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FINAL

REMEDIAL INVESTIGATION REPORT
OPERABLE UNIT NO. 7
(SITES 1, 28, AND 30)

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0231

JUNE 29, 1995

Prepared For:

DEPARTMENT OF THE NAVY
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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
ARV	Aquatic Reference Value
ATSDR	Agency for Toxic Substances and Disease Registry
ASTM	American Society for Testing Materials
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
bls	below land surface
BOD	biological oxygen demand
BRA	baseline human health risk assessment
Carc.	Carcinogenic Effects
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLEJ	Camp Lejeune
CLP	Contract Laboratory Program
COD	chemical oxygen demand
COPC	Contaminant of Potential Concern
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CSF	Carcinogenic Slope Factor
DOD	Department of the Defense
DoN	Department of the Navy
DQO	Data Quality Objective
EMD	Environmental Management Division (Camp Lejeune)
ERA	Ecological Risk Assessment
ER-L	Effects Range - Low
ESE	Environmental Science and Engineering, Inc.
°F	degrees Fahrenheit
FFA	Federal Facilities Agreement
FMF	Fleet Marine Force
FMFLANT	Fleet Marine Force Atlantic
FFSG	Force Service Support Group
ft	feet
ft/ft	foot per foot
gpm	gallons per minute
GSRA	Greater Sandy Run Area
GW	groundwater well
HA	Health Advisories
HEAST	Health Effects Assessment Summary Tables

HHAG	Human Health Assessment Group
HI	hazard index
HPIA	Hadnot Point Industrial Area
HQ	hazard quotient
IAS	Initial Assessment Study
ICRs	Estimated Incremental Lifetime Cancer Risks
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LOAEL	lowest-observed-adverse-effect-level
MAGTF	Marine Air Ground Task Force
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCL	maximum contaminant level
MF	Modifying Factor
mgd	million gallons per day
mg/L	milligram per liter
MILCON	Military Construction
msl	mean sea level
NACIP	Navy Assessment and Control of Installation Pollutants
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCP	National Contingency Plan
NCWQS	North Carolina Water Quality Standard
ND	Nondetect
NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic Atmosphere Administration
NOAEL	no-observed-adverse-effect-level
NOEL	no-observed-effect level
Noncarc.	Noncarcinogenic Effects
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NREA	Natural Resources and Environmental Affairs
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PRGs	Preliminary Remediation Goals

QA/QC	quality assurance/quality control
QI	Quotient Index
RBCs	Region II Risk Based Concentrations
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
RME	Responsible Maximum Exposure
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
Sj	Jaccard Coefficient
SMCL	Secondary Maximum Contaminant Level
SQC	Sediment Quality Criteria
Ss	Sϕrenson Index
SSV	Sediment Screening Value
SVOCs	Semivolatile Organic Compounds
TAL	Target Analyte List
TBC	To Be Considered
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TDS	total dissolved solids
TRV	Terrestrial Reference Value
TSS	total suspended solids
UBK	Uptake/Biokinetic
UCL	Upper Confidence Level
UF	Uncertainty Factor
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WAR	Water and Air Research, Inc.
WOE	weight-of-evidence
WQS	Water Quality Standards
WQSV	Water Quality Screening Values

19.0 INTRODUCTION

A detailed introduction is provided in Section 1.0 of Volume I. The Section 1.0 introduction describes the arrangement of OU No. 7 and the background and setting of MCB, Camp Lejeune.

20.0 SITE BACKGROUND AND SETTING

This section provides a description of the physical setting and a detailed history of both operations and previous investigations at Site 30, one of the three sites which comprise OU No. 7.

20.1 Site Description

Site 30, the Sneads Ferry Road Fuel Tank Sludge Area, is located along a tank trail that intersects Sneads Ferry Road from the west, approximately 1 1/6 miles south of the intersection with Marines Road and roughly 4 1/2 miles south of HPIA (see Figure 1-1). The site is located adjacent to the Combat Town Training Area. The surrounding training areas and adjacent artillery ranges are used to prepare specialized personnel for various tactical operations and to simulate amphibious assault conditions.

Much of the suspected disposal area is wooded with trees of less than three inches in diameter and dense understory. No visual signs of contamination (e.g., soil staining) or other evidence are present at Site 30 that would suggest where disposal activities occurred. The tank trail that leads to the suspected disposal area is occasionally used as part of field training exercises. The site itself lacks security or protective measures that prevent personnel from entering the area. Unimproved paths both surround and are found within the suspected disposal area of Site 30. One of two streams that comprise the headwaters of Frenchs Creek lies approximately 1,500 feet west of the site. Surface water runoff and groundwater flow direction is generally to the west and north toward Frenchs Creek. Figure 20-1 depicts the surface features at Site 30.

20.2 Site History

In 1970, sludge (i.e., rust and tank bottom deposits) from two 12,000 gallon tanks and wastewater from the washout of these tanks were disposed at this site by a private contractor. The contents of these two tanks, leaded gasoline containing tetraethyl lead and related compounds, were emptied prior to cleaning and transport. It is estimated that, at a minimum, 600 gallons of sludge and wastewater were removed from tanks and drained onto the ground surface after the cleaning process had been completed. This estimate is based upon the projected volume of material remaining below the outflow ports of the two 12,000 gallon tanks. Figure 20-1 depicts the approximate location of the suspected sludge and wastewater disposal area. Supplemental information suggests that the site was used for the disposal of similar wastes from other tanks. The composition of the waste is unknown but may have contained cleansing compounds and possibly diluted tetraethyl lead (Water and Air Research, 1983).

20.3 Previous Investigations

The following sections detail previous investigation activities at OU No.7, Site 30.

20.3.1 Initial Assessment Study

An IAS was conducted at Site 30 by WAR in 1983. The IAS team reviewed historical records and aerial photographs, performed field inspections, and conducted personnel interviews to evaluate potential hazards at Site 30. As a result of this process, the IAS report recommended that a confirmation study be performed at Site 30.

20.3.2 Confirmation Study

A two-part confirmation study was conducted at Site 30 by ESE from 1984 through 1987. The Verification Step was performed in 1984 and the Confirmation Step was performed in 1986 and 1987. The Confirmation Study at Site 30 focused on the presence of potential contaminants in groundwater, surface water, and sediment. Findings from the Confirmation Study are provided below.

20.3.2.1 Groundwater Investigation

Two shallow groundwater monitoring wells were installed during the Confirmation Study investigation at Site 30. Well 30-GW01 was installed during the 1984 Verification Step, within the suspected disposal area. The second well, 30-GW02, was installed in 1986. Well 30-GW02 was placed downgradient of the site, between the suspected disposal area and Frenchs Creek. Figure 20-2 depicts the locations of the two wells installed as part of the Confirmation Study at Site 30. Table 20-1 provides well depth and ground surface elevations for the two wells. The samples obtained from the two wells were analyzed for the following target compounds:

- Lead
- Oil and Grease
- Volatile Organic Compounds
- Xylenes (1986/1987 only)
- Ethylene dibromide (1986/1987 only)
- Methylethyl ketone (1986/1987 only)
- Methyl isobutyl ketone (1986/1987 only)

Chloroform was detected at a concentration of 2.6 µg/L in the groundwater sample from well 30-GW01, during the 1986 sampling round. Methylene chloride was identified at a concentration of 3.3 µg/L in the sample obtained from well 30-GW02, also during 1986. Neither of these two organic compounds were detected in 1984, which suggests that they may have been laboratory artifacts (ESE, 1990). Table 20-2 provides a summary of groundwater data collected during the Confirmation Study at Site 30.

Lead was detected in samples obtained from wells 30-GW01 and 30-GW02 at concentrations which exceeded the North Carolina standard and federal action level of 15 µg/L. The sample obtained from well 30-GW01 had a lead concentration of 58 µg/L during 1984; however, no lead was detected during 1986. Lead was detected in the sample from well 30-GW02 during the 1986 sampling round only, at a concentration of 30 µg/L. O&G also were detected in the groundwater samples collected during 1986 and 1987. Well 30-GW01 had an O&G concentration of 600 µg/L during the 1986 sampling round and well 30-GW02 had O&G concentrations of 100 and 9,000 µg/L.

20.3.2.2 Surface Water and Sediment Investigation

One surface water and sediment station was sampled in December 1986 as part of the Confirmation Study investigation at Site 30. Figure 20-2 depicts the location of the surface water and sediment sampling station on Frenchs Creek. The surface water sample was analyzed for the same parameters as the groundwater samples collected during the Confirmation Study. No detectable levels of target compounds were identified in the sample.

A single sediment sample was obtained from Frenchs Creek also in 1986. The sediment sample was analyzed for lead, O&G, and ethylene dibromide. Only O&G was detected at a concentration of 373 mg/kg.

20.3.2.3 Conclusions and Recommendations

Findings from the Confirmation Study suggest that O&G contaminants were present in both the suspected disposal area and stream bed sediments. However, it was not clear whether the presence of O&G in various media could be attributed to heavy vehicular traffic or the result of emergency vehicle maintenance in the Combat Town Training Area. Lead was detected in 1984 from well 30-GW01 and was present in both samples obtained from well 30-GW02, during 1986 and 1987. Each of these lead detections in groundwater exceeded state and federal standards.

The Site Summary Report recommended that further characterization of the suspected disposal area be performed to complete the RI/FS process. Following the characterization of potentially impacted environmental media, a risk assessment was also recommended to identify unacceptable risks to human health and the environment.

20.3.3 Additional Investigations

The Confirmation Study at Site 30 focused on the presence of potential contaminants in groundwater, surface water, and sediment. In addition to the two rounds of groundwater data collected during the Confirmation Study, a third round was collected by Baker in April 1993 to support RI scoping activities. Results of the groundwater sampling activity are presented below.

20.3.3.1 Groundwater Investigation

A third round of samples was obtained from both wells in 1993, as part of RI scoping activities. These samples were analyzed for the full TCL organic and TAL total metals using CLP protocols and Level IV data quality. A single detection, 2 µg/L, of chloroform was observed in the groundwater sample obtained from 30-GW01. The contaminant level suggests that this finding may be attributable to laboratory contamination (by-product of chlorination). The level of metals observed in 30-GW01 was generally greater than those found in 30-GW02. The following three metals were detected in the sample obtained from 30-GW01 and exceeded MCL and NCWQS levels:

- Cadmium at 10.7 µg/L (MCL and NCWQS - 5.0 µg/L)
- Chromium at 106 µg/L (MCL - 100 µg/L and NCWQS - 50 µg/L)
- Lead at 115 µg/L (Federal action level and NCWQS - 15 µg/L)

Mercury was also detected in well 30-GW01 at concentration of 0.88 µg/L; the NCWQS for mercury is 1.1 µg/L.

20.3.4 Aerial Photographic Investigation

This section describes the aerial photograph made available through USEPA Region IV. A black-and-white aerial photograph from 1964 was made available for examination of surface conditions at Site 30. Although the photograph was taken prior to the reported disposal event, 1970, information from the photograph was employed to evaluate a potential source areas of contamination. The aerial photograph from Site 30 was not annotated or included in the interim report. Figure 20-3 provides a reproduction of the Site 30 aerial photograph and illustrates conditions within the study area at that time, 1964.

20.3.4.1 Aerial Photograph - February 1964

The aerial photograph depicts a tank trail that intersects Sneads Ferry Road from the southwest. The suspected disposal area is believed to be located along the southern side of the trail (see Figure 20-1). In addition to the main trail, a number of smaller trails are visible throughout the area. No disposal or clearing activity is apparent at the time of the photograph, that would suggest future disposal operations. Figure 20-3 depicts surface conditions at the time of the photograph, February 1964.

20.4 Remedial Investigation Objectives

The purpose of this section is to define the RI objectives aimed at characterizing past waste disposal activities at Site 30, assessing potential impacts to public health and environment, and providing feasible alternatives for consideration during preparation of the ROD. The remedial objectives presented in this section have been identified through review and evaluation of existing background information, assessment of potential risks to public health and environment, and consideration of feasible remediation technologies and alternatives. As part of the remedial investigation at Site 30, soil, groundwater, surface water, and sediment investigations were conducted. The information gathered during these investigations was intended to fill previously existing data gaps and employed to generate human health risk values. Table 20-3 presents both the RI objectives identified for Site 30 and the criteria necessary to meet those objectives. In addition, the table provides a general description of the study or investigation efforts utilized to obtain the required information.

SECTION 20.0 TABLES

TABLE 20-1

SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS
CONFIRMATION STUDY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Well Depth (feet below ground surface)	Screen Interval Depth (feet below ground surface)	Well Diameter	Year Installed	Surface Elevation (feet above sea level)
30-GW01	21.5	6.5 - 21.5	2	1984	42.6
30-GW02	26.0	11 - 26	2	1986	36.8

Source: ESE, 1992

TABLE 20-2

DETECTED TARGET CONTAMINANTS IN GROUNDWATER
CONFIRMATION STUDY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Federal MCLs[1]	North Carolina WQS[2]	Well No./Date			
			30-GW01 07/06/84	30-GW01 12/04/86	30-GW02 12/04/86	30-GW02 03/06/87
Lead	15[3]	15	58	ND	30	ND
Oil & Grease	None	None	ND	600	100	9,000
Chloroform	0.1	0.19	ND	2.6	ND	ND
Methylene Chloride	5	5	ND	ND	3.3	ND

ND = Not Detected
Values reported are concentrations in micrograms per liter (μg/L); this approximates parts per billion (ppb).
Source: ESE, 1992.

(1) Federal maximum contaminant levels (MCLs) established under the Safe Drinking Water Act of 1986.

(2) NCWQS - North Carolina administrative code, Title 15A, NC DEHNR, Subchapter 2L, Section .0202 - Water Quality Standards (WQS) for groundwater, November 8, 1993. Class GA Standards.

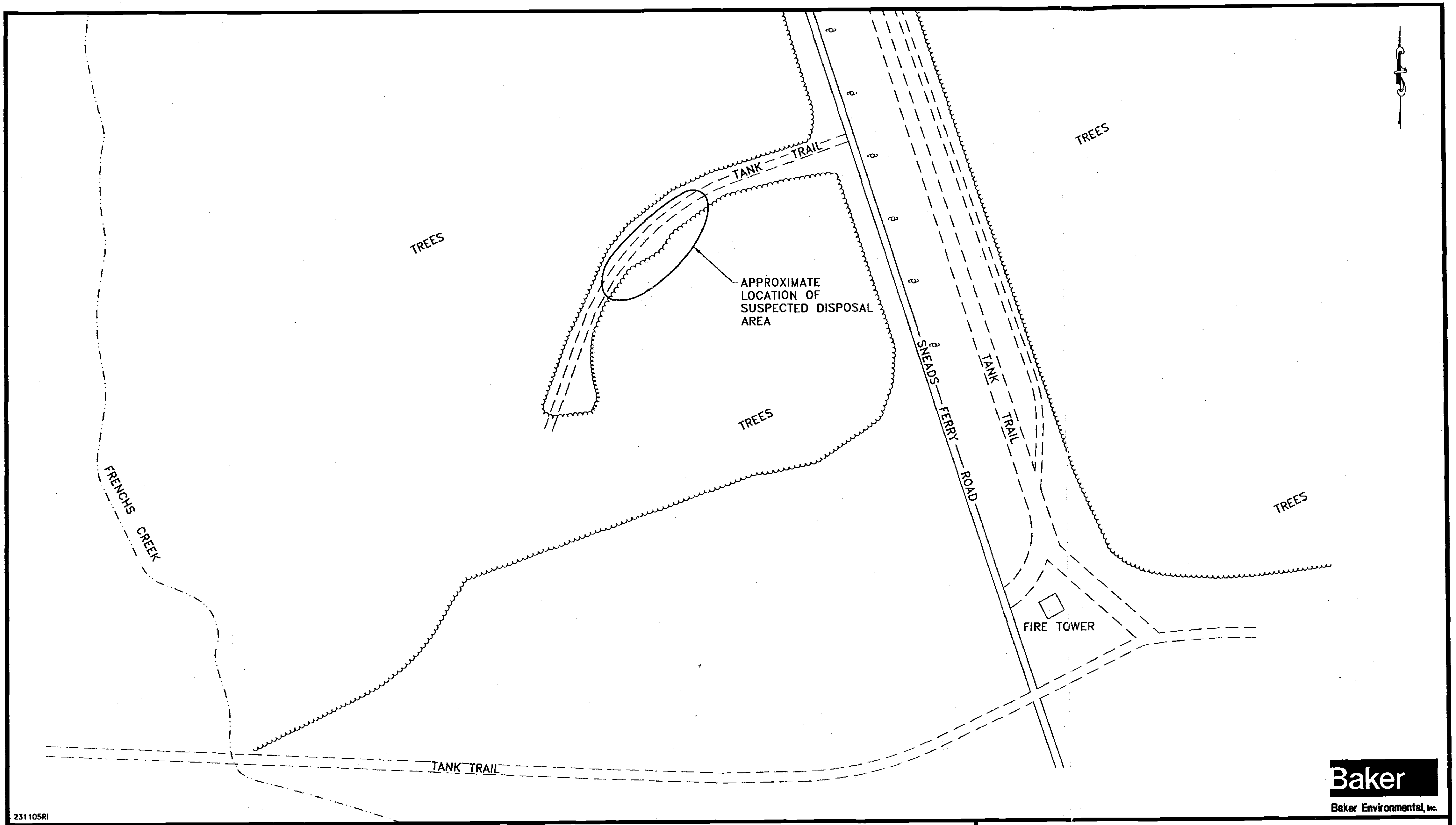
(3) Federal action level established under the Safe Drinking Water Act of 1986.

TABLE 20-3

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES
SITE 30 - SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective		Criteria for Meeting Objective	Proposed Investigation Study
1. Soil	1a.	Assess the extent, if any, of soil contamination at the sludge disposal area.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation
	1b.	Assess human health and ecological risks associated with exposure to surface soils.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation Risk Assessment
	1c.	Determine whether soil contaminants are migrating to groundwater.	Characterize volatile, semivolatile, metal, and TPH levels in surface and subsurface soils at disposal area.	Soil Investigation
2. Groundwater	2a.	Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b.	Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation
3. Sediment	3a.	Assess the nature and extent of sediment contamination.	Characterize contaminant levels in sediment.	Sediment Investigation
	3b.	Assess human health and ecological risks associated with exposure to contaminated sediments in Frenchs Creek.	Characterize the nature and extent of contamination in sediment.	Sediment Investigation in Frenchs Creek and Risk Assessment
4. Surface Water	4a.	Assess the presence or absence of surface water contamination in Frenchs Creek.	Determine surface water quality in Frenchs Creek adjacent to the site.	Surface Water Investigation
	4b.	Assess human health and ecological risks associated with exposure to contaminated surface water in Frenchs Creek.	Characterize the nature and extent of contamination in surface water.	Surface Water Investigation in Frenchs Creek

SECTION 20.0 FIGURES



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LEGEND

———	ASPHALT ROAD
– – –	UNIMPROVED ROAD (TANK TRAIL)
ø	UTILITY POLE
— · —	CREEK
﹏	VEGATATION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

1 inch = 300 ft.

FIGURE 20-1
SITE MAP
SITE 30 – SNEADS FERRY ROAD FUEL
TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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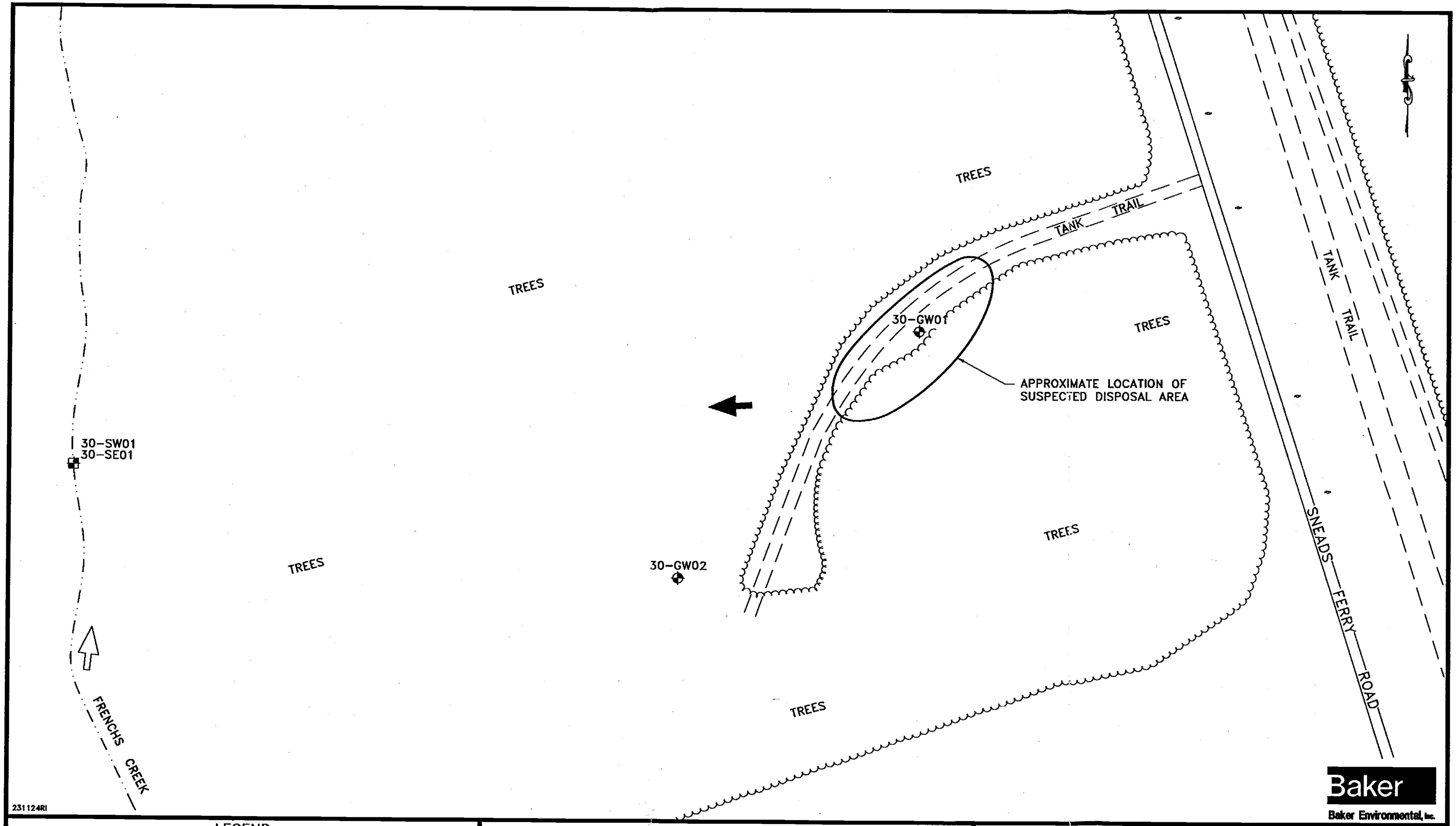

LEGEND

30-GW01 ⊕	SHALLOW MONITORING WELL (ESE, 1984)
30-SW01 30-SE01 ⊠	SURFACE WATER AND SEDIMENT SAMPLING STATION (ESE, 1986)
➡	APPROXIMATE GROUNDWATER FLOW DIRECTION
⇨	APPROXIMATE SURFACE WATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 & W.K. DICKSON, JUNE 1994

200 0 100 200 400

1 inch = 200 ft.

FIGURE 20-2
SAMPLING LOCATIONS
CONFIRMATION STUDY
SITE 30 - SNEADS FERRY ROAD
FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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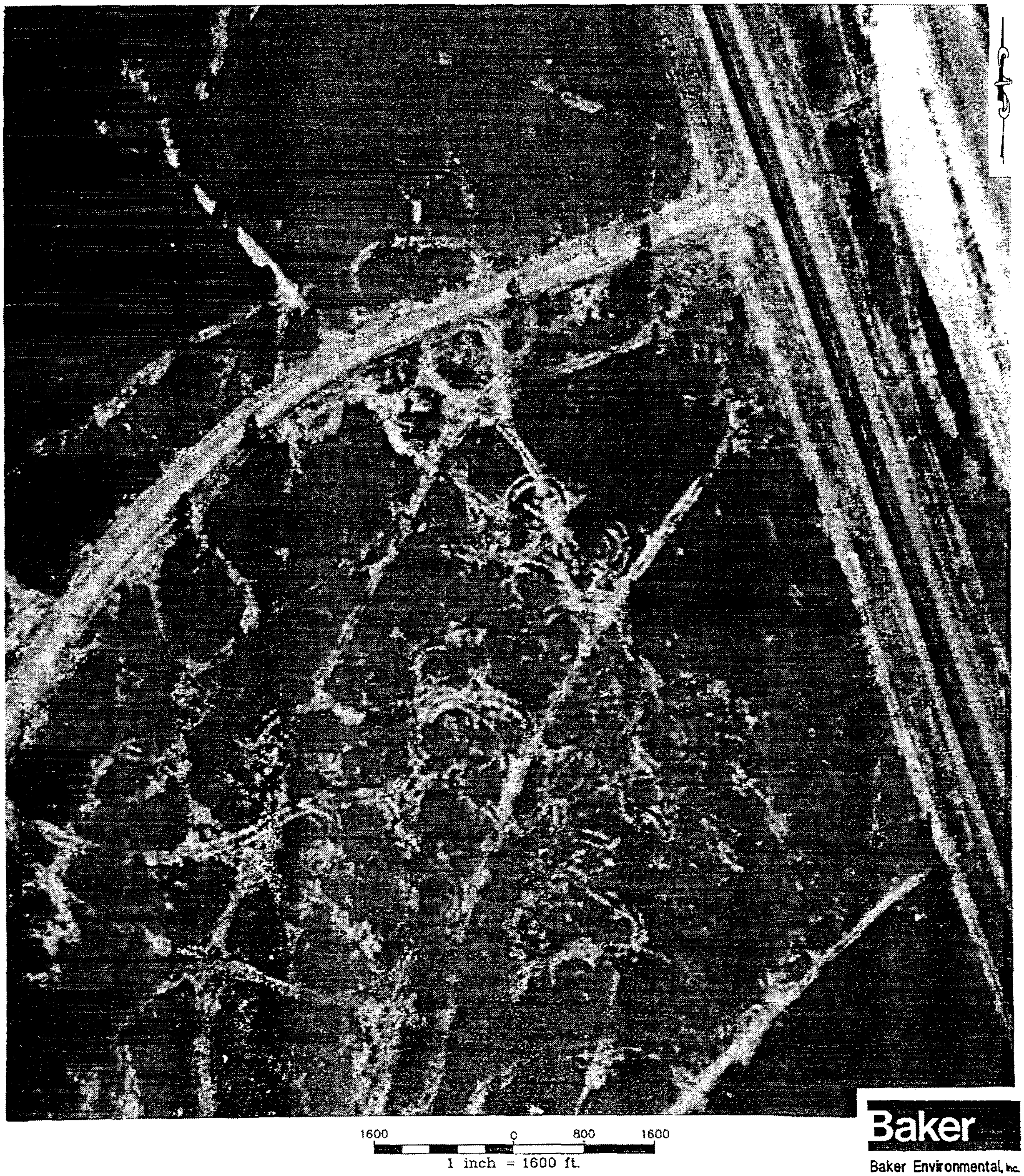

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FIGURE 20–3
AERIAL PHOTOGRAPH, FEBRUARY 1964
AERIAL PHOTOGRAPHIC INVESTIGATION
SITE 30 – SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO–0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE: EPIC, 1992

21.0 STUDY AREA INVESTIGATIONS

The field investigation program at OU No.7, Site 30, was initiated to characterize potential disposal related impacts and threats to human health and the environment resulting from previous operations, and disposal activities. This section discusses the site-specific RI field investigation activities that were conducted to fulfill that objective. The initial phase of the RI field investigation commenced on March 14, 1994, and continued through May 12, 1994. A second round of groundwater samples was collected in November of 1994. The RI field program at Site 30 consisted of a site survey; a soil investigation, which included drilling and sampling; a groundwater investigation, which included monitoring well installation and sampling; and a surface water and sediment investigation. The following sections detail the various investigation activities that were implemented during the RI.

21.1 Site Survey

The site survey task was performed in two phases: Phase I - Initial Survey of Site Features and Proposed Sampling Locations; and Phase II - Post Investigation Survey of Monitoring Wells. W.K. Dickson and Associates was retained to perform both phases of the site survey. Phase I of the survey task was conducted at Site 30 during the week of March 14, 1994. Based upon information supplied in the Final Site Summary Report (ESE, 1990), surface features within and surrounding the suspected disposal area were surveyed. The proposed soil boring and monitoring well locations, provided in the Final RI/FS Work Plan for OU No.7 (Baker, 1993a), were also surveyed and then marked with wooden stakes. Each sample location was assigned a unique identification number that corresponded to the site and sampling media.

Phase II of the site survey task was completed at Site 30 during the week of May 9, 1994. During Phase II, all existing and newly installed monitoring wells were surveyed. Any supplemental or relocated soil borings completed during the investigation were also surveyed. In addition, three staff gauges installed during the investigation were surveyed. For each sampling point, monitoring well, and staff gauge a latitude, longitude, and elevation in feet above mean sea level (msl) were recorded.

21.2 Soil Investigation

The soil investigation performed at Site 30 was intended to assess the nature and extent of contamination that may have resulted from previous disposal activities. Additionally, the soil investigation was performed to assess the human health, ecological, and environmental risks associated with exposure to surface and subsurface soils. The following sections describe soil sample collection procedures, locations, and the analytical program for soils at Site 30.

21.2.1 Drilling Procedures

Drilling activities at Site 30 commenced on March 21, 1994 and continued through March 24, 1994. Environmental Monitoring and Testing Corporation was retained to perform the drilling services. Soil borings were advanced by a truck-mounted drill rig using 3-1/4-inch inside diameter (ID) hollow stem augers. Split-spoon samples were collected from inside the augers according to ASTM Method D 1586-84 (ASTM, 1984). Due to the nature of soils and the shallow water table at Site 30, split spoons were also employed to collect subsurface samples without the use of augers. When conditions permitted (i.e., water table less than seven feet bgs) continuous split spoons were driven, without augers, from the surface and terminated at the water table. All drilling and sampling activities conducted at Site 30 were performed using Level D personnel protection. Soil cuttings obtained during the drilling program were collected, handled, and stored according to the procedures outlined in Section 21.6.

Two types of borings were installed during the soil investigation: exploratory borings (i.e., borings installed for sample collection and lithologic description) and borings advanced for monitoring well installation. Soil sampling intervals for the two types of borings differed only slightly, because of total depth requirements. Selected soil samples from each of the two types of borings were submitted for laboratory analysis (see Section 21.2.4). Soils obtained from test borings were collected from the surface (i.e., ground surface to a depth of twelve inches) and then at continuous two-foot intervals, starting at one foot bgs. Drilling and continuous sample collection continued until the boring was terminated at the approximate depth of the water table, which varied at Site 30 from 3 to 9 feet bgs. An additional split-spoon was driven below the water table to confirm both groundwater depth and the absence of a wetting front (i.e., perched water table). Soils obtained from the boring advanced for monitoring well installation were also retained from the ground surface and at continuous two-foot intervals to the water table. However, once below the water table, soil samples were collected at five-foot intervals until the pilot test boring was terminated. A summary of boring depths and sampling intervals for Site 30 is provided in Table 21-1.

Each split-spoon soil sample was classified in the field by a geologist. Soils were classified using the Unified Soil Classification System (USCS) by the visual-manual methods described in ASTM D-2488. Lithologic descriptions were recorded in a field logbook and later transposed onto boring log records. Soil classification included characterization of soil type, grain size, color, moisture content, relative density, plasticity, and other pertinent information such as indications of contamination. Lithologic descriptions of site soils are provided on Test Boring Records in Appendix A and on Test Boring and Well Construction Records in Appendix B.

21.2.2 Sampling Locations

Soil samples were collected throughout Site 30, as depicted on Figure 21-1. The sampling distribution was intended to evaluate the vertical and horizontal extent of contamination at the site. The selection of sample locations was based on review of historical aerial photographs, Camp Lejeune historical records, and previous investigation data. Review of historical information indicated that a disposal event was reported to have occurred within area designated as Site 30 (see Figure 20-1). The suspected disposal area lies on the south side of a tank trail that intersects Sneads Ferry Road from the west.

A total of 14 borings were advanced to assess suspected disposal practices at Site 30. As indicated on Figure 21-1, the boring locations are located within and surrounding the suspected disposal area. Five additional test borings, located approximately 250 feet east of Sneads Ferry Road, were established to supplement base background analytical information (refer to Figure 21-1).

21.2.3 Sampling Procedures

Surface (i.e., ground surface to 12 inches bgs) and selected subsurface (i.e., greater than one foot bgs) soil samples were retained for laboratory analysis. Both surface and subsurface samples were collected to evaluate the nature and both horizontal and vertical extent of potentially impacted soils. Only the surface soils, however, were employed for human health and ecological risk assessment evaluation. A summary of boring numbers, depths, intervals, and analytical parameters for Site 30 soil samples is provided in Table 21-1.

Soil samples were obtained via a drill rig (i.e., split-spoon samples) as described in the drilling procedures section. Because of the unconsolidated nature of surface soils, samples were collected using a decontaminated stainless steel spoon. When the sampling location was covered with grass or humus material the first inch of matted roots was removed. Deeper subsurface grab samples were collected with a split-spoon sampler in accordance with ASTM Method D 1586-84. The augers, split-spoons samplers, and stainless steel spoons were decontaminated prior to sample collection according to the procedures outlined in Section 21.5.

A minimum of two samples were retained for laboratory analysis from each of the boring locations. Soil samples retained for analysis were prepared and handled according to USEPA Region IV Standard Operating Procedures (SOPs). Samples collected for volatile organic analysis were extracted with a stainless-steel spoon from different sections of the split-spoon which represented the entire sampling interval. Precautions were taken not to aerate the sample so as to minimize volatilization. Samples retained for other analytical parameters (e.g., semivolatiles and metals) were first thoroughly homogenized and then placed in the appropriate laboratory containers.

Following sample collection, each sample retained for laboratory analysis was stored on ice in a cooler. Sample preparation also included documentation of sample number, depth, location, date, time, and analytical parameters in a field logbook. Chain-of-Custody documentation (provided in Appendix C), which include information such as sample number, date, time of sampling, and sampling personnel, accompanied the samples to the laboratory. Samples were shipped overnight via Federal Express to CEIMIC Corporation in Narragansett, Rhode Island for analysis.

21.2.4 Analytical Program

The analytical program initiated during the soil investigation at Site 30 focused on the suspected contaminants of concern, based on reported disposal practices. Soils collected from the former disposal area locations were analyzed for TCL volatile and semivolatile organics and TAL inorganics, and in a few cases, TPH. A summary of test boring numbers, depths, intervals, and analytical parameters for Site 30 is provided in Table 21-1.

In addition to analyzing for the contaminants of concern, one test boring was advanced and soils were collected for analysis of engineering parameters (i.e., particle size, and Atterberg limits). Engineering parameter samples consisted of composites of individual grab samples collected from the ground surface to the water table. Engineering parameter samples were prepared and handled as described in the previous section (i.e., samples were thoroughly homogenized).

21.2.5 Quality Assurance and Quality Control

Field QA/QC samples were also collected during the soil investigation. These samples were obtained to: (1) ensure that decontamination procedures were properly implemented (e.g., equipment rinsate samples); (2) evaluate field methodologies (e.g., duplicate samples); (3) establish field background conditions (e.g., field blanks and (4) evaluate whether cross-contamination occurred during sampling and/or shipping (e.g., trip blanks).

Section 3.2.5 of Volume I provides a detailed description of the QA/QC sampling program.

Table 21-2 summarizes field QA/QC sample types, sample frequencies, the number of QA/QC samples, and parameters analyzed.

21.2.6 Air Monitoring and Field Screening

Several air monitoring and field screening procedures were implemented during the drilling and sampling activities for health and safety and initial contaminant monitoring. During drilling, ambient air monitoring in the vicinity of the borehole was performed with a PID to monitor for airborne contaminants. Moreover, samples (i.e., split-spoon samples) were screened with a PID to measure for volatile organic vapor. Measurements obtained in the field were recorded in a field logbook and later transposed onto the Test Boring Records and the Test Boring Records and Well Construction Records, which are provided in Appendices A and B. Prior to daily monitoring, the field instruments were calibrated and documentation was recorded in a field logbook and on calibration forms.

21.3 Groundwater Investigation

The groundwater investigations performed at OU No. 7, Site 30, were intended to assess the nature and extent of contamination that may have resulted from previous disposal practices or site activities. Additionally, the groundwater investigation, was performed to assess human health and environmental risks associated with exposure to groundwater. The following subsections describe well installation procedures, sample collection procedures, and the analytical program employed during the groundwater investigation at Site 30.

Two rounds of groundwater samples were collected at Site 30. Round one, which included sample collection from all existing and newly installed wells, was conducted in April and May of 1994 and was part of the original scope of work. A second round of groundwater sampling was performed in November of 1994 and included the resampling of the round one wells. The second round was conducted to confirm the presence or absence of contaminants detected during round one, specifically metals and volatiles.

21.3.1 Monitoring Well Installation

One shallow Type II monitoring well (i.e., well installed without casing to seal off a confining layer) was installed at Site 30 on March 24, 1994. The location of the newly installed monitoring well, 30-GW03, is depicted on Figure 21-2. The monitoring well was situated to collect upgradient groundwater information. The information gathered from the suspected disposal area and upgradient areas was employed to characterize the nature and horizontal extent of contamination, and to evaluate the flow patterns of the surficial aquifer. In addition to the shallow well, a piezometer was also installed and was positioned to evaluate the flow pattern of the surficial aquifer in the immediate vicinity of the suspected disposal area. Placement of the newly installed monitoring well was based on review of historical aerial photographs, Camp Lejeune records, and analytical data from previous investigations.

The shallow monitoring well was installed upon completion the pilot test boring. The borehole was overdrilled with 6-1/4-inch ID hollow stem augers prior to shallow well installation. The shallow well was installed at a total depth of 17.5 feet bgs, approximately 10 feet below the water table encountered during the initial test boring. The shallow monitoring well and piezometer were installed at depths and with screen interception intervals sufficient to compensate for seasonal variations in the water table, which is known to fluctuate from 2 to 4 feet. Well construction details for the well and piezometer are summarized on Table 21-3, and well construction diagrams are shown on the Test Boring and Well Construction Records provided in Appendix B.

The shallow monitoring well was constructed of 2-inch nominal diameter, Schedule 40, flush-joint and threaded PVC casing. Justification for the use of PVC casing is provided in Appendix B of the Field Sampling and Analysis Plan for Operable Unit No.7 (Baker, 1993a). The well, upon completion, had a 15-foot screened interval comprised of a 10- and 5-foot long No. 10 (i.e., 0.01 inch) slotted screen section. A fine-grained sand pack (i.e., No. 1 silica sand), extending approximately 2 feet above the top of the screen, was placed in the annulus between the screen and the borehole wall from inside the augers during shallow well installation. A 2- to 3-foot sodium bentonite pellet seal was then placed, by dropping pellets down the borehole, above the sandpack. The bentonite pellets were then hydrated with potable water. The seal was installed to prevent cement or surface run-off from intruding into the sand pack. The remaining annular space was backfilled with a mixture of Portland cement and 5 percent bentonite. A 4-inch protective well casing with cover was then placed over the well and set into the cement. In addition, a protective locking cap was installed at the top of the PVC well. A 5-foot by 5-foot concrete pad was placed around the protective well casing and four protective bollard posts were installed around the corners of the concrete pad. Well tags, which provide construction information, were installed at the top of each well. Typical shallow Type II well construction details are shown on Figure 21-3.

21.3.2 Monitoring Well Development

Following well construction and curing of the bentonite seal, the newly installed monitoring well was developed to remove fine-grained sediment from the screen and to establish interconnection between the well and the surrounding formation. The shallow well was developed by a combination of surging and pumping. A total of 40 gallons of water were evacuated from the shallow well, followed by 10 minutes of surging, then continued pumping. Groundwater recovered during well development was temporarily stored in drums, then transferred into an on-site tanker (refer to Section 21.5 for IDW handling). The pumping hose, constructed of flexible PVC, was used once and discarded to minimize the potential for cross contamination.

A total of five borehole volumes were removed from the shallow well. Measurements of pH, specific conductance, and temperature were recorded at each volume to assist in determining well stabilization. Additionally, periodic flow and volume measurements were also recorded during development to evaluate flow rates of the shallow water-bearing zone. Well Development Forms that summarize this information are provided in Appendix D.

21.3.3 Water Level Measurements

Static water level measurements were collected after all well development activities had been completed. Measurements were recorded from top-of-casing (TOC) reference points, marked on the PVC casing at each existing and newly-installed well (refer to Section 13). A complete round of the measurements was collected on May 9, 1994. Groundwater measurements were recorded using an electric measuring tape. Measurements were recorded to the nearest 0.01 foot from TOC. Water level data from site monitoring wells and staff gauges were collected within a two hour period. The data were employed to evaluate the possible tidal effects of the New River on local groundwater.

21.3.4 Sampling Locations

Groundwater samples were collected from two existing shallow wells and the one newly installed shallow well during both sampling rounds at Site 30. The locations of the existing and newly installed monitoring wells are depicted on Figure 21-2.

21.3.5 Sampling Procedures

Groundwater samples were collected to confirm the presence of contamination in the shallow aquifer, which may have resulted from previous site disposal practices. At Site 30, the contaminants of concern were volatile and semivolatile organic compounds. Information regarding suspected contaminants was based upon previous investigative results and historical records. Accordingly, the sampling program initiated at Site 30 focused on these contaminants.

Prior to groundwater purging, a water level measurement from each well was obtained according to procedures outlined in Section 21.3.3. The total well depth was also recorded from each well to the nearest 0.1 foot using a decontaminated steel tape. Water level and well depth measurements were used to calculate the volume of water in each well and the volume of water necessary to purge the well.

A minimum of three to five well volumes were purged from each well prior to sampling. Measurements of pH, specific conductance, and temperature were taken after each well volume was purged to ensure that the groundwater characteristics had stabilized before sampling. In addition, turbidity was also measured during round two. These measurements were recorded in a field logbook and are provided in Table 21-4. Purge water was contained and handled as described in Section 21.6.

Round one groundwater samples were collected using decontaminated teflon bailers (i.e., bottom loading bailer). A single teflon bailer was employed to both sample and purge groundwater from each of the wells. The samples were introduced directly from the bailer into laboratory-prepared sample containers and stored on ice. Sample bottles for VOC analysis were filled first, followed by SVOCs, pesticides, PCBs, and TAL metals (total and dissolved). Volatile samples were collected by slowly pouring water from the bailer into 40 ml vials to minimize volatilization. Samples analyzed for dissolved metals were filtered in the field and sent in containers with nitric acid (HNO_3) preservative. The dissolved groundwater samples were filtered through a disposable 0.45 micron membrane using a peristaltic pump.

Analytical results from the first round of sampling exhibited total metal concentrations frequently in excess of state and federal groundwater standards. These elevated metal detections were primarily due to an abundance of total suspended solids, or colloids, in samples collected during the first round. Metals adhere to these colloids, thus yielding artificially high concentrations. The use of a bailer during sample acquisition tends to increase the percentage of colloids. Through agitation, colloids can move from the formation and through the sand pack into the well, and subsequently impact the sample. As a result, data from the first round of sampling reflect the presence of colloids rather than true groundwater conditions. The purpose of the second sampling round was to minimize sample disturbance, thus reducing the occurrence of colloids. The second round of groundwater data more accurately depicts actual groundwater conditions at Site 30.

During the round two sampling event, a low flow well purging and sampling technique was employed. The sampling methodology was developed in response to conversations with USEPA Region IV personnel in Athens, Georgia. A submersible pump (Redi-Flow 2), set two to three feet into the static water column, was used to purge each of the wells. While purging groundwater from each of the monitoring wells, a flow rate of less than one gpm was maintained. Samples collected for both organic and metal analyses were obtained directly from the pump discharge. The pump and associated tubing were decontaminated with a Liquinox soap solution and then thoroughly rinsed with deionized water (refer to Section 21.5 for decontamination procedures). Rinsate blanks were collected from the pump to verify that proper decontamination procedures were implemented.

Preparation of groundwater samples incorporated similar procedures as to those described for soil samples. Sample information including well number, sample identification, time and date of sample collection, samplers, analytical parameters, and required laboratory turnaround time was recorded in a field logbook and on the sample labels. Chain-of-custody documentation, provided in Appendix C, accompanied the samples to the laboratory.

21.3.6 Analytical Program

Two rounds of groundwater samples were analyzed from two existing shallow wells and one newly installed shallow well. During the round one groundwater sampling, representative samples were analyzed for the following: volatiles, semivolatiles, and TAL metals (total and dissolved). For round two, all three wells were sampled for TAL metals (total and dissolved), TSS, and TDS; a sample collected from 30-GW01 was also analyzed for TCL volatiles. Table 21-5 provides a summary of groundwater samples submitted for laboratory analysis. The groundwater samples were analyzed using Contract Laboratory Program (CLP) protocols and Level IV data quality.

In addition to analyzing for the contaminants of concern, one groundwater sample from shallow well 30-GW01 was submitted for analysis of water chemistry parameters. Water chemistry parameters include: alkalinity, biological oxygen demand, chemical oxygen demand, chloride, fluoride, total dissolved solids, total suspended solids, and total Kjeldahl nitrogen.

21.3.7 Quality Assurance and Quality Control

Field QA/QC samples were also submitted during the groundwater investigation. These samples included trip blanks, equipment rinsates, and duplicates. Equipment rinsates were collected from the sampling bailers prior to usage. Section 21.2.5 provides a summary of QA/QC samples collected during the investigation. Table 21-6 summarizes the QA/QC sampling program employed for the groundwater investigation conducted at Site 30.

21.3.8 Field Screening and Air Monitoring

Several air monitoring and field screening procedures were implemented during the groundwater sampling activities for health and safety and initial contaminant monitoring. Air monitoring and field screening procedures implemented at Site 30 included the screening of well heads and the purged groundwater with a PID for volatile organic vapors. Measurements obtained in the field were recorded in a field logbook. Note that prior to daily monitoring, the field instruments were calibrated and documentation was recorded in a field logbook and on calibration forms.

21.4 Surface Water and Sediment Investigation

An overview of the surface water and sediment investigation conducted at Site 30 is provided in this section. Surface water and sediment samples were collected at Site 30 from March 21, through April 8, 1994. Additionally staff gauges were installed in Frenchs Creek at each proposed surface water and sediment sampling station, prior to collecting samples. The following subsections describe the surface water and sediment sampling locations, sampling procedures, analytical program, and quality assurance and quality control program for Site 30.

21.4.1 Sampling Locations

A total of three surface water and six sediment samples were collected at Site 30. From each sampling station one surface water and two sediment samples were collected. The three sampling stations were located in Frenchs Creek, approximately 1,500 feet to the west of Site 30. Figure 21-4 depicts the locations of the three surface water and sediment sampling locations. Surface water samples were assigned the designation SW and SD was specified for identification of sediment samples.

