03.13-05/15/98-02020

Reference:
Contract
N62470-89-D-4814

CTO-0021

Administrative Record
Marine Corps Base
Camp Lejeune, North Carolina

Prepared For:

Department of the Navy
Atlantic Division
Naval Facilities
Engineering Command
Norfolk, Virginia

Under the

LANTDIV CLEAN Program

Comprehensive Long-Term
Environmental Action Navy

Baker

FOSTER WHEELER
FOSTER WHEELER ENVIRESPONSE, INC.

WESTON
MANAGERS DESIGNERS/CONSULTANTS

√ 03.13-05/15/98-02020

FINAL

FOCUSED REMEDIAL INVESTIGATION REPORT
OPERABLE UNIT NO. 15 (SITE 88)

MARINE CORPS BASE,
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0356

TEXT

MAY 15, 1998

Prepared for:

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

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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LIST OF ACRONYMS AND ABBREVIATIONS

AOCs	Areas of Concern
ARARs	Applicable Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
BCF	Bioconcentration Factor
bgs	below ground surface
BRA	Baseline Risk Assessment
BOD	Biochemical Oxygen Demand
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Program
COC	Chain-of-Custody
COD	Chemical Oxygen Demand
COPC	Contaminants of Potential Concern
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
CSF	Carcinogenic Slope Factor
CSFs	Cancer Slope Factors
CT	Central Tendency
CTO	Contract Task Order
cis-1,2-DCE	cis-1,2-Dichloroethene
trans-1,2-DCE	trans-1,2-Dichloroethene
D.O.	Dissolved Oxygen
DoN	Department of the Navy
DQO	Data Quality Objective
DRMO	Defense Reauthorization and Marketing Office
ECOCs	Ecological Contaminants of Concern
EPA-NCEA	USEPA - National Center for Environmental Assessment Office
°F	degrees Fahrenheit
FFA	Federal Facilities Agreement
FSAP	Field Sampling Analysis Plan
ft	feet
ft^2/day	square feet per day
gpm	gallons per minute
HEAST	Health Effects Assessment Summary Table
HHAG	Human Health Assessment Group
HI	Hazard Index

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

ICR	Incremental Cancer Risk
IDW	investigation derived waste
IR	Installation Restoration
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
MCB	Marine Corps Base
MCL	maximum contaminant level
MS/MSDs	matrix spike/matrix spike duplicates
MCAS	Marine Corps Air Station
MSL	mean sea level
mg/l	milligrams per liter
mgd	million gallons per day
MI	Mobility Index
MWR	Morale, Welfare, and Recreation
NC DENR	North Carolina Department of Environment, and Natural Resources
NCWQS	North Carolina Water Quality Standard
NEESA	Navy Energy and Environmental Support Activity
NFESC	Naval Facilities Engineering Service Center
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
O&G	Oil and Grease
OHM	OHM Remediation Services
OD	Outside Diameter
OU	operable unit
PAHs	Polynuclear Aromatic Hydrocarbons
PCB	polychlorinated biphenyl
PCE	Tetrachloroethene
PID	photoionization detector
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QI	quotient indices
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RfDs	Reference Doses

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

RI/FS	Remediation Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
S	Solubility
SDWA	Safe Drinking Water Act
SI	Site Inspection
SOPs	standard operating procedures
SPT	standard penetration test
SSV	Sediment Screening Values
SVOA	semivolatile organic analysis
SVOC	semivolatile organic compounds
SWSV	Surface Water Screening Values
TAL	Target Analyte List
TCA	1,1,2,2-tetrachloroethane
TCE	trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TPH	total petroleum hydrocarbon
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UCL	Upper Confidence Limit
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
VOA	volatile organic analysis
VOC	volatile organic compound
VP	vapor pressure
WOE	Weight of Evidence

EXECUTIVE SUMMARY

INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment and Natural Resources (NC DENR), the United States Department of the Navy (DoN) and the Marine Corps entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune in 1991. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are throughly investigated, and that appropriate CERCLA response and Resource Conservation Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect public health and welfare, and the environment (MCB Camp Lejeune FFA, 1989). The fiscal year 1998 Site Management Plan for MCB, Camp Lejeune, a primary document referenced in the FFA, identifies 42 sites that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 42 sites have been divided into 18 Operable Units (OUs). This report describes the Focused Remedial Investigation (RI) Report for OU No. 15 (Site 88).

SITE DESCRIPTION AND HISTORY

Operable Unit No. 15 (Site 88), also known as "Building 25, Morale, Welfare, and Recreation (MWR) Dry Cleaners", is located within MCB, Camp Lejeune. Site 88 is located on Post Lane Road, approximately 500 feet east of the intersection between Post Land Road and Main Service Road.

The Dry Cleaning facility consists of one main building, a surrounding lawn area, and several small sheds housing ancillary equipment. The main building is approximately 180 feet long by 50 feet wide. Within a lawn area on the north side of the main building are several steam lines, below grade concrete vaults, and shallow drainage channels. The concrete vault house a potion of the steam lines. Steam condensate from the steam lines is directed away from the main building by the shallow drainage channels.

Building 25 has been operating as a dry cleaning facility since the 1940s. An underground storage tanks (UST) area, consisting of five tanks, was formerly located on the north side of Building 25. These USTs are known to have been used to store dry cleaning fluids. The USTs were reportedly installed in the 1940s, at the time the building was constructed. These USTs were used in conjunction with the dry cleaning operations until the early 1970s. During this time, Varsol™ was stored in the USTs. (Varsol™ is a petroleum distillate dry cleaning fluid). Because of Varsol's flammability, its use was discontinued in the 1970s and replaced with tetrachloroethene (PCE). PCE was stored in 150 gallon aboveground storage tanks (ASTs) outside Building 25 in the same vicinity as the USTs from the 1970s to mid-1980s. It has been reported by dry cleaning personnel that spent PCE was disposed of in floor sewer drains. Currently, the dry cleaning machines are equipped with self containment units, eliminating the need for ASTs. There are two dry cleaning units in operation. One unit was brought on-line in December, 1986, and the second in March, 1995.

