laboratory analytical data after the last process monitoring event (18-month sampling event). An interim update presentation will be conducted by Parsons ES at NSA Mid-South after receiving laboratory analytical data for the second process monitoring event (6-month sampling event). Copies of the interim presentation will be made available.*

Comment 8) Page 6-1, 1st Paragraph. This section details what will be evaluated, but does not include any information as to how and why.

Parsons ES Response: *The objective of the field test is to determine if vegetable oil injection is a viable remedial alternative for chlorinated solvents at Site N-6. In general, the evaluation described in Section 6 is designed to determine the ability to deliver the carbon source (volume of injected oil and radius of influence); determine changes in contaminant concentrations and the rate of biodegradation; determine the geochemical conditions under which bioremediation is enhanced; and evaluate the influence of competing electron acceptors. The general methods for this evaluation are described in the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (U.S. Environmental Protection Agency [USEPA], 1998).*

USGS Comments dated 26 April 2000

General Comments

Comments received from Mr. Jack Carmichael were written into Mr. Carmichael's copy of the draft report.

Parsons ES Response: *In general, all editorial comments were incorporated in accordance with Parsons ES editorial guidelines. The following are clarifications to noted technical issues:*

- *Section 1, Figure 1.2. The potential source areas designated as "known" will be designated as "suspected". As noted in the text, actual dates or quantities of contaminant releases are unknown.*
- *Section 2, Page 2-1. The injection and monitoring well spacing is described in Parsons ES response to EnSafe Comment 4 above.*
- *Section 2, Figures 2.2 and 2.6. Locations and screened intervals for wells 007G25LF and 007G26LF will be added to Cross Section A-A'.*
- *Section 4.2.1, Page 4-4. Concerning NSA Mid-South support, refer to Parsons ES response to NSA Mid-South comments above.*
- *Section 4.2.2.4, Page 4-6. Monitoring well permits will be obtained from the Memphis and Shelby County Health Departments. Permits for the injection wells will be obtained from both the Memphis and Shelby County Health Department Water Quality Control Board and the State of Tennessee Department of Environment and Conservation.*
- *Section 4.2.3, Page 4-7. Waste handling will be in accordance with Parsons ES response to NSA Mid-South comments above.*
- *Section 4.3.2, Page 4-10. Soil samples will be collected directly from soil cores obtained by the Rotasonic drilling method.*
- *Section 4.3.3.1, Page 4-13; and Section 4.3.3.6, Page 4-16. Water for decontamination will be obtained from onsite City of Millington water supply.*
- *Section 4.3.3.4, Page 4-14. The monitoring wells will be grouted with a pumpable bentonite grout with no cement. The text will be changed accordingly.*
- *Table 4.4, Page 4-18. Dissolved oxygen will be measured using a direct reading meter in a flow through cell. Parsons ES experience with over 50 natural attenuation studies has been that it is important to use a consistent measuring technique at every sampling location, and that satisfactory results with calibrated direct reading meters can be obtained for sites with dissolved concentrations less than 1.0 milligrams per liter. A*