21.4.2 Sampling Procedures

At all sampling stations, surface water samples were collected by dipping the sample container directly into the water surface. Samples analyzed for volatiles were obtained first. Additional analytical fractions were collected immediately following the volatile fraction. Care was taken to avoid excessive agitation that could result in loss of VOCs. Water quality readings were taken at each sampling station (i.e., pH, specific conductance, and temperature). The water quality readings compiled during the surface water and sediment investigation are presented in Table 21-7.

Sediment samples were collected below the aqueous layer by driving a sediment corer, equipped with a plastic disposable tube, into the sediments. The sediment was then extruded from the disposable sampling tube and placed into the appropriate sample containers. Sampling containers were provided by the laboratory and certified to be contaminant free. The volatile fraction was collected first and immediately followed by the remaining analytical parameters. Samples to be analyzed for TCL semivolatile, and TAL metals were thoroughly homogenized prior to filling the sample jars. The first six inches of sediment at each station were submitted for analyses separately from sediments collected at the 6- to 12-inch depth. Surface water and sediment sampling activities were performed at downstream sampling locations first and then proceeded, in order, to upstream stations. All sample locations were marked by placing a pin flag or wooden stake at the nearest point along the bank.

21.4.3 Analytical Program

The analytical program at Site 30 was intended to accurately assess the nature and extent of contamination in surface waters and sediments that may have resulted from past disposal activities. As a result, the analytical program focused on suspected contaminants of concern and the overall quality of surface water and sediment. Both surface water and sediment samples were analyzed for TCL volatile and semivolatile organics and TAL inorganics. In addition, surface water samples were analyzed for water hardness. A summary of the surface water and sediment analytical program is provided in Table 21-8.

21.4.4 Quality Assurance and Quality Control

Field QA/QC samples were also collected during the surface water and sediment investigation at Site 30, including duplicate samples, equipment rinsate samples, and trip blanks. Table 21-9 provides a summary of the QA/QC sampling program conducted during the surface water and sediment investigation at Site 30. Section 21.2.5 lists the various QA/QC samples collected during the sampling program at Site 30 and the frequency at which they were obtained.

21.5 Decontamination Procedures

Decontamination procedures performed in the field were initiated in accordance with USEPA Region IV SOPs. Sampling and drilling equipment were divided into two decontamination groups, heavy equipment and routine sample collection equipment. Heavy equipment included the drill rig, hollow-stem augers, drill and sampling rods. Routine sample collection equipment included split spoons, stainless steel spoons and bowls, and teflon bailers.

For heavy equipment, the following procedures were implemented:

- Removal of caked-on soil with brush
- Steam clean with high-pressure steam
- Air dry

For routine sample collection equipment, the following procedures were implemented:

- Clean with distilled water and laboratory detergent (Lacunas soap solution)
- Rinse thoroughly with distilled water
- Rinse twice with isopropyl alcohol
- Air dry
- Wrap in aluminum foil, if appropriate

Temporary decontamination pads were constructed of wood and plastic to minimize spillage onto the ground surface. Decontamination fluids generated during the field program were containerized and handled according to the procedures outlined in Section 21.6.

21.6 Investigation Derived Waste (IDW) Handling

Field investigation activities at Site 30 resulted in the generation of various IDW. This IDW included drilling mud, soil cuttings, well development and purge water, and solutions used to decontaminate non-disposable sampling equipment. The general management techniques utilized for the IDW were as follows:

1. Collection and containerization of IDW material.
2. Temporary storage of IDW while awaiting confirmatory analytical data.
3. Final disposal of aqueous and solid IDW material.

The management of the IDW was performed in accordance with guidelines developed by the USEPA Office of Emergency and Remedial Response, Hazardous Site Control Division.

Both non-contaminated and contaminated wastewater were sent off site to a licensed hazardous waste disposal facility. The IDW soils were returned, based on confirmatory analytical data, to their respective source areas. Appendix F provides information on the management and disposal of the IDW.

SECTION 21.0 TABLES

TABLE 21-1

SOIL SAMPLING SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Depth of Borehole (feet, bgs)	Sampling Interval (feet, bgs)	Analytical Parameters							
			TCL Organics	TAL Metals	TPH	TCL VOA	TCL SVOA	TCLP	Engineering Parameters$^{(1)}$	Duplicate Sample
30-SB01	9	0-1.0		X		X	X			
		7-9		X	X	X	X			
30-SB02	9	0-1.0		X		X	X			
		5-7		X	X	X	X			
30-SB03	9	0-1.0		X		X	X			
		5-7		X	X	X	X			
30-SB04	9	0-1.0		X		X	X			
		5-7		X		X				
30-SB05	7	0-1.0		X		X	X			X
		5-7		X	X	X	X			X
30-SB06	9	0-1.0		X		X	X			
		5-7		X		X	X			
30-SB07	9	0-1.0		X		X	X			
		5-7		X	X	X	X			
30-SB08	7	0-1.0		X		X	X			
		3-5		X		X	X			
30-SB09	7	0-1.0		X		X	X			
		3-5		X		X	X			
30-SB10	9	0-1.0		X		X	X			X
		5-7		X	X	X	X			X
30-SB11	9	0-1.0		X		X	X			
		5-7		X		X	X			
30-BB-SB12$^{(2)}$	7	0-1.0		X		X	X			
		5-7		X		X	X			
30-BB-SB13$^{(2)}$	5	0-1.0		X		X	X			
		1-3		X		X	X			
30-BB-SB14$^{(2)}$	3	0-1.0		X		X	X			
		1-3		X		X	X			
30-BB-SB15$^{(2)}$	5	0-1.0		X		X	X			
		1-3		X		X	X			
30-BB-SB16$^{(2)}$	7	0-1.0		X		X	X			
		3-5								
30-SB17	8	0-8/ composite						X	X	
30-SB18	9	0-1.0		X						
		5-7		X						
30-SB19	7	0-1.0		X						
		3-5		X						

TABLE 21-1 (Continued)

SOIL SAMPLING SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Depth of Borehole (feet, bgs)	Sampling Interval (feet, bgs)	Analytical Parameters							
			TCL Organics	TAL Metals	TPH	TCL VOA	TCL SVOA	TCLP	Engineering Parameters(1)	Duplicate Sample
30-SB20	9	0-1.0		X						
		5-7		X						
30-GW03(2)(3)	17.5	0-1.0		X		X	X			
		1-3		X		X	X			

Notes: (1) Engineering parameters include full TCLP, RCRA hazardous waste characteristics, grain size, and Atterberg limits.

(2) Background or control sample location.

(3) Monitoring well test boring.

TABLE 21-2

QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM
SOIL INVESTIGATION
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample(1)	Frequency of Collection	Number of Samples	Analytical Parameters
Trip Blanks(2)	One per cooler	9	TCL Volatiles
Field Blanks(3)	One per event	--	--
Equipment Rinsates(4)	One per day	6	TCL Volatiles/TCL Semivolatiles/ TAL Metals
Field Duplicates(5)	10% of sample frequency	6	TCL Volatiles/TCL Semivolatiles/ TAL Metals

Notes:

(1) QA/QC sample types defined in Section 21.2.5 in text.

(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.

(3) Field blank not collected during soil investigation.

(4) Equipment rinsates collected from various sampling equipment (e.g., stainless steel spoons).

(5) Field duplicate samples presented in Appendix F.

TABLE 21-3

SUMMARY OF WELL CONSTRUCTION DETAILS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Sand Pack Interval Depth (feet, below ground surface)	Bentonite Interval Depth (feet, below ground surface)
30-GW03	3/24/94	43.17	40.5	17.5	17.5	2.4-17.5	1.5-17.5	0.5-1.5
30-PZ01(2)	3/23/94	35.33	32.5	26	25	20-20.5	19-26	15.5-18

Notes: (1) msl = mean sea level
(2) Piezometer well
Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD 27) CF = 0.9999216 from USMC Monument Toney.
Vertical datum NGVD 29.

TABLE 21-4

SUMMARY OF GROUNDWATER FIELD PARAMETERS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Depth of Well (ft.)(1)	Purge Volume (gals.)	Field Parameters			
Date of Measurement			Well Volume	Specific Conductance at 25°C (micromhos/cm)	Temperature (°C)	pH (S.U.)
30-GW03	20.24	2.49	3	80	18	5.20
4-21-94			4	80	18.5	5.16
			5	90	18	5.09
30-GW02	22.50	3.52	3	90	18	4.85
4-21-94			4	80	18	4.93
			5	80	17.5	4.88
30-GW01	22.70	2.14	3	50	17	5.05
4-21-94			4	50	17	5.00
			5	50	17	4.90

Notes: (1) Well depth taken from below ground surface (bgs)

TABLE 21-4

SUMMARY OF GROUNDWATER FIELD PARAMETERS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Depth of Well (ft.)(1)	Purge Volume (gals.)	Field Parameters				
Date of Measurement			Well Volume	Specific Conductance at 25°C (micromhos/cm)	Temperature (°C)	pH(2) (S.U.)	Turbidity(4) (T.U.)
30-GW01	22.70	2.14	3	50	17	5.05	NA
4-21-94			4	50	17	5.00	NA
			5	50	17	4.90	NA
11-11-94		2.01	2	39	19.4	4.9	0.85
			3	40	19.6	5.12	0.30
			4	35	19.3	5.08	0.26
30-GW02	22.50	3.52	3	90	18	4.85	NA
4-21-94			4	80	18	4.93	NA
			5	80	17.5	4.88	NA
11-11-94		3.6	6	42	19.4	5.01	7.0
			7	41	19.3	5.07	5.9
			8	41	19.2	5.07	4.1
30-GW03	20.24	2.49	3	80	18	5.20	NA
4-21-94			4	80	18.5	5.16	NA
			5	90	18	5.09	NA
11-11-94		2.56	5	100	18.2	6.06	48
			6	99.5	12.9	6.39	45
			7	99.5	18.6	5.5	43

Notes: NA - Not Available
(1) Well depth taken from below ground surface (bgs)
(2) S.U. - Standard Units
(3) T.U. - Turbidity Units

TABLE 21-5

GROUNDWATER SAMPLING SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Analytical Parameters						
	TCL Organics	TCL VOA	TCL SVOA	TAL Metals	Dissolved TAL Metals	Water Chemistry Parameters(1)	Duplicate Sample
30-GW01		X	X	X	X	X	
30-GW02		X	X	X	X		X
30-GW03(2)		X	X	X	X		

Notes: (1) Water chemistry parameters include alkalinity, biological oxygen demand, chemical oxygen demand, biological oxygen demand, chloride, fluoride, total dissolved solids, total suspended solids, and total Kjeldahl nitrogen.

(2) Background or control sample location.

TABLE 21-5

GROUNDWATER SAMPLING SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Location	TCL VOA	TCL SVOA	TAL Metals	Dissolved TAL Metals	Water Chemistry(1)	Duplicate Sample
30-GW01	X●	X	X●	X●	X●	
30-GW02	X	X	X●	X●	●	X
30-GW03(2)	X	X	X●	X●	●	

Notes: (1) Water chemistry parameters include alkalinity, biological oxygen demand, chemical oxygen demand, chloride, fluoride, total dissolved solids (TDS), total suspended solids (TSS), and total kjeldahl nitrogen. For round two, water chemistry parameters only include TSS and TDS.

(2) Upgradient sample location.

X - Indicates round one analyses
● - Indicates round two analyses

TABLE 21-6

QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM
GROUNDWATER INVESTIGATION
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample(1)	Frequency of Collection	Number of Samples	Analytical Parameters
Trip Blanks(2)	One per cooler	1	TCL Volatiles
Field Blanks(3)	One per event	--	--
Equipment Rinsates(4)	One per day	1	TCL Volatiles/TCL Semivolatiles/ TAL Metals
Field Duplicates(5)	10% of sample frequency	1	TCL Volatiles/TCL Semivolatiles/ TAL Metals

Notes:
(1) QA/QC sample types defined in Section 21.2.5 in text. Includes both round one and round two samples.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Field blank not collected during groundwater investigation.
(4) Equipment rinsates collected from various sampling equipment (e.g., bailer).
(5) Field duplicate samples presented in Appendix F.

TABLE 21-7

SUMMARY OF FIELD WATER QUALITY PARAMETERS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Identification	Sample Location	Salinity (ppt)	Conductivity (micromhos/cm)	DO (mg/L)	pH (S.U.)	Temperature (deg. C)
30-SW/SD01	Surface	0	16.6	2.2	4.1	13.7
30-SW/SD02	Surface	0	19.5	6.2	5.1	16.4
30-SW/SD03	Surface	0	286	5.4	5.5	15.6

Notes: Sample Location = Water surface or water bottom
DO = Dissolved Oxygen level
ppt = parts per thousand
mg/L = milligrams per liter
S.U. = Standard Units
deg. C = degrees Celsius
SW/SD = Surface water/sediment sample

TABLE 21-8

SURFACE WATER AND SEDIMENT SAMPLING SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Sample Matrix	Sample Depth$^{(1)}$	Analytical Parameters					
			Full TCL Organics	TCL VOA	TCL SVOA	TAL Metals	Water Hardness	Duplicate Sample
30-W/SD01	SW	NA		X	X	X	X	X
	SD	0-6"		X	X	X		X
	SD	6-12"		X	X	X		
30-SW/SD02	SW	NA		X	X	X	X	
	SD	0-6"		X	X	X		
	SD	6-12"		X	X	X		
30-SW/SD03	SW	NA		X	X	X	X	
	SD	0-6"		X	X	X		
	SD	6-12"		X	X	X		

Notes: (1) NA - Not applicable for surface water samples.
SW - Surface Water
SD - Sediment

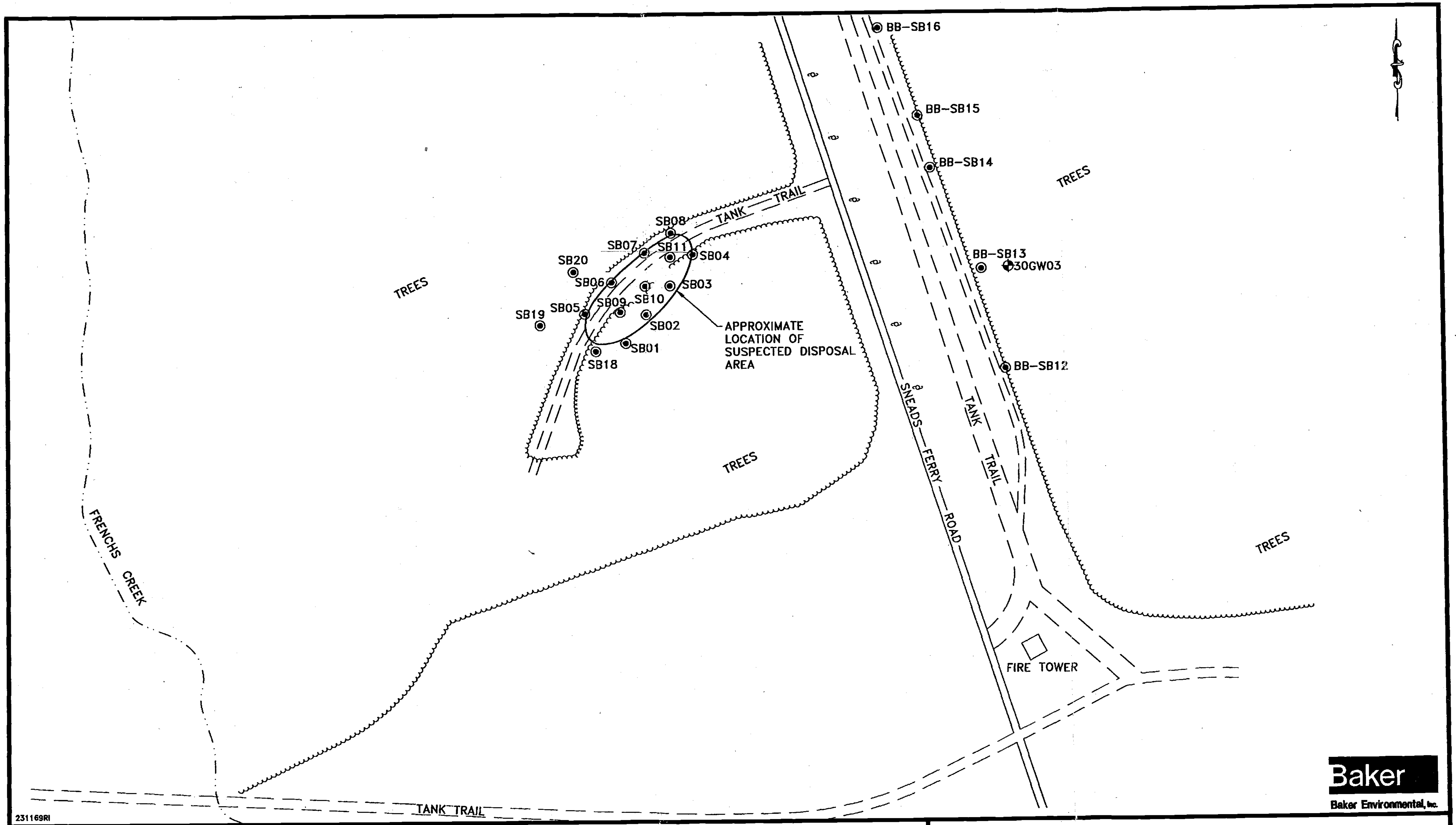
TABLE 21-9

QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM
SURFACE WATER AND SEDIMENT INVESTIGATION
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample(1)	Frequency of Collection	Number of Samples	Analytical Parameters
Trip Blanks(2)	One per cooler	1	TCL Volatiles
Field Blanks(3)	One per event	--	--
Equipment Rinsates(4)	One per day	1	TCL Organics/TAL Metals
Field Duplicates(5)	10% of sample frequency	1	TCL Organics/TAL Metals

Notes:
(1) QA/QC sample types defined in Section 21.2.5 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Field blank not collected during investigation.
(4) Equipment rinsates collected from various sampling equipment (e.g., corer).
(5) Field duplicate samples presented in Appendix F.

SECTION 21.0 FIGURES



Baker
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LEGEND

30-GW03 ⯐	PILOT TEST BORING FOR SHALLOW MONITORING WELL
SB01 ◉	SOIL BORING LOCATION
BB-SB12 ◉	BASE BACKGROUND SOIL BORING LOCATION
═══	ASPHALT ROAD
– – –	UNIMPROVED ROAD
∞	UTILITY POLE

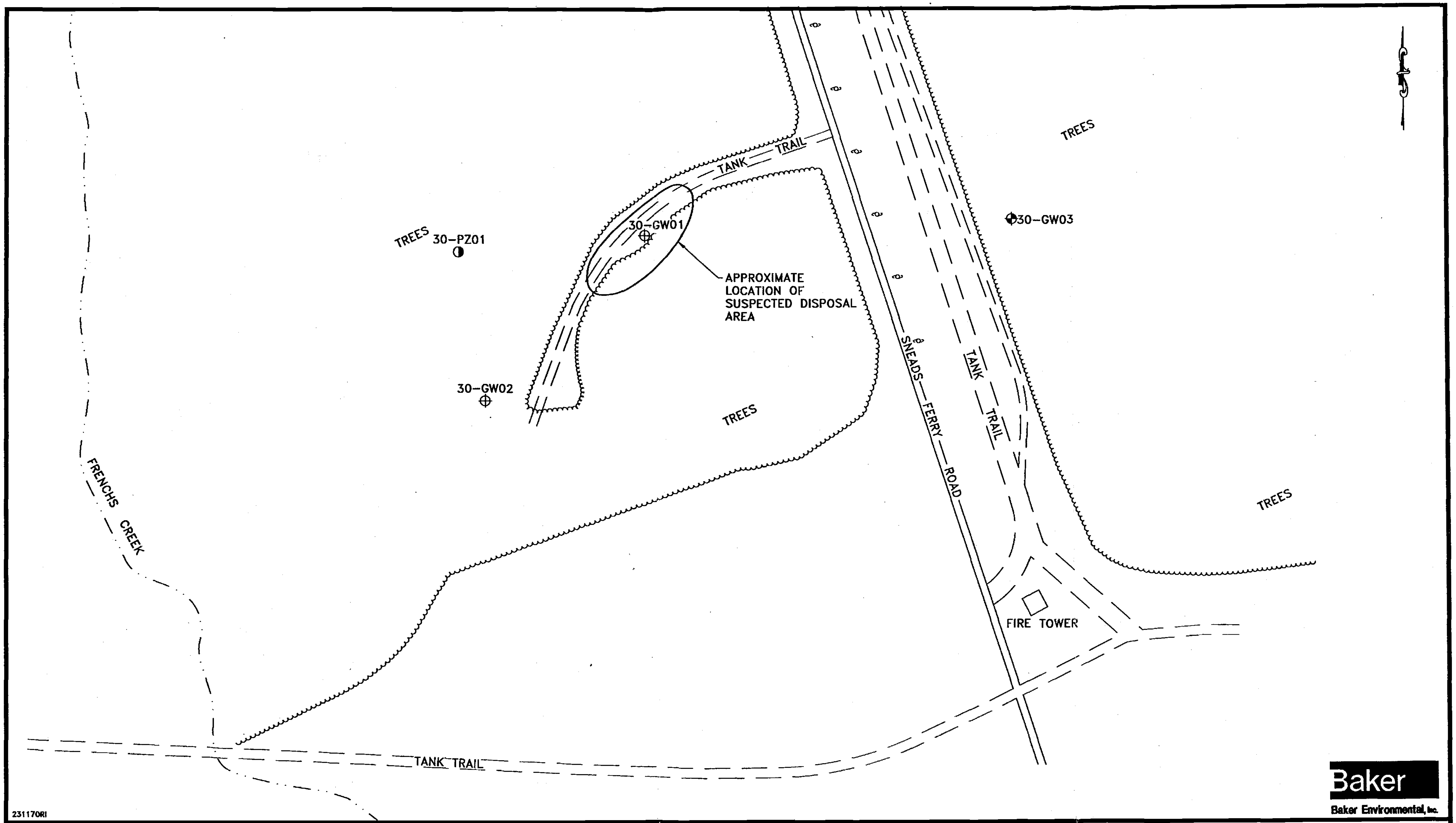
SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

1 inch = 300 ft.

FIGURE 21-1
SURFACE AND SUBSURFACE SOIL SAMPLING LOCATIONS
SITE 30 - SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U032



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LEGEND

30-GW01 ⊕	EXISTING SHALLOW MONITORING WELL (ESE, 1984,1986)
30-GW3 ⊕	NEWLY INSTALLED SHALLOW MONITORING WELL (BAKER, 1994)
30-PZ01 ◑	NEWLY INSTALLED PIEZOMETER (BAKER, 1994)
═══	ASPHALT ROAD
‒ ‒ ‒	UNIMPROVED ROAD
⌀	UTILITY POLE

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

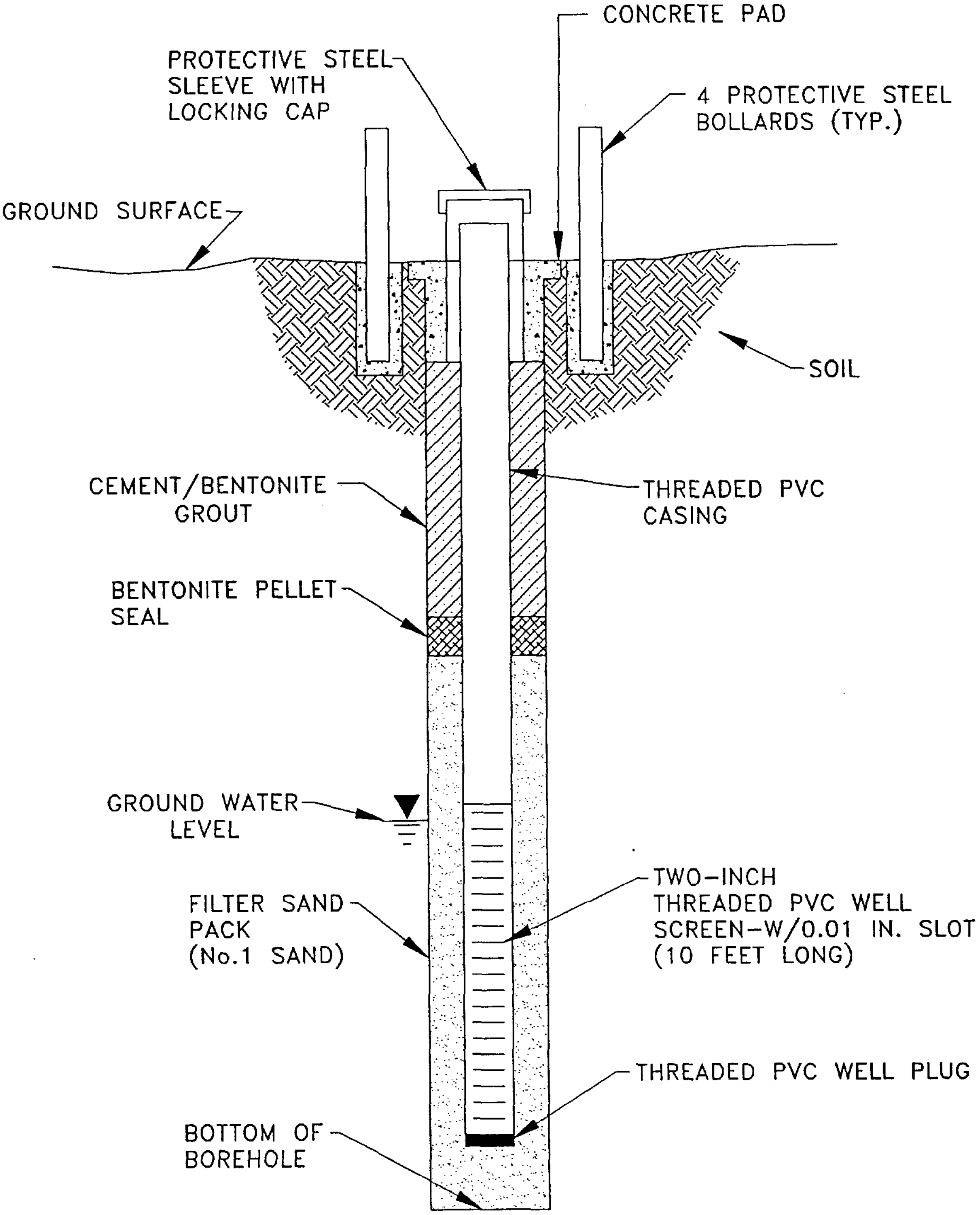
300 0 150 300 600

1 inch = 300 ft.

FIGURE 21-2
SHALLOW MONITORING WELL LOCATIONS
SITE 30 - SNEADS FERRY ROAD FUEL
TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U042

231171RI



N.T.S.

Baker
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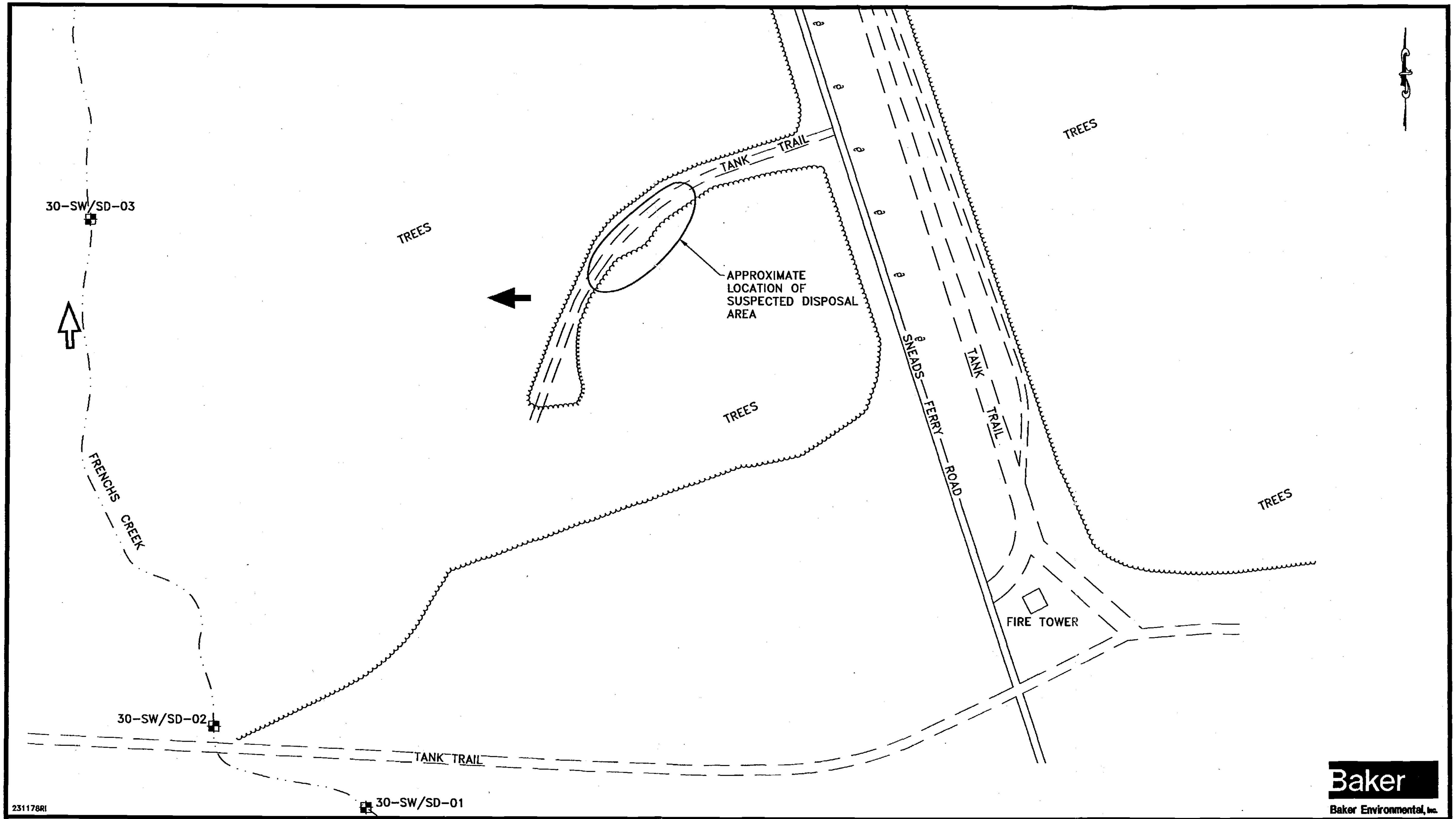
FIGURE 21-3
TYPICAL SHALLOW TYPE II GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- 30-SW/SD-01 ⊞ SURFACE WATER AND SEDIMENT SAMPLE STATION
- ═ ASPHALT ROAD
- ╌ UNIMPROVED ROAD (TANK TRAIL)
- ∞ UTILITY POLE
- ➡ APPROXIMATE GROUNDWATER FLOW DIRECTION
- ⇨ APPROXIMATE SURFACE WATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 21-4
SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS
SITE 30 - SNEADS FERRY ROAD
FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U05Z

22.0 SITE PHYSICAL CHARACTERISTICS

Section 22.0 of this report presents information on site-specific physical characteristics. Included in this section is a discussion on the topography, surface water hydrogeology and drainage features, geology, hydrogeology, ecology, and water supply wells identified near the site.

22.1 Topography

The topography at Site 30 is relatively flat with land surface elevations occurring between 32 and 45 feet above msl. Ground surface slopes slightly to the north-northwest toward Frenchs Creek. A man-made topographic high (mounds) is situated just west of the site.

22.2 Surface Water Hydrology and Drainage Features

There are no major surface water features within the boundary of Site 30. Frenchs Creek, located approximately 1,600 feet to the west, is the closest surface water body. The head waters of the creek are located southwest of Site 30, and flow is toward the north in the direction of the New River. Based on surface water elevation data (Table 22-1) from staff gauges and groundwater elevation data from on-site wells, Frenchs Creek appears to receive localized groundwater discharge (i.e., gaining stream) from the Site 30 area.

22.3 Subsurface Soil Conditions

22.3.1 Geology

The shallow soils underlying Site 30 consist of sand and silty-sand and classify as SM under the USCS. Sands are fine-grained with varied amounts of silt (5 to 10 percent). The appearance of the soils encountered at Site 30 is generally consistent with soils described for Sites 1 and 28 ("undifferentiated" Formation). Based on the standard penetration tests, the relative density of the soils ranged from very loose to dense.

As shown on Figure 22-1, two cross-sections depicting shallow soil lithologies from west to east (A to A') and north to south (B to B') across Site 30 were developed. The cross-sections presented on Figures 22-2 and 22-3 indicate that Site 30 is underlain by sand. No significant change in the lithology was observed to depths of 25 feet bgs.

22.3.2 Surface Soils

Information regarding site soil conditions was obtained from the Soil Survey publication prepared by the U.S. Department of Agriculture - SCS for Camp Lejeune, North Carolina (SCS, 1984). As part of the RI, a limited number of soil samples were evaluated for geotechnical properties and classified according to the USCS. The findings of that evaluation, provided in Appendix H, were used to confirm SCS survey results. Because of operational activities at Site 30, however, the soils described in the SCS publication may differ from current site conditions.

The Kureb (KuB) fine sand unit underlies Site 30 and is typically found in wooded areas throughout MCB, Camp Lejeune. Kureb fine sands are found on uplands and convex divides between drainageways. Kureb soils are well drained and range from one to six percent slopes. Because of its rapid infiltration rate, Kureb soil tends to be used for military training areas and unsurfaced roads. Generally Kureb soils range from strongly acidic, pH 4.5, to neutral, pH 7.3, and are classified under the USCS as SP, SP-SM (i.e., fine sand). Table 22-2 provides a summary of soil physical properties found at Site 30.

22.4 Hydrogeology

The hydrogeologic setting was evaluated by installing a network of shallow monitoring wells throughout Site 30, and by installing staff gauges in Frenchs Creek. Two rounds of groundwater and surface water level measurements were collected. The initial round of measurements (March 19, 1994) was collected prior to the investigation, and therefore, only includes the existing wells. Groundwater elevations measured in shallow wells on May 9, 1994 varied from 30.55 to 37.97 feet above msl. In the existing monitoring wells where two rounds of measurements were collected (March 19 and May 9, 1994), the water levels declined between 1.18 and 1.65 feet. The this slight decline in the water table appears to be the result of normal seasonal fluctuations. Groundwater elevation data are summarized on Table 22-3.

A groundwater elevation contour map was generated for the surficial aquifer based on the May 9, 1994 data. As shown on Figure 22-4, groundwater flow is to the west-northwest in the direction of Frenchs Creek. An estimate of the average horizontal groundwater gradient for the surficial aquifer was calculated from the May 9, 1994 elevation data. Based on the May 9, 1994 data, the average gradient across the site is 0.015, indicating a moderately steep gradient.

Groundwater flow velocity within the surficial aquifer was estimated by employing a variation of Darcy's equation as described in Section 4.4. Based on an average hydraulic conductivity of 3.1 feet/day (Baker, 1992), an average horizontal groundwater gradient of 0.015, and a estimated effective porosity of 0.3 for silty-sands (Fetter, 1980), the estimated groundwater flow velocity is 0.15 feet/day (56 feet/year).

22.5 Ecology

Site 30 is located to the south of Marine Road, west of Sneads Ferry Road, and to the east of Frenchs Creek. The area located along either side of Frenchs Creek is described as mixed forest and scrub/shrub. The dominant trees include the loblolly pine (Pinus taeda), gray birch (Betula populifolia), and red maple (Acer rubrum). The dominant scrub/shrub vegetation includes southern bayberry (Myrica cerifera), American holly (Ilex opaca), and various rhododendrons. Inhabitants of this area may include white-tail deer (Odocoileus virginianus), wild turkey (Meleagris gallopavo), and various small mammals.

The area surrounding most of the site is described as coniferous forest with loblolly pine (Pinus taeda) in various levels of development dominating the vegetation. The ground cover is sparse exposing the soil, which is primarily sand. Inhabitants of this area may include white-tail deer (Odocoileus virginianus), wild turkey (Meleagris gallopavo), and various small mammals.

The area directly around the site is described as a large open dune area that is used by the base for tracked vehicle maneuvers. There are several pockets of standing trees with some herbaceous ground cover. The dominant vegetation is the few loblolly pines (Pinus taeda) that are located around the area. Inhabitants may include the wild turkey (Meleagris gallopavo), bobwhite quail (Colinus virginianus), and various song birds.

Site 30 is located within an area identified as a forage location for red-cockaded woodpeckers (Picaides borealis). Known woodpecker nesting colonies are present to the north, northeast, south, and southwest of the site. Woodpeckers may feed in the coniferous forest or in the pine trees on Site 30.

According to the soil survey performed at MCB, Camp Lejeune, the soil in this area is primarily Kureb fine sand. This soil type is generally found in the uplands, where nearly all of the acreage is in woodland. However, some unsurfaced roads used for tactical vehicles are routed through these areas. This area is also used for off-road maneuvers and bivouac. Most of the acreage is in sparse native vegetation adapted to drought conditions. The native trees are longleaf pine (Pinus palustris), turkey oak (Quercus laevis), and live oak (Quercus virginiana). The major understory includes pineland threeawn (Ranales sp.), panicum grasses (Panicum sp.), and sassafras (Sassafras albidum).

During the habitat evaluation, there were no wetlands identified as Site 30. However, the area along Frenchs Creek has been classified as a palustrine, forested, broad-leaved deciduous, needle-leaved evergreen wetland on the NWI maps. Site-specific habitat types are summarized on Table 22-4 and a biohabitat map for Site 30 is presented as Figure 22-5.

22.6 Identification of Water Supply Wells

Potable water supply wells within a one-mile radius of the site were identified by reviewing a USGS publication (Harned, et al., 1989) and conducting interviews with Activity personnel. Two supply wells, HP-632 and HP-640, were identified within a one-mile radius of the site. Both wells are currently operating according to Activity personnel. Table 22-5 summarizes well construction details and Figure 22-6 shows the locations of the two wells. Groundwater samples collected from wells HP-632 and HP-640 in 1992 did not exhibit any contaminant levels above the state or Federal standards.

SECTION 22.0 TABLES

TABLE 22-1

SUMMARY OF STAFF GAUGE READINGS
MARCH 19, 1994, AND MAY 10, 1994
SITE 30, SNEADS FERRY ROAD FUEL
TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Staff Gauge No.	Top of Staff Gauge Elevation (feet, above msl)(1)	Location	Staff Gauge Reading (feet) March 19, 1994	Staff Gauge Reading (feet) May 10, 1994	Top of Staff Gauge (feet)	Top of Water Elevation (feet, above msl) March 19, 1994	Top of Water Elevation (feet, above msl) May 10, 1994
30-SG01	35.33	Frenchs Creek	1.48	1.41	3.34	33.47	33.40
30-SG02	34.06	Frenchs Creek	1.10	1.05	3.34	31.82	31.77
30-SG03	14.62	Frenchs Creek	1.42	1.27	3.34	12.70	12.55

Notes: (1) msl = mean sea level
(2) Data not collected.

TABLE 22-2

SUMMARY OF SOIL PHYSICAL PROPERTIES
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Soil Name	Soil Symbol	USCS Classification	Depth (inches)	Moist Bulk Density (g/cc)	Permeability (cm/s)	Soil Reaction (pH)	Shrink-Swell Potential	Organic Matter (percent)
Kureb	KuB	SP, SP-SM	0 - 80	1.60 - 1.80	4.2×10^{-3} - 1.37×10^{-2}	4.5 - 7.3	Low	<2.0

Source: Soil Survey: Camp Lejeune, North Carolina, U. S. Department of Agriculture - Soil Conservation Service, 1984.

Notes:
SM - Loamy Fine Sand
SP - Fine Sand

TABLE 22-3

SUMMARY OF WATER LEVEL MEASUREMENTS ON MARCH 19, 1994, AND MAY 9, 1994
SITE 30, SNEADS FERRY ROAD FUEL
TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation (feet, above msl)[1]	Depth to Groundwater (feet, below top of casing) March 19, 1994	Depth to Groundwater (feet, below top of casing) May 9, 1994	Groundwater Elevation (feet, above msl) March 19, 1994	Groundwater Elevation (feet, above msl) May 9, 1994
30-GW01	44.71	8.66	10.31	36.05	34.40
30-GW02	38.86	4.84	6.02	34.02	32.84
30-GW03	43.17	(2)	5.20	(2)	37.97
30-PZ01	35.33	(2)	4.78	(2)	30.55

[1] msl = mean sea level

[2] Data not collected.

TABLE 22-4

SUMMARY OF HABITAT TYPES
SITE 30, SNEADS FERRY ROAD FUEL
TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB CAMP LEJEUNE, NORTH CAROLINA

Area Designation	Site Description	Dominant Vegetation	Fauna Present
30A	This area is described as a narrow strip of mixed forest and scrub/shrub which is located along Frenchs Creek.	Dominant trees include loblolly pine, gray birch, and red maple. The dominant scrub/shrub vegetation includes southern bayberry, American holly, and various rhododendrons.	This area is located near known red-cockaded woodpecker habitats. Other inhabitants may include white tail deer, wild turkey, and various small mammals.
30B	This area is described as coniferous forest and loblolly pine dominating most of the vegetation. The ground cover is sparse exposing the soil which is primarily sand.	Dominant vegetation includes loblolly pine in various levels of development.	These areas contain known populations of red-cockaded woodpecker. Other inhabitants may include whitetail deer, wild turkey, and various small mammals.
30C	This area is described as a large open dome area which is used by the base for tracked vehicle maneuver. There are several pockets of standing trees with some herbaceous ground cover.	The dominant vegetation is the few loblolly pines which are located around the area.	Red-cockaded woodpecker be present in area because it is close to known populations. Other inhabitants may include wild turkey, bobwhite quail, and song birds.

Note: Refer to Figure 22-5 for area designation locations.

TABLE 22-5

SUMMARY OF POTABLE WATER SUPPLY WELLS WITHIN THE VICINITY OF SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA REMEDIAL INVESTIGATION, CTO-0231 MCB CAMP LEJEUNE, NORTH CAROLINA

Supply Well Number	Well Depth (feet)	Screened Interval (feet)	Well Diameter (inches)	Approximate Distance/Direction to Closest Site[3] (feet)	Status of Well
HP-640	176	64-72 76-80 92-100 112-120 130-134 140-148 157-165 172-176	8	4,500/North	On
HP-632	145	NA	8	2,600/North	On

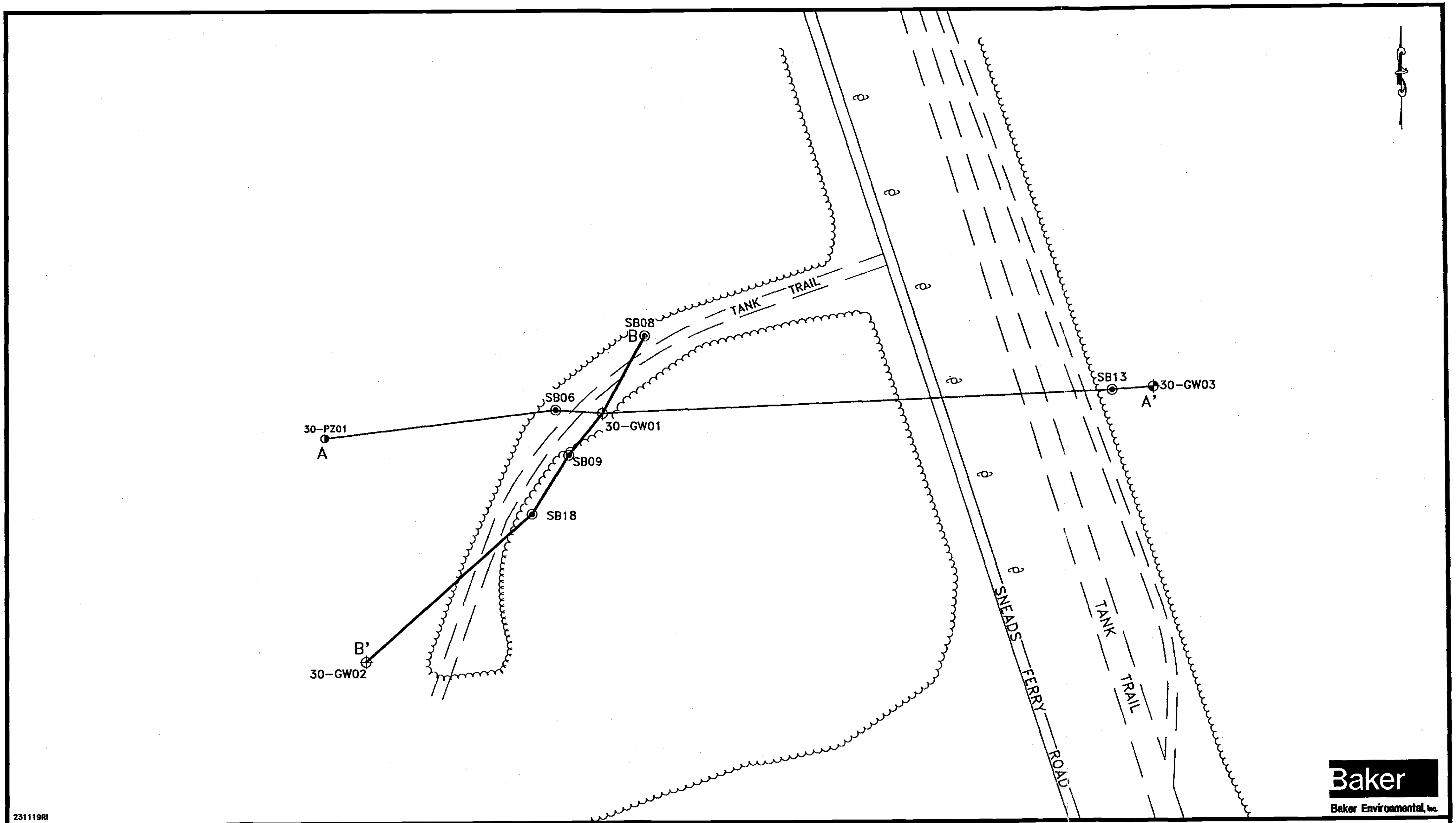
Notes: (1) Information obtained from "USGS Water Resources Investigation Report 89-4096" (Harned, et. al., 1989).

(2) Information not available.

(3) Distance measured from site boundary.

Refer to Figure 22-6 for the locations of the supply wells.