LAND USE DEMOGRAPHICS

Operable Unit No. 15 is located within the Hadnot Point area which comprises an area of 1,080 acres. Hadnot Point consists of a wide variety of land uses. The majority, of this area is taken up by troop housing, recreation, administrative and service buildings. Site 88 is surrounded by troop housing and service buildings.

Water supply wells within a one-mile radius of the sites were identified by reviewing base information. One supply well was identified to be within a one-mile radius of Site 88. This well has been closed and abandoned since the release of the Greenhorne & O'Mara, 1992 and the Geophex, Ltd., 1992 reports regarding supply well management. Thus, there are not active supply wells in the vicinity of Site 88.

NATURE OF CONTAMINATION

Soil

Chlorinated solvent compounds are the primary contaminants in subsurface soils.

The most frequently detected compound was tetrachloroethene (PCE). The next most-frequently detected compound was trichloroethene (TCE). Other VOCs detected include; total 1,2-dichloroethene (DCE), and cis-1,2-DCE. Detections of VOCs ranged from 0.1 ppb (PCE, TCE), to 3,500 ppb (PCE).

Groundwater

Chlorinated solvent compounds are the primary contaminants in groundwater at Site 88.

In groundwater samples collected from temporary wells, PCE was most frequently detected compound. TCE was the next most-frequently detected compound. Other VOC detections include cis-1,2-DCE, trans-1,2-DCE, 1,1,1-trichloroethane, and 1,1-dichloroethene. The maximum concentration observed in the temporary well was for PCE, at 54,881.7 ppb.

Chlorinated solvent compounds were also detected in the permanent wells. The most frequently detected compound was PCE, followed by TCE, trans-1,2-DCE, and cis-1,2-DCE. Other VOC detections included 1,1-dichloroethene, 1,1,1-trichloroethane, and vinyl chloride. The maximum concentration observed in either permanent wells was for PCE, at 9,100 ppb.

EXTENT CONTAMINATION

Soil

Chlorinated solvent compounds have been detected in subsurface soil samples located under and generally concentrated around the Building 25 area. Based on this pattern of detections in soil samples, it appears that the soil contamination is related to waste/product management practices at Building 25. The presence of VOCs were not evident in soil samples from borings in the vicinity of the EMD building, the water tower, or the military police building.

Groundwater

Groundwater contamination is evident at Site 88. PCE, TCE, and cis-1,2-DCE were detected above North Carolina Water Quality Standards (NC WQS) in a number of samples from shallow and intermediate monitoring wells (both permanent and temporary).

The highest PCE concentrations in the data set were observed at levels around 55,000 ppb. These groundwater samples were collected from wells located 200 and 400 feet northwest of the building. It should be noted that samples from wells installed close to Building 25 during another investigation exhibited concentrations around 170,000 ppb. The highest contaminant concentrations were generally observed in wells in the immediate vicinity of, and northwest of Building 25.

It is apparent that these VOCs have traveled downward, through the silt/clay layer and impacted the intermediate groundwater zone. However, the deep groundwater zone has not been impacted. No VOCs were detected in samples from the four deep monitoring wells.

The shallow groundwater has been impacted by VOCs in the area northwest and south of Building 25. The shallow contaminant plume has migrated approximately 700 feet west-northwest and northwest of Building 25. The shallow contaminant plume has also migrated approximately 300 feet south of Building 25.

Groundwater at the intermediate depth (approximately 50 feet bgs) has also been affected at Site 88. The contaminants in the area of Building 25 have migrated vertically and are present in the upper portions of the Castle Hayne aquifer. A discontinuous clayey layer at approximately 20 feet bgs appears not to have limited the vertical migration of the contaminants. At the intermediate depth, the contaminants have migrated approximately 700 feet to the northwest and 500 feet to the southwest of Building 25.

FATE AND TRANSPORT SUMMARY

The source area is located on the northern side of Building 25. The extent of the contamination suggests that the dissolved chlorinated solvent contamination is migrating from the source area to the south and northwest, along groundwater flow lines. The groundwater flow direction; however, does not fully account for the northwestern migration of the dissolved contaminants. It appears that the sewer line has enhanced the northwestward migration of contaminants from the source area. The TCE that extends north past the water tower appears to be a result of reductive dehalogenation of PCE and lateral dispersion, and is not related to the sewer line. It is apparent that flow in the sewer line is southerly.

A strong vertical groundwater flow component is evident at Site 88. It appears that dissolved contaminants have migrated vertically downward to the intermediate zone and also spread laterally. It appears that the silt/clay layer has not precluded the vertical migration of dissolved constituents.

Some evidence of biodegradation is apparent. The information gathered for this RI suggests that the contaminant source is PCE. The Base Laundry has used PCE in its dry cleaning operations. There is no record of the use of TCE or cis-1,2-DCE at the site. Therefore, the presence of TCE and cis-1,2-DCE is likely as daughter products of PCE. This occurs through the reductive dehalogenation process.

The nearest downgradient receptor appears to be Beaver Dam Creek. This creek is located approximately 1,500 feet to the northeast of the site. Based on the contaminant concentration distribution, it does not appear that the contaminant plume is migrating in the direction of Beaver Dam Creek. The plume appears to be migrating towards the New River. However, the water tower groundwater recharge area is affecting the plume migration, by either deflecting it or impeding its progress.

Based on the contaminant concentration distribution, the vertical extent of the contaminant plume extends to a depth of approximately 50 feet bgs. Significant further vertical migration seems unlikely due to the small vertical component of groundwater flow between the intermediate and deep monitoring wells.

QUALITATIVE RISK ASSESSMENT

One VOC, tetrachloroethene, was retained as a Contaminants of Potential Concern (COPC) for the subsurface soil. 1,1-Dichloroethene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride were retained as Site 88 groundwater COPCs. Given the frequency of detection, the concentrations, current land use of the site (i.e., location of dry cleaning facility), it is likely the presence of these compounds is site-related. However, given the fact that there are no drinking water supply wells within a one-mile radius of the site, it is unlikely that the presence of volatile compounds in the groundwater, even at concentrations that exceed federal and state standards, could currently present a potential for adverse human health effects.