SECTION 22.0 FIGURES



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SB06 ◉	SOIL BORING
30GW01 ⊕	EXISTING MONITORING WELL
30GW03 ⊕	NEWLY INSTALLED MONITORING WELL
30PZ01 ◐	NEWLY INSTALLED PIEZOMETER
A— A'	GEOLOGIC CROSS-SECTION TRAVERSE

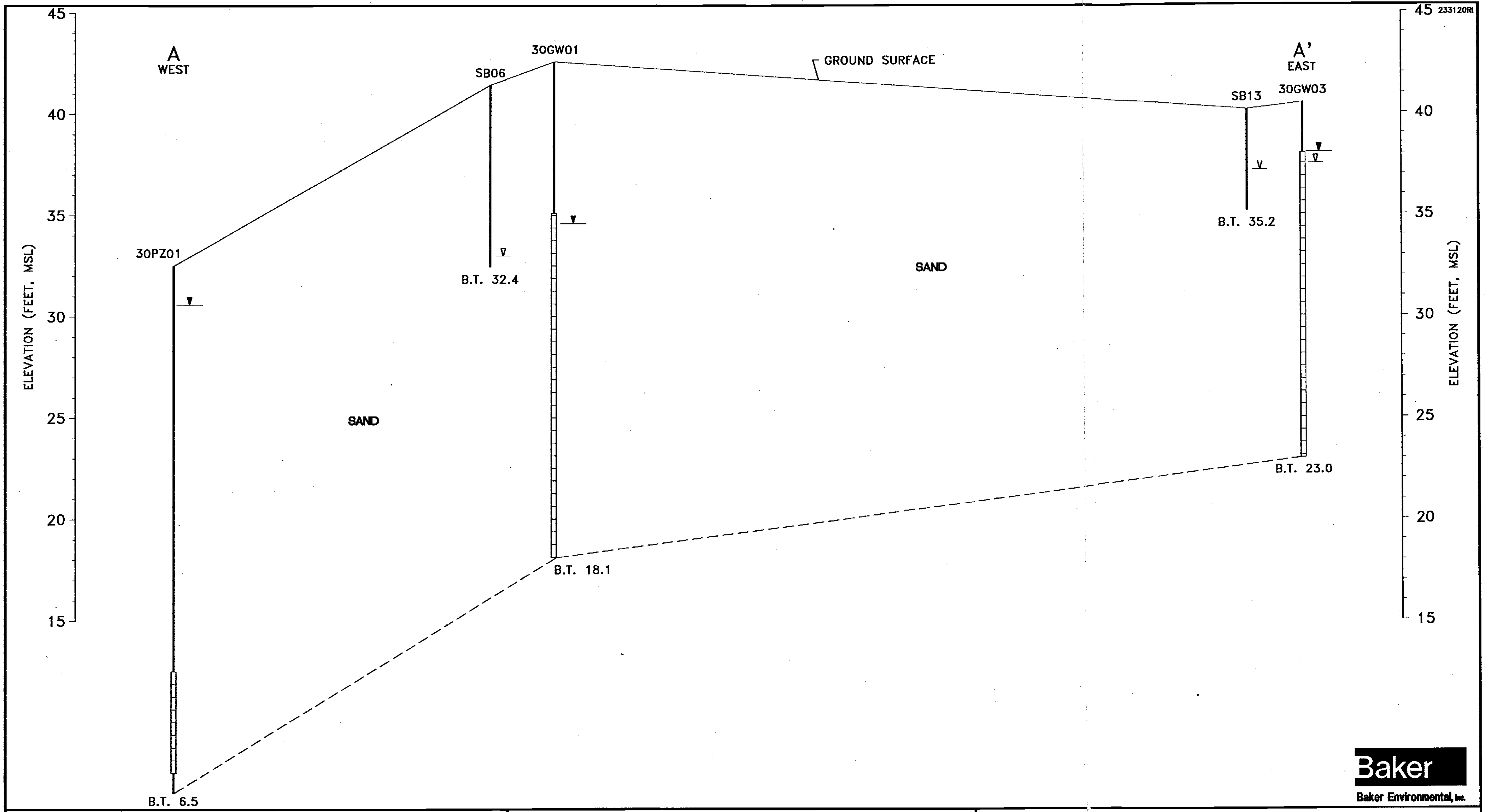
SOURCE: LANTDIV, OCT. 1991

200 0 100 200 400
1 inch = 200 ft.

FIGURE 22-1
GEOLOGIC CROSS-SECTION LOCATION MAP
SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U06Z



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LEGEND

- ▼ GROUNDWATER ELEVATION (5/9/94)
- ▽ GROUNDWATER ENCOUNTERED DURING DRILLING
- B.T. 6.5' BORING TERMINATED, ELEVATION MSL
- ▯ WELL SCREEN INTERVAL
- ——— ESTIMATED — — — PROJECTED

150 0 75 150 300

Horizontal Scale: 1 inch = 150 ft.

5 0 2.5 5 10

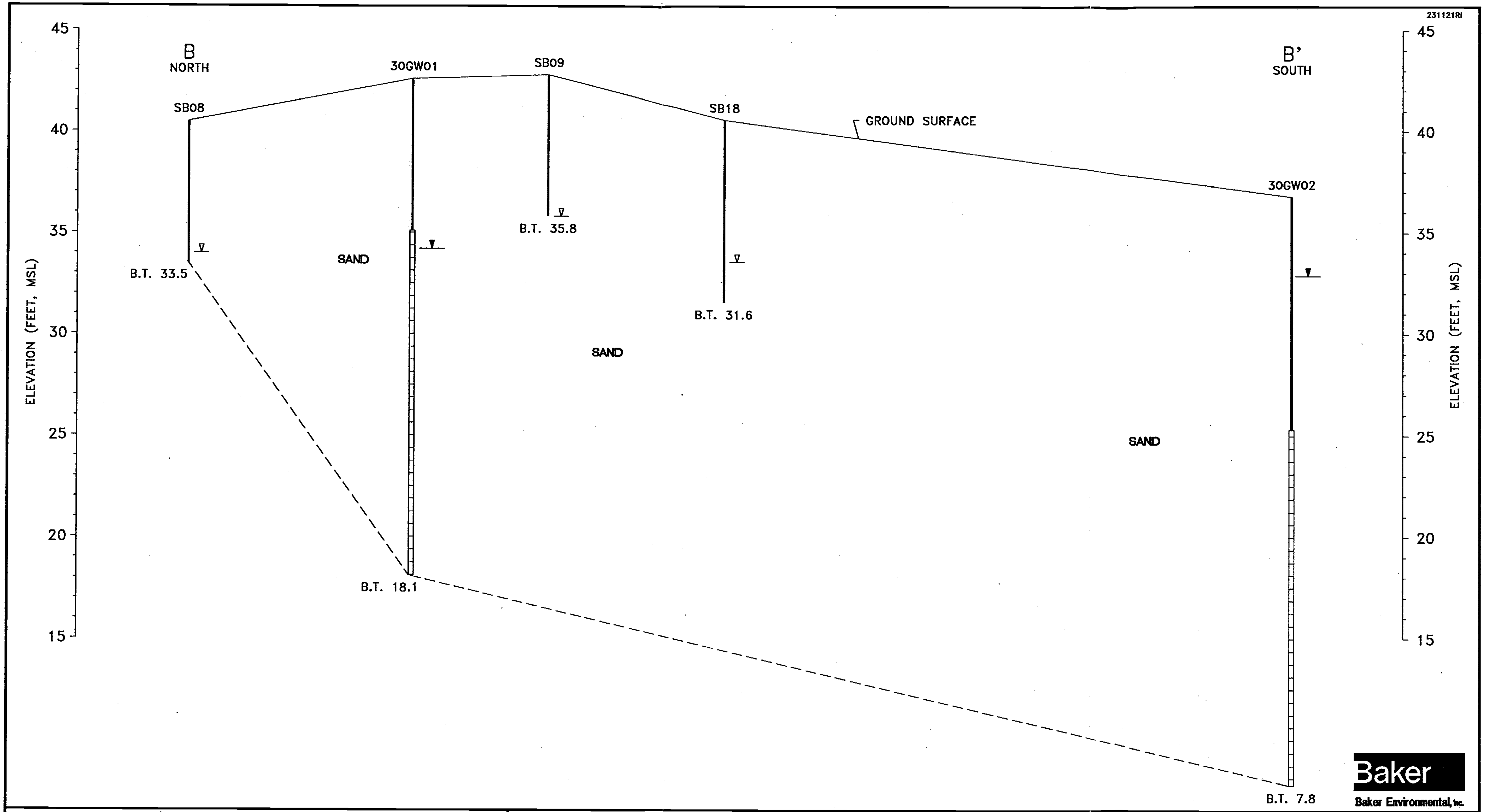
Vertical Scale: 1 inch = 5 ft.

THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 22-2
GEOLOGIC CROSS-SECTION A-A'
SHALLOW SOIL LITHOLOGY
SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U072



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LEGEND

▼	GROUNDWATER ELEVATION (5/9/94)
▽	GROUNDWATER ENCOUNTERED DURING DRILLING
B.T. 33.5'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
———	ESTIMATED
— — —	PROJECTED

80 0 40 80 160

Horizontal Scale: 1 inch = 80 ft.

5 0 2.5 5 10

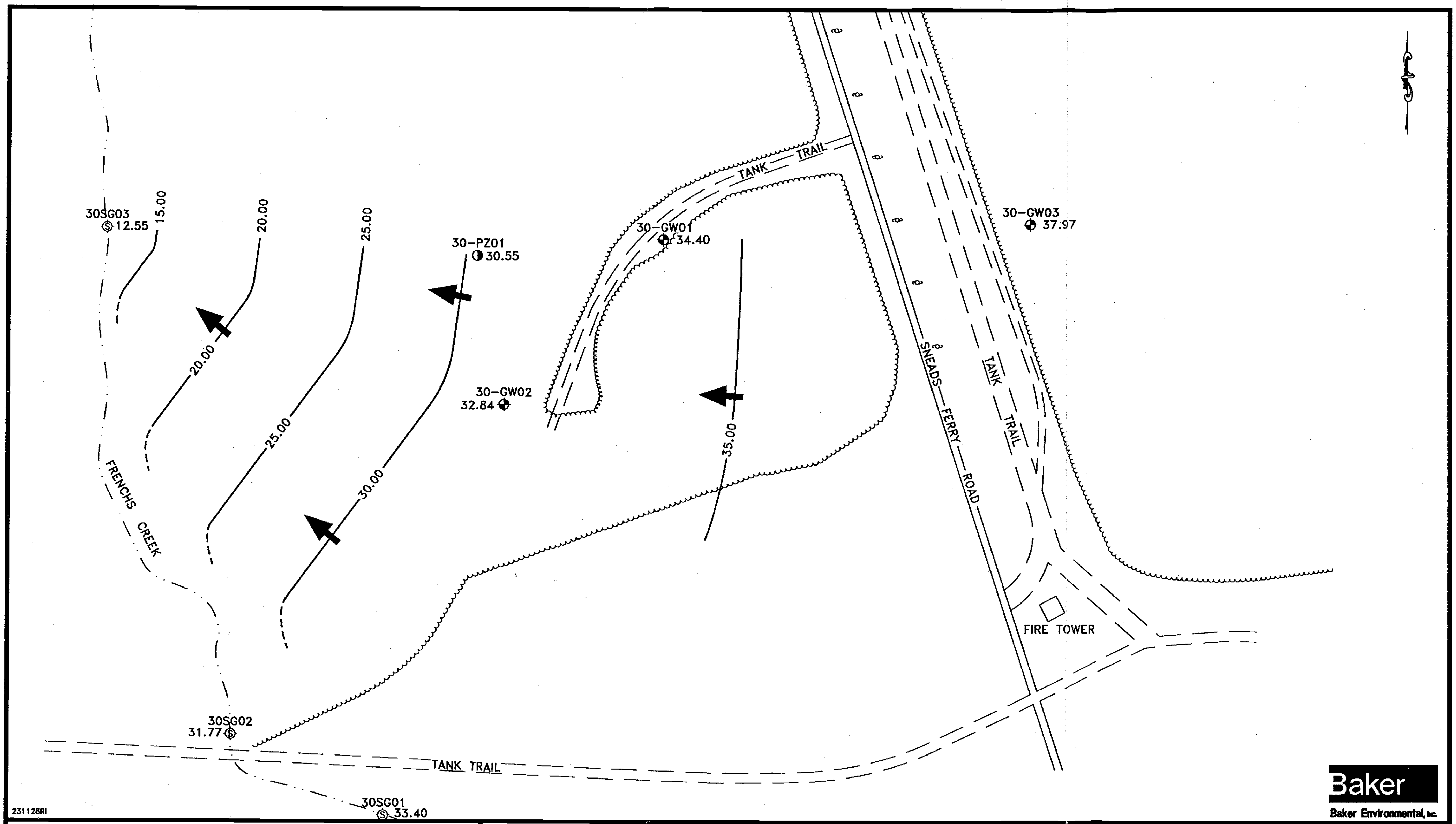
Vertical Scale: 1 inch = 5 ft.

THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 22-3
GEOLOGIC CROSS-SECTION B-B'
SHALLOW SOIL LITHOLOGY
SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U08Z



LEGEND

30-PZ01 ◑	PIEZOMETER	30SG01 Ⓢ	STAFF GAUGE
30-GW01 ⊕	SHALLOW MONITORING WELL		
33.40	GROUNDWATER ELEVATION(WELL SPECIFIC), FEET ABOVE MSL.		
—25.00—	GROUNDWATER ELEVATION CONTOUR LINE, FEET ABOVE MSL.		
➔	APPROXIMATE GROUNDWATER FLOW DIRECTION		

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

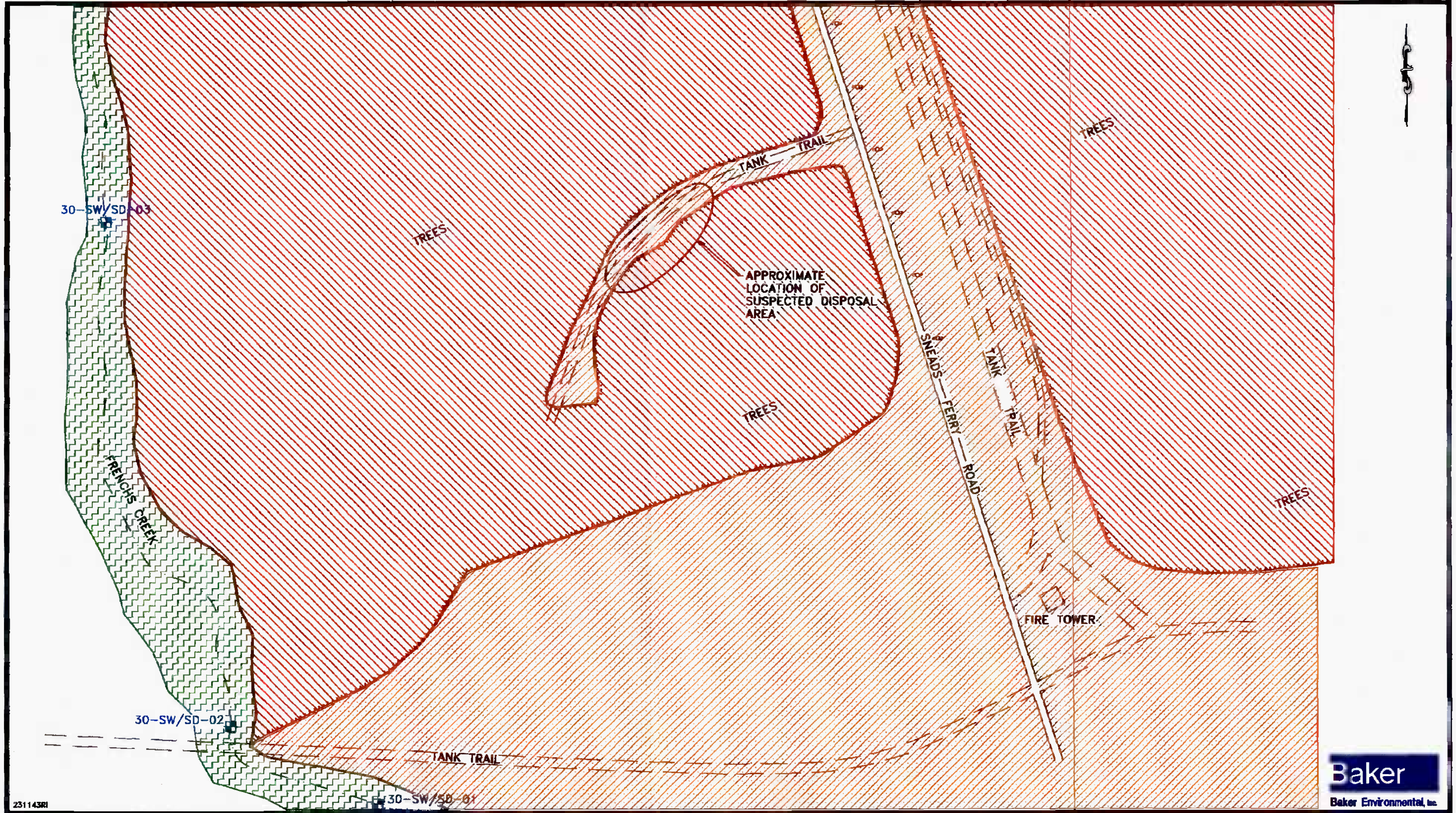
300 0 150 300 600

1 inch = 300 ft.

FIGURE 22-4
GROUNDWATER CONTOUR MAP FOR THE SURFICAIL AQUIFER – MAY 9, 1994
SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U092



LEGEND

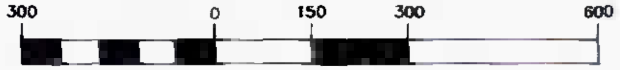
⊞ MIXED FOREST SCRUB/SHRUB, NEAR RED-COCKADE HABITAT

▧ CONIFEROUS FOREST, CONTAINS KNOWN POPULATION OF RED-COCKADE WOODPECKER.

▨ DUNE WITH STANDING TREES

30-SW/SD01 ■ SURFACE WATER AND SEDIMENT SAMPLING STATION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

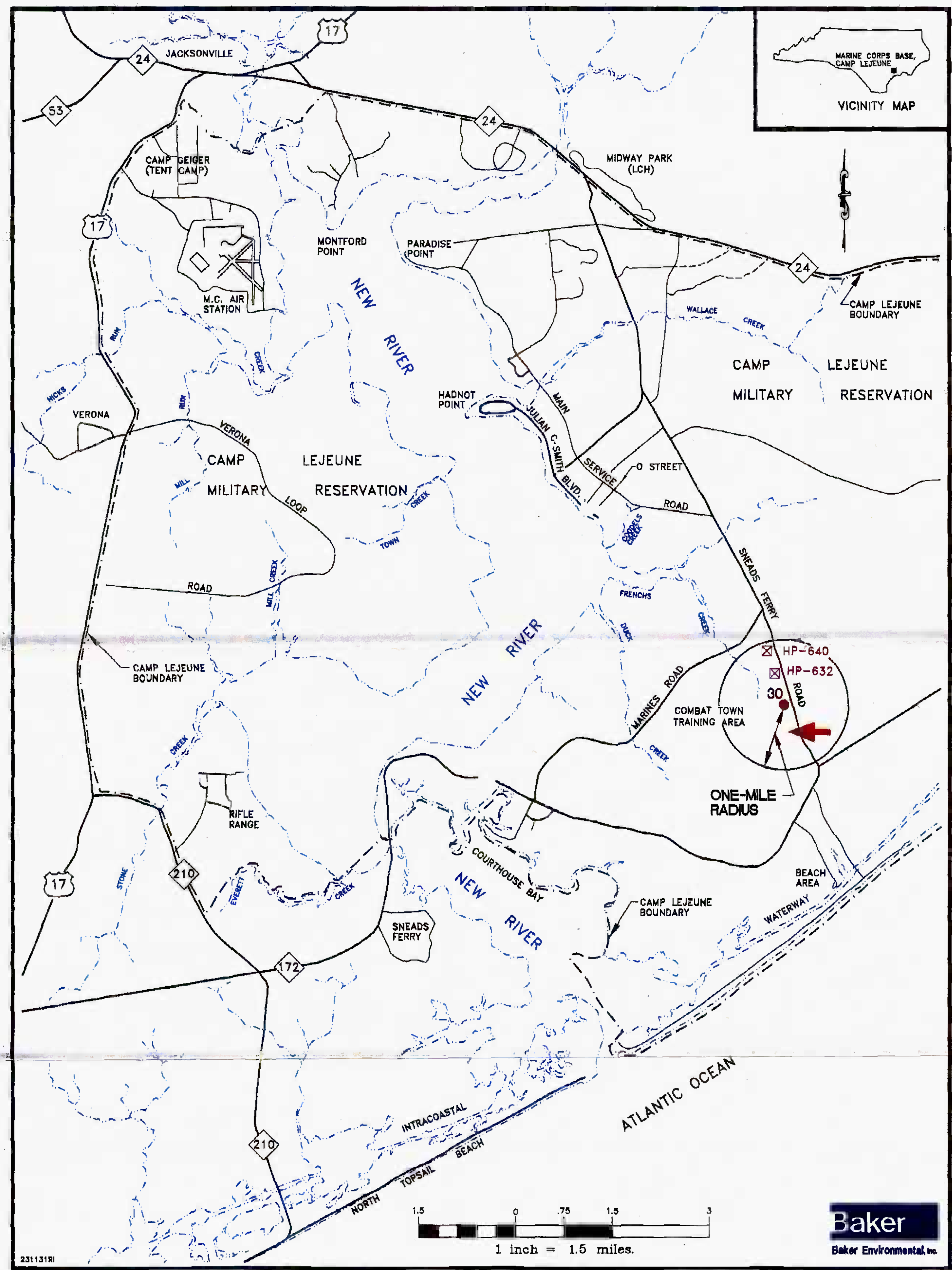


1 inch = 300 ft.

FIGURE 22-5
BIOHABITAT MAP
SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U10Y



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LEGEND

30 ● SITE AND SITE NUMBER

HP-632 ☒ POTABLE WATER SUPPLY WELL CURRENTLY IN SERVICE

➡ APPROXIMATE GROUNDWATER FLOW DIRECTION

FIGURE 22-6
POTABLE WATER SUPPLY WELLS WITHIN
ONE-MILE RADIUS OF SITE 30
REMEDIAL INVESTIGATION CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498V114

23.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the analytical findings from the RI performed at OU No. 7, Site 30. The objectives of this section are to characterize the nature and extent of contamination at Site 30. The characterization of contaminants was performed through sample collection and laboratory analysis of soil, groundwater, surface water, and sediment. Appendices F through L present the Field Duplicate Summaries, TCLP Results, Engineering Parameter Results, Quality Assurance and Quality Control Summaries, Sampling Summaries, Data and Frequency Summaries, and Statistical Summaries, respectively, for the various media at Site 30.

23.1 Data Quality

The entire data set generated during the RI was submitted for third-party data validation to Heartland Environmental Services, Inc. Procedures stipulated by the National Functional Guidelines for Organic (USEPA, 1991a) and Inorganic (USEPA, 1988) Analyses were adhered to during the validation process. Validation of the analytical data, through established procedures, served to reduce the inherent uncertainties associated with its usability. Data qualified as "J" were retained as estimated. Estimated analytical results within a data set are common and considered to be usable by the USEPA. Data may be qualified as estimated for several reasons including an exceedence of holding times, high or low surrogate recovery, or intra-sample variability. In addition, values may be assigned an estimated "J" qualifier if the reported value is below the Contract Required Detection Limit (CRDL) or the Contract Required Quantitation Limit (CRQL). Data assigned a rejected "R" qualifier were excluded from the usable data set. The entire Site 30 data set included analyses for over 3,500 separate contaminants in environmental media. However, none of those analyses were rejected as unusable.

Additional data qualifiers were employed during the validation of data. The "NJ" qualifier denotes that a compound was tentatively identified, but the reported value may not be accurate or precise. Compounds that were not detected and had inaccurate or imprecise quantitation limits were assigned the "UJ" qualifier.

23.1.1 Data Management and Tracking

The management and tracking of data from the time of field collection to receipt of the validated electronic analytical results is of primary importance and reflects the overall quality of analytical results. Field samples and their corresponding analytical tests were recorded on the chain-of-custody sheets, which have been provided in Appendix C. The chain-of-custody forms were checked against the Field Sampling and Analysis Plan (Baker, 1993a) to determine if all designated samples were collected for the appropriate parameters. Upon receipt of the laboratory results, a comparison to the field information was made to determine if each sample received by the laboratory was analyzed for the correct parameters. Similarly, the validated information was compared to the laboratory information as a final check. In summary, the tracking information was used to identify the following items:

- Identify sample discrepancies between the analysis plan and the field investigation
- Verify that the laboratory received all samples and analyzed for the correct parameters
- Verify that the data validator received a complete data set
- Ensure that a complete data set was available for each media of concern prior to entering results into the database

23.2 Non-Site Related Analytical Results

Many of the organic and inorganic constituents detected in various media at Site 30 are attributable to non-site related conditions or activities. Two primary sources of non-site related results include laboratory contaminants and naturally-occurring inorganic contaminants. In addition, non-site related operational activities and conditions may contribute to "on-site" contamination. A discussion of non-site related analytical results for Site 30 is provided in the following subsections.

23.2.1 Laboratory Contaminants

Blank samples provide a measure of contamination that has been introduced into a sample set during the collection, transportation, preparation, and/or analysis of samples. To remove non-site related contaminants from further consideration, the concentrations of chemicals detected in blanks were compared with concentrations of the same chemicals detected in environmental samples.

Common laboratory contaminants (i.e., acetone, 2-butanone, chloroform, methylene chloride, toluene, and phthalate esters) were considered as positive results only when observed concentrations exceeded ten times the maximum concentration detected in any blank. If the concentration of a common laboratory contaminant was less than ten times the maximum blank concentration, then it was concluded that the chemical was not detected in that particular sample (USEPA, 1989). The maximum concentrations of detected common laboratory contaminants in blanks were as follows:

●	Acetone	38 µg/L
●	Methylene Chloride	13 µg/L
●	bis-(2-Ethylhexyl)phthalate	120 µg/L
●	2-Butanone	7 µg/L
●	2-Hexanone	5 µg/L
●	Di-n-octylphthalate	41 µg/L

Blanks containing organic constituents that were not considered common laboratory contaminants (i.e., all other TCL compounds) were considered as positive results only when observed concentrations exceeded five times the maximum concentration detected in any blank (USEPA, 1989). All TCL compounds at less than five times the maximum level of contamination noted in any blank were considered to be not detected in that sample. The maximum concentrations of all other detected blank contaminants were as follows:

●	Chloromethane	10 µg/L
●	Bromomethane	9 µg/L
●	Toluene	2 µg/L

A limited number of solid environmental samples that exhibited high concentrations of tentatively identified compounds (TICs) underwent an additional sample preparation. Medium level sample preparation provides a corrected Contract Required Quantitation Limit (CRQL) based on the volume of sample used for analysis. The corrected CRQL produces higher detection limits than the low level sample preparation. A comparison to laboratory blanks used in the medium level preparation was used to evaluate the relative amount of contamination within these samples.

23.2.2 Naturally-Occurring Inorganic Contaminants

In order to differentiate inorganic contamination due to site operations from naturally-occurring inorganic contaminants in site media, the results of the sample analyses were compared to information regarding background conditions at MCB, Camp Lejeune. The following guidelines were used for each media:

Soil:	MCB, Camp Lejeune Background Soil Samples
Groundwater:	MCB, Camp Lejeune Background Groundwater Samples
Surface Water:	MCB, Camp Lejeune Background Surface Water Samples
Sediment:	MCB, Camp Lejeune Background Sediment Samples

The following subsections address the various comparison criteria used to evaluate the analytical results from soil, groundwater, surface water, and sediment samples collected at Site 30.

23.2.2.1 Soil

In general, chemical-specific ARARs are not available for soil. As a result, base-specific background concentrations have been compiled from a number of locations throughout MCB, Camp Lejeune to evaluate reference levels of inorganic contaminants in the surface and subsurface soil.

Organic contaminants, unlike inorganic contaminants, are not naturally-occurring. Therefore, it is probable that all organic contaminants detected in the surface and subsurface soils are attributable to activities that have or are currently taking place within and surrounding the study areas. Typical background concentration values for inorganic contaminants in soils at MCB, Camp Lejeune are presented in Appendix M. These ranges are based on analytical results of background samples collected in areas not known to have been impacted by operations or disposal activities adjacent to Sites 1, 2, 6, 28, 30, 41, 69, 74, and 78 (refer to Figure 1-2 for site locations throughout MCB, Camp Lejeune). In subsequent sections, which discuss the analytical results of samples collected during the soil investigation, only those inorganic contaminants with concentrations exceeding these ranges will be considered.

In general, background soil samples have been collected outside the known boundaries of those sites listed above and in areas with similar soil types. According to the SCS Soil Survey, the greatest portion of MCB, Camp Lejeune is underlain by a number of similar soil units. Soils found on this portion of the coastal plain are moderately to strongly acidic in nature and are classified under the USCS as SM, SM-SP (i.e., fine sand or loamy fine sand) Section 21.2 provides the locations of background soil borings completed at Site 30 during this investigation.

23.2.2.2 Groundwater

Unlike soil, chemical-specific ARARs are available for evaluation of groundwater analytical results. In the subsequent sections that address the analytical results of samples collected during the groundwater investigation, only those inorganic parameters with concentrations exceeding applicable state or federal regulations will be discussed. In order to supplement comparison criteria, a number of base-specific background (i.e., upgradient) samples were compiled as part of a study to evaluate levels of inorganic contaminants in groundwater at MCB, Camp Lejeune (refer to Appendix M).

Groundwater samples were analyzed for total and dissolved (i.e., "filtered") inorganic parameters. Concentrations of dissolved inorganics were found to be generally lower than total inorganics for each sample, particularly for heavy metals such as chromium, iron, lead, and manganese. A 0.45-micron filter was used in the field to remove small particles of silt and clay that would otherwise be dissolved during sample preservation, yielding higher concentrations of inorganic contaminants. The total metal analyses from unfiltered samples, thus reflect the concentrations of inorganics in the natural lithology and inorganic contaminants dissolved in the groundwater.

Relatively high concentrations of metals in unfiltered groundwater are not considered abnormal, based on experience gained from several other studies at MCB, Camp Lejeune (see Appendix M). The difference between the two analytical results (i.e., total and filtered) is important in terms of understanding and separating naturally-occurring elements (e.g., lead) from contamination by site operations (e.g., lead in gasoline).

USEPA Region IV requires that unfiltered inorganic concentrations be used in evaluating ARARs and risk to human health and the environment. In the subsequent sections, which discuss the groundwater sample analytical results, both total and dissolved inorganics that exceed applicable state or Federal limits will be presented and discussed.

Groundwater in the MCB, Camp Lejeune area is naturally rich in iron and manganese. Iron and manganese concentrations (i.e., total and filtered) in groundwater at MCB, Camp Lejeune often exceed the NCWQS of 300 and 50 μg/L, respectively. Elevated levels of iron and manganese, at concentrations above the NCWQS, were reported in samples collected from a number of base potable water supply wells which are installed at depths greater than 162 feet bgs. (Greenhorne and O'Mara, 1992). Similarly, iron and manganese were detected in samples obtained from the three monitoring wells at Site 30. During the first sampling round, iron and manganese concentrations exceeded the NCWQS but fell within the range of positive sample detections observed elsewhere at MCB, Camp Lejeune. There is no record of any historical use of iron or manganese at Site 30. In light of this, it is assumed that iron and manganese are naturally-occurring inorganic contaminants in groundwater, and their presence is not attributable to site operations.

23.2.2.3 Surface Water

In the subsequent sections which address the analytical results of samples collected during the surface water investigation, only those inorganic parameters with concentrations exceeding applicable state or federal regulatory limits will be discussed. In addition, base-specific background concentrations have been compiled from a number of locations throughout MCB, Camp Lejeune to supplement the evaluation of detected inorganic contaminants in surface water. Typical inorganic background concentration values for surface waters at MCB, Camp Lejeune are presented in Appendix M. These values are based on analytical results of background samples collected upgradient of areas known or suspected to have been impacted by operations or disposal activities. Inorganic parameters detected below these levels are assumed to be naturally-occurring elements.

23.2.2.4 Sediment

Base-specific inorganic background concentrations have been compiled from a number of locations throughout MCB, Camp Lejeune to supplement the evaluation of detected inorganic contaminants in sediment. Those inorganic contaminants that exceed applicable state or Federal regulatory limits were compared against base-specific background concentrations in subsequent sections. Typical inorganic background concentration values for sediments at MCB, Camp Lejeune are presented in Appendix M. These values are based on analytical results of background samples collected upgradient of areas known or suspected to have been impacted by operations or disposal activities. Inorganic parameters detected below these levels are assumed to be naturally-occurring elements.

23.3 Analytical Results

This section presents the results of the soil, groundwater, surface water, and sediment investigations performed at Site 30. A summary of site contamination, by media, is provided in Table 23-1.

23.3.1 Soil Investigation

Unique sample notations were employed to identify soil sampling locations and sample depths at Site 30. Samples designated with the prefix "GW" were collected from monitoring well pilot test borings. The following suffix designations refer to the depth at which a sample was obtained:

00 - ground surface to 12 inches bgs
01 - 1 to 3 feet bgs
02 - 3 to 5 feet bgs
03 - 5 to 7 feet bgs
04 - 7 to 9 feet bgs
05 - 9 to 11 feet bgs

Surface soil positive detection summaries for organic and inorganic contaminants are presented in Tables 23-2 and 23-3, respectively. Positive detection summaries of organic contaminants in subsurface soils are presented in Table 23-4; summaries for inorganic contaminants are provided in Table 23-5. The majority of soil samples collected at Site 30 were analyzed for TCL volatile and semivolatile organics and TAL inorganics using CLP protocols and Level IV data quality. A total of three surface and three subsurface soil samples were analyzed for TAL inorganics only. In addition, a limited number of soil samples underwent analyses for total petroleum hydrocarbons (TPH).

23.3.1.1 Surface Soil

A total of 14 surface soil samples were collected at Site 30. Eleven of those 14 samples were analyzed for both TCL volatile and semivolatile organics and TAL inorganics. As indicated on Table 23-1, the volatile organic compound 1,1,1-trichloroethane was detected in two surface soil samples retained from Site 30. The VOC 1,1,1-trichloroethane was detected at estimated concentrations of 2 J and 3 J µg/Kg from soil borings 30-SB06 and 30-SB07, respectively. Soil borings 30-SB06 and 30-SB07 are located adjacent to one another, north of the tank trail. No other positive detections of volatile or semivolatile organic compounds were observed among surface soil samples.

Fourteen of 23 TAL inorganics were detected in the 14 surface soil samples retained from Site 30 (antimony, arsenic, beryllium, cadmium, cobalt, nickel, selenium, silver, and thallium were not detected). None of the positive detections of priority pollutant metals exceeded base-specific (i.e., MCB, Camp Lejeune) background levels for surface soil (refer to Appendix M for base-specific inorganic background concentrations). Priority pollutant metals are a subset of TAL metals and include antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.

23.3.1.2 Subsurface Soil

A total of 14 subsurface (i.e., greater than one-foot bgs) soil samples from Site 30 were submitted for laboratory analysis. Eleven of the 14 samples were analyzed for TCL volatile and semivolatile organics and TAL metals, the remaining three subsurface soil samples were analyzed for TAL metals only. Results of these analyses indicate the presence of the organic compound 1,1,1-trichloroethane. The VOC 1,1,1-trichloroethane was detected at an estimated concentration of 2 J µg/Kg in sample 30-SB09, located near the center of the suspected disposal area. No other positive detections of volatile or semivolatile organic compounds were observed among subsurface soil samples.

Seventeen of 23 TAL inorganics were detected in subsurface soils at Site 30 (antimony, beryllium, cadmium, selenium, silver, and thallium were not detected). Chromium was the only TAL metal detected in subsurface soil at concentrations greater than base-specific inorganic background levels (refer to Appendix M for base-specific inorganic background concentrations). As indicated on Table 23-1, base-specific background chromium concentrations ranged from 0.7 to 10.5 µg/kg. The maximum chromium concentration among subsurface soil samples at Site 30 was 13.2 µg/kg. Four of the 12 chromium detections slightly exceeded the maximum base-specific background concentration. The four detections were scattered throughout the study area.

23.3.2 Groundwater Investigation

The groundwater investigation at Site 30 entailed the collection of three groundwater samples obtained from one newly installed and two existing shallow monitoring wells. The newly installed monitoring well, 30-GW03, was situated approximately 300 yards upgradient of the study area. Groundwater samples collected at Site 30 were analyzed for TCL volatile and semivolatile organics and TAL inorganics, both total and dissolved fractions, using CLP protocols and Level IV data quality. (Dissolved or filtered TAL inorganic results are presented in this report for comparative purposes only. These results were not used to evaluate site-related risks or to determine compliance with groundwater standards.)

A second, supplemental, round of samples was collected from each of the three shallow monitoring wells at Site 30. The analytical results from both sampling rounds are provided in the following subsections. Positive detection summaries of organic compounds from both the first and second sampling rounds are provided in Tables 23-6 and 23-9, respectively. No semivolatile organic compounds were detected in samples acquired during either sampling round. Total metal results from the first and second sampling rounds are presented in Tables 23-7 and 23-10, respectively. In addition, Tables 23-8 and 23-11 provide positive detection summaries for dissolved metals in groundwater samples obtained during the two sampling rounds. A comparison of analytical results from both rounds of groundwater samples is provided in Table 23-12.

Round One

A total of three shallow groundwater samples from Site 30 were submitted for laboratory analysis. The samples were collected from the uppermost portion of the surficial aquifer (i.e., the water table). As indicated in Table 23-1, the detection of organic compounds was limited to monitoring well 30-GW01, located near the center of the study area. Chloroform was the only organic compound identified during the first sampling round, at a concentration of 9 µg/L.

TAL metals, both total and dissolved fractions, were detected in samples obtained from each of the three monitoring wells at Site 30. Complete positive detection summaries for total and dissolved metal results are provided in Tables 23-7 and 23-8, respectively. Seventeen of the 23 TAL total metals were detected within at least one groundwater sample at Site 30 (antimony, beryllium, cadmium, silver, selenium, and thallium were not detected). Eleven of 23 TAL dissolved metals were also detected within at least one of the three groundwater samples (arsenic, beryllium, cadmium, cobalt, chromium, lead, mercury, silver, selenium, thallium, vanadium, and zinc were not detected). Chromium, iron, lead, and manganese were each detected among the three groundwater samples from Site 30 at concentrations that exceeded either Federal or state standards for total metals. Chromium, iron, lead, and manganese were detected at maximum concentrations of 111 J, 41,400 J, 59.1, and 181 µg/L, respectively. None of these positive detections, in excess of either MCL or NCWQS, were above base-specific background levels (refer to Appendix M).

Round Two

During the second sampling round, groundwater samples from each of the three shallow monitoring wells at Site 30 were submitted for laboratory analysis of TAL metals, both total and dissolved fractions, TDS, and TSS. Additionally, one groundwater sample from 30-GW01 was submitted for volatile organic analysis. Chloroform was once again detected in a groundwater sample obtained from 30-GW01. As indicted in Table 23-9, chloroform was detected at an estimated concentration of 3 J µg/L from 30-GW01. No other VOCs were detected.

Total and dissolved TAL metals were detected in each of the three shallow groundwater samples submitted for analysis from Site 30. Positive detection summaries for round two total and dissolved metal analyses are provided in Tables 23-10 and 23-11, respectively. Ten of 23 TAL total metals were detected in at least one shallow groundwater sample from Site 30 (antimony, arsenic, beryllium, cadmium, cobalt, copper, mercury, nickel, selenium, silver, thallium, vanadium, and zinc were not detected). Eight of 23 TAL dissolved metals were also detected within at least one of the three groundwater samples (aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, mercury, nickel, selenium, silver, thallium, vanadium and zinc were not detected). Iron was detected during the second sampling round at a concentration in excess of the 300 µg/L NCWQS, based on total metal analyses. Iron was detected at a concentration of 692 µg/L in sample 30-GW03, located approximately 300 yards upgradient of the study area. Table 23-12 provides a comparison of round one versus round two sampling results.

23.3.3 Surface Water Investigation

Environmental samples were collected from Frenchs Creek as part of the surface water investigation at Site 30. A total of three surface water samples were collected. Each of the surface water samples was analyzed for TCL volatile and semivolatile organics and TAL inorganics, using CLP protocols and Level IV data quality. Table 23-1 provides a summary of surface water results. Total metal results of samples retained from Frenchs Creek are presented in Table 23-13. Volatile and semivolatile organic compounds were not detected in any of three surface water samples.

Eleven of 23 TAL total metals were positively identified in the three surface water samples submitted for laboratory analysis from Frenchs Creek. As depicted in Table 23-1, lead and mercury were the only metals identified at concentrations in excess of either NOAA chronic screening values or NCWQS. Both lead and mercury detections were observed in sample 30-SW01, located upgradient of the study area. Lead and mercury were detected at concentrations of 2.3 J and 0.15 µg/L, respectively. No other total metal concentrations were in excess of screening values.

23.3.4 Sediment Investigation

Environmental samples were collected from Frenchs Creek as part of the sediment investigation at Site 30. A total of six sediment samples, two from each sampling station, were collected. At each sampling station a sample was collected from zero to six inches and also from six to twelve inches below the surface water and sediment interface. Each of the sediment samples was analyzed for TCL volatile and semivolatile organics and TAL inorganics, using CLP protocols and Level IV data quality. Table 23-1 provides a summary of contaminants in Frenchs Creek sediments. A positive detection summary of organic compounds found in Frenchs Creek is provided in Table 23-14. A positive detection summary of total metal results is presented in Table 23-15.

Volatile organic compounds were not detected among the six sediment samples retained for analysis from Frenchs Creek. The SVOC bis(2-ethylhexyl)phthalate (BEHP) was detected in two Frenchs Creek sediment samples. The concentrations of BEHP at locations 30-SD01 and 30-SD03 were 3,900 and 2,600 µg/kg, respectively. Both detections were in excess of the 1,200 µg/kg laboratory contaminant level and, therefore, are considered to represent an actual observation. Sixteen of 23 TAL metals were detected in at least 1 of the 6 sediment samples from Frenchs Creek. No TAL metal concentrations among the six sediment samples exceeded NOAA ER-L screening values.

23.4 Extent of Contamination

This section addresses the extent of contamination within soil, groundwater, surface water, and sediment environmental media at OU No. 7, Site 30.

23.4.1 Extent of Soil Contamination

Positive detections of organic compounds in surface and subsurface soil samples collected at Site 30 are depicted on Figures 23-1 and 23-2, respectively. The following subsection details the presence of organic contaminants in soil samples obtained from Site 30. As addressed in Section 23.3.1, none of the 28 samples submitted for analysis had TAL metal concentrations above base-specific background levels (see Appendix M), and therefore, the extent of metals contamination in soils at Site 30 will not be addressed. Additionally, semivolatile contaminants were not detected in any of the soil samples submitted for analysis. As a result of those analyses, the extent of semivolatile contamination in soil will not be addressed.

23.4.1.1 Volatiles

The only volatile compound identified within soils at Site 30 was 1,1,1-trichloroethane. Three positive detections were recorded in samples retained from the northern central portion of the study area. The VOC 1,1,1-trichloroethane was detected within two surface and one subsurface soil samples at very low concentrations (i.e., less than 3 J µg/kg). Given the limited extent, location along the tank trail, and low concentration of volatile contamination at Site 30, the presence of VOCs in soil is most likely the result of incidental equipment maintenance.

23.4.2 Extent of Groundwater Contamination

Positive detections of organic compounds in shallow groundwater samples collected at Site 30 are depicted on Figure 23-3. As addressed in Section 23.3.2, semivolatile contaminants were not detected in any of the groundwater samples submitted for analysis from Site 30. As a result of those analyses, the extent of SVOC contamination in groundwater will not be addressed.

23.4.2.1 Volatiles

Chloroform was the only volatile organic compound detected among the three groundwater samples obtained from Site 30. The single positive detection of chloroform was observed in a shallow groundwater sample obtained from monitoring well 30-GW01, located near the center of the suspected disposal area. Chloroform was detected at the trace concentrations of 9 and 3 J µg/L during the first and second sampling rounds, respectively. The lack of positive VOC detections in a sample obtained from a downgradient shallow monitoring well suggests that volatile contaminants have not migrated from the suspected disposal area. In addition, chloroform was not detected in any of the surrounding surface and subsurface soil samples. The residual level (i.e., less than 10 µg/L) of chloroform that was observed during both sampling rounds, is probably the result of incidental spillage of a small quantity rather than disposal. The entire area is used as for training and operation of mechanized vehicles, which may explain the presence of chloroform at this low concentration.

23.4.2.2 Metals

Inorganic contaminants were detected in each of the three groundwater samples submitted for analysis from Site 30. Iron was the only TAL total metal detected at levels in excess of either Federal MCL or North Carolina WQS criteria (see Table 23-1). A single positive detection of iron from the upgradient shallow monitoring well 30-GW03 exceeded the NCWQS of 300 µg/L. The iron detection of 692 µg/L in sample 30-GW03 did not exceed base-specific inorganic background concentrations. This concentration of iron is indicative of natural site conditions rather than disposal activities.

The decrease of total metal concentrations between the first and second sampling rounds was the result of modified sample acquisition procedures. Elevated total metals have been recorded at other MCB, Camp Lejeune sites and are likely the consequence of loose surficial soils. During the resampling, a low flow purge method was utilized to minimize the presence suspended solids or colloids in samples that are associated with the surficial soils. The resulting data set yielded a more accurate assessment of existing conditions. The DoN is currently evaluating the presence and distribution of total and dissolved metals in groundwater throughout the facility. The draft report "Evaluation of Metals in Groundwater at MCB, Camp Lejeune, North Carolina," (Baker, 1994) addressed the pervasiveness of total metals in groundwater and identified a number of potential causes. Preliminary conclusions of the study support the opinion that total metal concentrations in groundwater are due more to geologic conditions (i.e., naturally occurring concentrations and unconsolidated soils) and sample acquisition methods than to actual metal concentrations in the surficial aquifer.

23.4.3 Extent of Surface Water Contamination

Volatile and semivolatile organic contaminants were not detected in the three surface water samples submitted for analysis from Site 30 (see Section 23.3.3). As a result of those analyses, the extent of volatile and semivolatile contamination in surface water will not be addressed. Figure 23-4 presents TAL metal sampling results in excess of Federal or state surface water screening values. A summary of site contamination is presented in Table 23-1.

23.4.3.1 Metals

Lead and mercury were each identified once among the three Frenchs Creek surface water samples and, in both cases, at concentrations in excess of surface water screening values. As depicted on Figure 23-4, both lead and mercury were detected in excess of surface water screening values at sample station 30-SW01, located upgradient of the study area. Lead and mercury were detected at trace concentrations of 2.3 J and 0.15 µg/L, respectively. Frenchs Creek serves as the main drainage for the Combat Town Training Area. The use of mechanized vehicles throughout this area may help to explain the localized occurrence of both lead and mercury in the upgradient surface water sample.

23.4.4 Extent of Sediment Contamination

Positive detections of organic compounds in sediment samples collected at Site 30 are depicted on Figure 23-5. A summary of site contamination is presented in Table 23-1. As addressed in Section 23.3.4, VOCs were not detected in any of the six sediment samples submitted for analysis from Site 30. In addition, none of the total metals in sediment samples were detected in excess of screening values. As a result of these analyses, the extent of volatile organic and inorganic contamination in sediment will not be addressed.

23.4.4.1 Semivolatiles

As indicated on Figure 23-5, the semivolatile compound BEHP was positively detected in two of the six Frenchs Creek sediment samples. The two concentrations of BEHP were 2,600 and 3,900 µg/kg. The higher of the two positive BEHP detections was observed at sample station 30-SD01, located upgradient of the study area. The presence of semivolatile compounds in sediments is not uncommon in areas of high traffic. As previously mentioned, Site 30 is within the Combat Town Training Area and vehicles frequently use the area.

SECTION 23.0 TABLES

TABLE 23-1

SUMMARY OF SITE CONTAMINATION
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MCB, CAMP LEJEUNE, NORTHCAROLINA

Media	Fraction	Contaminants	Comparison Criteria		Site Contamination				
			ARAR	Base Background	Min.	Max.	Max. Location	Detection Frequency	Spatial Distribution
Surface Soil	Volatiles	1,1,1-Trichloroethane	NA	NA	2 J	3 J	30-SB07	2/11	both detections north of tank trail
	Semivolatiles	ND	NA	NA				0/11	
	Metals (1)	ND	NA	BB				0/14	
Subsurface Soil	Volatiles	1,1,1-Trichloroethane	NA	NA	2 J	2 J	30-SB09	1/11	center of suspected disposal area
	Semivolatiles	ND	NA	NA				0/11	
	Metals (1)	Chromium	NA	0.7 - 10.5	1.5	13.2	30-SB06	12/14	4 exceed BB, scattered
Groundwater	Volatiles (2)	Chloroform	NCWQS - 1.9	NA	3 J	9	30-GW01	1/3	1 exceeds ARAR, both rounds
	Semivolatiles	ND	MCL/NCWQS	NA				0/3	
	Total Metals (3)	Iron	NCWQS - 300	BB	692	692	30-GW03	1/3	1 exceeds ARAR, upgradient
Surface Water	Volatiles	ND	NOAA/NCWQS	NA				0/3	
	Semivolatiles	ND	NOAA/NCWQS	NA				0/3	
	Metals (3)	Lead	NOAA - 1.32	1.2 - 10.4	2.3 J	2.3 J	30-SW01	1/3	1 exceeds ARAR, upgradient
		Mercury	NCWQS - 0.012	0.52	0.15	0.15	30-SW01	1/3	1 exceeds ARAR, upgradient
Sediment	Volatiles	ND	NA	NA				0/6	
	Semivolatiles	BEHP	NA	NA	74 J	3,900	30-SD01	6/6	2 exceed 10X lab/blank contaminant
	Metals (3)	ND	NOAA	BB				0/6	

Notes:

- Concentrations are presented in µg/L for liquid and µg/Kg for solids (ppb), metal concentrations for soils and sediments are presented in mg/Kg (ppm).

(1) Metals in both surface and subsurface soils were compared to the range of base background positive detections for priority pollutant metals only (i.e., antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc).

(2) An additional groundwater sample was collected from the well (30-GW01) which exhibited concentrations of volatiles during the first round.

(3) Metals in groundwater, surface water, and sediment were compared to the range of positve detections in upgradient samples at MCB, Camp Lejeune.

ARAR - Applicable or Relevant and Appropriate Requirements
BB - Base background (refer to Appendix M)
BEHP - bis(2-ethylhexyl)phthalate
NA - Not applicable
NCWQS - North Carolina Water Quality Standard
ND - Not detected
NOAA - National Oceanic and Atmospheric Administration
MCL - Federal Maximum Contaminant Level
PAH - Polynuclear aromatic hydrocarbon

TAB. 3-2
SURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
VOLATILES AND SEMIVOLATILES

Sample ID:		30-SB06-00	30-SB07-00	30-SB08-00	30-SB09-00
Sample Depth:		0-1'	0-1'	0-1'	0-1'
Date Sampled:		3/23/94	3/22/94	3/23/94	3/23/94
	UNITS				
VOLATILES					
Acetone	UG/KG	10 J	10 J	25	ND
1,1,1-Trichloroethane	UG/KG	2 J	3 J	ND	ND
SEMIVOLATILES					
bis(2-Ethylhexyl)phthalate	UG/KG	ND	ND	ND	37 J

UG/KG - micrograms per kilogram
J - estimated
ND - not detected

TAB[illegible]-3
SURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

Sample ID:		30-SB01-00	30-SB02-00	30-SB03-00	30-SB04-00	30-SB05-00	30-SB06-00	30-SB07-00	30-SB08-00	30-SB09-00	30-SB10-00
Sample Depth:		0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'	0-1'
Date Sampled:		3/22/94	3/23/94	3/22/94	3/23/94	3/22/94	3/23/94	3/22/94	3/23/94	3/23/94	3/22/94
	UNITS										
Aluminum	MG/KG	56.0	77.6	61.2	39.0	596	104	254	167	198	237
Barium	MG/KG	ND	ND	ND	ND	2.2	2.2	1.5	ND	ND	1.5
Calcium	MG/KG	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	MG/KG	1.4	ND	ND	ND	ND	ND	1.4	2.0	1.9	ND
Copper	MG/KG	ND	ND	ND	ND	2.3	ND	ND	1.1	ND	ND
Iron	MG/KG	167	205	153	194	470	156	295	179	359	247
Lead	MG/KG	ND	1.6	ND	1.6	3.2	1.9	2.2	1.8	1.5	3.7
Magnesium	MG/KG	ND	7.1	7.3	5.6	13.3	9.2	7.5	5.8	ND	7.4
Manganese	MG/KG	4.7 J	5.7 J	5.3 J	8.6 J	6.0 J	5.1 J	8.0 J	4.4 J	5.7 J	2.6 J
Mercury	MG/KG	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND
Potassium	MG/KG	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.5
Sodium	MG/KG	8.4	ND	20.1	10.1	19.2	18.3	15.9	16.1	9.4	ND
Vanadium	MG/KG	1.5	1.4	1.7	1.6	1.8	1.0	1.7	1.1	2.0	1.2
Zinc	MG/KG	ND	ND	ND	ND	5.7	ND	ND	ND	ND	ND

MG/KG - milligrams per kilogram
J - estimated
ND - not detected

TAB [illegible] 3-3
SURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-SB11-00		30-SB18-00	30-SB19-00		30-SB20-00
	Sample Depth:	0-1'		0-1'	0-1'		0-1'
	Date Sampled:	3/22/94		4/8/94	4/8/94		4/8/94
	<u>UNITS</u>						
Aluminum	MG/KG	1390		222	1060		159
Barium	MG/KG	2.3		2.2	2.1		1.6
Calcium	MG/KG	ND		ND	92.1	J	ND
Chromium	MG/KG	1.6		ND	ND		ND
Copper	MG/KG	1.0		ND	1.5		1.4
Iron	MG/KG	1050		266	607		241
Lead	MG/KG	8.0		3.3	2.7		2.5
Magnesium	MG/KG	31.1		11.3	39.4		9.4
Manganese	MG/KG	4.1	J	8.3	7.8		8.3
Mercury	MG/KG	0.07		ND	ND		ND
Potassium	MG/KG	19.3		ND	ND		ND
Sodium	MG/KG	ND		ND	ND		ND
Vanadium	MG/KG	3.0		1.9	3.1		1.4
Zinc	MG/KG	ND		1.9	3.1		1.4

MG/KG - milligrams per kilogram
J - estimated
ND - not detected

TAB -4
SUBSURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
VOLATILES AND SEMIVOLATILES

Sample ID:		30-SB01-04	30-SB03-03	30-SB05-03	30-SB06-03	30-SB07-03	30-SB08-02	30-SB09-02	30-SB10-03	30-SB11-03
Sample Depth:		7-9'	5-7'	5-7'	5-7'	5-7'	3-5'	3-5'	5-7'	5-7'
Date Sampled:		3/22/94	3/22/94	3/22/94	3/23/94	3/22/94	3/23/94	3/23/94	3/22/94	3/22/94
	UNITS									
VOLATILES										
Acetone	UG/KG	34	ND	ND	9 J	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	UG/KG	ND	ND	ND	ND	ND	ND	2 J	ND	ND
SEMIVOLATILES										
bis(2-Ethylhexyl)phthalate	UG/KG	110 J	140 J	100 J	ND	720	45 J	ND	380	810

UG/KG - micrograms per kilogram
J - estimated
ND - not detected

TAB[illegible]-5
SUBSURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-SB01-04	30-SB02-03	30-SB03-03	30-SB04-03	30-SB05-03	30-SB06-03	30-SB07-03	30-SB08-02	30-SB09-02	30-SB10-03
	Sample Depth:	7-9'	5-7'	5-7'	5-7'	5-7'	5-7'	5-7'	3-5'	3-5'	5-7'
	Date Sampled:	3/22/94	3/23/94	3/22/94	3/23/94	3/22/94	3/23/94	3/22/94	3/23/94	3/23/94	3/22/94
Percent Solids		85.0	87.0	83.0	83.0	71.0	82.0	86.0	86.0	90.0	89.0
	<u>UNITS</u>										
Aluminum	MG/KG	1010 J	1130	2270 J	9110	3200 J	8810	1300 J	1050	1170	6130 J
Arsenic	MG/KG	ND	ND	ND	1.4	1.1	1.3	ND	ND	ND	0.62
Barium	MG/KG	1.2	ND	ND	5.6	3.2	4.4	ND	ND	1.6	5.1
Calcium	MG/KG	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	MG/KG	5.9 J	4.2	4.2 J	10.9	4.1	13.2	1.6 J	2.1	1.5	10.7 J
Cobalt	MG/KG	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	MG/KG	1.8	ND	ND	3.0	1.4	5.2	ND	ND	ND	3.4
Iron	MG/KG	762 J	249	134 J	4080	1610 J	2980	536 J	448	615	2850 J
Lead	MG/KG	1.6	1.6	3.0	2.5	2.8	3.6	ND	1.7	1.6	3.1
Magnesium	MG/KG	13.4	7.9	ND	88.0	38.6	80.1	9.0	16.3	20.4	66.1
Manganese	MG/KG	8.4 J	4.5 J	2.9 J	4.7 J	9.8 J	3.4 J	6.4 J	3.1 J	4.0 J	5.6 J
Mercury	MG/KG	ND	0.07	0.19	0.37	ND	ND	0.06	0.08	ND	0.06
Nickel	MG/KG	1.8	ND	ND	ND	2.0	ND	3.5	ND	ND	2.5
Potassium	MG/KG	17.8	ND	ND	ND	40.8	ND	ND	ND	6.2	58.2
Sodium	MG/KG	ND	20.3	ND	10.7	ND	19.3	ND	23.8	ND	ND
Vanadium	MG/KG	1.7	1.4	0.73	9.6	4.2	6.7	1.4	1.4	1.7	6.4
Zinc	MG/KG	1.1	ND	0.70	ND	1.4	ND	ND	ND	ND	1.5

MG/KG - milligrams per kilogram
ND - not detected
J - estimated

TABLE -5
SUBSURFACE SOIL - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-SB11-03	30-SB18-03	30-SB19-02	30-SB20-03
	Sample Depth:	5-7'	5-7'	3-5'	5-7'
	Date Sampled:	3/22/94	4/8/94	4/8/94	4/8/94
Percent Solids		89.0	82.7	85.8	84.8
	<u>UNITS</u>				
Aluminum	MG/KG	327	9730	2480	2530
Arsenic	MG/KG	ND	0.99	ND	ND
Barium	MG/KG	ND	11.0	2.2	3.7
Calcium	MG/KG	ND	41.3 J	33.8 J	ND
Chromium	MG/KG	1.6	11.6	ND	ND
Cobalt	MG/KG	0.66	1.0	ND	ND
Copper	MG/KG	0.97	4.4	1.9	1.5
Iron	MG/KG	204	2790	542	2460
Lead	MG/KG	1.4	4.4	3.0	3.6
Magnesium	MG/KG	9.8	171	50.0	47.3
Manganese	MG/KG	2.2 J	6.9	5.2	6.5
Mercury	MG/KG	ND	ND	ND	ND
Nickel	MG/KG	ND	2.9 J	ND	ND
Potassium	MG/KG	8.4	151	ND	ND
Sodium	MG/KG	ND	ND	ND	ND
Vanadium	MG/KG	0.97	9.7	3.1	7.1
Zinc	MG/KG	ND	2.1	0.91	1.5

MG/KG - milligrams per kilogram
ND - not detected
J - estimated

TABL -6
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
VOLATILES AND SEMIVOLATILES

	Sample ID:	30-GW01-01
	Date Sampled:	4/21/94
	UNITS	
VOLATILES		
Chloroform	UG/L	9

UG/L - micrograms per liter

TABLE 3-7
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO -0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-GW01-01		30-GW02-01		30-GW03-01	
	Date Sampled:	4/21/94		4/21/94		4/21/94	
	UNITS						
Aluminum	UG/L	42700		136000	J	24700	
Arsenic	UG/L	3.7		25.8		ND	
Barium	UG/L	48.0		126		42.7	
Calcium	UG/L	953		2220		1610	
Chromium	UG/L	36.7	J	111	J	27.8	J
Cobalt	UG/L	ND		10.5	J	ND	
Copper	UG/L	11.2		27.8		9.6	
Iron	UG/L	9930		41400	J	4930	
Lead	UG/L	59.1		27.6	J	14.8	
Magnesium	UG/L	1850		7300		1550	
Manganese	UG/L	38.8		181		46.6	
Mercury	UG/L	ND		0.13		0.32	J
Nickel	UG/L	21.7		61.2		ND	
Potassium	UG/L	1600		7440	J	704	
Sodium	UG/L	4180		8980		8600	
Vanadium	UG/L	31.9		123		14.1	
Zinc	UG/L	ND		237		ND	

UG/L - micrograms per liter
J - estimated
ND - not detected

TABL -8
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
DISSOLVED METALS

	Sample ID:	30-GW01D-01	30-GW02D-01	30-GW03D-01
	Date Sampled:	4/21/94	4/21/94	4/21/94
	UNITS			
Aluminum	UG/L	135	ND	109
Antimony	UG/L	ND	37.9 J	ND
Barium	UG/L	9.0	17.3	ND
Calcium	UG/L	1020	2560	1200
Copper	UG/L	ND	ND	6.5
Iron	UG/L	ND	141 J	1040
Magnesium	UG/L	643	1170	877
Manganese	UG/L	ND	46.4	23.3
Nickel	UG/L	ND	ND	7.8
Potassium	UG/L	ND	625 J	ND
Sodium	UG/L	4580	9810	7920

UG/L - micrograms per liter
J - estimated
ND - not detected

TABLE [illegible]-9
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 2
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
VOLATILES

Sample ID:		30-GW01-02
Date Sampled:		11/11/94
	UNITS	
Chloroform	UG/L	3 J

UG/L - micrograms per liter
J - estimated

TAB. -10
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
DISSOLVED METALS

	Sample ID:	30-GW01D-01	30-GW02D-01	30-GW03D-01
	Date Sampled:	4/21/94	4/21/94	4/21/94
	UNITS			
Aluminum	UG/L	135	ND	109
Antimony	UG/L	ND	37.9 J	ND
Barium	UG/L	9.0	17.3	ND
Calcium	UG/L	1020	2560	1200
Copper	UG/L	ND	ND	6.5
Iron	UG/L	ND	141 J	1040
Magnesium	UG/L	643	1170	877
Manganese	UG/L	ND	46.4	23.3
Nickel	UG/L	ND	ND	7.8
Potassium	UG/L	ND	625 J	ND
Sodium	UG/L	4580	9810	7920

UG/L - micrograms per liter
J - estimated
ND - not detected

TAB -11
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 2
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
DISSOLVED METALS

Sample ID:		30-GW01D-02	30-GW02D-02	30-GW03D-02
Date Sampled:		11/11/94	11/11/94	11/11/94
	UNITS			
Barium	UG/L	15.4	12.3	23.7
Calcium	UG/L	1180	1660	2050
Copper	UG/L	10.4	9.2	ND
Iron	UG/L	ND	ND	406
Magnesium	UG/L	728	759	1300
Manganese	UG/L	9	25.9	14.3
Potassium	UG/L	199	426	387
Sodium	UG/L	4090	4790	15100

UG/L - micrograms per liter
ND - not detected

TABLE 23-12

COMPARISON OF GROUNDWATER ANALYTICAL RESULTS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Detected Contaminants	Round 1 Results				Round 2 Results			
	Min.	Max.	Freq.	Max. Location	Min.	Max.	Freq.	Max. Location
Volatiles								
Chloroform	9	9	1/3	30-GW01	3 J	3 J	1/3	30-GW01
Total Metals								
Aluminum	24,700	136,000 J	3/3	30-GW02	782	2,210	2/3	30-GW03
Arsenic	3.7	25.8	2/3	30-GW02	ND	ND	0/3	NA
Barium	42.7	126	3/3	30-GW02	15	31.4	3/3	30-GW03
Calcium	953	2,220	3/3	30-GW02	1,720	2,080	2/3	30-GW03
Chromium	27.8 J	111 J	3/3	30-GW02	9.3	9.3	1/3	30-GW01
Cobalt	10.5 J	10.5 J	1/3	30-GW02	ND	ND	0/3	NA
Copper	9.6	27.8	3/3	30-GW02	ND	ND	0/3	NA
Iron	4,930	41,400 J	3/3	30-GW02	692	692	1/3	30-GW03
Lead	14.8	59.1	3/3	30-GW01	1.3	1.8	2/3	30-GW03
Magnesium	1,550	7,300	3/3	30-GW02	566	1,320	3/3	30-GW03
Manganese	38.8	181	3/3	30-GW02	7.7	15.3	3/3	30-GW01
Mercury	0.13	0.32 J	3/3	30-GW03	ND	ND	0/3	NA
Nickel	21.7	61.2	3/3	30-GW02	ND	ND	0/3	NA
Potassium	704	7,440 J	3/3	30-GW02	370	447	2/3	30-GW02
Sodium	4,180	8,980	3/3	30-GW02	3,410	15,000	3/3	30-GW03
Vanadium	14.1	123	3/3	30-GW02	ND	ND	0/3	NA
Zinc	237	237	3/3	30-GW02	ND	ND	0/3	NA
Dissolved Metals								
Aluminum	109	135	2/3	30-GW01	ND	ND	0/3	NA
Antimony	37.9 J	37.9 J	1/3	30-GW02	ND	ND	0/3	NA
Barium	9.0	17.3	2/3	30-GW02	12.3	23.7	3/3	30-GW03
Calcium	1,020	2,560	3/3	30-GW02	1,180	2,050	3/3	30-GW03
Copper	6.5	6.5	1/3	30-GW03	9.2	10.4	2/3	30-GW01
Iron	141 J	1,040	2/3	30-GW03	406	406	1/3	30-GW03
Magnesium	643	1,170	3/3	30-GW02	728	1,300	3/3	30-GW03
Manganese	23.3	46.4	2/3	30-GW02	9.0	25.9	3/3	30-GW02
Nickel	7.8	7.8	1/3	30-GW03	ND	ND	0/3	NA
Potassium	625 J	625 J	1/3	30-GW02	199	426	3/3	30-GW02
Sodium	4,580	9,810	3/3	30-GW02	4,090	15,100	3/3	30-GW03

Notes: Groundwater concentrations are presented in µg/L (ppb)
J - Estimated
NA - Not applicable
ND - Not detected

TABL. -13
SURFACE WATER - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-SW01	30-SW02	30-SW03
	Date Sampled:	3/23/94	3/23/94	3/23/94
	<u>UNITS</u>			
Aluminum	UG/L	1480	383	373
Barium	UG/L	10.2	ND	10.3
Calcium	UG/L	2080	4220	9660
Copper	UG/L	6.0	ND	ND
Iron	UG/L	829	495	595
Lead	UG/L	2.3 J	ND	ND
Magnesium	UG/L	650	700	840
Manganese	UG/L	5.5 J	3.3 J	11.1 J
Mercury	UG/L	0.15	ND	ND
Potassium	UG/L	220	229	321
Sodium	UG/L	4440	5030	4800

UG/L - micrograms per liter
J - estimated
ND - not detected

TAB[illegible]-14
SEDIMENT - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
VOLATILES AND SEMITVOLATILES

Sample ID:		30-SD01-06	30-SD01-612	30-SD02-06	30-SD02-612	30-SD03-06	30-SD03-612
Sample Depth:		0-6"	6-12"	0-6"	6-12"	0-6"	6-12"
Date Sampled:		3/25/94	3/25/94	3/24/94	3/24/94	3/24/94	3/24/94
	UNITS						
VOLATILES							
Acetone	UG/KG	ND	120	ND	ND	ND	63
2-Butanone	UG/KG	ND	30	ND	ND	ND	ND
SEMIVOLATILES							
bis(2-Ethylhexyl)phthalate	UG/KG	500 J	3900	74 J	370 J	2600	770

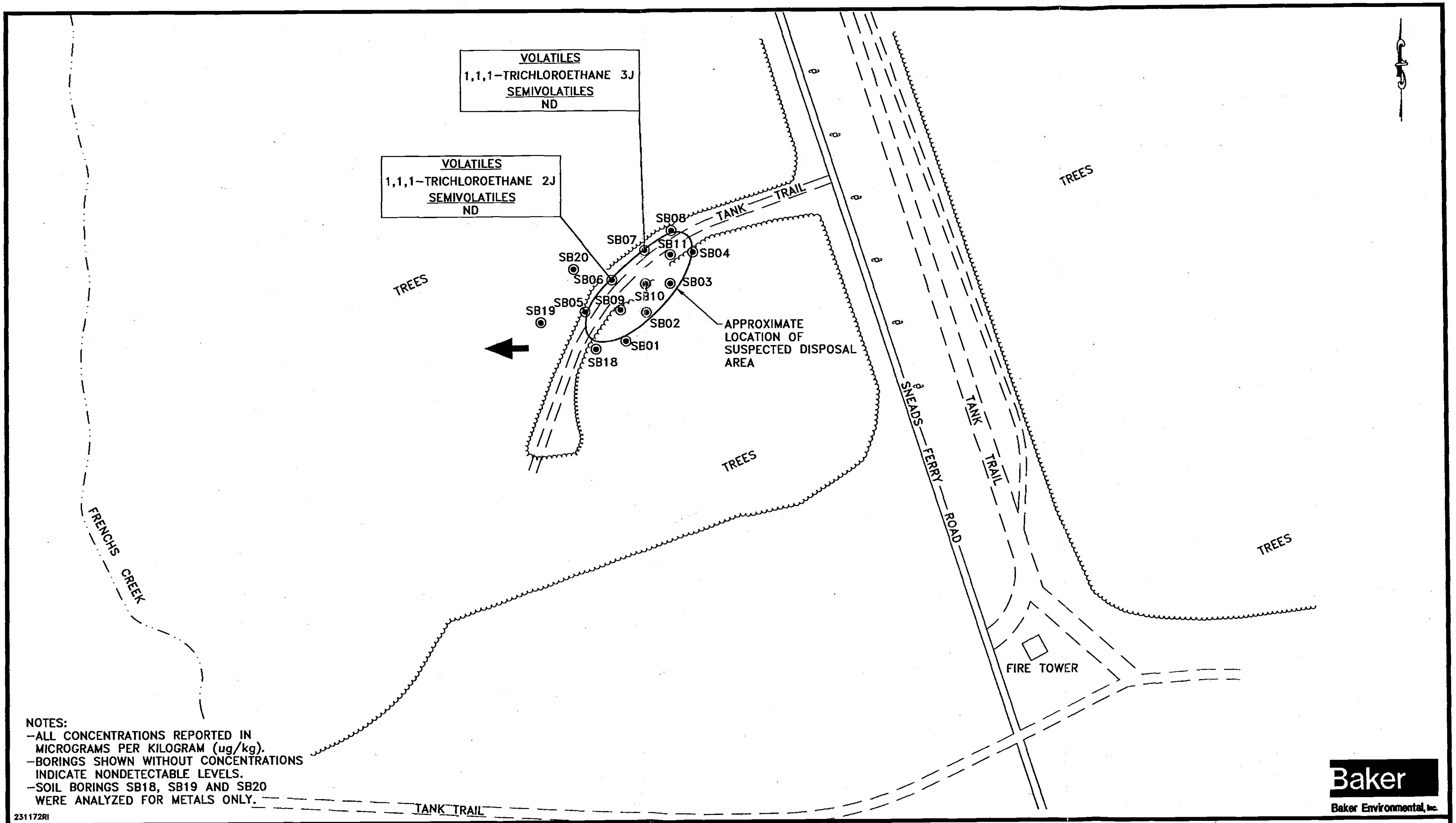
UG/KG - micrograms per kilogram
J - estimated
ND - not detected

TABL -15
SEDIMENT - POSITIVE DETECTION SUMMARY
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO - 0231
MCB, CAMP LEJEUNE, NORTH CAROLINA
TOTAL METALS

	Sample ID:	30-SD01-06	30-SD01-612	30-SD02-06	30-SD02-612	30-SD03-06	30-SD03-612
	Sample Depth:	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"
	Date Sampled:	3/25/94	3/25/94	3/24/94	3/24/94	3/24/94	3/24/94
Percent Solids		30.0	40.0	76.0	75.0	73.0	44.0
	UNITS						
Aluminum	MG/KG	2320	1490	528	2010	636	3390
Barium	MG/KG	9.1	8.0	10.1	4.1	ND	7.1
Beryllium	MG/KG	ND	ND	ND	ND	ND	0.37
Cadmium	MG/KG	ND	ND	0.60	ND	ND	ND
Calcium	MG/KG	646	192	342	127	233	4650
Chromium	MG/KG	7.5	6.1	2.2	2.4	ND	7.9
Cobalt	MG/KG	ND	ND	0.77	ND	ND	ND
Copper	MG/KG	9.5	ND	5.8	2.8	ND	2.3
Iron	MG/KG	755	595	377	643	213	842
Lead	MG/KG	15.5	5.5	3.7	3.7	1.3	2.9
Magnesium	MG/KG	133	116	ND	68.7	24.0	129
Manganese	MG/KG	19.0	8.5	3.9	5.8	3.0	7.5
Nickel	MG/KG	ND	ND	ND	1.9 J	ND	5.8 J
Potassium	MG/KG	102	101	27.4	70.9	37.5	121
Vanadium	MG/KG	5.3	2.9	1.9	3.6	ND	6.0
Zinc	MG/KG	11.3	2.9	9.2	6.6	2.5	6.3

MG/KG - milligrams per kilogram
J - estimated
ND - not detected

SECTION 23.0 FIGURES



NOTES:
- ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
- BORINGS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.
- SOIL BORINGS SB18, SB19 AND SB20 WERE ANALYZED FOR METALS ONLY.

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LEGEND

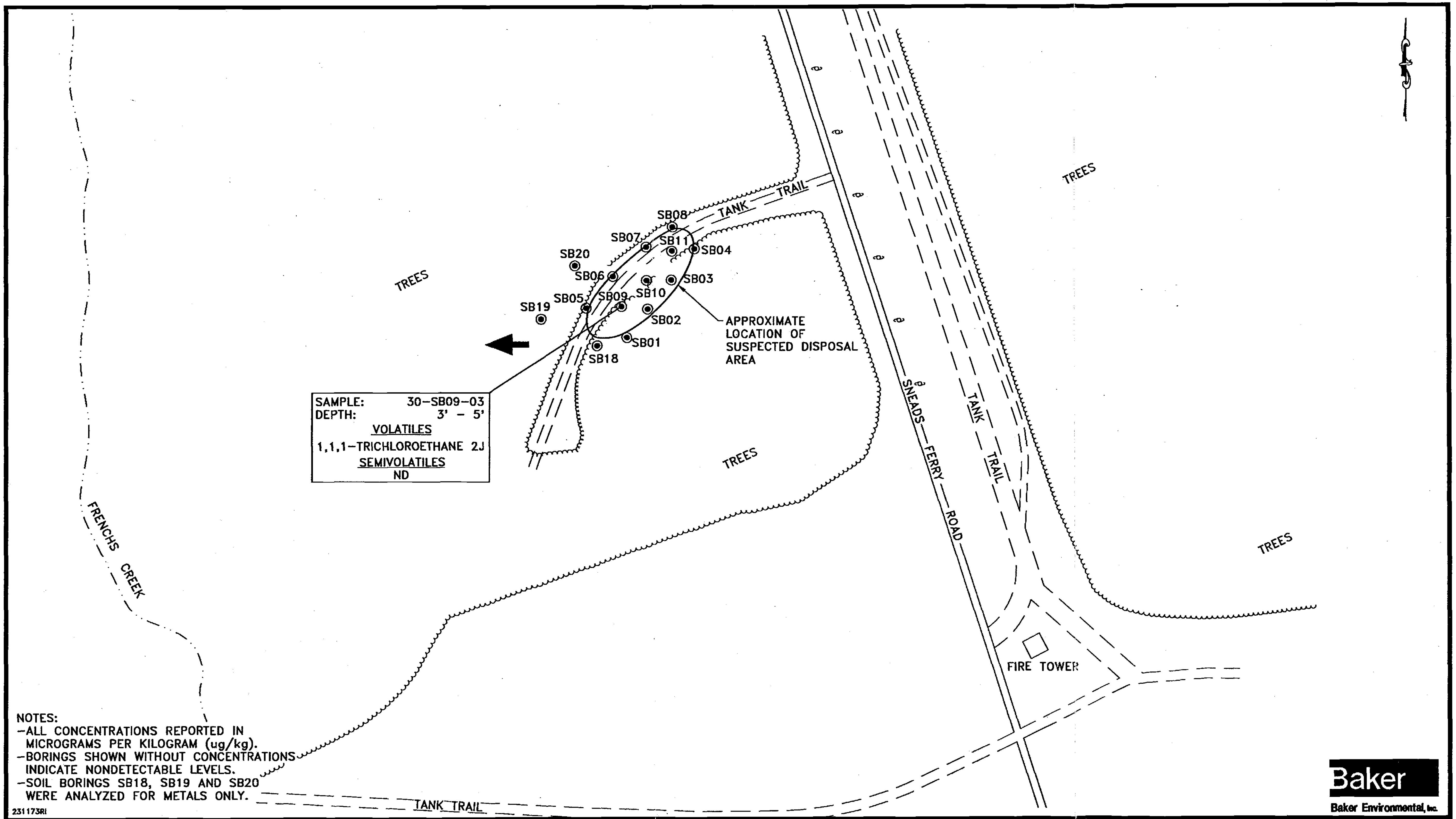
SB01 ◉ SOIL SAMPLING LOCATION
═══ ASPHALT ROAD
– – – UNIMPROVED ROAD (TANK TRAIL)
UTILITY POLE
➔ APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600
1 inch = 300 ft.

FIGURE 23-1
POSITIVE DETECTIONS OF VOLATILE AND SEMIVOLATILE ORGANIC COMPOUNDS IN SURFACE SOILS
SITE 30 – FRENCH CREEK LIQUIDS DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U122



SAMPLE:	30-SB09-03
DEPTH:	3' - 5'

VOLATILES

1,1,1-TRICHLOROETHANE 2J

SEMIVOLATILES

ND

NOTES:
- ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
- BORINGS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.
- SOIL BORINGS SB18, SB19 AND SB20 WERE ANALYZED FOR METALS ONLY.

231173RI

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Baker Environmental, Inc.

LEGEND

SB01 ◉	SOIL SAMPLING LOCATION
——	ASPHALT ROAD
— — —	UNIMPROVED ROAD (TANK TRAIL)
⊸	UTILITY POLE
➔	APPROXIMATE GROUNDWATER FLOW DIRECTION

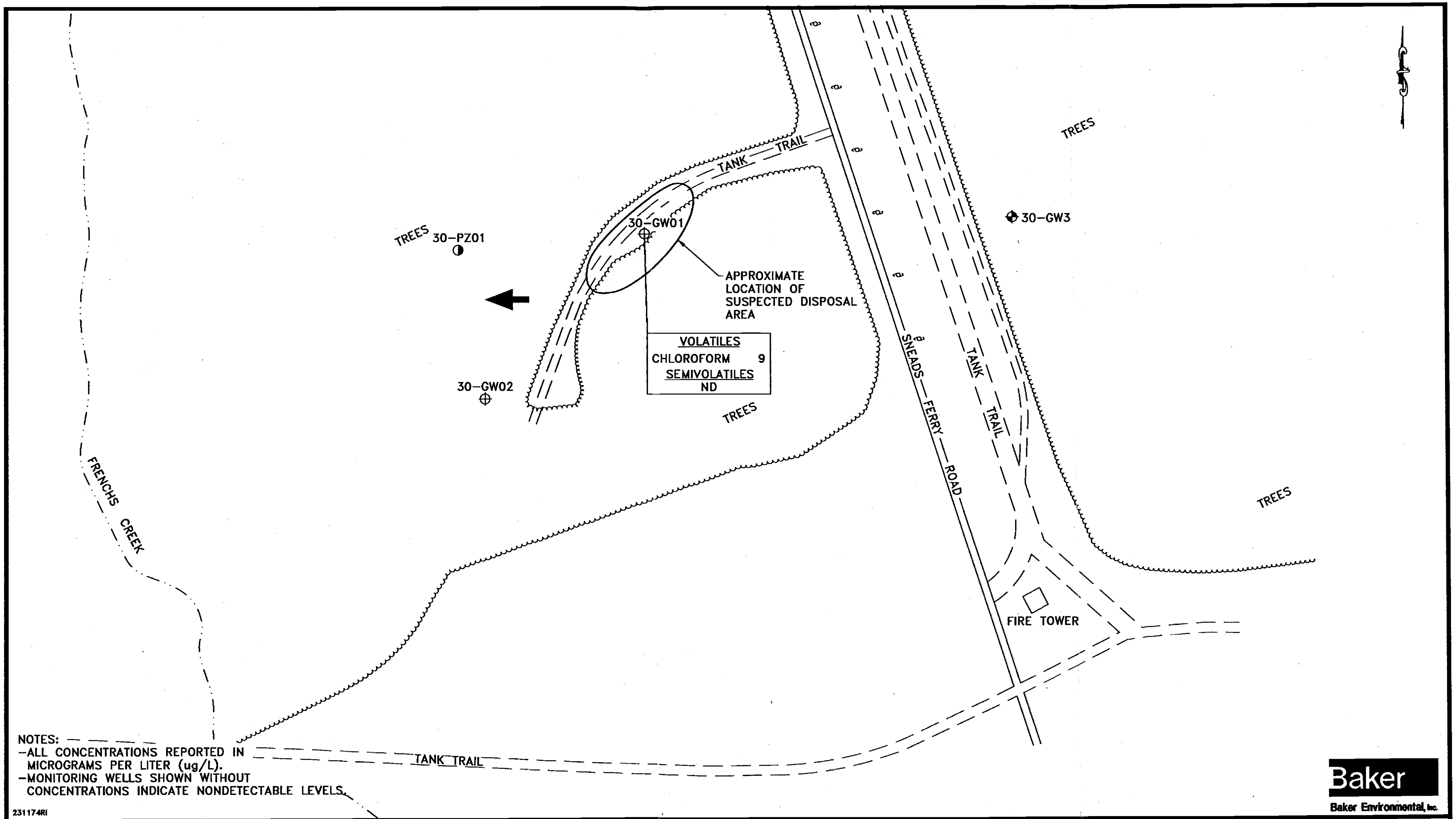
SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 23-2
POSITIVE DETECTIONS OF VOLATILE AND SEMIVOLATILE ORGANIC COMPOUNDS IN SUBSURFACE SOILS
SITE 30 - FRENCH CREEK LIQUIDS DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498 U132



NOTES:
-ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
-MONITORING WELLS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.

231174RI

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Baker Environmental, Inc.

LEGEND

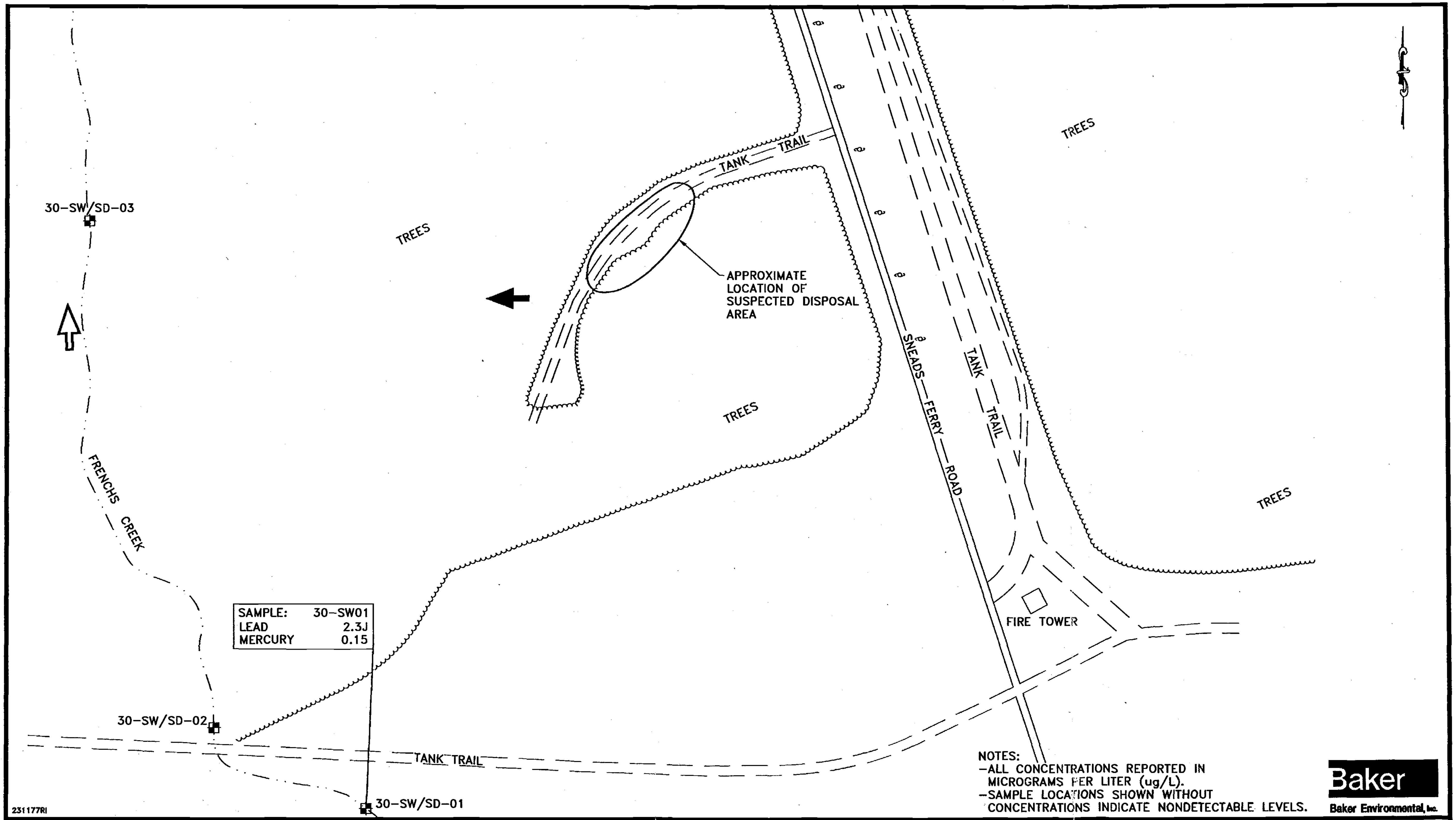
30-GW01 ⊕	EXISTING SHALLOW MONITORING WELL (ESE, 1984,1986)
30-GW3 ⊕	NEWLY INSTALLED SHALLOW MONITORING WELL (BAKER, 1994)
30-PZ01 ◑	NEWLY INSTALLED PIEZOMETER (BAKER, 1994)
═══	ASPHALT ROAD
═ ═ ═	UNIMPROVED ROAD (TANK TRAIL)
⊘	UTILITY POLE
➡	APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600
1 inch = 300 ft.

FIGURE 23-3
POSITIVE DETECTIONS OF VOLATILE AND SEMIVOLATILE ORGANIC COMPOUNDS IN SHALLOW GROUNDWATER
SITE 30 – FRENCH CREEK LIQUIDS DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U142

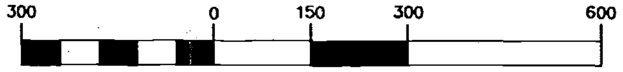


NOTES:
-ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
-SAMPLE LOCATIONS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.

LEGEND

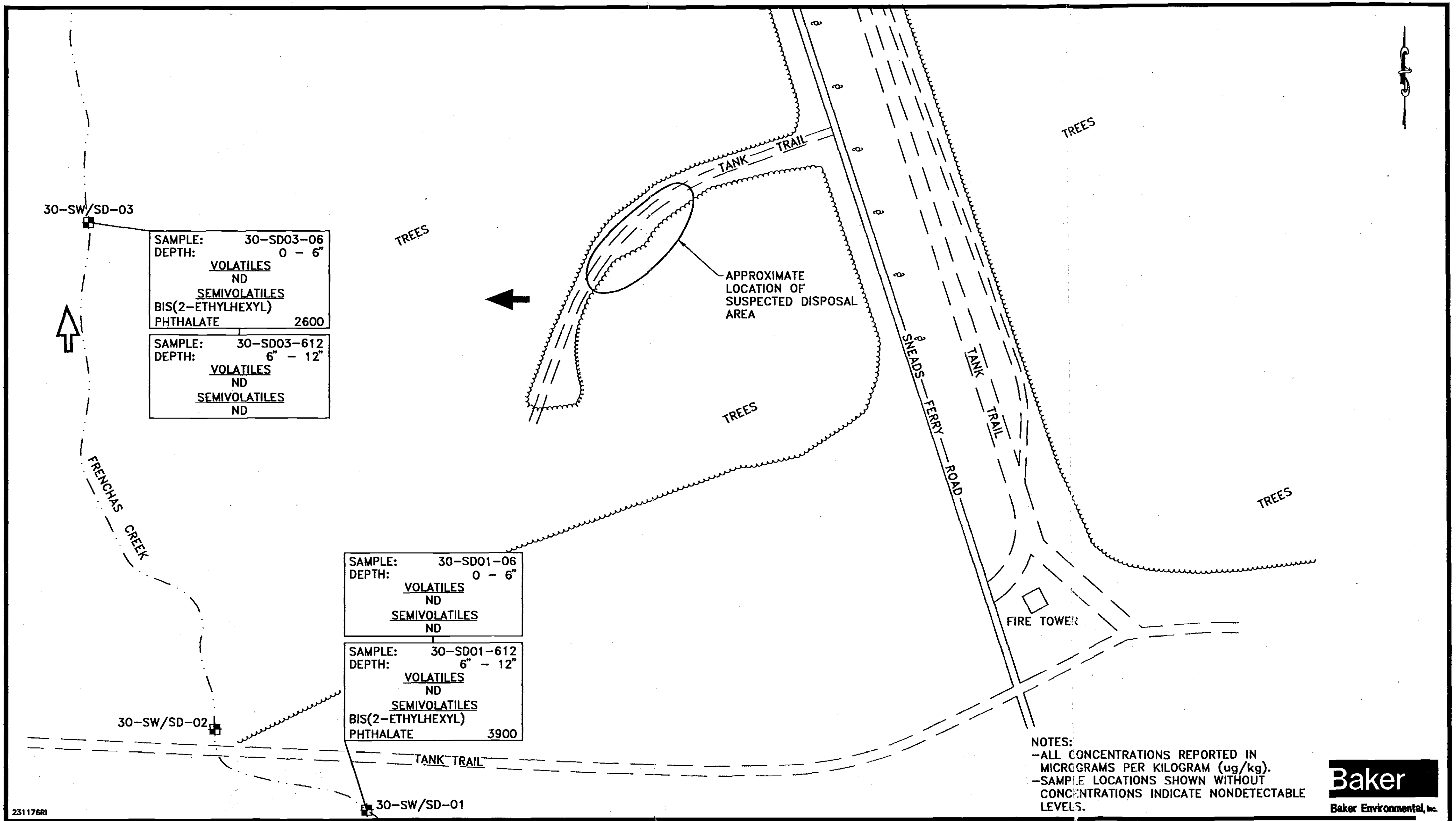
30-SW/SD-01 ⊞	SURFACE WATER AND SEDIMENT SAMPLING STATION
═	ASPHALT ROAD
╌	UNIMPROVED ROAD (TANK TRAIL)
ᴓ	UTILITY POLE
➡	APPROXIMATE GROUNDWATER FLOW DIRECTION
⇨	APPROXIMATE SURFACE WATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994



1 inch = 300 ft.

FIGURE 23-4
POSITIVE DETECTIONS OF TAL METALS ABOVE FEDERAL SCREENING VALUES IN SURFACE WATER
SITE 30 – FRENCH CREEK LIQUIDS DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE: 30-SD03-06
DEPTH: 0 - 6"
VOLATILES
ND
SEMIVOLATILES
BIS(2-ETHYLHEXYL) PHTHALATE 2600

SAMPLE: 30-SD03-612
DEPTH: 6" - 12"
VOLATILES
ND
SEMIVOLATILES
ND

SAMPLE: 30-SD01-06
DEPTH: 0 - 6"
VOLATILES
ND
SEMIVOLATILES
ND

SAMPLE: 30-SD01-612
DEPTH: 6" - 12"
VOLATILES
ND
SEMIVOLATILES
BIS(2-ETHYLHEXYL) PHTHALATE 3900

NOTES:
-ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
-SAMPLE LOCATIONS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.

Baker
Baker Environmental, Inc.

LEGEND

30-SW/SD-01 ⊞	SURFACE WATER AND SEDIMENT SAMPLING STATION
═	ASPHALT ROAD
╌	UNIMPROVED ROAD (TANK TRAIL)
∞	UTILITY POLE
➡	APPROXIMATE GROUNDWATER FLOW DIRECTION
⇨	APPROXIMATE SURFACE WATER FLOW DIRECTION

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600
1 inch = 300 ft.

FIGURE 23-5
POSITIVE DETECTIONS OF VOLATILE AND SEMIVOLATILE ORGANICE COMPOUNDS IN SEDIMENT
SITE 30 - FRENCH CREEK LIQUIDS DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498 V16Z

24.0 CONTAMINANT FATE AND TRANSPORT

The potential for a contaminant to migrate and persist in an environmental medium is critical when evaluating the potential for a chemical to elicit an adverse human health or ecological effect. The environmental mobility of a chemical is influenced by its physical and chemical properties, the physical characteristics of the site, and the site chemistry. This section presents a discussion of the various physical and chemical properties of contaminants detected at Site 30 of OU No.7 and their fate and transport through the environment.