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment and Natural Resources (NC DENR), the United States Department of the Navy (DoN) and the Marine Corps entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune in 1991. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are throughly investigated, and that appropriate CERCLA response and Resource Conservation Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect public health and welfare, and the environment (MCB Camp Lejeune FFA, 1989). The fiscal year 1998 Site Management Plan for MCB, Camp Lejeune, a primary document referenced in the FFA, identifies 42 sites that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 42 sites have been divided into 18 Operable Units (OUs).

1.1 Operable Unit Description

Operable units are formed as an incremental step toward addressing individual site concerns and to simplify the specific problems associated with a site or group of sites. As mentioned above, there are currently 42 Installation Restoration (IR) Program sites at MCB, Camp Lejeune which have been grouped into 18 operable units. Figure 1-1 depicts the locations of all 18 OUs and 42 sites at MCB, Camp Lejeune. This report describes the RI conducted at OU No. 15 (Sites 88). As shown on Figure 1-1, OU No. 15 (Site 88) is located in the eastern portion of MCB Camp Lejeune.

1.2 Report Organization

This Focused Remedial Investigation (RI) Report is divided into eight sections, including:

- Section 1.0 - Introduction
- Section 2.0 - Field Investigation
- Section 3.0 - Regional and Site Characteristics
- Section 4.0 - Nature and Extent of Contamination
- Section 5.0 - Contaminant Fate and Transport
- Section 6.0 - Baseline Human Health Risk Assessment
- Section 7.0 - Conclusions and Recommendations

The appendices referenced throughout the document include Appendices A through J. All of these appendices are included in Volume II of the RI report.

1.3 Site Description and History

This section summarizes information concerning the site description and history. Further information of this type can be found in the final Project Plans (Baker, 1996).

Operable Unit No. 15 (Site 88), also known as "Building 25, Morale, Welfare, and Recreation (MWR) Dry Cleaners", is located within MCB, Camp Lejeune (Figure 1-1). Site 88 is located on Post Lane Road, approximately 500 feet east of the intersection between Post Land Road and Main

Service Road (Figure 1-2). The study area of Site 88 encompasses approximately 12 acres mainly to the northwest of Building 25.

The Dry Cleaning facility consists of one main building, a surrounding lawn area, and several small sheds housing ancillary equipment. The main building is approximately 180 feet long by 50 feet wide. Within a lawn area on the north side of the main building are several steam lines, below grade concrete vaults, and shallow drainage channels. The concrete vault house a potion of the steam lines. Steam condensate from the steam lines is directed away from the main building by the shallow drainage channels.

Building 25 has been operating as a dry cleaning facility since the 1940s. As shown on Figure 1-2, an underground storage tanks (UST) area, consisting of five tanks, was formerly located on the north side of Building 25. These USTs are known to have been used to store dry cleaning fluids. The USTs were reportedly installed in the 1940s, at the time the building was constructed. These USTs were used in conjunction with the dry cleaning operations until the early 1970s. During this time, Varsol™ was stored in the USTs. (Varsol™ is a petroleum distillate dry cleaning fluid.) Because of Varsol's flammability, its use was discontinued in the 1970s and replaced with tetrachloroethene, or perchloroethene (PCE). PCE was stored in one 150 gallon aboveground storage tank (AST) outside Building 25 in the same vicinity as the USTs from the 1970s to mid-1980s. It has been reported by dry cleaning personnel that spent PCE was disposed of in floor sewer drains. Currently, the dry cleaning machines are equipped with self containment units, eliminating the need for AST, which was subsequently removed. There are two dry cleaning units in operation. One unit was brought on-line in December, 1986, and the second in March, 1995.

1.4 Previous and Current Investigations

The following sections provide information on the previous investigations conducted Site 88. The information summarized in this document is for the purpose of providing relevant background information which has been used to assess the site.

1.4.1 Underground Storage Tank Removals at Building 25

As previously mentioned, five USTs were located on the north side of Building 25. During removal of the tanks in November 1995, soil contamination was identified and impact to the groundwater was suspected. OHM performed the removal of the five USTs at Building 25. As a follow-up to the removal of the tanks, a four-well site check was conducted in November 1995 by OHM to identify and/or verify the suspected contaminant impact in the subsurface soil and groundwater. The locations of these four initial temporary monitoring wells are shown on Figure 2-1. The activities and findings of the initial Investigation included:

- Installation of three temporary monitoring wells (TW01 through TW03) around the former UST location and one (TW04) on the opposite side (south) of the building.
- Analysis of subsurface soil samples revealed levels of PCE ranging from 13 µg/kg to 55 µg/kg in three of the four well borings, 1,2-dichloroethene (DCE) (total) at a concentration of 9 µg/kg, and two common laboratory contaminants (acetone and methylene chloride). Several metals also were detected in the subsurface soil samples. No pesticides, polychlorinated biphenyls (PCBs), total petroleum

hydrocarbons (TPH), or semivolatile compounds were detected in any of the subsurface soil samples.

- One groundwater sample was collected from each of the four temporary monitoring wells and analyzed for full target compound list (TCL) organics, target analyte list (TAL) metals and TPH. Iron and nickel were detected above the North Carolina 2L Water Quality Standard (WQS) in all four wells. These metals are not believed to be associated with the site. TPH was detected in two of the groundwater samples at 628 μg/L and 552 μg/L. Bis(2-ethylhexyl)phthalate and naphthalene were detected in the groundwater; however, bis(2-ethylhexyl)phthalate is not likely to be associated with the site and is considered a laboratory contaminant. The TPH and naphthalene could be present as a result of Varsol™ management in the former USTs. PCE was detected in all the groundwater samples at concentrations ranging from 416 μg/L to 29,200 μg/L. 1,2-dichloroethene was also detected in the samples at concentrations of 154 μg/L and 10,000 μg/L. Trichloroethylene was detected at a concentration of 2,750 μg/L. No pesticides or PCBs were detected in the four groundwater samples.

1.4.2 Phase I Investigation Report

Based on the OHM's findings of chlorinated solvents in the temporary monitoring wells, Baker initiated a remedial site investigation in a phased approach. Phase I of the investigation was conducted in July and August of 1996. A Phase I investigation report was issued by Baker in November 1996. The phase II field investigation was conducted in April and May of 1997.

The scope of the Phase I Investigation was to evaluate the nature and extent of the threat to public health and the environment and to provide information to more effectively locate permanent monitoring wells during Phase II. The soil and groundwater data from the Phase I Investigation are being used in conjunction with the Phase II Investigation to fully characterize the Site in terms of the nature and extent of contamination. Details of the Phase I investigation methodologies and results are presented in this RI Report.

1.4.3 DNAPL Investigation and Remedial Activities

Based on the results of the Phase I Investigation, Naval Facilities Engineering Service Center (NFESC) has selected Site 88 as a candidate site to test their surfactant-enhanced aquifer remediation on-site treatment system technology. NFESC has contracted Duke Engineering and Services (DE&S [formerly Intera]) to conduct a dense non-aqueous phase liquid (DNAPL) investigation and treatability study to determine the suitability of Site 88 as a test site. The DNAPL Investigation thus far has been conducted in two phases. The purpose of the first phase was to identify the presence of any PCE DNAPL. The second phase was conducted to further characterize the extent of the DNAPL area, including a determination of surficial aquifer hydraulic properties. No report is expected to be issued by DE&E until the completion of all work related to the investigation of the DNAPL source.

Though the primary purpose of the DNAPL Investigation was a study the suitability of the site to test a treatment system, the investigation provided additional information on the nature and extent of soil contamination. The DNAPL Investigation indicated the high concentrations of VOCs in the subsurface soil samples, and presence of free phase PCE in a localized area on the north side of Building 25. A silt/clay layer was observed to be present at a depth of approximately 20 feet bgs.

This layer was also observed to be present throughout the study area. It is apparent from the DNAPL investigations that this clay layer is a capillary barrier, preventing further vertical migration of the DNAPL.

Since the completion of the two DNAPL Investigation phases, additional work have been conducted at Site 88, and may be summarized as follows:

- An additional investigation was conducted in November 1997. This investigation served to further identify the extent of DNAPL contamination and the extent and depth of the silt/clay layer. This investigation included the installation of 12 CPT borings and 18 direct-push soil borings.

- In December 1997 wells were installed for free phase DNAPL recovery, Partitioning Inter-well Tracer Testing (PITT), and ultimately, the SEAR. A total of 14 wells were installed during this effort.

- In January, 1998 a free phase DNAPL pilot recovery study was performed. This pilot study was conducted to determine how, and at what rate DNAPL could be removed from the aquifer.

- A full-scale free phase DNAPL recovery was initiated in February 1998. The effort included pumping of groundwater and DNAPL from six wells containing DNAPL.

- The PITT was initiated in March 1998 and is continuing at the submittal of this Final Focused RI. The effort included a initial conservative tracer test as well as a conservative and reactive tracer test.

PCE DNAPL remediation was essentially begun at the beginning of the free phase DNAPL recovery. The PITT process, while not designed as a removal action, will remove some PCE DNAPL. It is anticipated that NFESC will begin removal of residual-phase PCE in the late summer/early fall of 1998 through the surfactant-enhanced aquifer remediation (SEAR) process.

1.5 Remedial Investigation Objectives

The source history, that is its location and chemicals used, is known (refer to Section 1.3). Previous investigations confirmed that the primary concern at Site 88 is chlorinated solvent contamination in groundwater and subsurface soil (refer to Section 1.4). The scope of this focused RI is to evaluate the nature and extent of the threat to public health and the environment caused by the release of hazardous substances related to the base laundry facility. Based on the foreknowledge of what these hazardous substances were, this remedial investigation "focused" on the nature and extent of chlorinated solvent contamination in groundwater and subsurface soil. The primary difference between a "focused" RI and a "traditional" RI is a narrower list of analytical parameters. As a result of the knowledge of the site contaminants and the narrower list of analytical parameters, the risk assessment was conducted in a qualitative approach. The RI also provides data required to establish feasible alternatives for consideration during preparation of the Record of Decision (ROD). The RI was conducted through the sampling of environmental media including groundwater and subsurface soil, evaluating the resultant analytical and geologic data, and performing a qualitative assessment of the findings. 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. Table 1-1 presents both the RI objectives identified for OU 15 and the criteria necessary to meet those objectives. In addition, the table provides a general description of the study or investigation efforts required to obtain the necessary information. The different media investigations conducted at the sites are described in Section 2.0 of this report.

1.6 References

Baker 1996. Final Project Plans OU No. 16 (Sites 89 and 93) Marine Corps Base, Camp Lejeune North Carolina.

Federal Facilities Agreement (FFA) Between United States Environmental Protection Agency, Region IV: The North Carolina Department of Environment, Health and Natural Resources and North Carolina. North Carolina Natural Heritage Program, Division of Parks and Recreation, Department of Environment, Health, and Natural Resources, Raleigh, North Carolina.

SECTION 1.0 TABLES

TABLE 1-1

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES
OPERABLE UNIT NO. 15 (SITE 88)
REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objective	Criteria for Meeting Objective	Investigation/Study
1. Soil	1a. Assess the extent of soil contamination at Site 88.	Characterize contaminant levels in subsurface soils.	Soil Investigation
	1b. Assess human health risks associated with exposure to soils at the site.	Characterize contaminant levels soils at the study area.	Soil Investigation Risk Assessment
	1c. Determine whether contamination from soils is migrating to groundwater.	Characterize subsurface soil and leaching potential. Characterize shallow and intermediate groundwater.	Soil Investigation Groundwater Investigation
	1d. Evaluate treatment alternatives, if required.	Characterize areas of concern above action levels. Evaluate effectiveness and implementability of technologies.	Soil Investigation Feasibility Study Bench or Pilot-Scale Testing
2. Groundwater	2a. Assess health risks posed by potential future usage of shallow and intermediate groundwater.	Evaluate groundwater quality and compare to groundwater criteria and risk-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess nature and extent of shallow and intermediate groundwater contamination.	Characterize groundwater quality. Compare to relevant North Carolina and Federal groundwater standards.	Groundwater Investigation
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the aquifer (flow direction/velocity).	Groundwater Investigation