24.1 Chemical and Physical Properties Impacting Fate and Transport

Table 24-1 presents the physical and chemical properties associated with the organic contaminants detected during this investigation. These properties determine the inherent environmental mobility and fate of a contaminant. These properties include:

- Vapor pressure
- Water solubility
- Octanol/water partition coefficient
- Organic carbon adsorption coefficient (sediment partition)
- Specific gravity
- Henry's Law constant
- Mobility index

A discussion of the environmental significance of each of these properties follows.

Vapor pressure provides an indication of the rate at which a chemical may volatilize. It is of primary significance at environmental interfaces such as surface soil/air and surface water/air. Volatilization can be important when evaluating groundwater and subsurface soils, particularly when selecting remedial technologies. Vapor pressure for monocyclic aromatics are generally higher than vapor pressures for PAHs. Contaminants with higher vapor pressures (e.g., volatile organic compounds [VOCs]) will enter the atmosphere at a quicker rate than the contaminants with low vapor pressures (e.g., inorganics).

The rate at which a contaminant is leached from soil by infiltrating precipitation is proportional to its water solubility. More soluble contaminants (e.g., VOCs) are usually more readily leached than less soluble contaminants (e.g., inorganics). The water solubilities indicate that the volatile organic contaminants including monocyclic aromatics are usually several orders-of-magnitude more soluble than PAHs. Consequently, highly soluble compounds such as the chlorinated VOCs will migrate at a faster rate than less water soluble compounds.

The octanol/water partition coefficient (K_{ow}) is the ratio of the chemical concentration in octanol divided by the concentration in water. The octanol/water partition coefficient has been shown to correlate well with bioconcentration factors in aquatic organisms and adsorption to soil or sediment. Specifically, a linear relationship between octanol/water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor - BCF) has been established (Lyman et al., 1982). The coefficient is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available.

The organic carbon adsorption coefficient (K_{oc}) indicates the tendency of a chemical to adhere to soil particles organic carbon. The solubility of a chemical in water is inversely proportional to the K_{oc}. Contaminants with high soil/sediment adsorption coefficients generally have low water solubilities. For example, contaminants such as PAHs are relatively immobile in the environment and are preferentially bound to the soil. These compounds are not subject to aqueous transport to the extent of compounds with higher water solubilities. Erosional properties of surface soils may, however, enhance the mobility of these bound soils contaminants.

Specific gravity is the ratio of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a contaminant will have a tendency to "float" or "sink" (as an immiscible liquid) in water if it exceeds its corresponding water solubility.

Vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. These two parameters can be used to estimate an equilibrium concentration of a contaminant in the water phase and in the air directly above the water. This can be expressed as Henry's Law Constant.

A quantitative assessment of mobility has been developed that uses water solubility (S), vapor pressure (VP), and organic carbon partition coefficient (K_{oc}) (Laskowski, 1983). This value is referred to as the Mobility Index (MI). It is defined as:

$$MI = \log((S*VP)/K_{oc})$$

A scale to evaluate MI is presented by Ford and Gurba (1984):

Relative MI	**Mobility Description**
> 5	extremely mobile
0 to 5	very mobile
-5 to 0	slightly mobile
-10 to -5	immobile
< -10	very immobile

24.2 Contaminant Transport Pathways

Based on the evaluation of existing conditions at Site 30, the following potential contaminant transport pathways have been identified.

- On-site atmospheric deposition of windblown dust.
- Leaching of sediment contaminants to surface water.
- Migration of contaminants in surface water.
- Leaching of soil contaminants to groundwater.
- Migration of groundwater contaminants off site.
- Groundwater infiltration from the shallow aquifer to the deep aquifer.

Contaminants released to the environment could also undergo the following during transportation:

- Physical transformations: volatilization, precipitation
- Chemical transformations: photolysis, hydrolysis, oxidation, reduction
- Biological transformation: biodegradation
- Accumulation in one or more media

The following paragraphs describe the potential transport pathways listed above.

24.2.1 On-Site Deposition of Windblown Dust

Wind can act as a contaminant transport pathway agent by eroding exposed soil and exposed sediment and blowing it off site. This is influenced by: wind velocity, the grain size/density of the soil/sediment particles and the amount of vegetative cover over the soil or sediment.

A majority of the surface area of Site 30 is primarily sand and dirt. There is some potential for fugitive dust generation at the site.

24.2.2 Leaching of Sediment Contaminants to Surface Water

When in contact with surface water, contaminants attached to sediment particles can disassociate from the sediment particle into surface water. This is primarily influenced by the physical and chemical properties of the contaminant, (i.e., water solubility, K_{oc}) and the physical and chemical properties of the sediment particle (i.e., grain size, f_{oc}).

At Site 30, there was one surface water body of concern. Similar constituents were found in the surface water and sediment samples collected from this area of concern (e.g., primarily metals).

24.2.3 Leaching of Soil Contaminants to Groundwater

Contaminants that adhere to soil particles or have accumulated in soil pore spaces can leach and migrate vertically to the groundwater due to precipitation. The rate and extent of this migration is influenced by the depth to the water table, amount of precipitation, rate of infiltration, the physical and chemical properties of the soil, and the physical and chemical properties of the contaminant.

Groundwater samples were collected from shallow and deep monitoring wells at Site 30. The groundwater analytical results can be compared to soil sample analytical results to determine if contaminants detected in soil have migrated or may migrate in the future, to underlying groundwater. These results were discussed in detail in Section 23.0, Nature and Extent of Contamination.

24.2.4 Migration of Groundwater Contaminants

Contaminants leaching from soils to underlying groundwater can migrate as dissolved constituents in groundwater in the direction of groundwater flow. Three general processes govern the migration of dissolved contaminants caused by the flow of water: (1) advection, movement caused by flow of groundwater; (2) dispersion, movement caused by irregular mixing of waters during advection; and (3) retardation, principally chemical mechanisms which occur during advection. Subsurface transport of the immiscible contaminants is governed by a set of factors different from those of dissolved contaminants.

Advection is the process which most strongly influences the migration of dissolved organic solutes. Groundwater, under water table aquifer conditions (i.e., unconfined aquifer), generally flows from regions of the subsurface where the water table is under a higher head (i.e., recharge areas) to regions of where the water table is under a lower head (i.e., discharge areas). Hydraulic gradient is the term used to describe the magnitude of this force (i.e., the slope of the water table). The gradient typically follows the topography for shallow, uniform sandy aquifers which are commonly found in coastal regions. In general, groundwater flow velocities, in sandy aquifers, under natural gradient conditions are probably between 32.8 feet/year to 328 feet/year (10 meters/year to 100 meters/year) (Lyman, et al., 1982).

The average seepage velocity of groundwater flow at Site 30 for both the shallow and deep water-bearing zones can be estimated by using a variation of Darcy's equation:

$$Vx = (K*i)/Ne$$

where,

Vx = average seepage velocity
K = hydraulic conductivity (cm/sec)
i = hydraulic gradient
Ne = effective porosity

For the shallow lithology at Site 30 of OU No.7, the hydraulic conductivity (K) was estimated at 3.1 ft/day (Baker, 1992). The average calculated groundwater gradient was 0.015. An estimated effective porosity of 0.3 was used for silty-sands (Fetter, 1980). This resulted in an estimated groundwater flow velocity is 0.15 ft/day or 56 ft/yr.

Based on soil lithology information obtained during the test borings and groundwater elevation data, there are two aquifer systems underlying OU No. 7. The aquifers are separated by a thin semi-confining layer (typically less than three feet) of sandy-clay. Although the semi-confining layer exists, there is vertical groundwater movement between the aquifers. Data obtained from a pump test performed within Hadnot Point (ESE, 1988) indicated a hydraulic conductivity (or leakage characteristic) ranging from $1.4x10^{-3}$ ft/day (4.9×10^{-7} cm/sec) to $5.1x10^{-2}$ ft/day (1.8×10^{-5} cm/sec) for the semi-confining clayey interval. This range of values suggests that the clayey interval has a high enough permeability to permit vertical movement of groundwater between the aquifers. Accordingly, contaminants introduced in the shallow soils over time could migrate vertically from the surficial to the Castle Hayne aquifer.

Dispersion results from two basic processes, molecular diffusion and mechanical mixing. The kinetic activity of dissolved solutes results in diffusion of solutes from a zone of high concentration to a lower concentration. Dispersion and spreading during transport result in the dilution of contaminants (maximum concentration of contaminant decreases with distance from the source). For simple hydrogeological systems, the spreading is reported to be proportional to the flow rate. Spreading is largely scale dependent. Furthermore, dispersion in the direction of flow is often observed to be markedly greater than dispersion in the directions transverse (perpendicular) to the flow. Because detailed studies to determine dispersive characteristics at the site were not conducted, longitudinal and transverse dispersivities are estimated based on similar hydrogeological systems (Mackay, et al., 1985).

Some dissolved contaminants may interact with the aquifer solids encountered along the flow path through adsorption, partitioning, ion exchange, and other processes. The interactions result in the contaminant distribution between aqueous phase and aquifer solids, diminution of concentrations in the aqueous phase, and retardation of the movement of the contaminant relative to groundwater flow. The higher the fraction of the contaminant sorbed, the more retarded its transport. Certain halogenated organic solvents sorption is affected by hydrophobility (antipathy for dissolving in water) and the fraction of solid organic matter in the aquifer solids (organic carbon content). If the aquifer is homogeneous, sorption of hydrophobic organic solute should be constant in space and time. If the sorptive interaction is at equilibrium and completely reversible, the solute should move at a constant average velocity equal to the groundwaters average velocity divided by the retardation factor.

Organic contaminants can be transformed into other organic compounds by a complex set of chemical and biological mechanisms. The principal classes of chemical reactions that can affect organic contaminants in water are hydrolysis and oxidation. However, it is believed that most chemical reactions occurring in the groundwater zone are likely to be slow compared with transformations mediated by microorganisms. Certain organic groundwater contaminants can be biologically transformed by microorganisms attached to solid surfaces within the aquifer. Factors which affect the rates of biotransformation of organic compounds include: water temperature and pH, the number of species of microorganisms present, the concentration of substrate, and presence of microbial toxicants and nutrients, and the availability of electron acceptors. Transformation of a toxic organic solute is no assurance that it has been converted to harmless or even less harmless hazardous products. Biotransformation of common groundwater contaminants, such as TCE, TCA, and PCE, can result in the formation of such intermediates as vinyl chloride (Mackay, et al., 1985).

The interaction of non-ionic organic compounds with solid phases can also be used to predict the fate of the highly nonpolar organic contaminants (i.e., 4,4'-DDT, PCBs). Sorptive binding is proportional to the organic content of the sorbent. Sorption of non-ionic organic pesticides can be attributed to an active fraction of the soil organic matter (Lyman et al., 1982). The uptake of neutral organics by soils results from their partitioning to the solutes aqueous solubility and to its liquid-liquid (e.g., octanol-water) partition coefficient (Chiou, 1979). Currently, literature information is available on the interrelation of soil organic properties to the binding of pesticides, herbicides, and high molecular weight pollutants such as PCBs. Organic matrices in natural systems that have varying origins, degrees of humification, and degrees of association with inorganic matrices exhibit dissimilarities in their ability to sorb non-ionic organic contaminants.

The soils and sediments formed or deposited on the land surface can act as a reservoir for inorganic contaminants. Soils contain surface-active mineral and humic constituents involved in reactions that affect metal retention. The surfaces of fine-grained soil particles are very chemically active. The surface soils can be negatively charged, positively charged or electronically neutral.

Opposite charged metallic counterions from solutions in soils (i.e., groundwater) are attracted to these charged surfaces. The relative proportions of ions attracted to these various sites depends on the degree of acidity or alkalinity of the soil, on its mineralogical composition, and on its content of organic matter. The extent of adsorption depends on either the respective charges on the adsorbing surface and the metallic cation.

In addition to these adsorption reactions, precipitation of new mineral phases also may occur if the chemical composition of the soil solution becomes supersaturated with respect to the insoluble precipitates. Of the probable precipitates, the most important of these phases are hydroxides, carbonates, and sulfides. The precipitation of hydroxide minerals is important for metals such as iron and aluminum, the precipitation of carbonate minerals is significant for calcium and barium, and the precipitation of sulfide minerals dominates the soil chemistry of zinc, cadmium, and mercury. A number of precipitates may form if metals are added to soils the concentration of metal in solution will be controlled, at equilibrium, by the solid phase that results in the lowest value of the activity of the metallic ion in solution (Evans, 1989).

Table 24-2 presents the general processes which influence the aquatic fate of contaminants at Site 30.

The following paragraphs summarize the site-specific fate and transport data for some contaminants of potential concern at Site 30.

24.3 Fate and Transport Summary

The following paragraphs summarize the contaminant group fate and transport data for contaminants detected in media collected at Site 30.

24.3.1 Volatile Organic Compounds

VOCs (i.e., vinyl chloride, TCE, and PCE) tend to be mobile in environmental media as indicated by their presence in groundwater and their corresponding MI values. Their environmental mobility is a function of high water solubilities, high vapor pressures, low K_{ow} and K_{oc} values, and high mobility indices.

Without a continuing source, VOCs do not generally tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal.

24.3.2 Polynuclear Aromatic Hydrocarbons

Low water solubilities, high K_{ow} and K_{oc} indicate a strong tendency for PAHs to adsorb to soils. Of the PAHs, fluoranthene, is probably the best marker compound, since it is consistently the most abundant of the PAHs measured and provides the strongest correlation with total PAH values. Benzo(ghi) perylene is usually the most abundant compound in soils with low PAH values but becomes less important with increasing total PAH values. Other PAH are benzo(a)anthracene, chrysene, pyrene, benzo(ghi) perylene, benzo(b)fluoranthene and phenanthrene. Their mobility indices indicate that they are relatively immobile from a physical-chemical standpoint. An exception is naphthalene, which is considered only slightly immobile because of somewhat higher water solubility (Jones, et al., 1989).

PAHs generally lack adequate vapor pressures to be transmitted via vaporization and subsequent airborne transport. However, surface and shallow surface soil particles containing PAHs could potentially be subject to airborne transport and subsequent deposition, especially during mechanical disturbances such as vehicle traffic or digging (Jones, et al., 1989).

PAHs are somewhat persistent in the environment. In general their persistence increases with increasing ring numbers. Photolysis and oxidation may be important removal mechanisms in surface waters and surficial soils, while biodegradation could be an important fate process in groundwater, surface soils or deeper soils. PAHs are ubiquitous in nature. The presence of PAHs in the soil may be the result of aerially deposited material, and the chemical and biological conditions in the soil which result in selective microbial degradation/breakdown.

24.3.3 Pesticides/Polychlorinated Biphenyls

Pesticides/PCBs are persistent and immobile contaminants in environmental media. Pesticides travel at varying rates through soil, mainly due to their affinity for soil surfaces. The soil sorption coefficient (K_d) is the distribution of a pesticide between soil and water. In general, the K_d values are higher for high organic carbon soil than for low organic carbon soils. Therefore, soils with high K_d values will retain pesticides (i.e., 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD). As evidenced by the ubiquitous nature of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, volatilization is an important transport process from soils and waters.

PCBs have low vapor pressures, low water solubilities, and high K_{oc} and K_{ow} values. Adsorption of these contaminants to soil and sediment is the major fate of these contaminants in the environment.

24.3.4 Inorganics

Inorganics can be found as solid complexes at ambient temperature and pressure in soils at the site. Inorganic ions exist in pure solutions as hydrated ions. Groundwater, as opposed to a pure solution, is a highly complex chemical system which is heavily influenced by the mineralogy of the substrate. Factors affecting the transport of inorganics in saturated soils are interactive and far more complex and numerous than those affecting the transport of organic contaminants.

The most complicated pathway for inorganic contaminants is migration in subsurface soils and groundwaters, where oxidation reduction potential (Eh) and pH play critical roles. Table 24-3 presents an assessment of relative inorganic environmental mobilities as a function of Eh and pH. Soils at MCB Camp Lejeune are relatively neutral, therefore, inorganics in the subsurface soil should be relatively immobile.

Transport of inorganic species in groundwater is mainly a function of the inorganic's solubility in solution under the chemical conditions of the soil-solution matrix. The inorganic must be dissolved (i.e. in solution) for leaching and transport by advection with the groundwater to occur. Generally, dynamic and reversible processes control solubility and transport of the dissolved metal ions. Such process include precipitation/dissolution, adsorption/desorption, and ion exchange.

Inorganics could be sorbed onto colloidal materials, theoretically increasing their inherent mobility in saturated porous media. It is important to note, however, that colloids themselves are not mobile in most soil/water systems.

Inorganics such as arsenic and chromium depend upon speciation to influence their mobility. Speciation varies with the chemistry of the environmental medium and temporal factors. These variables make the site-specific mobility of an inorganic constituent difficult to assess.

SECTION 24.0 TABLES

TABLE 24-1

ORGANIC PHYSICAL AND CHEMICAL PROPERTIES
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log Kow	Log Koc	Specific Gravity (g/cm^3)	Henry's Law Constant (atm-m^3/mole)	Mobility Index	Comments
Bis(2-ethylhexyl)phthalate	6.45E-06	0.3	5.11	4-5	NA	1.1E-05	NA	NA

NA = Not Available

Reference: Howard, 1990

TABLE 24-2

PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Processes					
	Sorption	Volatilization	Biodegradation	Photolysis-Direct	Hydrolysis	Bioaccumulation
Pesticides/PCBs						
Aldrin	+	+	?	-	-	+
Chlordane	+	+	?	-	-	+
DDD	+	+	-	-	-	+
DDE	+	+	-	+	-	+
DDT	+	+	-	-	+	+
Dieldrin	+	+	-	+	-	+
Endosulfan and Endosulfan Sulfate	+	+	+	?	+	-
Endrin and Endrin Aldehyde	?	?	?	+	-	+
Heptachlor	+	+	-	?	++	+
Heptachlor Epoxide	+	-	?	?	-	+
PCBs	+	+	+(1)	?	-	+
Halogenated Aliphatic Hydrocarbons						
Chloromethane (methyl chloride)	-	+	-	-	-	-
Dichloromethane (methylene chloride)	-	+	?	-	-	-
1,1-Dichloroethane (ethylidene chloride)	-	+	?	-	-	-
1,2-Dichloroethane (ethylene dichloride)	-	+	?	-	-	-
1,1,2-Trichloroethane	?	+	-	-	-	?
Chloroethene (vinyl chloride)	+	-	-	-	-	-
1,1,-Dichloroethene (vinylidene chloride)	?	+	?	-	-	?
Trichloroethene	-	+	?	-	-	-
Tetrachloroethene (perchloroethylene)	-	+	+	-	-	-

TABLE 24-2 (Continued)

PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Processes					
	Sorption	Volatilization	Biodegradation	Photolysis-Direct	Hydrolysis	Bioaccumulation
Bromodichloromethane	?	?	?	?	-	+
Dichlorodifluoromethane	?	+	-	?	-	?
Monocyclic Aromatics						
Benzene	+	+	-	-	-	-
Ethylbenzene	?	+	?	-	-	-
Toluene	+	+	?	-	-	-
Phenol	-	+	+	-	-	-
2,4-Dimethyl phenol (2,4-xylenol)	-	-	?	+	-	-
Phthalate Esters						
Dimethyl phthalate	+	-	+	-	-	+
Dicthyl phthalate	+	-	+	-	-	+
Di-n-butyl phthalate	+	-	+	-	-	+
Di-n-octyl phthalate	+	-	+	-	-	+
Bis (2-ethylhexyl) phthalate	+	-	+	-	-	+
Butyl benzyl phthalate	+	-	+	-	-	+
Polycyclic Aromatic Hydrocarbons						
Acenaphthene(3)	+	-	+	+	-	-
Acenaphthylene(3)	+	-	+	+	-	-
Fluorene(3)	+	-	+	+	-	-
Naphthalene	+	-	+	+	-	-
Anthracene	+	+	+	+	-	-
Fluoranthene(3)	+	+	+	+	-	-

TABLE 24-2 (Continued)

PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Processes					
	Sorption	Volatilization	Biodegradation	Photolysis-Direct	Hydrolysis	Bioaccumulation
Phenanthrene(3)	+	+	+	+	-	-
Benzo(a)anthracene	+	+	+	+	-	-
Benzo(b)fluoranthene(3)	+	-	+	+	-	-
Benzo(k)fluoranthene(3)	+	-	+	+	-	-
Chrysene(3)	+	-	+	+	-	-
Pyrene(3)	+	-	+	+	-	-
Benzo(g,h,i)perylene(3)	+	-	+	+	-	-
Benzo(a)pyrene	+	+	+	+	-	-
Dibenzo(a,h)anthracene(3)	+	-	+	+	-	-
Ideno(1,2,3-cd)pyrene(3)	+	-	+	+	-	-

++	Predominate fate determining process
+	Could be an important fate process
-	Not Likely to be an important process
?	Importance of process uncertain or not known

Notes: (1) Biodegradation is the only process known to transform polychlorinated biphenyls under environmental conditions, and only the lighter compounds are measurably biodegraded. There is experimental evidence that the heavier polychlorinated biphenyls (five chlorine atoms or more per molecule) can be photolyzed by ultraviolet light, but there are no data to indicate that this process is operative in the environment.

(2) Based on information for 4-nitrophenol.

(3) Based on information for PAHs as a group. Little or no information for these compounds exists.

Source: USEPA. 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Groundwater - Part I.

TABLE 24-3

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Relative Mobility	Environmental Conditions			
	Oxidizing	Acidic	Neutral/ Alkaline	Reducing
Very high			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg, Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:

Se = Selenium
Zn = Zinc
Cu = Copper
Ni = Nickel
Hg = Mercury
Ag = Silver
As = Arsenic

Cd = Cadmium
Ba = Barium
Pb = Lead
Fe = Iron
Cr = Chromium
Be = Beryllium
Zn = Zinc

Source: Swartzbaugh, et al. "Remediating Sites Contaminated with Heavy Metals." Hazardous Materials Control, November/December 1992.

25.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

The following subsections present the baseline human health risk assessment (BRA) conducted for Site 30, Snead's Ferry Road Fuel Tank Sludge Area. This assessment was performed in accordance with the USEPA document Risk Assessment Guidance for Superfund, Human Health Evaluation Manual: Part A (USEPA, 1989). The purpose of the BRA is to assess whether the contaminants of potential concern (COPCs) at the site pose a current or future risk to human health in the absence of remedial action. COPCs are site-related contaminants used to quantitatively estimate human exposures and associated potential health effects. Because the purpose of the risk assessment is to estimate the degree of risk to human health and to be protective of human health, the approach of the USEPA guidance is designed to be conservative. This protectiveness is achieved by the use of assumptions and models that result in upper bound estimates of risk, i.e., the true or actual risk is expected to fall between the estimated value and zero. As a result, the actual site risks are unlikely to exceed the estimated upper bound values and are probably lower. The following paragraphs present a brief overview of the risk assessment process and how the assessment affects further activity at the sites.

For the BRA, both current and future land use exposure scenarios were assumed for the site. The current scenario reflects potential human exposure pathways to the COPCs that currently exist at the site (i.e., exposure pathways currently available). Likewise, the future use scenario represents exposure pathways that are conceivable in the future (e.g., residential development). The future use is typically determined by zoning and the environmental setting of the site. The development of current and future use exposure scenarios is consistent with the methodology for baseline risk assessment, as specified by USEPA.

The National Contingency Plan (NCP) stipulates a range of acceptable cancer risk levels of 1×10^{-4} to 1×10^{-6} for total risk at a hazardous waste site (USEPA, 1990). These cancer risk levels represent the probability of an individual developing cancer over his or her lifetime if exposed to the COPCs at the site. For example, a risk level of 10^{-6} is the probability that one person in 1,000,000 exposed persons will develop cancer in a lifetime. The total noncarcinogenic acceptable risk level is a hazard index of less than or equal to 1.0. This noncancer risk level depicts a level at or below which adverse systemic effects are not expected in the exposed population.

A remedial action is recommended when either the total cancer or noncancer risks are above the criteria established by the NCP. Some form of remedial action also is necessary when either the current or future exposure point concentrations at the site are above the applicable or suitable analogous standards (e.g., maximum contaminant levels [MCLs] for drinking water) for those COPCs for which standards exist. When a remedial action is necessary, applicable or relevant and appropriate requirements (ARARs) and/or risk-based cleanup levels are used in determining acceptable concentrations in the environmental media. No remedial response is required when the cancer and noncancer criteria and the ARARs are not exceeded.

25.1 Introduction

The BRA investigates the potential for COPCs to affect human health and/or the environment, both now and in the future, under a "no further remedial action scenario." The BRA process evaluates the data generated during the sampling and analytical phase of the RI, identifying areas of interest and contaminants of concern with respect to geographical, demographic, physical, and biological characteristics of the study area. These, combined with the current understanding of physical and chemical properties of the site-associated constituents (with respect to environmental fate and transport processes), are then used to estimate the concentrations of contaminants at the end points of logical exposure pathways. Finally, contaminant intakes by hypothetical receptors are determined and combined with the toxicological properties of the contaminants to estimate (inferentially) the potential public health impacts posed by constituents detected at the site.

The BRA for Site 30 was conducted in accordance with current USEPA Risk Assessment Guidance (USEPA, 1989 and USEPA, 1991), and USEPA Region IV Supplemental Risk Guidance (USEPA, 1992d).

The components of the BRA include the following:

- Hazard Identification: determination as to whether a substance has the potential to elicit an adverse effect (toxicity) upon exposure to humans
- Exposure Assessment: identification of the human population(s) likely to be exposed and the development of specific exposure pathways for the population(s)
- Toxicity Assessment: quantification of the relationship between the human exposure and the probability of occurrence (risk) of a toxic response
- Risk Characterization: information collected during the exposure and toxicity assessment is combined to develop a quantitative estimation of the potential risk.
- Uncertainty Analysis: identification and discussion of any major sources of uncertainty pertaining to the finding of the BRA
- Conclusions: summarization and conclusion of the results of the BRA relating to the total site risk are drawn

Each of these components of the BRA is discussed and addressed for the site. Introductory text is presented first, followed by a site-specific discussion. Referenced tables and figures are presented after the text portion of this section.

25.2 Hazard Identification

Data generated during the remedial investigation and previous studies at the site were used to draw conclusions and to identify data gaps in the BRA. The data were evaluated to assess which were of sufficient quality to include in the risk assessment. The objective when selecting data to include in the risk assessment was to provide accurate and precise data to characterize contamination and evaluate exposure pathways.

25.2.1 Data Evaluation and Reduction

The initial hazard identification step entailed the validation and evaluation of the site data to determine its usability in the risk assessment. This process resulted in the identification of COPCs for the site. During this validation and evaluation, data that would result in inaccurate conclusions (e.g., data that were rejected or attributed to blank contamination, as qualified by the validator) were reduced within the data set. Data reduction entailed the removal of unreliable data from the original data set based on the guidelines established by USEPA. A summary of the data quality was presented in Section 23.1.

25.2.2 Identify Data Suitable for Use in a Quantitative Risk Assessment

To provide for accurate conclusions to be drawn from sampling results, analytical data were reviewed and evaluated. During this review and evaluation, data that would lead to inaccurate conclusions (e.g., data rejected by the validator) were reduced within each data set. This section presents the criteria that were used to review, reduce, and summarize the analytical data. These criteria are consistent with USEPA guidance for data reduction.

Five environmental media were investigated at the site during this RI: surface soils, subsurface soils, groundwater, surface water, and sediment. At Site 30, surface soil, subsurface soil, groundwater, surface water and sediment were assessed for potential risk to human receptors.

It is important to note that pesticides/PCBs were not analyzed for in site surface soils, subsurface soils, surface water, and sediment because it was reasonably determined that past site activities did not involve the use of these compounds. Consequently, these media were not investigated for impact from past pesticide/PCB use.

Information relating to the nature and extent of contamination at the site is provided in detail in Section 23 of this volume of the report. The discussion provided in Section 23 of this report also was utilized in the selection of COPCs at the site. The reduced data sets for all media of concern at the site are provided in Appendices K and L of this report.

25.2.3 Criteria Used in Selection of COPCs

This section presents the selection of COPCs for the media of concern at the site. As exemplified by the data summary tables in Appendix K, the number of constituents positively detected at least once during the field investigation is large. Quantifying risk for all positively identified parameters may distract from the dominant risks presented by the site. Therefore, the validated data set (i.e., resulting data set after applying the criteria listed in the previous section) was reduced to a list of COPCs. As mentioned previously, COPCs are site-related contaminants used to quantitatively estimate human exposures and associated potential health effects.

The selection of the COPCs was based on a combination of detected concentrations; toxicity; frequency of detection; comparison to background values, including site-specific, base-wide and published ranges; and comparison of physiochemical properties, including mobility, persistence, and toxicity. In addition, historical information pertaining to past site activities was considered. USEPA guidance states that a contaminant may not be retained for quantitative evaluation in the BRA if: (1) it is detected infrequently in an environmental medium (e.g., less than 5 percent per 20 samples per data set), (2) it is absent or detected at low concentrations in other media, or (3) site history does not provide evidence the contaminant to be present (USEPA, 1989). To provide additional insight, comparisons of results to applicable and available federal and state criteria and Region III Risk-Based Concentrations (RBCs) (USEPA, 1994) were used. A brief description of the selection criteria used in choosing final COPCs is presented below. A contaminant did not need to meet the criteria of these three categories in order to be retained as a COPC.

25.2.3.1 Site History

Historically, sludge collected from storage tanks containing fuels such as leaded gasoline were disposed of in this area. In addition, cleaning solvents used as part of the sludge removal process were disposed.

In 1984, 1986 and 1993, the groundwater was sampled and analyzed for contaminants by ESE and Baker, respectively. Levels of methylene chloride, chloroform, cadmium, chromium, lead, and mercury were detected. In the surface water and sediment samples collected from Frenchs Creek in 1986, no VOCs or metals were detected.

During the most recent sampling event (Baker, 1994), samples of background surface and subsurface soil, site surface and subsurface soil, groundwater, surface water, and sediment were collected. A second round of groundwater samples was collected using a different sampling method to reduce turbidity. A discussion of this sampling event is presented in Section 3.0 of this report.

The data from the first round of sample collection were used to assess potential risk, with the exception of the groundwater data. The first round of groundwater results indicated elevated levels of metals. Therefore, a second round of groundwater data was collected for metals analysis. The second round results overall were less than the round one results. It was determined that the second round metals results were more representative of the site groundwater. Therefore, the second round metals groundwater data were used to assess risk.

25.2.3.2 Frequency of Detection

In general, constituents that were detected infrequently (e.g., equal to or less than 5 percent, when at least 20 samples of a medium are available) may be anomalies due to sampling, analytics or other problems. It should be noted, however, that detected constituents were individually evaluated prior to exclusion from the BRA. Physiochemical properties (i.e., fate and transport) and toxicological properties for each detected constituent were evaluated (see following sections).

25.2.3.3 Comparison to Background

Sample concentrations were compared to site-specific (i.e., twice the base-wide average concentration) background levels. Background information was available for all media of concern at the site. Groundwater results were compared to results from the upgradient wells for the site. In addition to site background levels, (as presented in a study of base-wide inorganic levels [Baker, 1994]), soil metal concentrations were compared to published background levels, as recommended by USEPA guidance (USEPA, 1989). The soil metal background ranges are typical levels found in the eastern U.S. (USGS, 1984). Soil metal concentrations within the observed range were considered to be naturally-occurring and/or representative of background conditions. The results of this comparison are presented in Tables 25-1 through 25-6.

25.2.3.4 Physiochemical Properties

The physical and chemical properties of a contaminant are responsible for its transport in the environment. These properties, in conjunction with site conditions, determine whether a contaminant will tend to volatilize into the air from surface soils or surface waters or be transported via advection or diffusion through soils, groundwaters, and surface waters. Physical and chemical properties also describe a contaminant's tendency to adsorb onto soil/sediment particles. Environmental mobility can correspond to either an increased or decreased potential to affect human health and/or the environment.

Persistence

The persistence of a contaminant in the environment depends on factors such as the microbial content of soil and water, organic carbon content, the concentration of the contaminant, climate, and the ability of the microbes to degrade the contaminant under site conditions. In addition, chemical degradation (i.e., hydrolysis), photochemical degradation, and certain fate processes, such as sorption, may contribute to the elimination or retention of a particular compound in a given medium.

Toxicity

The potential toxicity of a contaminant is an important consideration when selecting COPCs for further evaluation in the human health assessment. For example the weight-of-evidence (WOE) classification should be considered in conjunction with concentrations detected at the site. Some effects considered in the selection of COPCs include carcinogenicity, mutagenicity, teratogenicity, systemic effects, and reproductive toxicity. Bioaccumulation and bioconcentration properties may affect the severity of the toxic response in an organism and/or subsequent receptors and are evaluated if relevant data exist.

Despite their inherent toxicity, certain inorganic contaminants are essential nutrients. Essential nutrients need not be considered for further consideration in the quantitative risk assessment if they are present in relatively low concentrations (i.e., below twice the average base-wide background levels or slightly elevated above naturally occurring levels) or if the contaminant is toxic at doses much higher than those that could be assimilated through exposures at the site. Because of the difficulty of determining nutrient levels that were within acceptable dietary levels, only essential nutrients present at low concentrations (i.e., only slightly elevated above background) were eliminated from the BRA. Essential nutrients, however, were included in the ecological risk evaluation.

25.2.3.5 Contaminant Concentrations in Blanks

Sample concentrations were compared quantitatively to investigation-related blank concentrations. Sample concentrations of parameters that are typical laboratory or field contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) that exceeded blank concentrations by a factor of 10 and other parameter concentrations that exceeded blank concentrations by a factor of five were considered to be site related. Parameters not meeting this criteria were considered artifacts from field or laboratory practices and treated as non-detects.

At Site 30, the following organics were found in the blanks at the following levels: acetone (38 ug/L), methylene chloride (13 ug/L), 2-butanone (4 ug/L), 2-hexanone (5 ug/L) and bis(2-ethylhexyl)phthalate (BEHP)(49 ug/L). Upon application of the 5-10 rule previously discussed, the blank levels for comparison are as follows: acetone (380 ug/L), methylene chloride (130 ug/L), 2-butanone (40 ug/L), 2-hexanone (50 ug/L), and BEHP (490 ug/L).

25.2.3.6 Federal and State Criteria and Standards

Constituents detected at each site were compared to state and federal standards, criteria, and/or To Be Considered levels (TBCs). These comparisons may provide some insight as to the relative potential for health impacts resulting from the site. It should be noted that COPC concentrations were directly compared to each standard/criteria/TBC. This comparison did not take into account the additive or synergistic effects of those constituents without standards or criteria. Consequently, conclusions regarding potential risk posed by the site cannot be inferred from this comparison. A brief explanation of the standards/criteria/TBCs used for the evaluation of COPCs is presented in Section 7.0 of Volume I.

As stated previously, COPCs in all media of concern at the site were compared to criteria. The results of the standard/criteria/TBC comparison for the site are presented in Tables 25-1 through 25-6. The results are discussed in Section 25.6.

25.2.4 Contaminants of Potential Concern (COPCs)

The following sections present an overview of the analytical data obtained for each medium of concern at the site and the subsequent retention or elimination of COPCs using the aforementioned criteria for selection of COPCs.

25.2.4.1 Surface Soil

No COPCs were identified for Site 30 surface soil.

In surface soil, the following metals were detected at levels below site background ranges: aluminum, barium, chromium, copper, lead, manganese, mercury, vanadium, and zinc. Calcium, iron, magnesium, potassium, and sodium are essential nutrients. Consequently, these chemicals were not included as COPCs.

Although TCA was detected in the surface soil at a frequency greater than 5 percent, the maximum concentration does not exceed the Region III residential soil RBC (i.e., 3 μg/kg vs. 700,000 μg/kg). Consequently, it was not included as a COPC.

BEHP and acetone were found in the surface soils, but were excluded as common laboratory contaminants. Both chemicals were detected at levels below the blank concentrations.

25.2.4.2 Subsurface Soil

In subsurface soil, the COPCs were identified as the following chemicals: aluminum, arsenic, chromium, cobalt, copper, manganese, mercury, nickel, and vanadium. These COPCs were found frequently and at levels that exceeded site background levels.

Barium was detected in the subsurface soils, but was excluded from the risk evaluation because of low frequency of detection (less than 5 percent). Lead and zinc were detected at concentrations below site background levels. Essential nutrients also were excluded. Acetone was excluded as a common laboratory contaminant. It was found below blank levels. Consequently, these chemicals were not included as COPCs.

Although TCA was detected in the subsurface soil at a frequency greater than 5 percent, the maximum concentration does not exceed the Region III residential soil RBC (i.e., 2 µg/kg vs. 700,000 µg/kg). Consequently, it was not included as a COPC.

Although the detected levels of BEHP in subsurface soil exceeded blank levels, the maximum concentration in subsurface soil was 810 µg/kg, which is significantly less than the Region III residential soil RBC of 46,000 µg/kg. Consequently, it was not included as a COPC.

25.2.4.3 Groundwater

In the groundwater, no COPCs were identified.

Aluminum, barium, chromium, lead, and manganese were found at levels below standards/criteria/TBCs, including federal and state MCLs and Region III RBCs for tap water.

Essential nutrients also were excluded. In shallow and deep groundwater, these chemicals included calcium, iron, magnesium, potassium, and sodium.

Chloroform was found in the shallow and deep groundwater. However, it was detected at a level below both federal and state MCLs (see Section 25.6, Standard/Criteria/TBCs Comparison Results). Consequently, it was not included as a COPC.

25.2.4.4 Surface Water

In the surface water, the following chemicals were identified as COPCs: aluminum, lead, manganese, and mercury. These metals were found frequently and at levels that exceeded site background levels.

Barium was found at concentrations below site background levels. Copper was found at low levels (i.e., a maximum level of 6 ug/L). Calcium, iron, magnesium, potassium, and sodium are essential nutrients. As a result, these constituents were not included as COPCs.

No VOCs or SVOC were found in the surface water at Site 30.

Table 25-5 presents these comparison results.

25.2.4.5 Sediment

The following chemicals were selected as COPCs for the sediment: aluminum, chromium, copper, lead, manganese, nickel, vanadium, and zinc. These COPCs were found frequently and at concentrations that exceeded site background levels.

Barium was found at a concentration within the site background range levels (i.e., 10 mg/kg vs. 4 mg/kg to 16.3 mg/kg). Beryllium, cadmium, and cobalt were found at low frequencies of detection. Calcium, iron, magnesium, potassium and sodium are essential nutrients. Acetone and MEK were found at levels below the concentrations found in the laboratory blanks. BEHP was found in six of six samples. Four of these six detections exceeded blank levels. However, BEHP was not found at elevated levels in any of the other media at Site 30. It was not found in the surface water. Additionally, BEHP is considered a common laboratory contaminant. As a result, these chemicals were not included as COPCs.

Table 25-6 provides the comparison results. Table 25-7 presents a summary of the COPCs chosen for all media of concern for Site 30. Also included on the table are the constituents excluded from COPC selection and the rationale for their exclusion.

25.3 Exposure Assessment

The exposure assessment addresses each potential exposure pathway via soil (surface and subsurface), groundwater, surface water, sediment, air, and biota. To determine if human exposure via these pathways may occur in the absence of remedial action, an analysis including the identification and characterization of exposure pathways was conducted. The following four elements were examined to determine if a complete exposure pathway was present:

1. a source and mechanism of chemical release
2. an environmental transport medium
3. a feasible receptor exposure route
4. a receptor exposure point

The exposure scenarios presented in the following sections are used to estimate individual risks. Unless otherwise noted, all the statistical data associated with the factors used in the dose evaluation equations for assessing exposure were obtained from the Exposure Factors Handbook (USEPA, 1989b) and the accompanying guidance manuals. A reasonable maximum exposure (RME) scenario was utilized in this assessment, which is consistent with USEPA Region IV recommendations regarding human health risk assessment. As a result, the exposure scenarios presented include RME assumptions for the input parameters in the dose evaluation equations. These values are summarized in Table 25-8.

A mathematical model to estimate exposure concentrations was used. To estimate exposure from the inhalation of volatile contaminants in groundwater while showering, the "Integrated Household Exposure Model for Use of Tap Water Contaminated with Volatile Organic Chemicals," developed by S.A. Foster and P.C. Chrostowski, was applied. This model is presented in Appendix O.

25.3.1 Potential Human Receptors and Adjacent Populations

The following sections provide a summary of the potential exposure pathways and receptors at Site 30.

25.3.1.1 Site Conceptual Model for Site 30

A site conceptual model of potential sources, migration pathways, and human receptors was developed to encompasses all current and future potential routes of exposure at all three sites. This document is presented in Appendix Q. Figure 25-1 presents the potential exposure pathways and receptors for Site 30. Qualitative descriptions of current and future land use patterns in the vicinity of OU No.7 were provided in the site model. All available analytical data and meteorological data were considered, in addition to general understanding of the demographics of surrounding habitats.

From this information, the following general list of potential receptors were developed for inclusion in the quantitative health risk analysis:

- Current military personnel
- Future on-site residents (child and adult)
- Future construction worker

The following sections present a description of the potential exposure pathways and receptors evaluated for risk at Site 30.

25.3.1.2 Current and Future Scenarios

At present, the site is used by the on-site military personnel for training. Specifically, the area north of the site is used for the training exercises by military personnel and an access road is located on the northern border of the site. Access to the site by trespassers is not restricted. Frenchs Creek and Sneads Ferry Road border the site. The site is sandy with some wooded areas.

Potential receptors are the on-site military personnel. It is unlikely that trespassers, both adults and children, will be potential receptors because the area is primarily used for military training exercises. The potential exposure pathways include surface soil incidental ingestion, dermal contact, and inhalation. Exposure to the surface water and sediment in Frenchs Creek via incidental ingestion and dermal contact is also viable for the current military receptors. Groundwater (see next paragraph) and subsurface soil exposure were not considered to be viable pathways in the current scenario.

Site 30 is similar to Sites 1 and 28; a future residential exposure scenario is not likely because the site is a military restricted area. It is assumed that the present activities at this site will continue into the foreseeable future. However, to be conservative, groundwater (both shallow and deep) and subsurface soil exposure for a residential child and adult was assessed. In addition, surface water and sediment exposure was assumed for the future residential receptors. Similarly, subsurface soil exposure to a construction worker was evaluated.

Potable Water Supply

At present, potable water for the site is supplied by the base treatment facilities via water supply wells. However, there are two potable water supply wells within a one-mile radius of Site 30. These wells, HP-632 and HP-640, were sampled in 1992 and did not exhibit any contaminant levels above federal or state standards. Consequently, current exposure to groundwater was not assessed. Future potable groundwater use was assumed for risk assessment.

25.3.2 Exposure Pathways

In general, the migration of COPCs from site soil sources could potentially occur by the following routes:

- Vertical migration of potential contaminants from surficial soils to subsurface soils.
- Leaching of potential contaminants from subsurface soils to the water-bearing zones.
- Vertical migration from shallow water-bearing zones to deeper flow systems.

- Horizontal migration in groundwater in the direction of groundwater flow.
- Groundwater discharge into local streams.
- Wind erosion and subsequent deposition of windblown dust.

The potential for a constituent to migrate spatially and persist in environmental media is important in the estimation of potential exposure. This section describes the potential exposure pathways presented on Figure 25-1 associated with each medium and each potential human receptor group. Each pathway is then qualitatively evaluated for further consideration in the quantitative risk analysis. Table 25-9 presents the potential human exposure scenarios for Site 30.

25.3.2.1 Surface Soil

The potential release source considered in the soil pathway was the chemical residuals in the surface soils. The release mechanisms considered were volatilization, fugitive dust generation/deposition, leaching, and surface runoff. The transport media were the surface soils and air. The routes for human exposure to the contaminated soils included inhalation, ingestion, and dermal contact. Potential exposure points from the site were areas of human activity on and adjacent to the site.

Soil Ingestion and Dermal Contact

Surface soil incidental ingestion and dermal contact are complete exposure pathways at Site 30. These exposure pathways were assessed for the current military at the site.

Soil Inhalation Via Volatilization

The soil represents a potential source of exposure at the site via volatilization of COPCs. The potentially exposed population includes current military personnel and future residential adults and children who may inhale contaminated air (i.e., subsurface soil as surface soil in the future case). However, no VOCs were identified as COPCs in either media at the site. As a result, this pathway is not considered to be significant for the site and was not evaluated for the surface soils.

Soil Inhalation Via Fugitive Dust Generation

The surface soils in the current case and the subsurface soils in the future case represent a potential source of exposure at the site via fugitive dust generation from wind erosion and vehicular traffic on surface soils. Current military personnel and residential children and adults in the future case may inadvertently inhale the liberated contaminated particulates as outdoor dust while engaging in outdoor activities.

Surface and subsurface soil samples were collected on-site from each area of concern. Potential exposures to these soils may occur through incidental ingestion, absorption via dermal contact, and inhalation of airborne particulate containing COPCs.

25.3.2.2 Subsurface Soil

The potential release source considered in the subsurface soil pathway was the chemical residuals in the contaminated soils. The release mechanism considered was leaching to groundwater. The transport medium was the groundwater infiltrating the subsurface soil. Therefore, exposure to subsurface soils would be indirect (i.e., leaching of contaminants to groundwater). As such, subsurface soil exposure was addressed in the groundwater pathway analysis. Additionally, subsurface soil exposure was mentioned as part of the soil medium. It was assumed that the subsurface soil would be excavated and used for surface grading or landscaping in the foreseeable future. As a result, exposure to subsurface soil via ingestion, dermal contact, and inhalation was evaluated for the future construction worker and the child and adult receptor. It was assumed that this exposure would result from outdoor activities.

25.3.2.3 Groundwater

The potential release source considered in evaluating the groundwater pathway was contaminated soils. The release mechanism considered was soil leaching. The transport medium was the groundwater. The routes considered for human exposure to the groundwater were direct ingestion of groundwater, dermal contact during showering, and inhalation of volatilized contaminants during showering.

Residences located on-site in the future scenario were considered to be potential exposure points. It was conservatively assumed that a potable well will be installed on-site. However, as stated previously, it is not expected that this future residential scenario will be implemented at these military sites. As a result, future groundwater risks on-site were assessed conservatively in accordance with guidance.

25.3.2.4 Surface Water

Potential release sources considered in evaluating the surface water pathway were the contaminated soils and groundwater. The release mechanisms considered were surface runoff and groundwater seepage. The transport medium was the surface water. The potential routes considered for human exposure to the contaminated surface water were incidental ingestion, dermal contact, and inhalation. Potential exposure points were areas of human activity on and adjacent to the site.

Current military personnel and future residents were evaluated for this pathway. Exposure while participating in training exercises and outdoor recreational activities was assessed.

25.3.2.5 Sediment

The chemical residuals in the contaminated soils and groundwater are the potential release sources to be considered in the sediment pathway. The routes for human exposure to the contaminated sediments by the sediment pathway include ingestion and dermal contact. Potential exposure points from the site are areas of human activity adjacent to the site.

Like the surface water exposure scenario, current military personnel and future residents were evaluated for this pathway. Exposure while participating in training exercises and outdoor recreational activities was assessed.