SECTION 1.0 FIGURES

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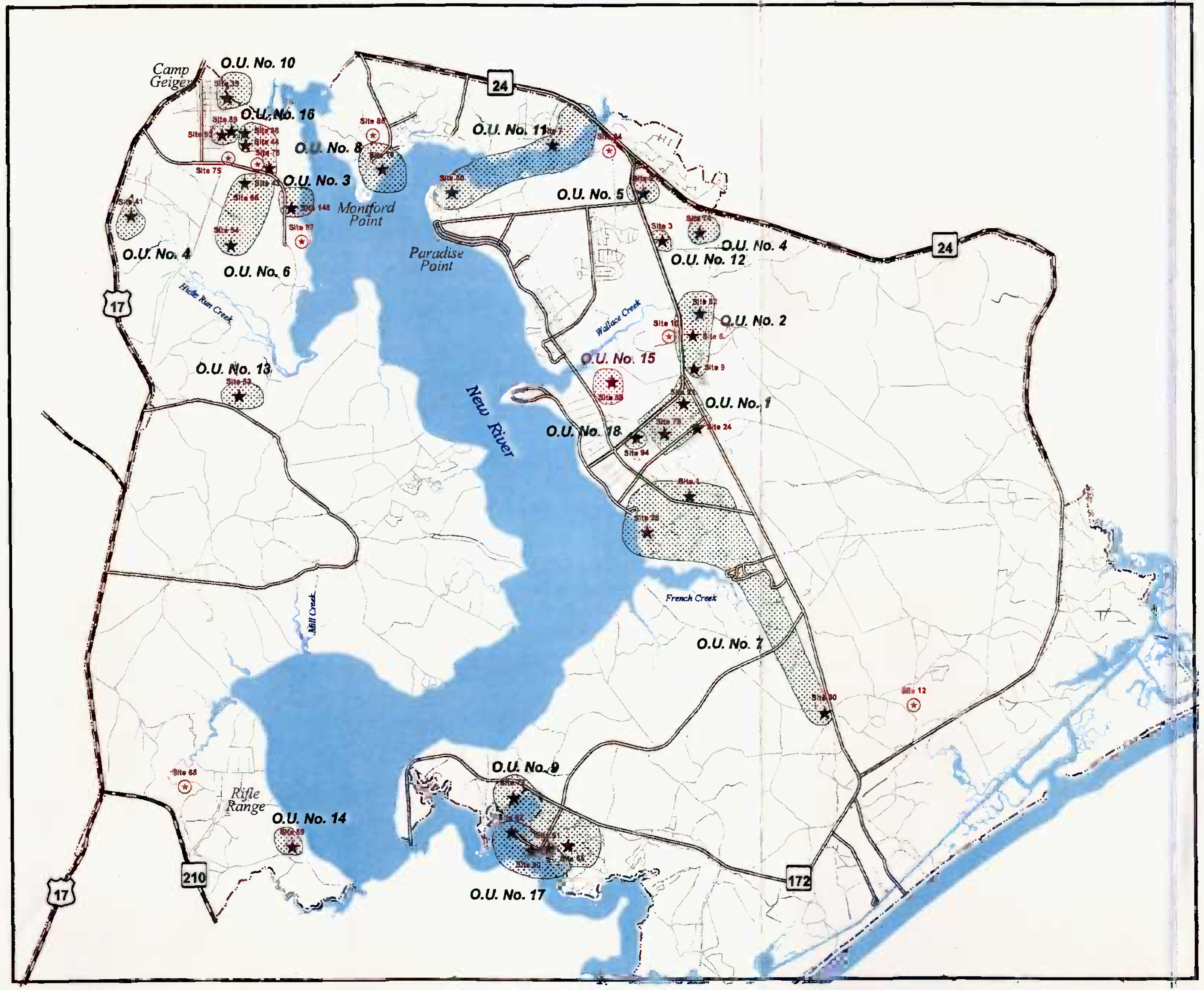


LEGEND

★ Remedial Investigation Site

⊛ Pre-Remedial Investigation Site

▨ Operable Unit Boundary

▨ Operable Unit No. 15 Boundary

Secondary Highway

Primary Highway

Light Duty Road

Camp Lejeune Boundary

N
W E
S

Scale
0 1 2 3 Miles

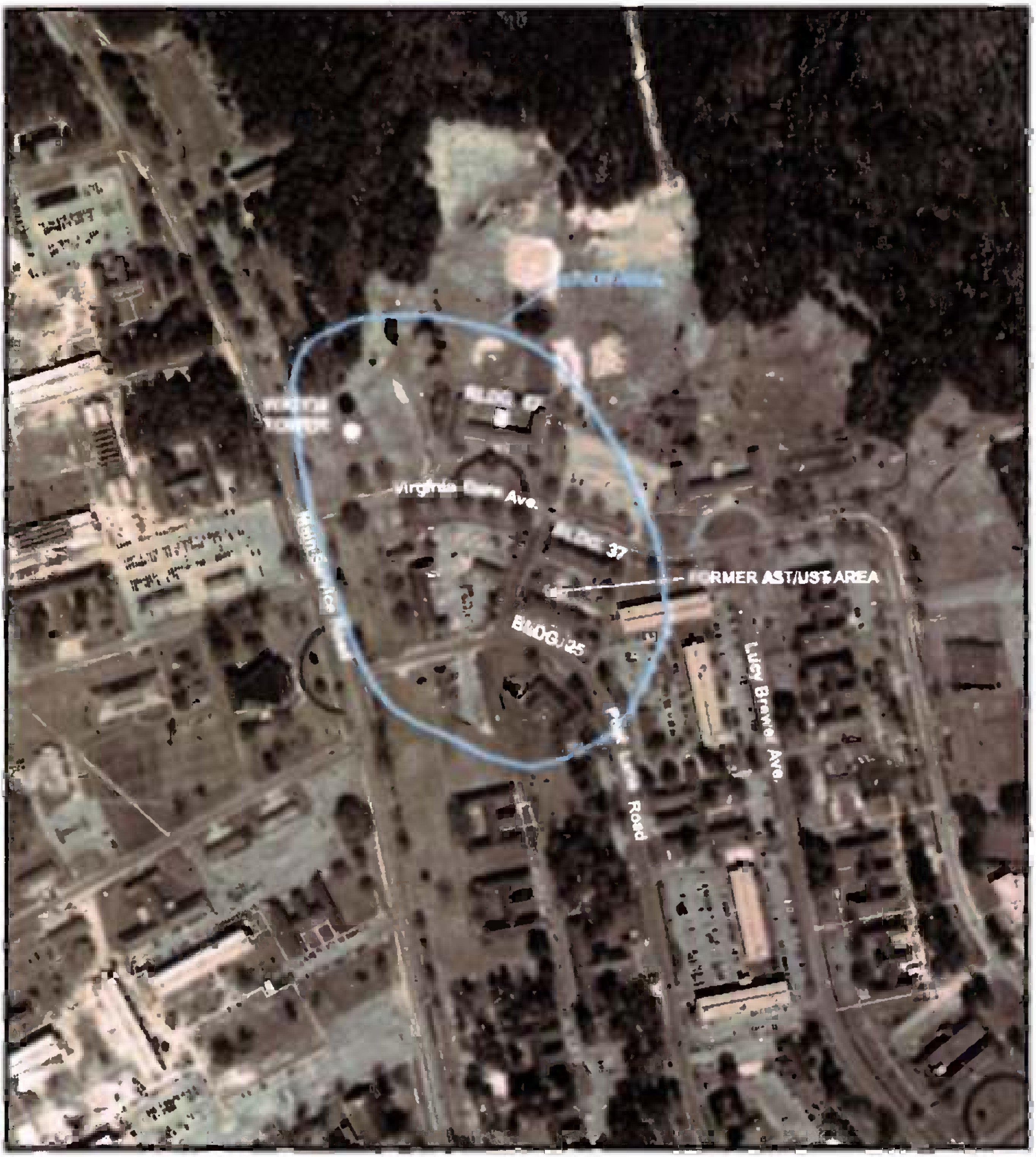
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

OPERABLE UNITS AND SITE LOCATIONS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 1 - 1

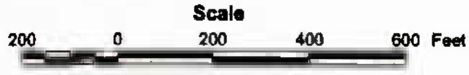
02020 N 02Y

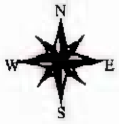


LEGEND

Approximate Boundary of the Study Area

Scale





MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SITE PLAN
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 1 - 2

2.0 FIELD INVESTIGATION

This section discusses the site-specific focused RI field activities that were conducted to fulfill the objectives identified in Section 1.5. The RI field investigation activities for Site 88 were conducted in two phases. The initial phase of RI field investigation sampling activities commenced on July 25, 1996, and continued through August 28, 1996. The second phase of the RI field investigation commenced on April 11, 1997, and continued through June 2, 1997. The RI field program activities at Site 88 primarily consisted of a site survey, a subsurface soil investigation, and groundwater investigation. The following sections detail the various investigative activities which were implemented during the RI.

Investigative procedures and methodologies for the RI conducted at Site 88 are provided in Section 6.0 of the Final Field Sampling and Analysis Plan (FSAP), for Operable Unit (OU) No. 15, (Baker, 1996, 1997).

2.1 Site Survey

The site survey task was performed during both phases of the RI at Site 88. Surface features (i.e., buildings, structures, tree lines, utilities, roads, parking areas, fences, etc.) were surveyed during the Phase I investigation. This information was used for creation of the base map that was used throughout the investigation. Following both phases, the location (i.e., longitude and latitude) and elevation (referenced to mean sea level [msl]) of each final sample point sampled during that phase was surveyed. For monitoring wells, the elevation of the surrounding ground surface (or top of well cover for flush mount monitoring wells), and top of polyvinyl chloride (PVC) casing were surveyed. All surveying was referenced to the North Carolina State Plane Coordinates System, and was conducted by Lanier Surveying, Inc, a licensed professional surveyor in the State of North Carolina.

2.2 Subsurface Soil Investigation

Subsurface soil samples were collected to assess site contamination and to provide lithological information for the evaluation of geologic and hydrogeological conditions. Subsurface soil samples were collected from selected monitoring wells (permanent and temporary) and soil borings that were advanced at Site 88 (Figure 2-1).

Surface soils were not investigated in this RI. Surface soil contamination would be expected in the vicinity of the former AST where surface soil would be exposed to spills or leaks. This AST was located in the area where the former underground storage tanks USTs were located. OHM excavated and disposed these soils as part of their 1995 UST removal effort. The excavation was backfilled with clean soil.

All subsurface soil samples were classified in the field by the Baker Field Geologist. Soils were classified using the Unified Soil Classification System (USCS) via visual-manual methods that are described in American Society for Testing and Materials (ASTM) D-2488. Lithologic descriptions were recorded in a field logbook and later entered into 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 the site soils are provided on the Test Boring and Well Construction Records which are presented in Appendix A. Information obtained from the soil borings were used to generate hydrogeologic cross-sections which describe the subsurface conditions of OU No. 15. These cross-sections and related discussions are presented in Section 3.0.

Soil borings were typically advanced in clusters (i.e., shallow, intermediate, and deep juxtaposed soil borings) or in pairs (i.e., shallow and intermediate juxtaposed soil borings). The depths, locations, and designations of soil borings are discussed in Section 2.3.1 and 2.3.2.

During the Phase I investigation, a total of 19 soil borings were advanced at Site 88 with temporary monitoring wells installed in each of the soil borings. This included 15 shallow and 4 intermediate wells at the site.

It should be noted that four existing shallow temporary monitoring wells (IR88-TW01 through TW04) were present at the time of the Phase I investigation. The wells were installed under the direction of OHM in November 1995 and were drilled using a GeoProbe drill rig. Baker provided technical oversight of the drilling and sampling of these initial temporary wells. These temporary monitoring wells were constructed with 5 to 10 feet of one-inch outside diameter (OD) polyvinyl chloride (PVC) well screen and approximately 10 feet of riser. The wells were located close to Building 25 and were related to the closure and investigation of the original tanks at the site.

During the Phase II investigation, a total of 46 soil borings were advanced at the site with temporary monitoring wells installed in 19 of the borings and permanent monitoring wells installed in 21 of the borings. The remaining six soil borings included two located inside of Building 25 and four in the immediate vicinity of the building.