25.3.2.6 Air

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: release of contaminated particulates (i.e., fugitive dust generation) and volatilization of contaminants from soil and groundwater. The transport mechanism is the air, and the potential exposure points are the areas of human activity on and adjacent to the site.

Fugitive Dust Generation

This air pathway was evaluated as a source of exposure outdoors at the site via fugitive dust generation of contaminants. Air exposure may occur when surface soils become airborne due to wind erosion or vehicular traffic. It is assumed that all current and future receptors may inhale soil particulates while engaging in outdoor activities. This exposure pathway is further assessed in Section 25.4.2, Exposure Pathways, under Surface Soil and Subsurface Soil.

Volatilization

The air pathway via volatilization of contaminants from groundwater is a source of exposure at Site 30. It is assumed in the future scenario that an adult and child receptor will inhale volatilized contaminants present in groundwater while showering. This pathway is further discussed in Section 25.4.2, Exposure Pathways, under Groundwater. Also, see the section on Surface Soil for a discussion of the volatilization of contaminants from surface soil.

25.3.2.7 Biota

The potential release sources to be considered in evaluating exposure via fish consumption are contaminated surface water and sediments. Fish can uptake contaminants present in these media by bioaccumulation and biomagnification. The exposure route for human receptors is fish ingestion.

As stated previously, no biota samples were collected from Site 30. Consequently, this exposure pathway is incomplete and was not evaluated as part of the BRA for this site.

25.3.3 Quantification of Exposure

The concentrations used in the estimation of chronic daily intakes (CDIs) must be representative of the type of exposure being considered. Exposure to groundwater, sediments and surface waters can occur discretely or at a number of sampling locations. These media are transitory in that concentrations change frequently over time. Averaging transitory data obtained from multiple locations is difficult and requires many more data points at discrete locations than exist within the site. As a result, the best way to represent groundwater, sediment, and surface water contaminants from an exposure standpoint is to use a representative exposure concentration. Soils are less transitory than the aforementioned media and in most cases, exposure occurs over a wider area (i.e., residential exposure). Therefore, an upper confidence interval was used to represent a soil exposure concentration. Soil data collected from each of these areas was used separately in estimating the potential human health risks under current and future exposure scenarios. The human health assessment for future groundwater use considered groundwater data collected from all of the monitoring wells within a site and estimated risks to individuals per area of concern.

Since all the data sets originate from a skewed underlying distribution and since log-normal distribution best fits the majority of environmental data sets, the log-normal distribution was used to represent all facility media. This ensures conservatism in the estimation of chronic daily intake associated with potential exposures. Ninety-five percent upper confidence levels (95 percent UCL) derived for log-normal data sets produce concentrations in excess of the 95 percent interval derived assuming normality. For the sake of conservatism, the 95 percent UCL for the log-normal distribution was used for each contaminant in a given data set for quantifying potential exposure. For exposure areas with limited amounts of data or extreme variability in measured data, the

95 percent UCL can be greater than the maximum measured concentration; therefore, in cases where the 95 percent UCL for a contaminant exceeds the maximum detected value in a given data set, the maximum result was used in the estimate of exposure of the 95 percent UCL However, the true mean may still be higher than this maximum value (i.e., the 95 percent UCL indicates a higher mean is possible), especially if the most contaminated portion of the site has not been sampled.

The following criteria were used to calculate media-specific average concentrations for each parameter that was detected at least once:

- For results reported as "non-detect" (e.g., ND, U, etc.), a value of one-half of the sample-specific detection limit was used to calculate the mean. The use of one-half the detection limit commonly is assigned to non-detects when averaging data for risk assessment purposes, since the actual value could be between zero and a value just below the detection limit.

  Reported concentrations that were less than the detection limit were used to calculate the mean. Typically, these values are qualified with a "J" meaning that the value was estimated.

- Reported concentrations qualified with "R" were excluded from the data set. The data flag "R" means that the QA/QC data indicated that analytical results were not usable for quantitative purposes.

The reduced data were summarized by medium and analytical parameter type (i.e., organics and inorganics) for the site. For each parameter detected during the sampling programs, the frequency of detection, maximum concentration, minimum concentration, average (arithmetic mean) concentration and both the normal and log-normal upper 95 percent level for the arithmetic average were summarized. This information is presented in Appendix R. It should be noted that the number times analyzed may differ per parameter per media per area of concern. This is primarily due to data rejected because of QA/QC problems and excluded from the data set. Consequently, these data are not reflected in the number of times analyzed. Data and frequency summaries and statistical summaries are presented in Appendices K and L, respectively.

25.3.4 Calculation of Chronic Daily Intakes

In order to numerically estimate the risks for current and future human receptors at Site 30, a CDI must be estimated for each COPC in every retained exposure pathway. Appendix R contains the specific CDI equations for each exposure scenario of interest at Site 30. These equations were adopted from USEPA guidance (USEPA, 1989a).

The following paragraphs present the general equations and input parameters used in the calculation of CDIs for each potential exposure pathway. Input parameters were taken from USEPA's default exposure factors guidelines where available and applicable. All inputs not defined by USEPA were derived from USEPA documents concerning exposure or from best professional judgment. All exposure assessments incorporate the representative contaminant concentrations in the estimation of intakes. Therefore, only one exposure scenario was developed for each exposure route/receptor combination.

Carcinogenic risks were calculated as an incremental lifetime risk and, therefore, incorporate terms representing the exposure duration (years) over the course of a lifetime (70 years, or 25,550 days).

Noncarcinogenic risks, on the other hand, were estimated using the concept of an average annual exposure. The intake incorporates terms like the exposure time and/or frequency that represent the number of hours per day and the number of days per year that exposure occurs. In general, noncarcinogenic risks for many exposure routes (e.g., soil ingestion) are greater for children than adults because of the differences in body weights, similar exposure frequencies and higher ingestion rates.

Future residential exposure scenarios consider one to six year old children weighing 15 kg, and adults weighing 70 kg on average. For current/future military personnel an exposure duration of four years was used to estimate a military residence. A one-year duration was used for future construction worker scenarios.

25.3.4.1 Incidental Ingestion of Soil

The CDI for COPCs detected in soil was estimated for all potential human receptors and was expressed as:

$$CDI = \frac{C \times IR \times CF \times Fi \times EF \times ED}{BW \times AT}$$

Where:

C = Contaminant concentration in soil (mg/kg)
IR = Ingestion rate (mg/day)
CF = Conversion factor (1×10^{-6} kg/mg)
Fi = Fraction ingested from source (dimensionless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs associated with the potential ingestion of soils.

Military Personnel

During daily activities at OU No.7, military personnel may be exposed to COPCs by incidental surface soil ingestion. The IR for military personnel exposed to surficial soils was assumed to be 100 mg/day (USEPA, 1989) and 100 percent of the exposure was assumed to occur from facility soils containing COPCs. An exposure frequency (EF) of 250 days per year was used in conjunction with an exposure duration of 4 years. An averaging time (AT) of 70 years or 25,550 days was used for exposure to potentially carcinogenic compounds while an averaging time of 1,460 (4 years x 365 days/year) days was used for noncarcinogenic exposures. An adult average body weight (BW) of 70 kg was used (USEPA, 1989).

Future On-Site Residents

Future on-site residents may be exposed to COPCs in the surficial soils during recreation or while landscaping around their homes. Children and adults could potentially be exposed to COPCs in soils by incidental ingestion via hand to mouth contact. Ingestion rates (IR) for adults and children in this scenario were assumed to be 100 mg/day and 200 mg/day, respectively. EFs for both receptor groups was assumed to be 350 days per year. The residential exposure duration (ED) was divided into two parts. First, a six-year exposure duration was evaluated for young children, which accounts for the period of highest soil ingestion (200 mg/day), and second a 30-year exposure was assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) (USEPA, 1991). The BW for a resident child was assumed to be 15 kg, representing younger individuals. The rationale was that the younger child (1 to 6 years), as a resident, will have access to affected on-site soils. The body weight for the future resident adult is assumed to be 70 kg. Averaging times of 25,550 days for potential carcinogens and 10,950 days (30 years x 365 days/year) for noncarcinogenic constituents was used for estimating potential CDIs for adults. An AT of 2,190 days (6 years x 365 days/year) was used to estimate CDIs for children potentially exposed to noncarcinogens.

Future Construction Worker

During excavation activities construction workers could potentially be exposed to COPCs through the incidental ingestion of subsurface soil. The IR for future construction workers exposed to subsurface soils was assumed to be 480 mg/day (USEPA, 1991). An exposure frequency of 90 days per year was used in conjunction with an exposure duration of one year (USEPA, 1991). An adult BW of 70 kg was used.

A summary of the exposure factors used in the estimation of soil CDIs associated with incidental ingestion is presented in Table 25-8.

25.3.4.2 Dermal Contact with Soil

Chronic daily intakes from potential dermal contact with soils containing COPCs was expressed using the following equation:

$$CDI = \frac{C \ x \ CF \ x \ SA \ x \ AF \ x \ ABS \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:

C = Contaminant concentration in soil (mg/kg)
CF = Conversion factor (kg/mg)
SA = Skin surface available for contact (cm^2)
AF = Soil to skin adherence factor (1.0 mg/cm^2)
ABS = Absorption factor (dimensionless) - 0.01 organics, 0.001 inorganics (USEPA, Region IV, 1992d)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from dermal contact with soils.

Military Personnel

During construction activities, base personnel may absorb COPCs by dermal contact. The exposed skin surface area (4,300 cm^2) was limited to the head (1,180 cm^2), arms (2,280 cm^2), and hands (840 cm^2) (USEPA, 1992). Values for exposure duration (ED), exposure frequency (EF), body weight (BW), and averaging time (AT) were the same as those used for the incidental ingestion of soil scenario. The values for AF and ABS were provided above and are in accordance with USEPA and Region IV guidance.

Future On-Site Residents

Future on-site residents could also be potentially exposed to COPCs in on-site soil through dermal contact during activities near their home. Skin surface areas (SA) used in the on-site resident exposure scenario were developed for a reasonable worst case scenario for an individual wearing a short-sleeved shirt, shorts, and shoes. The exposed skin surface area was limited to the head, hands, forearms, and lower legs. Thus, applying 25 percent of the total body surface area results in a default of 5,800 cm^2 for adults. The exposed skin surface for a child (2,300 cm^2) was estimated using an average of the 50th (0.866 m^2) and the 95th (1.06 m^2) percentile body surface for a six-year-old child multiplied by 25 percent (USEPA, 1992). Exposure duration, exposure frequencies, body weights, and averaging times were the same as those discussed for the incidental ingestion scenario presented previously. The values for AF and ABS were provided above and are in accordance with USEPA and Region IV guidance.

Future Construction Worker

Dermal contact with subsurface soil COPCs could potentially occur during excavation. Skin surface area (SA) used for the construction worker exposure scenario were developed for an individual wearing a short-sleeved shirt, long pants, and boots. The exposed skin surface area (4,300 cm^2) was limited to the head (1,180 cm^2), arms (2,280 cm^2), and hands (840 cm^2) (USEPA, 1992). The exposure frequency and exposure duration are the same as those discussed for incidental ingestion of subsurface soil. The values for AF and ABS were provided above and are in accordance with USEPA and Region IV guidance. A summary of the soil exposure assessment input parameters for dermal contact is presented in Table 25-8.

25.3.4.3 Inhalation of Fugitive Particulates

Exposure to fugitive particulates was estimated for future residents and civilian base personnel. These populations may be exposed during daily recreational or work-related activities. The chronic daily intake of contaminants from the inhalation of particulates was estimated using the following equation:

$$CDI = \frac{C \times IR \times EF \times ED \times 1/PEF}{BW \times AT}$$

Where:

C = Contaminant concentration in soil (mg/kg)
IR = Inhalation rate (m^3/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
$1/PEF$ = Particulate emission factor (m^3/kg)
BW = Body weight (kg)
AT = Averaging time (days)

The PEF relates the concentration in soil with the concentration of respirable particles in the air from fugitive dust emissions. This relationship is derived by Cowherd (1985). The particulate emissions from contaminated sites are caused by wind erosion, and, therefore, depend on erodibility of the surface material. A default PEF obtained from USEPA guidance (USEPA, 1989b) was used in this assessment.

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from the inhalation of particulates.

Military Personnel

During work, military personnel may inhale COPCs emitted as fugitive dust. An inhalation rate 30 m^3/day was used for military personnel (USEPA, 1991). Values for exposure duration, exposure frequency, body weight, and averaging time were the same as those used for the incidental ingestion scenario.

Future On-Site Residents

Future on-site residents could also be potentially exposed to COPCs in on-site soil through inhalation of particulates during activities near their homes. Inhalation rates (IR) used in the on-site resident exposure scenario were 20 m^3/day and 10 m^3/day for adults and children, respectively (USEPA, 1989). Exposure frequencies, duration, body weight, and averaging time were the same as those used for the incidental ingestion scenario. Table 25-8 presents the exposure factors used to estimate CDIs associated with the particulate inhalation scenario.

Future Construction Worker

During work related activities, there is a potential for construction workers to inhale COPCs emitted as fugitive dust. An inhalation rate 20 m^3/day was used (USEPA, 1991). Values for exposure duration, exposure frequency, body weight, and averaging time were the same as those used for the incidental ingestion scenario.

25.3.4.4 Ingestion of Groundwater

The CDI of contaminants associated with the future potential consumption of groundwater was estimated using the following general equation:

$$CDI = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where:

C = Contaminant concentration is groundwater (mg/L)
IR = Ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from the ingestion of groundwater.

Future On-Site Residents

Exposure to COPCs via ingestion of groundwater was retained as a potential future exposure pathway for both children and adults. An IR of 1.0 L/day was used for the amount of water consumed by a 1 to 6-year-old child weighing 15 kg. This ingestion rate provides a conservative exposure estimate (for systemic, noncarcinogenic toxicants) designed to protect young children who could potentially be more affected than adolescents or adults. This value assumes that children obtain all the tap water they drink from the same source for 350 days/year (which represents the exposure frequency [EF]). An averaging time (AT) of 2,190 days (6 years x 365 days/year) is used for noncarcinogenic compound exposure. The ingestion rate (IR) for adults was 2 liters/day (USEPA, 1989a). The ED used for the estimation of adult CDIs was 30 years (USEPA, 1989), which represents the national upper-bound (90th percentile) time at one residence. The averaging time for noncarcinogens was 10,950 days. An averaging time (AT) of 25,550 days (70 years x 365 days/year) was used to evaluate exposure for both children and adults to potential carcinogenic compounds. Table 25-8 is a summary of the input parameters for the ingestion of groundwater scenarios.

25.3.4.5 Dermal Contact with Groundwater

The CDI associated with the dermal contact with groundwater was estimated using the following general equation:

$$CDI = \frac{C \ x \ SA \ x \ PC \ x \ ET \ x \ EF \ x \ ED \ x \ CF}{BW \ x \ AT}$$

Where:

C = Contaminant concentration is groundwater (mg/L)
SA = Surface area available for contact (cm^2)
PC = Dermal permeability constant (cm/hr)
ET = Exposure time (hour/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
CF = Conversion factor (1 L/1000 cm^3)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of risk from dermal contact with groundwater.

Future On-Site Residents

Children and adults could be exposed to COPCs through dermal contact with groundwater while bathing or showering. It was assumed that bathing would take place 350 days/year using site groundwater as the sole source. The whole body skin surface area (SA) available for dermal absorption was estimated to be 10,000 cm^2 for children and 23,000 cm^2 for adults (USEPA, 1992). The permeability constant (PC) reflects the movement of a chemical across the skin and into the blood stream. The permeability of a chemical is an important property in evaluating actual absorbed dose, yet many compounds do not have literature PC values. For contaminants in which a PC value has not been established, the permeability constant was calculated (See Appendix O). An exposure time (ET) of 0.25 hour/day was used to conservatively estimate the duration of bathing or showering. The exposure duration, body weight, and averaging time were the same as those used for the ingestion of groundwater scenario.

Table 25-8 presents the exposure factors used to estimate CDIs associated with the future dermal contact with COPCs in groundwater.

25.3.4.6 Inhalation of Volatile Organics While Showering

In order to quantitatively assess the inhalation of contaminants volatilized from shower water, the model developed by Foster and Chrostowski (1986) was utilized. Contaminant concentrations in air were modeled by estimating the following: the rate of chemical releases into air (generation rate), the buildup of VOCs in the shower room air while the shower was on, the decay of VOCs in the shower room after the shower was turned off, and the quantity of airborne VOCs inhaled while the shower was both on and off. The contaminant concentrations calculated to be in the air were then used as the concentration term.

The CDI associated with the inhalation of airborne (vapor phase) VOCs from groundwater while showering was estimated using the following general equation:

$$CDI = \frac{C \ x \ IR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:

C = Contaminant concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hr)
ET = Exposure time (hr/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Future On-Site Residents

Both children and adults could inhale vaporized volatile organic COPCs during showering. It was assumed that showering would take place 350 days/year, using site groundwater as the sole water source, for children weighing 15 kg, and adults weighing 70 kg. An inhalation rate of 0.6 m^3/hr was used for both receptors (USEPA, 1989). An exposure time of 0.25 hrs/day was used for both receptors (USEPA, 1989). The exposure duration and averaging times remained the same as for groundwater ingestion. Table 25-8 presents the exposure factors used to estimate CDIs associated with the inhalation of VOCs from groundwater while showering.

25.3.4.7 Incidental Ingestion of Surface Water

The CDI for contaminants associated with incidental ingestion of surface water was expressed using the following equation:

$$CDI = \frac{C \ x \ IR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:

C = Contaminant concentration in surface water (mg/L)
IR = Ingestion rate (L/day)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from the incidental ingestion of surface water.

Current Military Personnel

Current military personnel may incidentally ingest surface water while engaging in training exercises in Frenchs Creek. They may conservatively ingest surface water at a rate of 0.005 L/hour, (USEPA, 1989b). In addition, an exposure frequency (EF) of 45 days/year (9 days/month x 5 months) and an exposure duration (ED) of 4 years (USEPA, 1989). The exposure time for swimming, 2.6 hours/day, was conservatively assumed for all receptors. A summary of the surface water exposure factors associated with incidental ingestion of surface water is presented in Table 25-8.

Future Children and Adults

Adults and children who may potentially come into contact with the surface water were assumed to conservatively ingest surface water at a rate of 0.005 L/hour (USEPA, 1989). In addition, an exposure frequency (EF) of 45 days/year (9 days/month x 5 months), an ET of 2.6 hours/day, and an exposure duration (ED) of 6 years (age 1-6) for a child, and 30 years for an adult were used (USEPA, 1989).

25.3.4.8 Dermal Contact with Surface Water

The CDIs of contaminants associated with the dermal contact of surface water were expressed using the following general equation:

$$CDI = \frac{C \ x \ SA \ x \ PC \ X \ ET \ x \ ED \ x \ EF}{BW \ x \ AT}$$

Where:

C = Contaminant concentration in surface water (mg/L)
CF = Conversion factor (1 L/1000 cm^3)
SA = Surface area available for contact (cm^2)
PC = Chemical-specific dermal permeability constant (cm/hr)
ET = Exposure time (hour/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from dermal contact with surface water.

Current Military Personnel

Current military personnel may come in contact with surface water during training exercises in Frenchs Creek. The SA is 5,800 cm^2 (USEPA, 1989). An exposure frequency (EF) of 45 days/year (9 days/month x 5 months) and an exposure duration (ED) of 4 years was used (USEPA, 1989). PC values are chemical-specific. For contaminants for which a PC value has not been established, the permeability constant was calculated (see Appendix O). A summary of the surface water exposure factors associated with incidental ingestion of surface water is presented in Table 25-8.

Future Children and Adults

The SA for adults and children who may come into contact with the surface water was assumed to be 5,800 and 2,300 cm^2, respectively, as previously described in the soil exposure scenario. In addition, an exposure frequency (EF) of 45 days/year (9 days/month x 5 months) and an exposure duration (ED) of 6 years (age 1-6) for a child, and 30 years for an adult were used (USEPA, 1989). Like the military receptor, it was conservatively assumed that 2.6 hours/day would be the exposure time for these receptors. The values for PC were chemical-specific. For COPCs with no PC available, the PC was calculated (see Appendix O).

25.3.4.9 Incidental Ingestion of Sediment

The CDI from the incidental ingestion of sediment was expressed using the following general equation:

$$CDI = \frac{C \ x \ IR \ x \ EF \ x \ ED \ x \ CF}{BW \ x \ AT}$$

Where:

C = Contaminant concentration in sediment (mg/kg)
CF = Conversion factor (kg/mg)
IR = Ingestion rate of sediment (mg/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from the incidental ingestion of sediments.

Current Military Personnel

Current military personnel may incidentally ingest COPCs in sediments during training occurring in the surface water bodies at Site 30. An ingestion rate (IR) of 100 mg/day was used in calculating the chronic daily intake. The exposure frequency (EF) of 45 days/year (9 days/month x 5 months) was used as a conservative site-specific assumption. An exposure duration (ED) of 4 years was used. An averaging time (AT) of 70 years or 25,550 days was used for exposure to potentially carcinogenic compounds while an averaging time of 1,460 (4 years x 365 days/year) days was used for noncarcinogenic exposures. An adult average body weight (BW) of 70 kg was used (USEPA, 1989). A summary of exposure factors for this scenario is presented in Table 25-8.

Future Children and Adults

Incidental ingestion of COPCs in sediments is also possible during activities in the surface water bodies at Site 30. An ingestion rate (IR) of 100 mg/day was used in calculating the chronic daily intake for children and adults. The exposure frequency (EF) of 45 days/year (9 days/month x 5 months) was used as a conservative site-specific assumption. An exposure duration (ED) of 6 years and 30 years was used in the estimation of exposure to COPCs for a child and adult, respectively.

25.3.4.10 Dermal Contact with Sediment

The CDIs of contaminants from the dermal contact of sediments were expressed using the following general equation:

$$CDI = \frac{C \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT}$$

Where:

C = Contaminant concentration in sediment (mg/kg)
CF = Conversion factor (kg/mg)
SA = Surface area available for contact (cm^2/day)
AF = Adherence factor (1.0 mg/cm^2)
ABS = Absorption factor (dimensionless) - 0.01 organics, 0.001 inorganics (USEPA, Region IV, 1992d)
EF = Exposure frequency (days/year)

ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

The following paragraphs discuss the exposure assumptions used in the estimation of exposure to COPCs from dermal contact with sediment.

Current Military Personnel

During daily activities at Site 30, military personnel may be exposed to COPCs by dermal contact with sediment. Like the soil exposure scenario, the SA was assumed to be 5,800 cm^2 (USEPA, 1989). The adherence factor was 1.0. An exposure frequency (EF) of 45 days per year was used in conjunction with an exposure duration of 4 years. An averaging time (AT) of 70 years or 25,550 days was used for exposure to potentially carcinogenic compounds while an averaging time of 1,460 (4 years x 365 days/year) days was used for noncarcinogenic exposures. An adult average body weight (BW) of 70 kg was used. Table 25-8 provides a complete summary of the input parameters used in the estimation of CDIs for this scenario.

Future Children and Adults

Future on-site residents may be exposed to COPCs in sediment through dermal contact during activities in the adjacent surface water. Like the soil exposure scenarios, skin surface areas (SA) used in the on-site resident exposure scenario were developed for a reasonable worst case scenario for an individual wearing a short-sleeved shirt, shorts, and shoes. The exposed skin surface area was limited to the head, hands, forearms, and lower legs. Thus, applying 25 percent of the total body surface area results in a default of 5,800 cm^2 for adults. The exposed skin surface for a child (2,300 cm^2) was estimated using an average of the 50th (0.866 m^2) and the 95th (1.06 m^2) percentile body surface for a six-year-old child multiplied by 25 percent. The child SA was calculated using information presented in USEPA guidance (USEPA, 1992). Exposure duration, exposure frequencies, body weight, and averaging times were the same as those discussed for the surface water exposure scenario presented previously. The values for AF and ABS were provided with the equation and are in accordance with USEPA and Region IV guidance.

25.4 Toxicity Assessment

The purpose of this section is to define the toxicological values used to evaluate the exposure to the COPCs identified in Section 25.2.4. A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of the review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with potential exposure to various contaminants.

Human data from occupational exposures are often insufficient for determining quantitative indices of toxicity because of uncertainties in exposure estimates and inherent difficulties in determining causal relationships established by epidemiological studies. For this reason, animal bioassays are conducted under controlled conditions and their results are extrapolated to humans. There are several stages to this extrapolation. First, to account for species differences, conversion factors are used to extrapolate from test animals to humans. Second, the relatively high doses administered to test animals must be extrapolated to the lower doses more typical of human exposures. For potential noncarcinogens, safety factors and modifying factors are applied to animal results when developing acceptable human doses. For potential carcinogens, mathematical models are used to extrapolate effects at high doses to effects at lower doses. Epidemiological data can be used for inferential purposes to establish the credibility of the experimentally derived indices.

The available toxicological information indicates that many of the COPCs have both potential carcinogenic and noncarcinogenic health effects in humans and/or experimental animals. Although the COPCs may cause adverse health and environmental impacts, dose-response relationships and the potential for exposure must be evaluated before the risk to receptors can be determined. Dose-response relationships correlate the magnitude of the dose with the probability of toxic effects, as discussed in the following section.

An important component of the risk assessment is the relationship between the dose of a compound (amount to which an individual or population is potentially exposed) and the potential for adverse health effects resulting from the exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated. The published information on doses and responses is used in conjunction with information on the nature and magnitude of exposure to develop an estimate of risk.

Standard carcinogenic slope factors (CSFs) and/or reference doses (RfDs) have been developed for many of the COPCs. This section provides a brief description of these parameters.

25.4.1 Carcinogenic Slope Factor

CSFs are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen (USEPA, 1989a). This factor is generally reported in units of $(mg/kg/day)^{-1}$ and is derived through an assumed low-dosage linear multistage model and an extrapolation from high to low dose-responses determined from animal studies. The value used in reporting the slope factor is the upper 95th percent confidence limit.

These slope factors are also accompanied by USEPA weight-of-evidence (WOE) classifications, which designate the strength of the evidence that the COPC is a potential human carcinogen.

In assessing the carcinogenic potential of a chemical, the Human Health Assessment Group (HHAG) of USEPA classifies the chemical into one of the following groups, according to the weight of evidence from epidemiologic and animal studies:

Group A - **Human Carcinogen** (sufficient evidence of carcinogenicity in humans)
Group B - **Probable Human Carcinogen** (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
Group C - **Possible Human Carcinogen** (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
Group D - **Not Classifiable as to Human Carcinogenicity** (inadequate or no evidence)
Group E - **Evidence of Noncarcinogenicity for Humans** (no evidence of carcinogenicity in adequate studies)

25.4.2 Reference Dose

The RfD is developed for chronic and/or subchronic human exposure to chemicals and is based solely on the noncarcinogenic effects of chemical substances. It is defined as an estimate of a daily exposure level for the human population, including sensitive populations, that is not likely to cause an appreciable risk of adverse effects during a lifetime. The RfD is usually expressed as dose (mg) per unit body weight (kg) per unit time (day). It is generally derived by dividing a no-observed-(adverse)-effect-level (NOAEL or NOEL) or a lowest observed-adverse-effect-level (LOAEL) for the critical toxic effect by an appropriate uncertainty factor (UF). Effect levels are determined from laboratory or epidemiological studies. The UF is based on the availability of toxicity data.

UFs usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These UFs are presented below and were taken from the Risk Assessment Guidance Document for Superfund, Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989):

- A UF of 10 is to account for variation in the general population and is intended to protect sensitive populations (e.g., elderly, children).
- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to UFs, a modifying factor (MF) is applied to each reference dose and is defined as

- A MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default for the MF is 1.

Thus, the RfD incorporates the uncertainty of the evidence for chronic human health effects. Even if applicable human data exist, the RfD still maintains a margin of safety so that chronic human health effects are not underestimated.

Toxicity factors and the USEPA WOE classifications are presented in Table 25-10. The hierarchy (USEPA, 1989) for choosing these values was as follows:

- Integrated Risk Information System (IRIS, 1994)
- Health Effects Assessment Summary Table (HEAST, 1994)

The IRIS data base is updated monthly and contains both verified CSFs and RfDs. The USEPA has formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup to review and validate toxicity values used in developing CSFs. Once the slope factors have been verified via extensive peer review, they appear in the IRIS data base. Like the CSF Workgroup, the USEPA has formed a RfD Workgroup to review existing data used to derive RfDs. Once the reference doses have been verified, they also appear in IRIS.

HEAST on the other hand, provides both interim (unverified) and verified CSFs and RFDs. This document is published quarterly and incorporates any applicable changes to its data base.

Toxicity values will be obtained primarily from the Region III Risk-Based Concentration Table, which is based on IRIS, HEAST, and provisional and/or recommended USEPA toxicity values, in accordance with Region IV recommendations.

25.4.3 Dermal Adjustment of Toxicity Factors

Because there are few toxicity reference values for dermal exposure, oral values are frequently used to assess risk from dermal exposure. Most RfDs and some slope factors are expressed as the amount of substance administered per unit time and unit body weight, while exposure estimates for the dermal route are expressed as absorbed dose. Consequently, it may be necessary to adjust an oral toxicity value from an administered dose to an absorbed dose.

Region IV provides absorption efficiency values for each class of chemicals. They are as follows:

VOCs = 0.80
SVOCs = 0.50
Inorganics = 0.20
Pesticides/PCBs = 0.50

An adjusted oral RfD is the product of the absorption efficiency and the oral toxicity reference value. The adjusted oral CSF is the ratio of the oral toxicity value and the absorption efficiency. Table 25-11 presents of summary of the dermally-adjusted toxicity values used in this BRA.

25.5 <u>Risk Characterization</u>

This section presents and discusses the estimated incremental lifetime cancer risks (ICRs) and hazard indices (HIs) for identified potential receptor groups that could be exposed to COPCs via the exposure pathways presented in Section 25.3.

These quantitative risk calculations for potentially carcinogenic compounds estimate ICRs levels for an individual in a specified population. This unit risk refers to the cancer risk that is over and above the background cancer risk in unexposed individuals. For example, an ICR of $1\text{x}10^{-6}$ indicates that, for a lifetime exposure, one additional case of cancer may occur per one million exposed individuals.

The ICR to individuals was estimated from the following relationship:

$$ICR = \sum_{i=1}^{n} CDI_i \ x \ CSF_i$$

where CDI_i is the chronic daily intake (mg/kg/day) for compound i and CSF_i is the cancer slope in (mg/kg/day)-1 for contaminant i. The CSF is defined in most instances as an upper 95th percentile confidence limit of the probability of a carcinogenic response based on experimental animal data, and the CDI is defined as the exposure expressed as a mass of a substance contracted per unit body weight per unit time, averaged over a period of time (i.e., six years to a lifetime). The above equation was derived assuming that cancer is a non-threshold process and that the potential excess risk level is proportional to the cumulative intake over a lifetime.

In contrast to the above approach for potentially carcinogenic effects, quantitative risk calculations for noncarcinogenic compounds assume that a threshold toxicological effect exists. Therefore, the potential for noncarcinogenic effects is calculated by comparing CDIs with threshold levels (reference doses).

Noncarcinogenic effects were estimated by calculating the hazard index (HI) which is defined as:

$$HI = HQ_1 + HQ_2 + ...HQ_n \text{ or}$$

$$HI = \sum_{i=1}^{n} HQ_i$$

$$\text{where } HQ_i = CDI_i / RfD_i$$

HQi is the hazard quotient for contaminant i, CDI_i is the chronic daily intake (mg/kg/day) of contaminant i, and RfD_i is the reference dose (mg/kg/day) of the contaminant i over a prolonged period of exposure.

25.5.1 Human Health Risks

The following paragraphs present the quantitative results of the human health evaluation for each medium and area of concern at Site 30. These results are summarized in Table 25-12.

Estimated ICRs were compared to the target risk range of $1x10^{-4}$ to $1x10^{-6}$. A value of 1.0 was used for examination of the HI. The HI was calculated by comparing estimated CDIs with threshold levels below which, noncarcinogenic health effects are not expected to occur. Any HI equal to or exceeding 1.0 suggested that noncarcinogenic health effects were possible. If the HI was less than 1.0, then systemic human health effects were considered unlikely.

25.5.1.1 Current Military Personnel

The current military receptor was evaluated for potential noncarcinogenic and carcinogenic risk from exposure to the surface soil, surface water, and sediment at Site 30. No COPCs were identified in the surface soil. As a result, exposure to surface soil was not evaluated for potential risk. No carcinogenic COPCs were identified in the surface water or sediment. The noncarcinogenic risk (i.e., 8.9×10^{-3}) from exposure to surface water and sediment for this receptor did not exceed the acceptable risk level of one.

25.5.1.2 Future Residential Child

The child receptor was evaluated for potential risk from exposure to subsurface soil, surface water, and sediment in the future scenario. The total noncarcinogenic risk from exposure to these media was 0.2, which does not exceed the acceptable risk level of one. The total carcinogenic risk was 1.8×10^{-6}, which is within the target risk range of 1×10^{-4} to 1×10^{-6}. The potential risks to the child were within acceptable risk levels.

25.5.1.3 Future Residential Adult

The adult receptor was evaluated for potential risk from exposure to subsurface soil, surface water, and sediment in the future scenario. The total noncarcinogenic risk from exposure to these media was 0.062, which does not exceed the acceptable risk level of one. The total carcinogenic risk was 1.2×10^{-6}, which is within acceptable risk levels. The potential risks to the adult were within acceptable risk levels.

25.5.1.4 Future Construction Worker

The construction worker was evaluated for potential noncarcinogenic and carcinogenic risk from exposure to the subsurface soil in the future case. Both noncarcinogenic (i.e., 0.025) and carcinogenic risks (i.e., 3.9×10^{-8}) from exposure to the subsurface soil fell within the acceptable risk levels for this receptor.

25.6 Standards/Criteria/TBC Comparison Results

The following subsections provide a brief summary of the COPCs identified in each medium of concern which exceed a standard/criteria/TBC. The results of the comparisons between sediment results and criteria are in Section 26, Ecological Risk Assessment, of this report.

25.6.1 Surface Soil

On comparison of Site 30 background surface soil total metal concentrations to maximum USGS levels, there were no exceedances. On comparison of the total metal levels in the site surface soils to the maximum USGS levels and twice the average site background levels, no metals exceeded the levels.

25.6.2 Subsurface Soil

On comparison of Site 30 background subsurface soil total metal concentrations to maximum USGS levels, there were no exceedances. On comparison of the total metal levels in the site subsurface soils to the maximum USGS levels, no metals exceeded the levels. The following inorganic COPCs in the site subsurface soil exceeded twice the average site background level: aluminum (3/14), arsenic (4/14), chromium (4/14), cobalt (1/14), copper (4/14), iron (5/14), manganese (2/14), mercury (2/14), nickel (3/14), and vanadium (2/14). Barium, calcium, lead, magnesium, potassium, sodium, and zinc did not exceed site background levels.

25.6.3 Groundwater

Chloroform was detected in the groundwater at Site 30. On comparison to both Federal and state MCLs, there were no exceedances.

The following metals have Federal MCLs available for comparison: barium, chromium and lead. On comparison of total metals concentrations in the groundwater to federal MCLs, no metals exceeded the federal criteria.

The following metals have state MCLs available for comparison: barium, chromium, iron, lead and manganese. On comparison of total metals concentrations in the shallow and deep groundwater to state MCLs, only iron exceeded (1/3) the criteria.

25.6.4 Surface Water

Of the 11 metals found in the surface water, barium, copper, iron, lead, manganese, and mercury have Federal AWQC available for comparison. Of these metals, iron (3/3) and mercury (1/3) exceeded the human health criteria for ingestion of water and organisms. There are no state WQC available for the metals found in the surface water.

25.7 Sources of Uncertainty

Uncertainties may be encountered throughout the BRA process. This section discusses the sources of uncertainty involved with the following:

- Analytical data
- Exposure Assessment
- Toxicity Assessment
- Compounds Not Qualitatively Evaluated

In addition, the USEPA stresses the importance of recognizing the unique characteristics and circumstances of each facility and the need to formulate site-specific responses. However, many of the assumptions presented in this document were derived from USEPA guidance, which is designed to provide a conservative approach and cover a broad variety of cases. As such, the generic application of such assumptions to a site in the worst-case scenario may work against the objective of formulating a site-specific response to a constituent presence (i.e., it is possible that the site risks may be overestimated).

The following sections present a discussion of these sources of uncertainty and how the total site risks may be affected.

25.7.1 Analytical Data Uncertainty

The development of a BRA depends on the reliability of and uncertainties with the analytical data available to the risk assessor. Analytical data are limited by the precision and accuracy of the analytical method of analysis. In addition, the statistical methods used to compile and analyze the data (mean concentration, standard deviation, and detection frequencies) are subject to the uncertainty in the ability to acquire data.

Data validation serves to reduce some of the inherent uncertainty associated with the analytical data by establishing the usability of the data to the risk assessor who may or may not choose to include the data point in the estimation of risk. Data qualified as "J" (estimated) were retained for the estimation of risk at OU No.7. Data can be qualified as estimated for many reasons including a slight exceedance of holding times, high or low surrogate recovery, or intra-sample variability. Organic data qualified "B" (detected in blank) or "R" (unreliable) were not used in the estimation of risk because of the unusable nature of the data. The sampling and analytical program at Site 30 was comprehensive; therefore, the loss of some data points qualified "B" or "R" did not significantly increase the uncertainty in the estimation of risk.

25.7.2 Exposure Assessment Uncertainty

In performing exposure assessments, uncertainties can arise from two main sources. First, the chemical concentration to which a receptor may be exposed must be estimated for every medium of interest. Second, uncertainties can arise in the estimation of contaminant intakes resulting from contact by a receptor with a particular medium.

Estimating the contaminant concentration in a given medium to which a human receptor could potentially be exposed can be as simple as deriving the 95th percent upper confidence limit of the mean for a data set. More complex methods of deriving the contaminant concentration are necessary when exposure to COPCs in a given medium occurs subsequent to release from another medium, or when analytical data are not available to characterize the release. In this case, modeling is usually employed to estimate the potential human exposure.

The potential inhalation of fugitive dusts from affected soils was estimated in the BRA using USEPA's Rapid Assessment of Exposure to Particulate Emissions from Surface Contaminated Sites (Cowherd et al. 1985). The Cowherd model uses a site-specific PEF for wind erosion based on source area and vegetative cover. A conservative estimate of the PEF was derived for Site 30 by assuming that the entire area was not covered with vegetation and was unlimited in its erosion potential. Modeling results for fugitive dust emission exposure suggested that the potential risk associated with this pathway was not significant.

Groundwater samples were analyzed for total (unfiltered) and dissolved (filtered) inorganic contaminants. These samples were obtained from wells which were constructed using USEPA Region IV monitoring well design specifications. Groundwater taken from monitoring wells cannot be considered representative of potable groundwater or groundwater which is obtained from a domestic well "at the tap." The use of total inorganic analytical results overestimates the potential human health risks associated with potable use scenarios. However, for the sake of conservatism, total organic results were used to estimate the potential intake associated with groundwater use.

Currently, the shallow groundwater is not used as a potable source. Current receptors (military personnel, military dependents, and civilian base personnel) are exposed via ingestion, dermal contact, and inhalation to groundwater drawn from the deep zone. Therefore, assessing current risks to contaminants detected in the shallow aquifer for current receptors is unnecessary and, if estimated, may present an unlikely risk. Therefore, groundwater exposure to current receptors was not estimated for this investigation.

To estimate an intake, certain assumptions must be made about exposure events, exposure durations, and the corresponding assimilation of contaminants by the receptor. Exposure factors, have been generated by the scientific community and have undergone review by the USEPA. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of limited number of individuals. In all instances, values used in the risk assessment, scientific judgments, and conservative assumptions agree with those of the USEPA. Conservative assumptions designed not to underestimate daily intakes were employed throughout the BRA and should error conservatively, thus adequately protecting human health and allowing the establishment of reasonable clean-up goals.

25.7.3 Sampling Strategy Uncertainty

Soil represents a medium of direct contact exposure and often is the main source of contaminants released into other media. The soil sampling depth should be applicable for the exposure pathways and contaminant transport routes of concern and should be chosen purposely within that depth interval. If a depth interval is chosen purposely, a random sample procedure to select a sampling point may be established. The assessment of surface exposure at the site is certain based on collection of samples from the shallowest depth, zero to one foot. Subsurface soil samples are important, however, if soil disturbance is likely or leaching of chemicals to groundwater is of concern.

The surface soil samples at all sites were obtained directly or very near the suspected disposal areas. Therefore, these areas would be considered areas of very high concentration that would have a significant impact on exposures.

Because buried chemical agents may have been present, the subsurface soil investigation did not include extensive sampling. The subsurface soil concentrations used in determining construction workers' exposures were derived from subsurface soils that were considered around the site or off site. Consequently, the risk to future construction workers from ingestion and dermal contact with subsurface soils may be biased low. However, given the limited contaminants detected in the surface soil and groundwater, it does not appear as if additional subsurface soil sampling is needed.

25.7.4 Toxicity Assessment Uncertainty

In making quantitative estimates of the toxicity of varying doses of a compound to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are usually insufficient, if they are available at all. Human exposure data usually lack adequate concentration estimations and suffer from inherent temporal variability. Therefore, animal studies are often used; and, therefore, new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental animals, high doses of a compound are used over a relatively short time period. In this situation, a high dose means that experimental animal exposures are much greater than human environmental exposures. Therefore, when applying the results of the animal experiment to humans, the effects at the high doses must be extrapolated to approximate effects at lower doses.

In extrapolating effects from animals to humans and high doses to low doses, scientific judgment and conservative assumptions are employed. In selecting animal studies for use in dose-response calculations, the following factors are considered:

- Studies are preferred where the animal closely mimics human pharmacokinetics

- Studies are preferred where dose intake most closely mimics the intake route and duration for humans

- Studies are preferred which demonstrate the most sensitive response to the compound in question

For compounds believed to cause threshold effects (i.e., noncarcinogens), safety factors are employed in the extrapolation of effects from animals to humans and from high to low doses.

The use of conservative assumptions results in quantitative indices of toxicity that are not expected to underestimate potential toxic effects, but may overestimate these effects by an order of magnitude or more.

25.8 Conclusions of the BRA for Site 30

The BRA highlights the media of interest from the human health standpoint at Site 30 by identifying areas with risk values greater than acceptable levels. Current and future potential receptors at the site include current military personnel, future residents (i.e., children and adults), and future construction workers. The potential noncarcinogenic and carcinogenic risks associated with exposure to subsurface soil, surface water and sediment for the receptors evaluated at this site were within acceptable risk levels.

SECTION 25.0 TABLES

TABLE 25-1

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS FOR TOTAL METALS IN SURFACE SOIL
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum Value (mg/kg)	Maximum Value (mg/kg)	Average Arithmetic (mg/kg)	No. of Times Detected	No. of Times Analyzed	Frequency of Detection	Background Average (mg/kg)	No. Times Exceeds	USGS Background (mg/kg)	No. Times Exceeds
Aluminum	39.00	1390.00	330.10	14	14	100%	4201.05	0/14	100000	0/14
Barium	1.50	2.30	1.40	8	14	64%	13.61	0/14	1500	0/14
Calcium	92.10	92.10	14.50	1	14	14%	1064.06	0/14	280000	0/14
Chromium	1.40	2.00	1.10	5	14	86%	4.80	0/14	1000	0/14
Copper	1.00	2.30	0.90	5	14	64%	9.06	0/14	700	0/14
Iron	153.00	1050.00	327.80	14	14	100%	2515.18	0/14	100000	0/14
Lead	1.50	8.00	2.50	12	14	93%	24.70	0/14	300	0/14
Magnesium	5.60	39.40	11.30	12	14	93%	170.30	0/14	50000	0/14
Manganese	2.60	8.60	6.00	14	14	100%	14.19	0/14	7000	0/14
Mercury	0.05	0.07	0.03	2	14	43%	0.08	0/14	3.4	0/14
Potassium	8.50	19.30	8.40	2	14	43%	155.30	0/14	37000	0/14
Sodium	8.40	20.10	11.00	8	14	29%	61.93	0/14	50000	0/14
Vanadium	1.00	3.10	1.70	14	14	100%	6.52	0/14	300	0/14
Zinc	1.40	5.70	1.20	4	14	50%	9.67	0/14	2900	0/14

Note: The data frequencies do not included rejected data. Consequently, these values may differ slightly from the frequencies presented in Appendix K.

TABLE 25-2

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS
FOR TOTAL METALS IN SUBSURFACE SOIL
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum Value (mg/kg)	Maximum Value (mg/kg)	Average (mg/kg)	No. of Times Detected	No. of Times Analyzed	Frequency of Detection	Average Background (mg/kg)	No. Times Exceeds	USGS Background (mg/kg)	No. Times Exceeds
Aluminum	327.00	9730.00	3589.07	14	14	100%	6439.90	3/14	100000	0/14
Arsenic	0.62	1.40	0.58	5	14	36%	0.89	4/14	73	0/14
Barium	1.20	11.00	2.96	9	14	64%	11.06	0/14	1500	0/14
Calcium	33.80	41.30	14.13	2	14	14%	118.75	0/14	280000	0/14
Chromium	1.50	13.20	5.45	12	14	86%	8.52	4/14	1000	0/14
Cobalt	0.66	1.00	0.46	2	14	14%	0.90	1/14	70	0/14
Copper	0.97	5.20	1.89	9	14	64%	2.46	4/14	700	0/14
Iron	134.00	4080.00	1447.14	14	14	100%	2373.67	5/14	100000	0/14
Lead	1.40	4.40	2.46	13	14	93%	5.84	0/14	300	0/14
Magnesium	7.90	171.00	44.34	13	14	93%	209.74	0/14	50000	0/14
Manganese	2.20	9.80	5.26	14	14	100%	7.16	2/14	7000	0/14
Mercury	0.06	0.37	0.07	6	14	43%	0.19	2/14	3.4	0/14
Nickel	1.80	3.50	1.43	5	14	36%	2.06	3/14	700	0/14
Potassium	6.20	151.00	29.43	6	14	43%	241.18	0/14	37000	0/14
Sodium	10.70	23.80	11.40	4	14	29%	30.76	0/14	50000	0/14
Vanadium	0.73	9.70	4.01	14	14	100%	9.54	2/14	300	0/14
Zinc	0.70	2.10	1.00	7	14	50%	3.70	0/14	2900	0/14

Note: The data frequencies do not included rejected data. Consequently, these values may differ slightly from the frequencies presented in Appendix K.