2.2.1 Drilling Procedures

All of the soil borings completed during the Phase I and Phase II investigations were advanced via hollow stem augering and split-spoon sampling methods in general accordance with procedures outlined in ASTM Standard Method for Penetration Test and Split-Barrel Sampling of Soils (Designation D 1586). Split-spoons of 24-inch (nominal) length were used throughout the investigation. Generally, soil samples were collected continuously (at 2 foot intervals) beginning at the ground surface to the boring completion depth from the deepest soil boring in a cluster. Sample intervals for soil borings that were not sampled continuously were selected by the Baker Field Geologist. Sample intervals are shown on the Test Boring and Well Construction Records which are presented in Appendix A. For select sample intervals, relatively undisturbed Shelby tube samples were collected for analysis of geotechnical and hydrogeological parameters. These samples were collected in general accordance with ASTM Standard Practice for Thin-Walled Tube Sampling of Soils (Designation D 1587). All drilling and soil sampling activities were performed in Level D personal protective equipment. Soil cuttings and decontamination fluids generated during the investigation were managed in accordance with the procedures outlined in Section 2.6.

2.2.2 Laboratory Analysis of Subsurface Soil Samples

Subsurface soil samples from both investigation phases were analyzed for various parameters. Sixteen subsurface soil samples were submitted to the mobile laboratory and analyzed on site for volatile organic compounds. None of the subsurface soil samples collected at Site 88 during the Phase I investigation were submitted for fixed base laboratory analysis. Select subsurface soil samples collected during the Phase II investigation were submitted for the following laboratory analyses:

Parameter	Number of Samples
Target Compound List (TCL) volatiles	20
Engineering parameters including:	
▸ Total organic carbon (TOC)	5
▸ Grain size	5
▸ Bulk density	5
Vertical permeability	3

Samples for VOCs were not collected from every Phase II sample location. Phase I of the RI provided information on the extent of the comtamination through the use of temporary wells. The Phase II sampling program was designed to supplement the Phase I information through the use of temporary and permanent wells. Some permanent wells were located within the plume of groundwater contamination and others were located outside the plume to confirm the presence or absence of groundwater contamination. Since some permanent wells were located outside areas of groundwater contamination (as well as soil contamination), subsurface soil samples were not collected for VOCs.

Samples for metals analysis were not collected. Iron and nickel were detected in groundwater above NC 2L WQS. However, metals were not a part of the analytical suite because there is no historical evidence that associated metals with site operations. Additionally, these metals can occur in soils and groundwater naturally or anthropogenically.

The TCL analyses were performed to characterize the nature and extent of contamination in subsurface soils which is discussed in Section 4.0. The geotechnical engineering parameters including, vertical permeability, TOC, grain size, and bulk density are used for the assessment and development of remedial alternatives. Vertical permeability and grain size are also used for evaluation of hydrogeologic conditions which are discussed in Section 3.0. Results for the analyses of vertical permeability and the other geotechnical engineering/hydrogeologic parameters are presented in Appendix B.

Subsurface soil samples were shipped to the laboratory overnight via Federal Express for analysis. Sample tracking forms were updated by Baker throughout the investigation. Chain-of-custody forms were included with each shipping cooler that was sent to the laboratory. Internal sample tracking forms and chain-of-custody forms are included in Appendix C, sample documentation.

Table 2-1 presents a summary of the subsurface soil sampling program for Site 88. The summary includes the following: sample identification; sample interval; analyzed parameters; duplicate samples; and matrix spike/matrix spike duplicate (MS/MSD) samples. Analytical results are discussed in Section 4.0. Field quality assurance/quality control (QA/QC) samples are discussed in Section 2.4.

2.2.2.1 Air Monitoring and Field Screening

Ambient air monitoring in the vicinity of the borehole was performed with a photo ionization detector (PID) to monitor for airborne contaminants during drilling. In addition, split-spoon soil 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 and Well Construction Records which are provided in Appendix A. Prior to daily monitoring, the field instruments were calibrated and documentation was recorded in a field logbook or on calibration forms.

2.3 Groundwater Investigation

A groundwater investigation was conducted at Site 88 to define the nature and extent of contamination in the surficial aquifer and in the Castle Hayne aquifer which may have resulted from past site activities. The groundwater investigation included the following activities which are discussed in the proceeding sections:

- Temporary monitoring well installation
- Permanent monitoring well installation
- Monitoring well development
- Groundwater sample acquisition
- Groundwater level measurements
- On-site laboratory analysis
- Fixed-base laboratory analysis
- In situ hydraulic conductivity (slug) tests

2.3.1 Temporary Monitoring Well Installation

Temporary monitoring wells were situated spatially across the site to provide acquisition stations for sampling potentially impacted groundwater, to partially characterize the nature and extent of possible contamination, and to provide information used for placement of permanent monitoring well locations. Placement of the temporary wells was based on review of aerial photographs, previous investigations, site conditions, locations of underground utilities, and the overall scope and objectives of the project. Locations of the temporary monitoring wells presented in the Final Project Plans provided initial guidance, however, results of on-site laboratory data were used on a daily basis for the subsequent selection of additional temporary well locations. Temporary monitoring well location selection was a cooperative effort involving the Baker Site Manager, the Baker Project manager, Naval Facilities Engineering Command, Atlantic Division (LANTDIV), and MCB Camp Lejeune personnel.

All temporary monitoring wells were constructed of 1-inch diameter, schedule 40, flush-joint and threaded, PVC casing. The intermediate wells consisted of a 5-foot No. 10 (i.e., 0.01 inch) slot screen section, while the shallow wells consisted of a 10-foot No. 10 slot screen section. The screened sections of the wells were covered with a length of tubular nylon material known as a "well sock", which reduces the amount of fine grained material that moves through the screen and into the monitoring well. The temporary monitoring wells were left as "stick-up"for subsequent groundwater sampling. The identification of each temporary monitoring well was written on the outside of the PVC casing with a permanent marker. The shallow and intermediate temporary monitoring well locations for Site 88 are shown on Figure 2-2 and 2-3, respectively. A typical temporary monitoring well construction detail is shown on Figure 2-4. All of the monitoring well construction records are provided on the boring logs contained in Appendix A.

The temporary monitoring wells were installed after completing a soil boring to the appropriate depth as discussed in Section 2.2.1. In general, the shallow temporary monitoring wells were installed approximately 10 feet below the level at which the water table was encountered during drilling. The intermediate wells were installed to characterize the groundwater near the bottom of the surficial aquifer (approximately 50 ft. bgs).