TABLE 25-3

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS FOR TOTAL METALS IN GROUNDWATER
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum Value (μg/L)	Maximum Value (μg/L)	Arithmetic Average (μg/L)	No. of Times Detected	No. of Times Analyzed	Frequency of Detection	Federal MCL (μg/L)	No. Times Exceeds	State MCL (μg/L)	No. Times Exceeds	Federal Health Advisories (μg/L)			
											10 kg Child	No. Times Exceeds	70 kg Adult	No. Times Exceeds
Aluminum	782	2,210	1,085	2	3	67%	NA	NA	NA	NA	NA	NA	NA	NA
Barium	15	31.4	20.5	3	3	100%	2,000	0/3	2000	0/3	NA	NA	NA	NA
Calcium	1,720	2,080	1,394	2	3	67%	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	9.3	9.3	5.43	1	3	33%	100	0/3	50	0/3	200	0/3	800	0/3
Iron	692	692	296.3	1	3	33%	NA	NA	300	1/3	NA	NA	NA	NA
Lead	1.3	1.8	1.2	2	3	67%	5	0/3	15	0/3	NA	NA	NA	NA
Magnesium	566	1,320	916	3	3	100%	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	7.7	31.2	18.1	3	3	100%	NA	NA	50	0/3	NA	NA	NA	NA
Potassium	370	447	299	2	3	67%	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	3,410	15,000	8,073	3	3	100%	NA	NA	NA	NA	NA	NA	NA	NA

Note: The data frequencies do not included rejected data. Consequently, these values may differ slightly from the frequencies presented in Appendix K.

TABLE 25-4

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS
FOR ORGANICS IN GROUNDWATER
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum Value (μg/L)	Maximum Value (μg/L)	Arithmetic Average (μg/L)	No. of Times Detected	No. of Times Analyzed	Frequency of Detection	Federal MCL (μg/L)	No. Times Exceeds	State MCL (μg/L)	No. Times Exceeds	Federal Health Advisories (μg/L)			
											10 kg Child	No. Times Exceeds	70 kg Adult	No. Times Exceeds
Chloroform	9	9	3.7	1	3	33%	0.1	0/3	0.19	0/3	100	0/3	400	0/3

TABLE 25-5

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS FOR TOTAL METALS IN SURFACE WATER
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum Value (μg/L)	Maximum Value (μg/L)	Arithmetic Average (μg/L)	No. of Times Detected	Frequency of Detection	Federal AWQC (Water & Org.) (μg/L)	No. Times Exceeds	Federal AWQC (Org. Only) (μg/L)	No. Times Exceeds	State WQS (μg/L)	No. Times Exceeds	Site Background (μg/L)	Max. Conc. Exceeds (Y or N)
Aluminum	373	1480	745.3	3/3	100%	NA	NA	NA	NA	NA	NA	333.17	Y
Barium	10.2	10.3	8	2/3	67%	NA	NA	NA	NA	NA	NA	25.67	N
Calcium	2080	9660	5320	3/3	100%	NA	NA	NA	NA	NA	NA	17,566.50	N
Copper	6	6	4	1/3	33%	2.9	1/3	NA	NA	NA	NA	ND	Y
Iron	495	829	639.7	3/3	100%	NA	NA	NA	NA	NA	NA	575.67	Y
Lead	2.3	2.3	1.1	1/3	33%	220	0/3	NA	NA	NA	NA	ND	Y
Magnesium	650	840	730	3/3	100%	NA	NA	NA	NA	NA	NA	1,744.67	N
Manganese	3.3	11.1	6.6	3/3	100%	NA	NA	100	0/3	NA	NA	ND	Y
Mercury	0.15	0.15	0.1	1/3	33%	2.1	0/3	0.146	0/3	NA	NA	ND	Y
Potassium	220	321	256.7	3/3	100%	NA	NA	NA	NA	NA	NA	ND	Y
Sodium	4440	5030	4756.7	3/3	100%	NA	NA	NA	NA	NA	NA	9,830.00	N

Note: The data frequencies do not included rejected data. Consequently, these values may differ slightly from the frequencies presented in Appendix K.

TABLE 25-6

SUMMARY OF STANDARDS/CRITERIA COMPARISON RESULTS FOR TOTAL METALS IN SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Maximum Value (mg/kg)	Site Background (mg/kg)	Maximum Conc. Exceeds (Y or N)
Aluminum	3,390.00	1,165.57	Y
Barium	10.10	6.46	Y
Beryllium	0.37	0.09	Y
Cadnium	0.60	0.04	Y
Chromium	7.90	1.86	Y
Cobalt	0.77	ND	Y
Copper	9.50	0.75	Y
Lead	15.50	0.79	Y
Magnesium	133.00	45.25	Y
Manganese	19.00	3.63	Y
Mercury	0.15	ND	Y
Nickel	5.80	ND	Y
Vanadium	6.00	1.52	Y
Zinc	11.30	5.11	Y

Note: The essential nutrients, calcium, iron, magnesium, potassium, and sodium, were not included on this table.

TABLE 25-7

SUMMARY OF COPCs SURFACE SOIL, SUBSURFACE SOIL, GROUNDWATER, SURFACE WATER AND SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Surface Soil	Excluded - Low Frequency of Detection	Excluded - Within Off-site Background Levels	Excluded - Essential Nutrients	Excluded - Common Laboratory Contaminants
No COPCs were identified for Site 30 surface soil.	1,1,1-trichloroethane	aluminum barium chromium copper lead manganese mercury vanadium zinc	calcium iron magnesium potassium sodium	bis(2-ethylhexyl)phthalate acetone

TABLE 25-7 (Continued)

SUMMARY OF COPCs SURFACE SOIL, SUBSURFACE SOIL, GROUNDWATER, SURFACE WATER AND SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Subsurface Soil	Excluded - Low Frequency of Detection	Excluded - Within Site Background Levels	Excluded - Essential Nutrients	Excluded - Common Laboratory Contaminant
aluminum (NA) arsenic (c-Class A) chromium cobalt copper manganese mercury nickel vanadium	barium 1,1,1-trichloroethane	lead zinc	calcium iron magnesium potassium sodium	acetone bis(2-ethylhexyl)phthalate

Notes: (c) = Carcinogen and Class
(NA) = No USEPA-verified toxicological factors (i.e., RfDs and CSFs) available

TABLE 25-7 (Continued)

SUMMARY OF COPCs SURFACE SOIL, SUBSURFACE SOIL, GROUNDWATER, SURFACE WATER AND SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Groundwater	Excluded - Essential Nutrients	Excluded - Within Standards/Criteria
No COPCs were identified for Site 30 Groundwater	calcium magnesium potassium sodium	chloroform aluminum barium lead chromium manganese

TABLE 25-7 (Continued)

SUMMARY OF COPCs SURFACE SOIL,
SUBSURFACE SOIL, GROUNDWATER, SURFACE WATER AND SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Surface Water	Excluded - Within Off-site Background Levels	Excluded - Essential Nutrients	Within Standards/Criteria
aluminum (NA) lead (NA) manganese mercury	barium	calcium iron magnesium potassium sodium	copper

Notes: (c) = Carcinogen and Class
(NA) = No USEPA-verified toxicological factors (i.e., RfDs and CSFs) available

TABLE 25-7 (Continued)

SUMMARY OF COPCs SURFACE SOIL, SUBSURFACE SOIL, GROUNDWATER, SURFACE WATER AND SEDIMENT
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Sediment	Excluded - Low Frequency of Detection	Excluded - Within Off-site Background Levels	Excluded - Essential Nutrients	Excluded - Common Laboratory Contaminants/Blank Contamination
aluminum (NA) chromium copper lead (NA) manganese nickel vanadium zinc	beryllium cadmium cobalt	barium	calcium iron magnesium potassium sodium	acetone methyl ethyl ketone bis(2-ethylhexyl)phthalate

Notes: (NA) = No USEPA-verified toxicological factors (i.e., RfDs and CSFs) available

TABLE 25-8

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor			
		Child	Adult	Military Personnel	Construction Worker
Soil (mg/kg)					
Ingestion Rate, IR	mg/d	200	100	100	480
Fraction Ingested, FI	unitless	1	1	1	1
Exposure Frequency, EF	d/y	350	350	250	90
Exposure Duration, ED	y	6	30	4	1
Surface Area, SA	cm^2	2300	5800	4,300	4300
Absorption Factor, AF	mg/cm^3	1	1	1	1
Averaging Time, Noncarc., ATnc	d	2190	10,950	1,460	365
Averaging Time, Carc., ATcarc	d	25550	25,550	25,550	25,550
Body Weight, BW	kg	15	70	70	70
Conversion Factor, CF	kg/mg	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$
Absorbance Factor, ABS	unitless	Organics = 0.01; Inorganics = 0.001			
Sediment (mg/kg)					
Ingestion Rate, IR	mg/d	200	100	100	NA
Fraction Ingested, FI	unitless	1	1	1	NA
Exposure Frequency, EF	d/y	45	45	45	NA
Exposure Duration, ED	y	6	30	4	NA
Surface Area, SA	cm^2	2300	5800	5800	NA
Absorption Factor, AF	mg/cm^3	1	1	1	NA
Averaging Time, Noncarc., ATnc	d	2,190	10,950	1,460	NA
Averaging Time, Carc., ATcarc	d	25,550	25,550	25,550	NA
Body Weight, BW	kg	15	70	70	NA
Conversion Factor, CF	kg/mg	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$	NA
Absorbance Factor, ABS	unitless	Organics = 0.01; Inorganics = 0.001			
Surface Water (mg/L)					
Ingestion Rate, IR	L/h	0.005	0.005	0.005	NA
Exposure Time, ET	h/d	2.6	2.6	2.6	NA
Exposure Frequency, EF	d/y	45	45	45	NA
Exposure Duration, ED	y	6	30	4	NA
Surface Area, SA	cm^2	2300	5800	5800	NA
Averaging Time, Noncarc., ATnc	d	2,190	10,950	1,460	NA
Averaging Time, Carc., ATcarc	d	25,550	25,550	25,550	NA
Conversion Factor, CF	L/cm^3	0.001	0.001	0.001	NA

TABLE 25-8 (Continued)

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor			
		Child	Adult	Military Personnel	Construction Worker
Air (mg/m^3)					
Outdoor Air					
Inhalation Rate, IR	m^3/d	10	20	30	20
Exposure Frequency, EF	d/y	350	350	250	90
Exposure Duration, ED	y	6	30	4	1
Averaging Time, Noncarc., ATnc	d	2,190	10,950	1,460	365
Averaging Time, Carc,. ATcarc	d	25,550	25,550	25,550	25,550
Body Weight, BW	kg	15	70	70	70

References:

USEPA Risk Assessment For Superfund Volume I. Human Health Manual (Part A) Interim Final, December, 1989.

USEPA Exposure Factors Handbook, July, 1989.

USEPA Risk Assessment For Superfund Volume I. Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors" Interim Final. March 25, 1991.

USEPA Dermal Exposure Assessment: Principles and Applications. Interim Report. January, 1992.

USEPA Region IV Guidance for Soil Absorbance. (USEPA, 1992d)

TABLE 25-9

SUMMARY OF EXPOSURE PATHWAYS
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptor	Exposure Pathway
Current Military Personnel	Surface soil ingestion, dermal contact, and inhalation Surface water ingestion and dermal contact Sediment ingestion and dermal contact
Future Construction Worker	Subsurface soil ingestion, dermal contact, and inhalation
Future Residential Adult and Child	Subsurface soil ingestion, dermal contact, and inhalation Surface water ingestion and dermal contact Sediment ingestion and dermal contact

TABLE 25-10

SUMMARY OF HEALTH-BASED CRITERIA
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs	RfD (Oral) (mg/kg/d)	RfC (Inhal.) (mg/kg/d)	CSF (Oral) $(mg/kg/d)^{-1}$	CSF (Inhal.) $(mg/kg/d)^{-1}$	Weight-of-Evidence
METALS					
Aluminum	1.0	-	-	-	-
Arsenic	3.0E-04	-	1.75	15.1	A
Chromium	1.0	-	-	-	-
Cobalt	6.0E-02	-	-	-	-
Copper	3.71E-02	-	-	-	D
Lead	-	-	-	-	B2
Manganese (water) (food/soil)	5.0E-03 1.4E-01	1.43E-05	-	-	D
Mercury	3.0E-04	8.57E-05	-	-	D
Nickel	2.0E-02	-	-	-	-
Vanadium	7.0E-03	-	-	-	-
Zinc	3.0E-01	-	-	-	D

- = Not Available or Applicable

References:

IRIS, 1994
HEAST, 1994
USEPA, 1994

TABLE 25-11

SUMMARY OF DERMALLY-ADJUSTED HEALTH-BASED CRITERIA*
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs	Oral RfD (Dermally Adjusted) (mg/kg/d)	Oral CSF (Dernally Adjusted) $(mg/kg/d)^{-1}$	Weight-of-Evidence
METALS			
Aluminum	0.2	-	-
Arsenic	0.00006	8.75	A
Chromium	0.2	-	-
Cobalt	0.012	-	-
Copper	0.00742	-	D
Lead	-	-	B2
Manganese (water) (food/soil)	0.001 0.028	-	D
Mercury	0.00006	-	D
Nickel	0.004	-	-
Vanadium	0.0014	-	-
Zinc	0.06	-	D

- = Not applicable or available.

* = Oral toxicity values were dermally adjusted. Inhalation values were not adjusted.

References:

IRIS, 1994
HEAST, 1994
USEPA, 1994

TABLE 25-12

SUMMARY OF POTENTIAL RISKS
SITE 30: SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

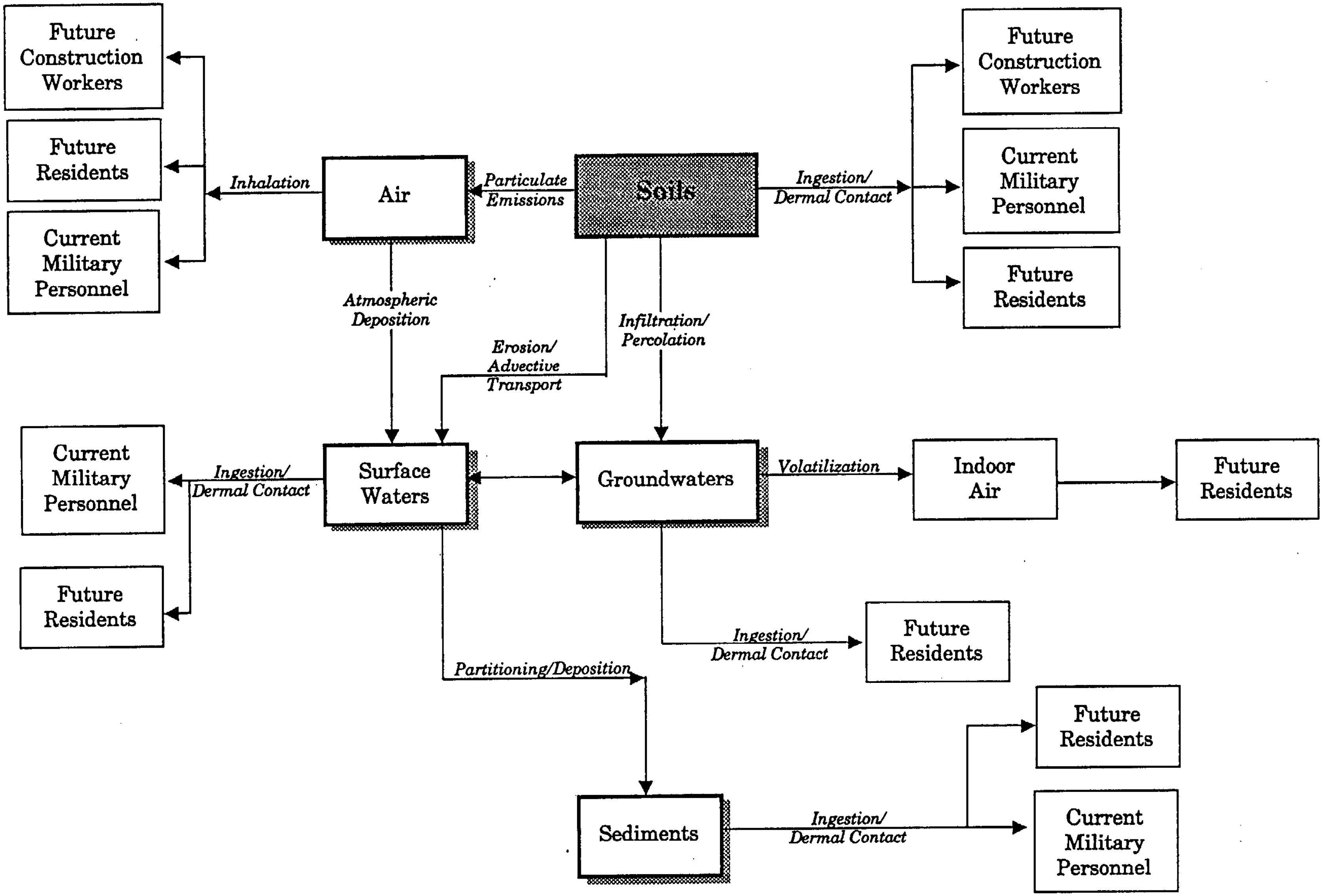
Exposure Pathway	Future Case		Future Case		Current Case		Future Case	
	Child Receptor		Adult Receptor		Military Receptor		Construction Worker	
	NC Risk	Carc Risk	NC Risk	Carc Risk	NC Risk	Carc Risk	NC Risk	Carc Risk
Subsurface Ingestion	1.8E-01	1.7E-06	2.0E-02	9.1E-07	-	-	2.4E-02	3.7E-08
Subsurface Dermal Contact	1.1E-02	9.8E-08	5.7E-03	2.6E-07	-	-	1.1E-03	1.7E-09
Subsurface Inhalation	2.1E-07	1.6E-10	8.9E-08	3.4E-10	-	-	2.3E-08	2.9E-12
total	1.9E-01	1.8E-06	2.5E-02	1.2E-06	-	-	2.5E-02	3.9E-08
Surface Water Ingestion	4.5E-04	-	3.5E-02	-	9.6E-05	-	-	-
Surface Water Dermal Contact	1.0E-03	-	5.6E-04	-	3.5E-05	-	-	-
total	1.5E-03	-	3.6E-02	-	1.3E-04	-	-	-
Sediment Ingestion	8.2E-03	-	8.8E-04	-	6.8E-03	-	-	-
Sediment Dermal Contact	4.7E-04	-	2.5E-04	-	2.0E-03	-	-	-
total	8.6E-03	-	1.1E-03	-	8.8E-03	-	-	-
Total	**2.0E-01**	**1.8E-06**	**6.2E-02**	**1.2E-06**	**8.9E-03**	**-**	**2.5E-02**	**3.9E-08**

Notes: NC = Noncarcinogenic Risk
Carc = Carcinogenic Risk
Total risks are within acceptable risk levels.
- = Not Applicable

SECTION 25.0 FIGURES

FIGURE 25-1

FLOWCHART OF POTENTIAL EXPOSURE PATHWAYS AND RECEPTORS SITE 30: SNEADS FERRY ROAD FUEL TANK SLUDGE AREA



26.0 ECOLOGICAL RISK ASSESSMENT

26.1 Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 directs USEPA to protect human health and the environment with respect to releases or potential releases of contaminants from abandoned hazardous waste sites (USEPA, 1989a). In addition, various Federal and state laws and regulations concerning environmental protection are considered criteria/standards or to be considered (TBC) criteria.

This section presents the ecological risk assessment (ERA) conducted at Site 30 for Operable Unit (OU) No. 7 that addresses the potential impacts to ecological receptors from site-related contaminants.

26.1.1 Objectives of the Ecological Risk Assessment

The objective of this ERA was to evaluate if past disposal practices at Site 30 may be adversely impacting the ecological integrity of the terrestrial and aquatic communities on, or adjacent to the site. This assessment also evaluated the potential effects of contaminants at Site 30 on sensitive environments including wetlands, protected species, and fish nursery areas. The conclusions of the ERA will be used in conjunction with the human health risk assessment to evaluate the appropriate remedial action for this site for the overall protection of public health and the environment.

26.1.2 Scope of the Ecological Risk Assessment

This ERA evaluated and analyzed the results from the RI and historical data collected during other studies. The RI included sampling and chemical analysis of the surface water, sediment, soil, and groundwater at Site 30. In addition, surface water and sediment samples were collected in May 1994 from three creeks in the White Oak River Basin (Holland Mill Creek, Hadnot Creek, and Webb Creek) to be used as off-site background (reference) stations.

Information used to evaluate sensitive environments was obtained from historical data and previous studies conducted at Marine Corps Base (MCB) Camp Lejeune, North Carolina. In addition, a qualitative habitat evaluation was conducted at the site to identify potential terrestrial receptors.

The media of concern for this ERA were the surface water, sediment, and surface soil. This ERA focused on adverse impacts to aquatic and terrestrial receptors. If potential risks are characterized for the ecological receptors, further ecological evaluation of the site and surrounding areas may be warranted.

The risk assessment methodologies used in this evaluation were consistent with those outlined in the Framework for Ecological Risk Assessment (USEPA, 1992e). In addition, information found in the following documents was used to supplement the USEPA guidance document:

- U.S. EPA Supplemental Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989a)

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

26.1.3 Organization of The Ecological Risk Assessment

Based on the USEPA Framework for Ecological Risk Assessment, an ERA consists of three main components: (1) Problem Formulation, (2) Analysis, and (3) Risk Characterization (USEPA, 1992e). The problem formulation section (Section 26.2) includes a preliminary characterization of exposure and effects of the stressors to the ecological receptors. During the analysis (Section 26.3), the data are evaluated to determine the exposure and potential effects on the ecological receptors from the stressors. Finally, in the risk characterization (Section 26.4), the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. Section 26.5 evaluates the potential impact on the ecological integrity at the site from the contaminants detected in the media. Section 26.6 presents an uncertainty analysis, while Section 26.7 summarizes the conclusions of the ERA.

26.2 Problem Formulation

Problem formulation is the first step of an ERA and includes a preliminary characterization of exposure and effects, as well as scientific data needs, policy and regulatory issues, and site-specific factors to define the feasibility, scope, and objectives for the ERA (USEPA, 1992e).

The results of the various site investigations indicated the presence of contaminants in the surface water, sediment, soil, and groundwater. CERCLA directs USEPA to protect the environment with respect to releases of contaminants. Because ecological receptors may be exposed to the contaminants detected at Site 30, an ERA was performed.

Three types of information are needed to evaluate potential links between the contaminants of potential concern (COPCs) and the ecological endpoints. First, chemical analyses of the appropriate media are necessary to establish the presence, concentrations, and variabilities of the COPCs. Second, ecological surveys are necessary to establish if adverse ecological effects have occurred. Finally, toxicological information is necessary to evaluate the potential effects of the COPCs on the ecological receptors. The combination of all three types of data allows the assessment of the relative contribution of other potential causes of the observed effects (as measured by the ecological endpoints) that may be unrelated to the toxic effects of the contaminants of concern (e.g., habitat alterations and natural variability). Therefore, confidence in cleanup and monitoring decisions is greatly enhanced when based on a combination of chemical, ecological, and toxicological data.

Chemical analyses were performed on samples collected from the surface water, sediment, soil, and groundwater to evaluate the presence, concentrations, and variabilities of the COPCs. A habitat characterization conducted as part of Baker's field activities during the RI was used to generate a biohabitat map (refer to section 22.5 for biohabitat map). Based on these observations and available habitat information, potential ecological receptors were identified. Finally, toxicological information for the COPCs detected in the media was obtained from available references and literature and was used to evaluate the potential adverse ecological effects to the ecological receptors.

The components of the problem formulation include stressor characteristics, ecosystems potentially at risk, ecological effects, endpoint selection, and a conceptual model. The following sections discuss each of these components and how they were evaluated in this ERA.

26.2.1 Stressor Characteristics

One of the initial steps in the problem formulation stage of an ERA is identifying the stressor characteristics. The term "stressor" is defined as any physical, chemical, or biological entity that can induce an adverse effect (USEPA, 1992e). For this ERA, the stressors that were evaluated include the contaminants detected in the surface water, sediment, and surface soil. Contaminants in the subsurface soil and groundwater were not evaluated in this ERA, although the stressors introduced by groundwater discharge to surface water and soil erosion are considered..

The nature and extent of these contaminants were discussed in Section 23 of this report. Table 26-1 lists the contaminants that were detected in each media at Site 30. The location of samples was based on historical information available for the site and a site visit to evaluate potential ecosystems and ecological receptors. Figure 20-1, 20-2, and 20-4 illustrates these sample locations. Tables 25-1 through 25-6 present a comparison of the inorganics detected in the surface soil, surface water, and sediment to twice the average base background concentrations or to the range of positive detects from the off-site reference stations.

26.2.1.1 Contaminants of Potential Concern (COPCs)

The COPCs for the ERA were selected following the same basic procedures and criteria used for selecting the COPCs for the Baseline Human Health Risk Assessment (refer to section 25. for more explanation of selection of COPCs). However, COPCs will differ from those selected for the Human Health Risk Assessment. These differences can be the result of toxicity differences, (some of the constituents detected may have a greater or lesser adverse impact to ecological receptors than to human receptors) and the criteria and standards that are used for ecological receptors are different than those used for human receptors.

Quantifying risk for all positively identified contaminants may distract from the dominant risks driving contaminants at the site. Ecological risks (and human health risks) are additive, including chemicals that are not significant, as determined by the COPC selection process, will generate an overestimate of risk. The chemical acting alone may not pose an adverse risk, but, in conjunction with the remaining chemicals, the chemical contributes to the total site risk. Consequently, to include all detected parameters without taking into account other factors, such as detection frequency, background contribution, and site history, would generate an overly conservative risk. Therefore, the data set was reduced to a list of COPCs. The criteria used in selecting the COPCs from the constituents detected during the field sampling and analytical phase of the investigation were: historical information; prevalence; mobility; persistence; toxicity; comparison to investigation-associated field and laboratory blank information; and comparison to background or naturally occurring levels. Table 26-2 presents the COPC selection summaries.

COPCs - Surface Water

Surface water samples were collected at Site 30 from Frenchs Creek.

There were no VOCs or SVOCs detected in the surface water samples. Pesticides and PCBs were not analyzed for in the surface water because it was reasonably determined that past site activities did not involve the use of these compounds.

The following inorganics detected in the surface water samples were not addressed in the ERA because they were common naturally occurring chemicals and were not expected to be ecologically significant at the detected concentrations: calcium, magnesium, potassium, and sodium. Copper and barium were not retained as COPCs because they were detected at concentrations within off-site background concentrations.

The following inorganics detected in the surface water samples at Site 30 were included in the ERA because they could not be excluded based on the criteria stated above: aluminum, iron, lead, manganese, and mercury.

COPCs - Sediments

Sediment samples were collected at Site 30 from Frenchs Creek. Pesticides and PCBs were not analyzed for in the surface water because it was reasonably determined that past site activities did not involve the use of these compounds.

The following VOCs and SVOC detected in the sediment samples were not addressed in the ERA because they were common laboratory and/or decontamination contaminants and/or were detected in the associated QA/QC samples: acetone, 2-butanone, and bis(2-ethylhexyl)phthalate. Also, acetone and 2-butanone were detected infrequently.

The following inorganics detected in the sediment samples were not addressed in the ERA because they are common naturally occurring chemicals and were not expected to be ecologically significant at the detected concentrations: calcium, magnesium, potassium, and sodium. Barium was not retained as a COPC because it was detected at a concentration within the off-site background concentrations. Beryllium, cadmium, and cobalt were not retained as COPCs because they were detected infrequently.

The following chemicals detected in the sediment samples were addressed in the ERA because they could not be excluded based on the criteria stated above: aluminum, chromium, copper, iron, lead, manganese, nickel, vanadium, and zinc.

COPCs - Biota Samples

Biota samples were not collected at Site 30.

COPCs - Surface Soils

Surface soil samples were collected at Site 30. Pesticides and PCBs were not analyzed for in the surface soil because it was reasonably determined that past site activities did not involve the use of these compounds.

The following VOC and SVOC detected in the surface soil samples were not addressed in the ERA because they were common laboratory and/or decontamination contaminants and/or were detected in the associated QA/QC samples: acetone and bis(2-ethylhexyl)phthalate. 1,1,1-Trichloroethane was not retained as a COPC because it was detected infrequently and below soil screening levels.

The following inorganics detected in the surface soil were not addressed in the ERA because they were common naturally occurring chemicals and were not expected to be ecologically significant at the detected concentrations: calcium, magnesium, potassium, and sodium. Aluminum, barium, chromium, copper, iron, lead, manganese, mercury, vanadium, and zinc were not retained as COPCs because they were detected at concentrations within off-site background concentrations.

There were no chemicals retained as COPCs in the surface soil at Site 30.

26.2.1.2 Physical/Chemical Characteristics of COPCs

Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include bioconcentration factors (BCFs) water solubility, organic carbon partition coefficient, octanol water partition coefficient, and vapor pressure. Table 26-3 summarizes these values for the COPCs identified in the sediment and surface water samples at the site. Information from these tables was used in the risk characterization to assess the fate and transport of the constituents and the potential risks to the environmental receptors at each site. The following paragraphs discuss the significance of each parameter included in the table.

Bioconcentration factors measure the tendency for a chemical to partition from the water column or sediment and concentrate in aquatic organisms. Bioconcentration factors are important for ecological receptors because chemicals with high BCFs could accumulate in lower-order species and subsequently accumulate to toxic levels in species higher up the food chain. The BCF is the concentration of the chemical in the organism at equilibrium divided by the concentration of the chemical in the water. Therefore, the BCF is unitless.

Water solubility is important in the ecological environment because it measures the tendency for a chemical to remain dissolved in the water column, partition to soil or sediment, or bioconcentrate in aquatic organisms. Chemicals with high water solubilities tend to be more bioavailable to aquatic organisms. However, they will not significantly bioconcentrate in the organisms. On the other hand, chemicals with a low water solubility will remain bound to the sediment and soils but may bioconcentrate in organisms to a significant degree.

The organic carbon partition coefficient (K_{oc}) measures the tendency for a chemical to partition between soil or sediment particles containing organic carbon and water. This coefficient is important in the ecological environment because it determines how strongly an organic chemical will be bound to the organics in the sediments.

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical concentration in octanol divided by the concentration in water. The octanol/water partition coefficient has been shown to correlate well with bioconcentration factors in aquatic organisms and with adsorption to soil or sediment.

The vapor pressure measures the tendency for a chemical to partition into air. This parameter is important for the ecological environment because it can be used to determine the concentrations of the constituents in air.

26.2.2 Ecosystems Potentially at Risk

Based on the site-specific and regional ecology, ecological receptors were potentially at risk from contaminants at the site (refer to sections 1.2.6 and 22.5 for regional and site-specific ecology, respectively). Contaminants were detected in the surface water, sediment, soil, and groundwater samples at the site. Potential receptors of contaminants in surface water and sediment include aquatic flora and fauna and some terrestrial faunal species. Potential receptors of contaminants in soils include deer, rabbits, foxes, raccoons, birds and other terrestrial fauna as well as terrestrial flora. This ERA will not evaluate contamination in the groundwater.

26.2.3 Ecological Effects

The ecological effects data that were used to assess potential risks to aquatic and/or terrestrial receptors in this ERA include aquatic reference values (ARVs) from the following sources: North Carolina Water Quality Standards, USEPA Water Region IV Quality Screening Values, USEPA Ambient Water Quality Criteria, the Aquatic Information Retrieval Database, and Sediment Screening Values, and terrestrial reference values. The following paragraphs discuss each of the above data sources.

The North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR) has promulgated Water Quality Standards (WQS) that are used to evaluate the quality of waters in North Carolina. These WQS meet the requirements of both federal and state law. These standards are regulatory values and are enforceable.

The USEPA Region IV Waste Management Division (Region IV) has adopted Water Quality Screening Values (WQSV) for chemicals detected at hazardous waste sites (USEPA, 1993). These values are intended as preliminary screening tools to review chemical data from hazardous waste sites. Exceedances of the screening level values indicate that there may be a need for further investigation of the site.

Section 304(a)(1) of the Clean Water Act of 1977 (P.L. 95-217) requires the Administrator of the USEPA to publish criteria for water quality that accurately reflect the latest scientific knowledge on the type and extent of all identifiable effects on health and welfare that may be expected from the presence of pollutants in any body of water, including groundwater. In accordance with the Clean Water Act, the USEPA Office of Water Regulations and Standards, Criteria and Standards Division has published Ambient Water Quality Criteria (AWQC) documents for several chemicals. These documents can be used to evaluate potential risks to aquatic organisms. In addition, potential risks to aquatic plants from contaminants can be evaluated using these documents.

The Aquatic Information Retrieval Database (AQUIRE) database is an on-line system that contains information on acute, chronic, bioaccumulative, and sublethal effects data from tests performed on freshwater and saltwater organisms excluding bacteria, birds, and aquatic mammals. This database can be accessed to evaluate potential risks to aquatic organisms.

Currently, promulgated sediment quality criteria do not exist. Until these criteria are developed, USEPA Region IV is using Sediment Screening Values (SSV) compiled by NOAA for evaluating the potential for chemical constituents in sediments to cause adverse biological effects (USEPA, 1992f), where applicable these SSVs were updated based on the literature. The lower ten percentile (Effects Range-Low [ER-L]) and the median percentile (Effects Range-Median [ER-M]) of biological effects have been developed for several of the chemicals identified during the sediment investigations at Site 30. If sediment contaminant concentrations are above the ER-M, adverse effects on the biota are considered probable. If contaminant concentrations are between the ER-M and ER-L, adverse effects on the biota are considered possible. Finally, if contaminant concentrations are below the ER-L, adverse effects on the biota are considered unlikely (USEPA, 1992f).

There are no standards, criteria, or other screening values for assessing potential impacts to terrestrial ecological receptors from contaminants in soils. A literature search was conducted to identify levels of contaminants in the soil that could cause adverse effects to terrestrial flora and invertebrates. However, these data cannot be used to evaluate potential risks to other terrestrial fauna (e.g., birds, deer, rabbits), since the exposure doses for these species are different than exposure doses for invertebrates and plants, which are in constant direct contact with the contaminants in the soil. In addition, the sensitivity of the organisms to the COPCs is not similar.

Terrestrial reference values (TRVs) for evaluating estimated chronic daily intakes (CDIs) of COPCs for the deer, quail, rabbit, fox, and raccoon were calculated from available toxicity data. The TRVs were developed from No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs) obtained from the Integrated Risk Information System (IRIS), toxicological profiles for specific chemicals, and information from other reference books. These values are used to assess the potential effects of contaminants on terrestrial fauna.

26.2.4 Ecological Endpoints

The information compiled during the first stage of problem formulation (stressor characteristics, ecosystems potentially at risk, and ecological effects) was used to select the ecological endpoints for this ERA. The following section of this report contains a description of the ecological endpoints selected for this ERA and the reason they were selected.

There are two primary types of ecological endpoints: assessment endpoints and measurement endpoints. Assessment endpoints are environmental characteristics, which, if they were found to be significantly affected, would indicate a need for remediation (e.g., decrease in sports/fisheries). Measurement endpoints are quantitative expressions of an observed or measured effect of the contamination of concern. Measurement endpoints may be identical to assessment endpoints (e.g., measurement of abundance of organisms), or they may be used as surrogates for assessment endpoints (e.g., toxicity test endpoints).

26.2.4.1 Assessment Endpoints

Assessment endpoints are the ultimate focus of risk characterization and link the measurement endpoints to the risk management process (USEPA, 1992e). There are five criteria that an assessment endpoint should satisfy (Suter, 1993):

- Societal relevance
- Biological relevance
- Unambiguous operational definition
- Accessibility to prediction and measurement
- Susceptibility to the hazardous agent

Societal relevance is important because risk to ecological receptors of little intrinsic interest to the public (e.g., nematodes, zooplankton) are unlikely to influence decisions unless they can be shown to indicate risks to biota of direct human interest (e.g., fish, wildlife) (Suter, 1993). The biological significance of a property is determined by its importance to a higher level of the biological hierarchy (Suter, 1993). The endpoint should be well defined and operational with a subject and a characteristic of the subject (USEPA, 1989d). The endpoint should be measurable (e.g., numbers of individuals) or predictable from measurements (e.g., toxicity tests). Finally, the endpoint must be susceptible to the contaminant being assessed. The assessment endpoints used in this ERA were decreased integrity of aquatic and terrestrial floral and faunal communities.

Aquatic organisms are socially relevant because humans enjoy the sport of fishing and aquatic organisms also are a food source for many people. The organisms are biologically relevant because they serve as food sources for other aquatic and terrestrial organisms. The endpoint is defined with a subject (aquatic organisms), and a characteristic of the subject (decreased integrity to aquatic organisms). The risk may be predicted by contaminant concentrations in media exceeding published aquatic reference values. Finally, aquatic organisms are susceptible to the COPCs at Site 30. This is explained in Section 26.5.2, Site Conceptual Model.

Terrestrial organisms (e.g., rabbits, deer, fox, raccoon, quail) are socially relevant because humans enjoy the sport of hunting and terrestrial organisms also are a food source for many people. The organisms are biologically relevant because they serve as food sources for other terrestrial organisms and some also consume smaller mammals and plants which potentially have been contaminated. The endpoint is defined with a subject (rabbits, deer, fox, raccoon, and quail communities), and a characteristic of the subject (decreased integrity to rabbits, deer, fox, raccoon, and quail). The TRVs can be used to predict risks to terrestrial organisms. Finally, terrestrial organisms are susceptible to the COPCs at Site 30.

26.2.4.2 Measurement Endpoints

A measurement endpoint, or "ecological effects indicator" as it is sometimes called, is used to evaluate the assessment endpoint. Therefore, measurement endpoints must correspond to, or be predictive of, assessment endpoints. In addition, they must be readily measurable, preferably quickly and inexpensively, using existing techniques. Measurement endpoints must take into consideration the magnitude of the contamination and the exposure pathway. The measurement endpoint should be an indicator of effects that are temporally distributed. Low natural variability in the endpoint is preferred to aid in attributing the variability in the endpoint to the contaminant. Measurement endpoints should be diagnostic of the pollutants of interest, as well as broadly applicable to allow comparison among sites and regions. Also, measurement endpoints should be standardized (e.g., standard procedures for toxicity tests). Finally, it is desirable to use endpoints that already are being measured (if they exist) to determine baseline conditions.

Endpoints are divided into four primary ecological groups: individual, population, community, and ecosystem endpoints. Individual endpoints (e.g., death, growth, tissue concentrations) are evaluated through toxicity tests, models, and other methods used to assess the effects on individual organisms. Population endpoints (e.g., occurrence, abundance, reproductive performance) are evaluated to determine presence and absence of species through field studies. Community endpoints (e.g., number of species, species diversity) are used to describe the complexity of the community. Finally, ecosystem endpoints (e.g., biomass, productivity, nutrient dynamics) are used to determine the effects between groups of organisms, and between organisms and the environment. Individual, population, and community endpoints were evaluated in this assessment.

The primary goal in deciding upon which ecological endpoints to evaluate was to determine the current effects that the contamination is having on the environment. The following sections discuss the measurement endpoints that were chosen for the ERA.

Aquatic Endpoints

Aquatic biota samples (e.g., fish and benthic macroinvertebrates) were not collected as part of the field activities at Site 30. Aquatic species are expected to inhabit Site 30 and be exposed to the COPCs. Potential effects from contaminants detected at Site 30 on these species were evaluated by comparing exposure levels of COPCs in the surface water and sediments to aquatic reference values (i.e., NCWQS, WQSV, AWQC, and SSVs).

Terrestrial Endpoints

As discussed earlier in this report, several terrestrial faunal species inhabit MCB Camp Lejeune including deer, birds, and small mammals potentially and are exposed to the COPCs at Site 30. Potential effects from contaminants detected at Site 30 on these species were evaluated by comparing the CDIs to TRVs. The assessment and measurement endpoints for this ERA were the potential for individual effects caused by exceedences of TRVs.

26.2.5 The Conceptional Model

This section of the report contains a list of hypotheses regarding how the stressors might affect ecological components of the natural environment:

- Aquatic receptors may be adversely affected by exposure to contaminated water, sediment, and contaminated biota they ingest.
- Terrestrial receptors may be adversely affected by exposure to contaminants in the surface water and surface soil.
- Terrestrial receptors may be adversely affected by exposure to contaminated biota they ingest.

26.3 Analysis Phase

The next phase after problem formulation is the analysis phase, which consists of the technical evaluation of the potential effects and exposure of the stressor on the ecological receptor. This phase includes the ecological exposure characterization and the ecological effects characterization.

26.3.1 Characterization of Exposure

Characterization of exposure evaluates the interaction of the stressor with the ecological component. The following sections characterize the exposure in accordance with the stressors, ecosystem, exposure analysis, and exposure profile.

26.3.1.1 Stressor Characterization: Distribution or Pattern of Change

The remedial investigations involved collecting samples from four media: surface water, sediment, soil, and groundwater. The analytical results and source identification are discussed in Section 23.3 of this report. The extent of contamination is discussed in Section 23.4 of this report.

26.3.1.2 Ecosystem Characterization

The regional ecology of the coastal plain and the habitats present at Site 30 are presented in Section 1.9 of this report; information on sensitive environments and endangered species also is included in Section 1.9. Site-specific ecology is presented in Section 22.5 of this report.

Site Description

Site 30 is located along a tank trail which intersects Sneads Ferry Road from the southwest, approximately 6,000 feet south of the intersection with Marines Road. One of two streams which comprise the headwaters of Frenchs Creek lie approximately 1,500 feet west of the site. The site is located approximately 3,000 feet northwest of the Combat Town Training Area. Wooded areas and unimproved paths both surround and are found within Site 30.

Sludge from fuel tanks that were used to store leaded gasoline and wastewater from the washout of these tanks was disposed of at this site, by a private contractor. Other reports suggest that the site was used for the disposal of similar wastes from other tanks.

Reference Stations

Off-site reference stations were located in three creeks in the White Oak River watershed: Hadnot Creek, Holland Mill Creek, and Webb Creek. Surface water and sediment samples were collected from these creeks for chemical analysis

The sampling of these creeks was initially supposed to consist of three stations from each creek; one upstream freshwater station, one midstream freshwater/saltwater station, and one downstream saltwater station. Samples from an upstream freshwater station was not collected in Webb Creek because a good undisturbed location was not identified. Therefore, two upstream locations were sampled in Hadnot Creek.

The White Oak River watershed is smaller than the New River watershed. It begins in the Hoffman Forest, flows approximately 48 miles, and empties into the Atlantic Ocean. Approximately 77 percent of the watershed is within the Hoffman Forest and the Croatan National Forest. This watershed has very little development; Swansboro is the largest town in the watershed. Therefore, the reference stations should be representative of an aquatic system with relatively few impacts from point and non-point sources of industrial pollution.

26.3.1.3 Exposure Analysis/Profile

The next step in the characterization of exposure is to combine the spatial and temporal distributions of both the ecological component and the stressor to evaluate exposure. This section of the ERA addresses and quantifies each exposure pathway via surface water, sediment, air, soil, and groundwater.

To determine if ecological exposure via these pathways may occur in the absence of remedial actions, an analysis was conducted including the identification and characterization of the exposure pathways. The following four elements were examined to determine if a complete exposure pathway was present:

- A source and mechanism of chemical release
- An environmental transport medium
- A feasible receptor exposure route
- A receptor exposure point

Potential Exposure Scenarios

This section discusses the potential exposure scenarios at Site 30 including surface water, sediment, soil, groundwater, and air. The location of samples was based on historical information available for the site and a site visit to evaluate potential ecosystems and ecological receptors.

Surface Water Exposure Pathway

Potential release sources to be considered in evaluating the surface water pathway are contaminated surface soil and groundwater. The release mechanisms to be considered are groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated surface waters are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the surface water on site or off site and downgradient of the site.

COPCs were detected in the surface water, demonstrating a release from a source to the surface water transport medium. Potential receptors that may be exposed to contaminants in surface waters in/or around surface water include fish, benthic macroinvertebrates, deer, birds, and other aquatic and terrestrial life.

Aquatic organisms (i.e., fish, benthic macroinvertebrates) are exposed to contaminants in the surface water by ingesting water while feeding and by direct contact. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the surface water. Overall, aquatic organisms have a high exposure to contaminants in the surface water. Potential decreased integrity of aquatic receptors from contaminants in the surface water was evaluated in this ERA by direct comparisons of contaminant concentrations in the surface water to published water quality standards and criteria and by evaluating the results of the ecological surveys.

Terrestrial faunal receptors potentially are exposed to contaminants in the surface water through ingestion and dermal contact. The magnitude of the exposure depends on the feeding habits of the receptors and the amount of time they reside in the contaminated waters. In addition, terrestrial species may ingest organisms (e.g., fish, insects, plants) that have bioconcentrated contaminants from the surface water. Potential decreased integrity of terrestrial receptors from contaminants in the surface water was evaluated in this ERA by comparing CDI to TRVs. Total exposure of the terrestrial receptors to the COPCs in the surface waters was determined by estimating the CDI dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day.

Sediment Exposure Pathway

The potential release sources to be considered in evaluating the sediment pathway are contaminated surface soil and groundwater. The release mechanisms to be considered are groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated sediments are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the sediment.

COPCs were detected in the sediment, demonstrating a release from a source to the sediment transport medium. Potential receptors that may be exposed to contaminants in sediment include benthic macroinvertebrates, bottom feeding fish, aquatic vegetation, and other aquatic life.

Aquatic organisms are exposed to contaminants in the sediment by ingesting sediment while feeding and by direct contact. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the sediment. Overall, aquatic organisms have a high exposure to contaminants in the sediment. Potential decreased integrity of aquatic receptors from contaminants in the sediment was evaluated in this ERA by direct comparisons of contaminant concentrations in the sediment to SSVs and by evaluating the results of the ecological surveys.

Terrestrial faunal receptors potentially are exposed to contaminants in the sediment through ingestion and dermal contact. The magnitude of the exposure depends on the feeding habits of the receptors and the amount of time they reside in the contaminated sediments. In addition, terrestrial species may ingest organisms (e.g., fish, insects, small mammals, plants) that have bioconcentrated contaminants from the sediment. Potential decreased integrity of terrestrial receptors from contaminants in the sediment was qualitatively evaluated in this ERA.

Soil Exposure Pathway

Potential release sources to be considered in evaluating the soil pathway are surface or buried wastes and contaminated soil. The release mechanisms to be considered are fugitive dust, leaching, tracking, and surface runoff. The transport medium is the soil. The potential routes to be considered for ecological exposure to the contaminated soils are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the soils.

COPCs were not retained for the surface soil, therefore, comparisons to literature values and CDI to TRV comparisons were not conducted. Potential receptors that may be exposed to contaminants in surface soil at/or around surface soil in the areas of detected COPCs included deer, fox, raccoon, rabbits, birds, plants, and other terrestrial life.

Terrestrial receptors potentially are exposed to contaminants in the soils through ingestion, dermal contact, and/or direct uptake (for flora). The magnitude of the exposure depends on the feeding habits of the receptors and the amount of time they reside in the contaminated soils. In addition, terrestrial species may ingest organisms (e.g., insects, small mammals, plants) that have bioconcentrated contaminants from the soils. Because there were no COPCs retained in the surface soil, potential decreased integrity of terrestrial receptors from contaminants in the surface soils were not directly evaluated in this ERA.

Groundwater Exposure Pathway

The potential release source to be considered in evaluating the groundwater pathway is contaminated soils. The release mechanism to be considered is leaching. The routes to be considered for ecological exposure to the contaminated groundwater are ingestion and dermal contact. Groundwater discharge to area surface waters may represent a pathway for contaminant migration. Since organisms are not directly exposed to groundwater at Site 30, the groundwater-to-surface water exposure is accounted for in the surface water section of the ERA.

Air Exposure Pathway

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: release of contaminated particulates and volatilization from surface soil, groundwater, and surface water. The potential exposure points for receptors are areas on or adjacent to the site.

No data have been collected to document exposure to receptors via the air pathway. However, based on the low concentrations of VOCs detected in the soil, sediments, and surface water, and the negligible vapor pressure of pesticides and metals, the air concentration of the COPCs is not expected to cause a decrease in integrity of the terrestrial receptors. Therefore, this pathway was not evaluated as part of the ERA.

26.3.2 Ecological Effects Characterization

The potential ecological effects on aquatic receptors were determined by direct comparisons of contaminant concentrations in surface water and sediment to aquatic reference values. Potential ecological effects on terrestrial receptors were evaluated by comparison to literature values and by comparing the CDIs to TRVs. The following sections further discuss the aquatic reference values comparisons and the CDI to TRV comparisons to evaluate the potential ecological effects to aquatic and terrestrial receptors from the COPCs.

Contaminant concentrations detected in the surface water at Site 30 were compared to the NC DEHNR WQS, USEPA WQSV, USEPA AWQC, and other toxicity values obtained from USEPA AWQC documents, to determine if there were any exceedances of the published values. In addition, each COPC positive detect was compared to the WQS, the acute and chronic WQSVs, and the acute and chronic AWQC using the quotient ratio method. This yields a value termed the Quotient Index (QI). A QI greater than unity indicates a potential for adverse effects to aquatic life. The ratio of each positive detection and the aquatic reference values were calculated for each COPC. The quotient ratio method and results of the QI calculations are discussed in Risk Characterization (Section 26.4). Also, inorganic COPCs detected in the surface water were compared to Camp Lejeune base-wide concentrations of these contaminants.

Contaminant concentrations detected in the sediments at Site 30 were compared the SSVs to determine if there were any exceedances in the established values. In addition, each positively-detected COPC was compared to the Region IV lower 10 percentile (ER-L) and median percentile (ER-M) using the quotient ratio method. Because the screening values are set to be protective of the aquatic environment, any exceedances of these values indicate a potentially toxic environment for the aquatic organisms inhabiting the water body. A QI also was calculated for the sediments. In addition, inorganic COPCs detected in the sediment were compared to Camp Lejeune base-wide concentrations of these contaminants.

26.3.2.1 Surface Water Quality

Table 26-4 contains the freshwater North Carolina WQS, the Region IV USEPA WQSV, and the USEPA AWQC for the COPCs detected at Site 30.

The water quality values for the following metals are water hardness dependent: cadmium, chromium, copper, lead, nickel, and zinc. In general, the higher the water hardness (in mg/L of $CaCO_3$) the higher the water quality value. A hardness concentration of 50 mg/L $CaCO_3$ was used to calculate these values.

There are no WQS, WQSV, or AWQC values for manganese in freshwater. The potential impact to aquatic species from this chemical in the surface water was evaluated using the results of acute and chronic tests obtained from the AQUIRE database (AQUIRE, 1993). The maximum detected concentration of this chemical in the surface water was below the adverse effects levels obtained from the database. Therefore, no decrease in the integrity of the aquatic community from these chemicals is expected, and this COPC will not be further evaluated in this ERA.

The following sections discuss the surface water quality results at Site 30. These sections contain comparisons of the contaminants detected in the surface water at the site to their aquatic reference values (ARVs).

Three surface water samples collected at Site 30 were analyzed for TCL organics, and TAL inorganics. Aluminum exceeded the acute WQSV and acute AWQC in one sample and the chronic WQSV and chronic AWQC in three samples. Lead exceeded the chronic WQSV and AWQC in one sample. Mercury exceeded the NCWQS, the chronic WQSV, and the chronic AWQC in one sample.

The surface water COPCs were also compared to base-wide concentrations. Aluminum was detected at concentrations above the average and median base-wide concentrations. Iron and manganese were detected at concentrations below the base-wide average and median concentrations. Lead was detected once in the surface water at Site 30 at a concentration below the average and median base-wide concentrations. Mercury was detected once in the surface water at a concentrations above the base-wide average concentration and below the median concentration.

26.3.2.2 Sediment Quality

Table 26-5 contains the sediment SSVs for the COPCs detected at Site 30. Sediment samples were collected from zero to six inches, and six to twelve inches at most of the sediment stations. Some sediment stations only were sampled at a depth of zero to six inches due to sampler refusal.

The following COPCs detected in the sediments do not have SSVs: aluminum, iron, manganese, and vanadium. There is limited, if any, data assessing the effects on aquatic organisms exposed to these chemicals in sediment samples. Therefore, the effects of these chemicals on aquatic organisms were not determined as part of this ERA.

No TCL organics or TAL inorganics detected in the Site 30 sediments exceeded the ER-L or ER-M values.

The sediment COPCs were compared to Camp Lejeune sediment base-wide average and median concentrations. Aluminum was detected at concentrations below both the average and median base-wide concentrations. Chromium, copper, and lead were detected at concentrations below the base-wide average concentration and slightly above the base-wide median concentration. Iron, vanadium, and zinc were detected at concentrations below both the average and median sediment base-wide concentrations. Manganese and nickel were detected at concentrations above the average and median base-wide sediment concentrations.

26.3.2.3 Terrestrial Chronic Daily Intake

As discussed above, there are no standards, criteria, or other screening values for assessing potential impacts to terrestrial receptors from contaminants in soils. However, a Chronic Daily Intake model was used to estimate the exposure of contaminants in the surface soils and surface water to terrestrial receptors. Although no COPCs were retained in the surface soil, contaminants detected in the surface soil were incorporated in the model if they were retained as COPCs in the surface water. The following describes the procedures used to evaluate the potential soil exposure to terrestrial fauna at Site 30 by both direct and indirect exposure to COPCs via water (surface water), soil, and food chain transfer.

Contaminants of potential concern at Site 30 are identified in Section 26.2.1.1 for each media. Based on the regional ecology and potential habitat at the site, the indicator species used in this analysis are the white-tailed deer, cottontail rabbit, red fox, raccoon, and the bobwhite quail. The exposure points for these receptors are the surface soils, surface water, and biota transfers. The routes for terrestrial exposure to the COPCs in the soil and water are incidental soil ingestion, drinking water, vegetation (leafy plants, seeds and berries) ingestion, fish ingestion, and small mammal ingestion.

Total exposure of the terrestrial receptors to the COPCs in the soil and surface waters was determined by estimating the Chronic Daily Intake (CDI) dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day. For this analysis, TRVs were developed from NOAELs or LOAELs obtained from the Integrated Risk Information System (IRIS, 1993) or other toxicological data in the literature (see Table 26-6).

CDI Calculations

Total exposure of the terrestrial receptors at Site 30 to the COPCs in the soil and surface waters was determined by estimating the CDI dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day. CDIs were estimated for the white-tailed deer, cottontail rabbit, bobwhite quail, raccoon, and red fox at Site 30. The estimated CDI dose of the receptors (bobwhite quail, cottontail rabbit, and white-tailed deer) to soils, surface water, and vegetation was determined using the following equation:

$$CDI = \frac{(Cw)(Iw) + [(Cs)(Bv \text{ or } Br)(Iv) + (Cs)(Is)][H]}{BW}$$

Where:

CDI = Total Exposure, mg/kg/d
Cw = Constituent concentration in the surface water, mg/L

Iw = Rate of drinking water ingestion, L/d
Cs = Constituent concentration in soil, mg/kg
Bv = Soil to plant transfer coefficient (leaves, stems, straw, etc.), unitless
Br = Soil to plant transfer coefficient in soil (fruits, seeds, tubers, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Is = Incidental soil ingestion, kg/d
H = Contaminated area/Home area range area ratio, unitless
BW = Body weight, kg

The estimated CDI dose of the raccoon was determined using the following equation.

$$CDI = \frac{(Cw)(Iw)+[(Cs)(Br)(Iv)+(Cs)(Is)+(Cf)(If)][H]}{BW}$$

where:

CDI = Total Exposure, mg/kg/d
Cw = Constituent concentration in the surface water, mg/L
Iw = Rate of drinking water ingestion, L/d
Cs = Constituent concentration in soil, mg/kg
Br = Soil to plant transfer coefficient (fruit, seeds, tubers, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Is = Incidental soil ingestion, kg/d
If = Rate of fish ingestion, kg/d
Cf = Constituent concentration in the fish, mg/kg (whole body concentrations)
H = Contaminated area/Home area range area ratio, unitless
BW = Body weight, kg

The estimated CDI dose of the red fox was determined using the following equation:

$$CDI = \frac{(Cw)(Iw)+[(Cs)(Br)(Iv)+(Cs)(Is)+(Cm)(Im)][H]}{BW}$$

where:

CDI = Total Exposure, mg/kg/d
Cw = Constituent concentration in the surface water, mg/L
Iw = Rate of drinking water ingestion, L/d
Br = Soil to plant transfer coefficient (fruit, seeds, tubers, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Cs = Constituent concentration in soil, mg/kg
Is = Incidental soil ingestion, kg/d
Im = Rate of small mammal ingestion, kg/d
Cm = Constituent concentrations in small mammals, mg/kg
where: Cm = (Cs)(Bv) + (Cs)(Is)
H = Contaminated area/Home area range area ratio, unitless
BW = Body weight, kg

Bioconcentration of the COPCs to plants was calculated using the soil to plant transfer coefficient (Bv or Br) for organics (Travis, 1988) and metals (Baes, 1984). Fish were not collected at Site 30; therefore, concentrations of COPCs in the fish were calculated. This was accomplished by multiplying the freshwater BCF by the surface water concentration of a specific chemical. Freshwater BCFs could not be located in the literature for aluminum and iron. These concentrations were assumed to be zero. If a chemical was not detected in the surface water, it was also assumed to be a nondetect in the fish. The concentrations of the COPCs in the soil (Cs) used in the model were the upper 95 percent confidence limit or the maximum concentration detected of each COPC at each site. The upper 95 percent confidence limit or the maximum concentration detected for each constituent was also used as the concentration of each COPC in the surface water. The exposure parameters used in the CDI calculations are presented in Table 26-7 and are summarized for each receptor below.

For the white-tailed deer, the feeding rate is 1.6 kg/d (Dee, 1991). The deer's diet was assumed to be 100 percent vegetation (leaves, stems, straw). The incidental soil ingestion rate is 0.019 kg/d (Scarano, 1993). The rate of drinking water ingestion is 1.1 L/d (Dee, 1991). The rate of vegetation ingestion is 1.6 kg/d. The body weight is 45.4 kg (Dee, 1991), and the home range is 454 acres (Dee, 1991).

For the eastern cottontail rabbit, the feeding rate is 0.1 kg/d (Newell, 1987). The rabbit's diet was assumed to be 100 percent vegetation (leaves, stems, straw). The incidental soil ingestion rate is 0.002 kg/d (Newell, 1987). The rate of drinking water ingestion is 0.119 L/d (USEPA, 1993d). The rate of vegetation ingestion is 0.1 kg/d. The body weight is 1.229 kg (USEPA, 1993d), and the home range is 9.29 acres (USEPA, 1993d).

For the bobwhite quail, the feeding rate is 0.014 kg/d (USEPA, 1993d). The quail's diet was assumed to be 100 percent vegetation (leaves, stems, straw). The incidental soil ingestion rate is 0.001 kg/d (Newell, 1987). The rate of drinking water ingestion is 0.019 L/d (USEPA, 1993d). The rate of vegetation ingestion is 0.014 kg/d. The body weight is 0.177 kg (USEPA, 1993d), and the home range is 8.89 acres (USEPA, 1993d).

For the red fox, the feeding rate is 0.446 kg/d (USEPA, 1993d). The fox's diet was assumed to be 20 percent vegetation (seed, berries) and 80 percent small mammals. The incidental soil ingestion rate is 0.012 kg/d (USEPA, 1993d). The rate of drinking water ingestion is 0.399 L/d (USEPA, 1993d). The rate of vegetation ingestion is 0.089 kg/d, the rate of small mammal ingestion is 0.356 kg/d. The body weight is 4.69 kg (USEPA, 1993d), and the home range is 1,771 acres (USEPA, 1993d).

For the raccoon, the feeding rate is 0.319 kg/d (USEPA, 1993d). The raccoon's diet was assumed to be 40 percent vegetation (nuts, seeds, berries) and 60 percent fish. The incidental soil ingestion rate is 0.030 kg/d (USEPA, 1993d). The rate of drinking water ingestion is 0.331 L/d (USEPA, 1993d). The rate of vegetation ingestion is 0.128 Kg/d and the rate of fish ingestion is 0.192 kg/d. The body weight is 3.99 kg (USEPA, 1993d), and the home range is 385 acres (USEPA, 1993d).

26.4 Risk Characterization

The risk characterization is the final phase of a risk assessment. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. This section evaluates the potential adverse effects on the ecological integrity at Site 30 from contaminants identified at the site.

A Quotient Index (QI) approach was used to characterize the risk to aquatic receptors from exposure to surface water and sediments. This approach characterizes the potential effects by comparing exposure levels of COPCs in the surface water and sediments to the aquatic reference values presented in Section 26.3.2, Ecological Effects Characterization. The QI is calculated as follows:

$$QI = \frac{EL}{ARV}$$

Where: QI = Quotient Index
EL = Exposure Level, mg/L or mg/kg
ARV = Aquatic Reference Value, mg/L or mg/kg

A QI of greater than "unity" is considered to be indicative of potential risk. Such values do not necessarily indicate that an effect will occur but only that a lower threshold has been exceeded. The evaluation of the significance of the QI has been judged as follows: (Menzie et. al., 1993)

- QI exceeds "1" but less than "10": some small potential for environmental effects;
- QI exceeds "10": significant potential that greater exposures could result in effects based on experimental evidence;
- QI exceeds "100": effects may be expected since this represents an exposure level at which effects have been observed in other species.

The risks characterized above provide insight into general effects upon animals in the local population. However, depending on the endpoint selected, they may not indicate if population-level effects will occur.

26.4.1 Surface Water

Table 26-4 contains a comparison of the COPCs identified in the surface water at Site 30 to the aquatic reference values to determine if they exceeded the published values. A QI ratio of the detected value at each sampling station and WQS, WQSVs, and AWQC was calculated for each COPC. A QI ratio greater than unity indicates a potential for decreased integrity of aquatic life. Table 26-8 presents only the ratios that are greater than unity for the COPCs at the site; these ratios also are presented on Figure 26-1.

Three surface water samples collected at Site 30 were analyzed for TCL organics and TAL inorganics. No TCL organics detected at Site 30 had QIs greater than unity when compared to the surface water aquatic reference values.

Aluminum had QIs greater than unity when compared to the acute WQSV and acute AWQC in one sample, and the chronic WQSV and chronic AWQC in three samples. Lead had a QI greater than unity when compared to the chronic WQSV in one sample. Mercury had QIs greater than when compared to the NCWQS, the chronic WQSV, and the chronic AWQC in one sample.

26.4.2 Sediment

Table 26-5 contains a comparison of the COPCs identified in the sediment to the ARVs to determine if exceedances of published values occurred. The QI ratio of the detected values at each sampling station and the ER-L and ER-M was calculated for each COPC at Site 30. A ratio greater than unity indicates a possibility for adverse effects to aquatic life.

Six sediment samples collected from three stations at Site 30 were analyzed for TCL organics and TAL inorganics. No TCL organics or TAL inorganics detected in the Site 30 sediments exceeded the ER-L or ER-M values.

26.4.3 Terrestrial Chronic Daily Intake Model

The following sections discuss the QIs calculated for the terrestrial receptors.

26.4.3.1 QI Calculations

The QI approach was also used to characterize the risk to terrestrial receptors. In this use of the QI, the risk are characterized by comparing the CDIs for each COPCs to the TRVs and is calculated as follows:

$$QI = \frac{CDI}{TRV}$$

Where: QI = Quotient Index
CDI = Total Exposure, mg/kg/day
TRV = Terrestrial Reference Value, mg/kg/day

Table 26-9 contains the QIs for the COPCs at Site 30. A QI of greater than "unity" is considered to be indicative of potential risk. Such values do not necessarily indicate that an effect will occur but only that a lower threshold has been exceeded. The evaluation of the significance of the QI has been judged as follows: (Menzie et. al., 1993)

- QI exceeds "1" but less than "10": some small potential for environmental effects;
- QI exceeds "10": significant potential that greater exposures could result in effects based on experimental evidence;
- QI exceeds "100": effects may be expected since this represents an exposure level at which effects have been observed in other species.

The risks characterized above provide insight into general effects upon animals in the local population. However, depending on the endpoint selected, they may not indicate if population-level effects will occur.

There are some differences of opinion found in the literature as to the effectiveness of using models to predict concentrations of contaminants found in terrestrial species. According to one source, the food chain models currently used incorporate simplistic assumptions that may not represent conditions at the site, bioavailability of contaminants, or site-specific behavior of the receptors. Simple food chain models can provide an effective means of initial characterization of risk; however, residue analyses, toxicity tests, and the use of biomarkers provide a better approach for assessing exposure (Menzie et. al., 1993).

The following sections discuss the results of the terrestrial CDI compared to the TRVs. TRVs could not be located for aluminum and iron. Therefore, these COPCs could not be included in this comparison. The CDI model was used to assess decreased integrity in terrestrial species from exposure to contaminants in surface water and surface soils.

At Site 30, the QIs of the CDI to the TRVs were less than unity for all the COPCs except manganese for the raccoon. The QI for manganese was 1.72 for the raccoon indicating a small potential for adverse effects. The total QI for the other indicator species also were less than unity indicating that the animals are not being adversely affected by the COPCs at the site.

26.4.4 Other Sensitive Environments

The portion of Frenchs Creek which traverses Site 30 is designated as freshwater. The potential impacts to the fish in these waters have already been discussed in this report. No areas within the boundaries of Site 30 are designated as unique or special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses.

There are no known spawning or nursery areas for resident fish species within Frenchs Creek. Therefore, there are no potential effects on spawning or nursing areas in Frenchs Creek.

Several threatened and/or endangered species are known to inhabit Camp Lejeune, as discussed in Section 1.9. The Red-cockaded woodpecker is known to inhabit Site 30. [Protected species at Camp Lejeune require specific habitats that correspond to the habitats identified at Site 30.] Therefore, potential adverse impacts to these protected species from contaminants at Site 30 may be possible. However, there were no significant exceedances of terrestrial reference values that would concur with their most significant critical habitat areas.

The potential impact to terrestrial organisms that are present at Site 30 is discussed in earlier sections of this report. The terrestrial organisms that may be breeding in contaminated areas at Site 30 may be more susceptible to chemical stresses due to the higher sensitivity of the reproductive life stages of organisms to these types of stresses. However, the characterization of risks due to exposure to site soils did not indicate a significant risk to these receptors.

26.5 Ecological Significance

This section essentially summarizes the overall risks to the ecology at the site. It addresses impacts to the ecological integrity at the Operable Unit from the COPCs detected in the media and evaluates the COPCs that are impacting the site to the greatest degree. This information, to be used in conjunction with the human health risk assessment, supports the selection of remedial action(s) for Site 30 that are protective of public health and the environment.

26.5.1 Aquatic Endpoints

The assessment endpoint used to evaluate the aquatic environment is decreased integrity of the aquatic community. In Frenchs Creek, aluminum, lead, and mercury exceeded the aquatic reference values in the upstream station, while only aluminum exceeded the aquatic reference values in the two downstream stations. The concentrations of aluminum in the two downstream stations were well below the concentration of aluminum detected in the upstream station. Therefore, although three COPCs in the surface water potentially may cause a decrease in the integrity of the aquatic community in Frenchs Creek, they do not appear to be site-related.

No COPCs detected in the sediments in Frenchs Creeks exceeded any of the sediment aquatic reference values. Therefore, the potential for a decrease in the integrity of the aquatic community in Frenchs Creek from COPCs in the sediment is very low.

26.5.2 Terrestrial Endpoints

The assessment endpoint used to evaluate the terrestrial environment is decreased integrity of terrestrial floral and faunal communities. During the habitat evaluation, no areas of vegetation stress or gross impacts from site contaminants were noted. In addition, no contaminants in the soil were retained as COPCs. Therefore, a comparison of soil COPC concentrations to soil toxicity values for terrestrial flora and invertebrates was not conducted because it was not necessary.

The terrestrial food chain model was used to evaluate potential risks to terrestrial receptors from COPCs at Site 30. Based on the comparison of the TRV to the CDI for the deer, rabbit, fox, raccoon, and quail, only the QI for the raccoon (1.72) exceeded one. Therefore, there is no significant potential for COPCs at Site 30 to decrease the integrity of the terrestrial community.

26.6 Uncertainty Analysis

The procedures used in this evaluation to assess risks to ecological receptors, as in all such assessments, are subject to uncertainties. The following discusses the uncertainty in the ERA.

The chemical sampling program at Site 30 consisted of surface water, sediment, soil, and groundwater analyses. The ecological investigation consisted of one sampling effort. The results of this sampling will only provide a "snapshot in time" of the ecological environment. Because the biotic community can have a high amount of natural variability, the "snapshot in time" may not be an accurate representation of actual site conditions. There also is uncertainty in the sampling methods used to collect the surface water and sediment samples.

In addition, there is uncertainty in the use of toxicological data in ecological risk assessments. The surface water and sediment values established by North Carolina and Region IV are set to be protective of a majority of the potential receptors. There will be some species, however, that will not be protected by the values because of their increased sensitivity to the chemicals. Also, the toxicity of chemicals mixtures is not well understood. All the toxicity information used in the ERA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals.

There is uncertainty in the ecological endpoint comparison. The values used in the ecological endpoint comparison (either the WQS of the SSV) are set to be protective of a majority of the potential receptors. There will be some species, however, that will not be protected by the values because of their increased sensitivity to the chemicals. Also, the toxicity of chemical mixtures is not well understood. All the toxicity information used in the ecological risk assessment for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals. In addition, there were several contaminants that did not have WQS or SSVs. Therefore, potential effects to ecological receptors from these chemicals cannot be determined.

The SSVs were developed using data obtained from freshwater, estuarine, and marine environments. Therefore, their applicability for use in evaluating potential effects on aquatic organisms from contaminants in estuarine habitats must be evaluated on a chemical specific basis because of differences in both the toxicity of individual contaminants to freshwater and saltwater organisms and the bioavailability of contaminants in the two aquatic systems. In addition, the toxicity of several of the metals (cadmium, chromium, copper, lead, nickel, and zinc) to aquatic organisms increases or decreases based on water hardness. Because water hardness was not available, a default value of 50 mg/L of $CaCO_3$ was used.

Several contaminants in the surface water exceeded applicable ARVs. Some of the surface water samples were collected from areas that were not considered ecologically significant. Therefore, although the ARVs may have been exceeded in these samples, the potential for them to impact aquatic life may not be significant.

Finally, there is also uncertainty in the chronic daily intake models used to evaluate decreased integrity to terrestrial receptors. Many of the input parameters are based on default values (i.e., ingestion rate) that may or may not adequately represent the actual values of the parameters. In addition, there is uncertainty in the ability of the indicator species to represent other species potentially exposed to COPCs at the site. Finally, terrestrial species will also be exposed to contaminants by ingesting fauna that have accumulated contaminants. This additional exposure route was not evaluated in this ERA because the high uncertainty associated with this exposure route.

26.7 Conclusions

Overall, there does not appear to be a significant risk to aquatic or terrestrial receptors from contaminants detected at this site.

26.7.1 Aquatic Ecosystem

Three metals were detected in the surface water at concentrations that may decrease the integrity of the aquatic community. However, because the concentration of contaminants was higher in the upstream station than in the downstream stations, the metals do not appear to be site related. No COPCs detected in the sediments exceeded any of the sediment aquatic reference values. Therefore, there does not appear to be a significant risk to the aquatic receptors from site-related COPCs.

26.7.2 Terrestrial Ecosystem

No contaminants detected in the surface soils were retained as COPCs. In addition, the QI for the terrestrial food chain model was greater than unity for only one species. The QI for the raccoon was slightly greater than one (1.72). Therefore, there does not appear to be a significant risk to the terrestrial receptors from site-related COPCs.

The Red-cockaded woodpecker is known to inhabit Site 30. However, the potential adverse impacts to these protected species is expected to be low since the terrestrial food chain model did not show an adverse risk to the bird species.

SECTION 26.0 TABLES

TABLE 26-1

LIST OF CONTAMINANTS DETECTED IN THE SURFACE WATER, SEDIMENT AND SURFACE SOIL SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA REMEDIAL INVESTIGATION, CTO-0231 MCB, CAMP LEJEUNE, NORTH CAROLINA

	Site 30		
	Surface Water	Sediment	Surface Soil
Analyte	Frenchs Creek	Frenchs Creek	Snead Ferry Road Fuel Tank Sludge Area
Volatiles			
Acetone		X	X
2-Butanone		X	
1,1,1-Trichloroethane			X
Semivolatiles			
Bis(2-ethylhexyl)phthalate		X	X
Inorganics			
Aluminum	X	X	X
Barium	X	X	X
Beryllium		X	
Cadmium		X	
Calcium	X	X	X
Chromium		X	X
Cobalt		X	
Copper	X	X	X
Iron	X	X	X
Lead	X	X	X
Magnesium	X	X	X
Manganese	X	X	X
Mercury	X		X
Nickel		X	
Potassium	X	X	X
Sodium	X		X
Vanadium		X	X
Zinc		X	X

TABLE 26-2

SUMMARY OF COPCs SURFACE WATER, SEDIMENT, AND SURFACE SOIL
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Surface Water	Excluded - Within Off-Site Background Levels	Excluded - Essential Nutrients
aluminum iron lead manganese mercury	barium copper	calcium magnesium potassium sodium

TABLE 26-2 (Continued)

SUMMARY OF COPCs SURFACE WATER, SEDIMENT, AND SURFACE SOIL
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Sediment	Excluded - Low Frequency of Detection	Excluded - Within Off-Site Background Levels	Excluded - Essential Nutrients	Excluded - Common Laboratory Contaminants/Blank Contamination
aluminum chromium copper iron lead manganese nickel vanadium zinc	beryllium cadmium cobalt acetone 2-butanone	barium	calcium magnesium potassium sodium	acetone 2-butanone bis(2-ethylhexyl)phthlate

TABLE 26-2 (Continued)

SUMMARY OF COPCs SURFACE WATER, SEDIMENT, AND SURFACE SOIL
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs Surface Soil	Excluded - Low Frequency of Detection	Excluded - Within Off-Site Background Levels	Excluded - Essential Nutrients	Excluded - Common Laboratory Contaminants
No COPCs were identified for Site 30 surface soil.	1,1,1-trichloroethane	aluminum barium chromium copper iron lead manganese mercury vanadium zinc	calcium magnesium sodium potassium	bis(2-ethylhexyl)phthlate acetone

TABLE 26-3

PHYSICAL/CHEMICAL CHARACTERISTICS OF THE COPCs
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	BCF (L/kg)	Water Solubility (mg/L)	Organic Carbon Partition Coefficient (mL/g)	Vapor Pressure (mm Hg)	Log Octanol/ Water Coefficient
Inorganics					
Aluminum	ND(1,3)	ND(1,3)	ND(1)	ND(1,3)	ND(1,3,4)
Chromium	16(5)	ND(1,3)	ND(1)	ND(1,2,3)	ND(1,3,4)
Copper	36(5)	ND(1,3)	ND(1)	ND(1,2,3)	ND(1,3,4)
Iron	ND(3)	ND(1,3)	ND(1)	ND(1,3)	ND(1,3,4)
Lead	49(5)	ND(1,3)	ND(1)	ND(1,2,3)	ND(1,3,4)
Manganese	350,000(3)	ND(1,3)	ND(1)	ND(1,3)	ND(1,3,4)
Mercury	3,760 - 5,500(5)	ND(1,3)	ND(1)	0.002(3)	ND(1,3,4)
Nickel	47(5)	ND(1,3)	ND(1)	ND(1,2,3)	ND(1,3,4)
Vanadium	ND(3)	ND(1,3)	ND(1)	ND(3)	ND(1,3,4)
Zinc	1(5)	ND(1,3)	ND(1)	ND(1,2,3)	ND(1,3,4)

(1) USEPA, 1986.
(2) Negligible (less than 0.1).
(3) SCDM, 1991.
(4) USEPA, 1985.
(5) USEPA, 1993.
ND = No data
BCF = Bioconcentration Factor

TABLE 26-4

FREQUENCY AND RANGE OF DETECTION COMPARED TO FRESHWATER NORTH CAROLINA WQSs, USEPA WQSVs, AND USEPA AWQC,
SITE 30, SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	Surface Water ARVs					Contaminant Frequency/Range		Comparison to ARVs				
	North Carolina (NCWQS)	Region IV Screening Values (USEPA WQSVs)		USEPA Water Quality Criteria (USEPA AWQC)		No. of Positive Detects/ No. of Samples	Range of Positive Detections	No. of Positive Detects Above NCWQS	No. of Positive Detects Above Screening Values		No. of Positive Detects Above USEPA AWQC	
		Acute	Chronic	Acute	Chronic				Acute	Chronic	Acute	Chronic
Inorganics (µg/L)												
Aluminum	NE	750	87	750	87	3/3	373 - 1,480	NA	1/3	3/3	1/3	3/3
Iron	1,000	NE	1,000	NE	1,000	3/3	495 - 829	0/3	NA	0/3	NA	0/3
Lead	25	34	1.32(1)	34(1)	1.34(1)	1/3	2.3	0/1	0/1	1/1	0/1	1/1
Manganese	NE	NE	NE	NE	NE	3/3	3.3J - 11.1J	NA	NA	NA	NA	NA
Mercury	0.012	2.4	0.012	2.4	0.012	1/3	0.15	1/1	0/1	1/1	0/1	1/1

NE = Not Established
NA = Not Applicable
(1) Criteria are hardness dependent

TABLE 26-5

FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING VALUES
SITE 30 - SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	Sediment Screening Values (SSVs)		Contaminant Frequency/Range		Comparison to Screening Values	
	ER-L	ER-M	No. of Positive Detects/No. of Samples	Range of Positive Detections	No. of Positive Detects Above ER-L	No. of Positive Detects Above ER-M
Inorganics (mg/kg)						
Aluminum	NE	NE	6/6	528 - 3,390	NA	NA
Chromium	80	145	5/6	2.2 - 7.9	0/5	0/5
Copper	70	390	4/6	2.3 - 9.5	0/4	0/4
Iron	NE	NE	6/6	213 - 842	NA	NA
Lead	35	110	6/6	1.3 - 15.5	0/6	0/6
Manganese	NE	NE	6/6	3 - 19	NA	NA
Nickel	30	50	2/6	1.9J - 5.8J	0/2	0/2
Vanadium	NE	NE	5/6	1.9 - 5.3	NA	NA
Zinc	120	270	6/6	2.5 - 11.3	0/6	0/6

NE = Not Established
NA = Not Applicable

TABLE 26-6

TERRESTRIAL REFERENCE VALUES AND SOIL TO PLANT TRANSFER COEFFICIENTS
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Soil to Plant Transfer Coefficient (Bv)	Soil-to-Plant Concentration (Br)*	Terrestrial Reference Value (TRV) mg/kg/day
Aluminum	0.004 (1)	0.00065 (1)	NA
Iron	0.004 (1)	0.001 (1)	NA
Lead	0.045 (1)	0.009 (1)	27.4 (2)
Manganese	0.250 (1)	0.050 (1)	0.14 (3)
Mercury	0.900 (1)	0.200 (1)	7.4 (4)

NA - Information not available
* - Br is assumed to be the same as Bv for organics
(1) Baes, 1984
(2) IRIS, 1993
(3) IRIS, 1991
(4) ATSDR, 1988

TABLE 26-7

TERRESTRIAL CHRONIC DAILY INTAKE MODEL EXPOSURE PARAMETERS
SITE 30 - SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Parameter	Units	White-Tailed Deer	Eastern Cottontail Rabbit	Bobwhite Quail	Red Fox	Raccoon
Food Source Ingestion	NA	Vegetation 100%	Vegetation 100%	Vegetation 100%	Small Mammals 80% Vegetation 20%	Vegetation 40% Fish 60%
Feeding Rate	kg/d	1.6(2)	0.1(3)	0.014(4)	0.446(4)	0.319(4)
Incident Soil Ingestion	kg/d	0.019(1)	0.002(3)	0.001(3)	0.012(4)	0.030(4)
Rate of Drinking Water Ingestion	L/d	1.1(2)	0.119(4)	0.019(4)	0.399(4)	0.331(4)
Rate of Vegetation Ingestion	kg/d	1.6	0.1	0.014	0.089	0.128
Body Weight	kg	45.4(2)	1.229(4)	0.177(4)	4.69(4)	3.99(4)
Rate of Small Mammal Ingestion	kg/d	NA	NA	NA	0.356	NA
Rate of Fish Ingestion	kg/d	NA	NA	NA	NA	0.192
Home Range Size	acres	454(2)	9.29(4)	8.89(4)	1,771(4)	385(4)

NA - Not Applicable

(1) Scarano, 1993

(2) Dee, 1991

(3) Newell, 1987

(4) USEPA, 1993d

TABLE 26-8

SURFACE WATER QUOTIENT INDEX FOR SITE 30[1]
SITE 30 - SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION, CTO-0231
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Sample Number	Sample Concentration (µg/L)[2]	North Carolina (NCWQS)[3] Quotient Ratio	Region IV Screening Values (USEPA WQSV)[4] Quotient Ratio		USEPA Ambient Water Quality Criteria (USEPA AWQC)[5] Quotient Ratio	
				Acute	Chronic	Acute	Chronic
Site 30							
Aluminum	30-SW01	1480	NA	1.9	17.0	1.9	17.0
	30-SW02	383	NA	0.51	4.4	0.51	4.4
	30-SW03	373	NA	0.49	4.3	0.49	4.3
Lead	30-SW01	2.3	0.09	0.07	1.7	0.03	0.72
Mercury	30-SW01	0.15	12.5	0.06	12.5	0.06	12.5

[1] Ratios of sample concentrations to established criteria and/or screening values

[2] µg/L = micrograms per liter

[3] NCWQS = North Carolina Water Quality Standards

[4] USEPA WQSV = U.S. Environmental Protection Agency Water Quality Screening Values

[5] USEPA AWQC = U.S. Environmental Protection Agency Ambient Water Quality Criteria

NA = Not Available

TABLE 26-9

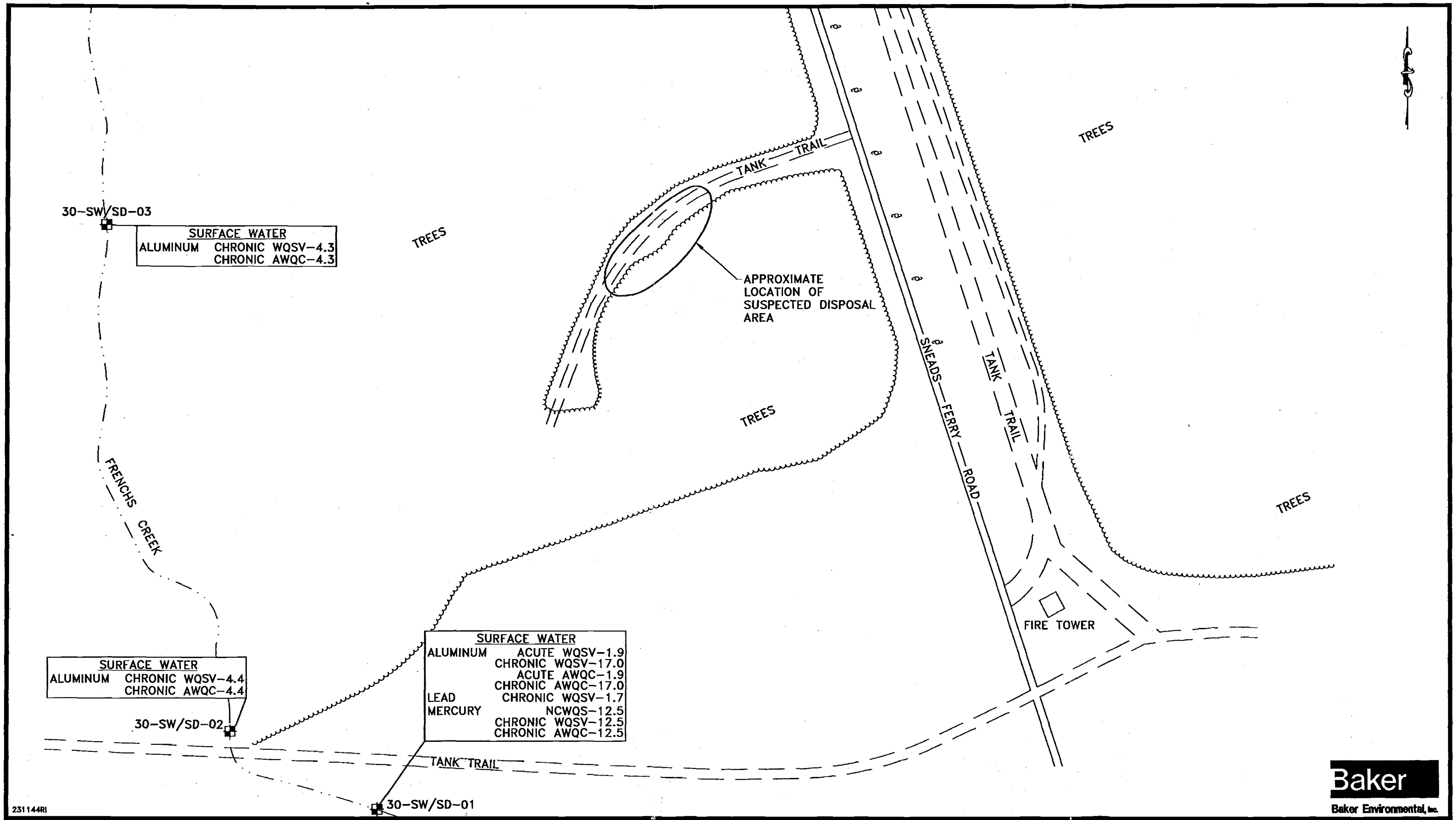
QUOTIENT INDEX RATIOS, TERRESTRIAL MODEL - SITE 30
MCB CAMP LEJEUNE, NORTH CAROLINA
REMEDIAL INVESTIGATION, CTO-0231

Contaminant of Concern	Bobwhite Quail	Red Fox	Cottontail Rabbit	Raccoon	Whitetail Deer
Aluminum	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA
Lead	8.32E-05	7.43E-06	4.90E-05	8.66E-06	2.35E-06
Manganese	8.29E-02	7.09E-03	6.98E-02	1.72E+00	2.45E-03
Mercury	2.24E-05	1.83E-06	2.11E-05	7.61E-06	6.59E-07
TOTAL	8.30E-02	7.10E-03	6.98E-02	1.72E+00	2.46E-03

NA - Terrestrial reference value not available, therefore a quotient index ratio could not be calculated.

- QI exceeds "1" but less than "10": some small potential for environmental effects;
- QI exceeds "10": significant potential that greater exposure could result in effects based on experimental evidence:
- QI exceeds "100": effects may be expected since this represents an exposure level at which effects have been observed in other species (Menzie et. al., 1993).

SECTION 26.0 FIGURES



LEGEND

30-SW/SD01 SURFACE WATER AND SEDIMENT SAMPLING STATION

ASPHALT ROAD

UNIMPROVED ROAD (TANK TRAIL)

UTILITY POLE

SOURCE: LANTDIV, FEB. 1992 AND W.K. DICKSON, JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 26-1
SURFACE WATER AND SEDIMENT QUOTIENT RATIO EXCEEDANCES FOR SITE 30 – SNEADS FERRY ROAD FUEL TANK SLUDGE AREA
REMEDIAL INVESTIGATION CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01498U17Z

27.0 CONCLUSIONS AND SUMMARY

The following conclusions were derived from the RI conducted at Site 30:

- The soils underlying Site 30 are generally consistent throughout the shallow subsurface (deep test borings were not drilled). The soils consist of mostly silty sands.

- The hydrogeologic characteristics of the study area were investigated by installing a network of shallow monitoring wells and staff gauges. Groundwater flow within the surficial aquifer was determined to be to the west-northwest with a moderate gradient of 0.015. Groundwater flow velocity within the surficial aquifer was estimated at 0.15 feet/day.

- Two operating water supply wells were identified within a one-mile radius of Site 30. Both wells are located hydraulically upgradient from the site and are not expected to be impacted by disposal of washwater from the tank cleaning operations at the site.

- A total of 14 surface soil samples were collected at Site 30. Eleven of those 14 samples were analyzed for both TCL volatile and semivolatile organics and TAL inorganics. The volatile organic compound 1,1,1-trichloroethane was detected in two surface soil samples retained from Site 30 at estimated concentrations of 2 J and 3 J µg/kg from soil borings 30-SB06 and 30-SB07, respectively. Soil borings 30-SB06 and 30-SB07 are located adjacent to one another, north of the tank trail. No other positive detections of volatile or semivolatile organic compounds were observed among surface soil samples.

- Fourteen of 23 TAL inorganics were detected in the 14 surface soil samples retained from Site 30 (antimony, arsenic, beryllium, cadmium, cobalt, nickel, selenium, silver, and thallium were not detected). None of the positive detections of priority pollutant metals exceeded base-specific (i.e., MCB, Camp Lejeune) background levels for surface soil.

- A total of 14 subsurface (i.e., greater than one-foot bgs) soil samples from Site 30 were submitted for laboratory analysis. Eleven of the 14 samples were analyzed for TCL volatile and semivolatile organics and TAL metals; the remaining three subsurface soil samples were analyzed for TAL metals only. Results of these analyses indicate the presence of the organic compound 1,1,1-trichloroethane detected at an estimated concentration of 2 J µg/kg in sample 30-SB09, located near the center of the suspected disposal area. No other positive detections of volatile or semivolatile organic compounds were observed among subsurface soil samples.

- Seventeen of 23 TAL inorganics were detected in subsurface soils at Site 30 (antimony, beryllium, cadmium, selenium, silver, and thallium were not detected). Chromium was the only TAL metal detected in subsurface soil at concentrations greater than base-specific inorganic background levels. The maximum chromium concentration among subsurface soil samples at Site 30 was 13.2 µg/kg. Four of the

12 chromium detections slightly exceeded the maximum, base-specific, background concentration. The four detections were scattered throughout the study area.

- A total of three shallow groundwater samples from Site 30 were submitted for laboratory analysis. The samples were collected from the uppermost portion of the surficial aquifer (i.e., the water table). Chloroform was the only VOC or SVOC identified during the first sampling round, at a concentration of 9 µg/L.

- TAL metals, both total and dissolved fractions, were detected in samples obtained from each of the three monitoring wells at Site 30. Seventeen of the 23 TAL total metals were detected within at least 1 groundwater sample at Site 30 (antimony, beryllium, cadmium, silver. selenium, and thallium were not detected). Eleven of 23 TAL dissolved metals were also detected within at least 1 of the 3 groundwater samples (arsenic, beryllium, cadmium, cobalt, chromium, lead, mercury, silver, selenium, thallium, vanadium, and zinc were not detected). Chromium, iron, lead, and manganese were each detected among the three groundwater samples from Site 30 at concentrations which exceeded either Federal or state standards for total metals. Chromium, iron, lead, and manganese were detected at maximum concentrations of 111 J, 41,400 J, 59.1, and 181 µg/L, respectively. None of these positive detections, in excess of either MCLs or NCWQS, were above base-specific background levels.

- During the second sampling round, groundwater samples from each of the three shallow monitoring wells at Site 30 were submitted for laboratory analysis of TAL metals, both total and dissolved fractions. Additionally, one groundwater sample from 30-GW01 was submitted for volatile organic analysis. Chloroform was once again detected in a groundwater sample obtained from 30-GW01 at an estimated concentration of 3 J µg/L from 30-GW01. No other VOCs were detected.

- Total and dissolved TAL metals were detected in each of the three shallow groundwater samples submitted for analysis from Site 30. Ten of 23 TAL total metals were detected in at least 1 shallow groundwater sample from Site 30 (antimony, arsenic, beryllium, cadmium, cobalt, copper, mercury, nickel, selenium, silver, thallium, vanadium, and zinc were not detected). Eight of 23 TAL dissolved metals were also detected within at least 1 of the 9 groundwater samples (aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, mercury, nickel, selenium, silver, thallium, vanadium and zinc were not detected). Iron was detected during the second sampling round at a concentration in excess of the 300 µg/L NCWQS, based on total metal analyses. Iron was detected at a concentration of 692 µg/L in sample 30-GW03, located approximately 300 yards upgradient of the study area.

- Eleven of 23 TAL total metals were positively identified in the 3 surface water samples submitted for laboratory analysis from Frenchs Creek. Lead and mercury were the only metals identified at concentrations in excess of either NOAA chronic screening values or NCWQS. Both lead and mercury detections were observed in sample 30-SW01, located upgradient of the study area. Lead and mercury were detected at concentrations of 2.3 J and 0.15 µg/L, respectively. No other total metal concentrations were in excess of screening values. Further, volatile and semivolatile compounds were not detected in any of the three surface water samples.

- Volatile organic compounds were not detected among the six sediment samples retained for analysis from Frenchs Creek. The SVOC bis(2-ethylhexyl)phthalate (BEHP) was detected in two Frenchs Creek sediment samples. The concentrations of BEHP at locations 30-SD01 and 30-SD03 were 3,900 and 2,600 µg/kg, respectively. Both detections were in excess of the 1,200 µg/kg laboratory contaminant level and, therefore, are considered to represent an actual observation. Sixteen of 23 TAL metals were detected in at least 1 of the 6 sediment samples from Frenchs Creek. No TAL metal concentrations among the six sediment samples exceeded NOAA ER-L screening values.

- The potential noncarcinogenic and carcinogenic risks associated with exposure to subsurface soil, surface water, and sediment for the receptors evaluated at this site were within acceptable levels.

- The red-cockaded woodpecker is known to inhabit Site 30. However, the potential adverse impacts to these protected species is expected to be low since the terrestrial food chain model did not show an adverse risk to the bird species.

- Three metals were detected in the surface water at concentrations that may decrease the integrity of the aquatic community. However, because the concentration of contaminants was higher in the upstream station than in the downstream stations, the metals do not appear to be site related. No COPCs detected in the sediments exceeded any of the sediment aquatic reference values. Therefore, there does not appear to be a significant risk to aquatic receptors from site-related COPCs.

- No contaminants detected in the surface soils were retained as COPCs. In addition, the QI for the terrestrial food chain model was greater than unity for only one species. The QI for the raccoon was slightly greater than one (1.72). Therefore, there does not appear to be a significant risk to the terrestrial receptors from site-related COPCs.

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