During the Phase I investigation a total of 19 temporary monitoring wells were installed at Site 88 between August 16, 1996, and August 20, 1996. Fifteen of the monitoring wells were considered shallow, ranging in depths of 15 to 20 feet below ground surface (bgs), and four were installed as intermediate temporary monitoring wells at a depth of approximately 50 feet bgs.

During the Phase II investigation, an additional 19 temporary monitoring wells were installed at the site between April 14, 1997 and April 29, 1997. Nine of the wells were considered shallow, with depths of approximately 25 feet bgs, while 10 intermediate temporary monitoring wells were installed to approximately 50 feet bgs. A summary of the construction data for the temporary monitoring wells at Site 88, including well identification, date installed, top of casing and ground surface elevations, boring and well depths, and screen intervals is presented on Table 2-2.

2.3.2 Permanent Monitoring Well Installation

Permanent monitoring wells were installed spatially across the site to facilitate groundwater sample collection from groundwater that has been impacted by past site activities and to characterize the nature and extent of groundwater contamination. The permanent monitoring wells provide secure, fixed groundwater sampling locations from which future samples may be acquired, and from which critical hydrogeologic data such as hydraulic conductivity, and groundwater depths, flow directions and gradients can be ascertained. The Final Project Plans provided initial guidance for permanent monitoring well locations. However, final placement of the permanent monitoring wells was selected based on the mobile laboratory results of groundwater samples collected from temporary monitoring well groundwater samples (as discussed in Section 4.0). Permanent monitoring well location selection was a cooperative effort involving the Baker Site Manager, the Baker Project Manager, LANTDIV, and MCB Camp Lejeune representatives.

Shallow, intermediate, and deep permanent monitoring wells were installed during the Phase II investigation to monitor different aquifer zones at Site 88. Figures 2-5, 2-6, and 2-7 illustrate the locations of the shallow, intermediate, and deep permanent monitoring wells at Site 88, respectively. The shallow permanent monitoring wells were screened across the water table (i.e., a portion of the monitoring well screen is above the level of the groundwater surface) to facilitate monitoring of the upper zone of the surficial aquifer. The intermediate permanent monitoring wells were installed to monitor the lower portions of the surficial aquifer zone (and upper portion of the Castle Hayne Aquifer at 88-MW05IW) at approximately 50 feet bgs. The deep permanent monitoring wells were installed to monitor the groundwater zone within the Castle Hayne aquifer at approximately 80 to 100 feet bgs. The hydrogeologic conditions at MCB, Camp Lejeune, including aquifer and confining unit descriptions, are discussed in Section 3.0.

Permanent monitoring wells were constructed of 2-inch diameter, schedule 40, flush-joint and threaded PVC casing. Well screen intervals were comprised of 10 feet (shallow monitoring wells) or 5 feet (intermediate and deep monitoring wells) lengths of No. 10 slot well screen. A sand pack consisting of "Morie" brand No. 1 sand was placed inside of the annulus between the screen/riser and the borehole wall from the bottom of the well to at least 2 feet above the top of the screen. A bentonite seal of 2 foot to 3 foot thickness for shallow wells, and approximately 5 foot thickness for intermediate and deep monitoring wells was placed above the sand pack. Above the bentonite seal, the annular space was filled with cement-bentonite grout to the ground surface.

As Site 88 is located in a very developed area of the base, the PVC riser was terminated below the level of the surrounding ground surface and a "flush-mount"protective well cover was installed. A typical permanent monitoring well construction diagram for below ground surface completion is presented in Figure 2-8. All permanent monitoring wells were installed using standard construction techniques as detailed in Section 6.0 of the Final FSAP. Monitoring well construction records are presented in Appendix A.

A total of 21 permanent monitoring wells were installed at Site 88 during the Phase II investigation, between April 18, 1997, and May 7, 1997. Nine shallow permanent monitoring wells were installed, ranging in depths of 15 to 25 feet bgs. A total of eight intermediate permanent monitoring wells were installed to depths of 50 feet bgs. Four deep permanent monitoring wells were installed at depths ranging from 85 to 100 feet bgs. Permanent monitoring well construction data for Site 88 is presented on Table 2-3. This table includes well identification, date installed, top of casing and ground surface elevations, boring and well depths, screen, sand pack, and bentonite seal intervals.

2.3.3 Monitoring Well Development

All permanent monitoring wells were developed prior to sampling using an inertial displacement (Waterra®) pump in accordance with the procedures outlined in Section 6.0 of the Final FSAP. During development operations, water quality and turbidity readings were recorded. The monitoring wells were developed until the groundwater was relatively clear and water quality readings were stable. The monitoring well development records are provided in Appendix D.

2.3.4 Water Level Measurements

Three rounds of static water level measurements were recorded at Site 88. Measurements were recorded from permanently marked reference points on the top of the PVC casing at each monitoring well. The surveyed reference points provide a fixed datum from which groundwater levels can consistently be measured. Groundwater measurements were recorded to the nearest 0.01 foot from the top-of-casing reference point using an electric water level meter. Groundwater level measurements were recorded for the shallow, intermediate, and deep monitoring wells on May 19, 1997, May 31, 1997, and July 24, 1997.

Water level measurements were recorded at each temporary monitoring well prior to groundwater sample acquisition during the Phase I investigation. However, as the measurements were recorded on different dates, and a much larger data set of measurements exist from the Phase II investigation (i.e., temporary and permanent monitoring wells), the Phase I measurements will not be discussed herein. All of the potentiometric maps and analyses of groundwater flow directions are based upon the Phase II data.

2.3.5 Groundwater Sample Acquisition

Groundwater samples were collected to assess whether contamination that may have resulted from previous activities at Site 88 was present in the aquifer underlying the site. Based upon previous investigative results and historical records, the contaminants of potential concern were primarily volatile organic compounds (VOCs).

A water level measurement was obtained from each well prior to groundwater purging. The total well depth was also recorded from each well to the nearest 0.1-foot prior to sampling (during Phase I), or prior to development (during Phase II). Water level and well depth measurements were used to calculate the volume of water in each well.

A minimum of three to five well volumes were purged from each well prior to sampling. Measurements of pH, specific conductance, temperature, turbidity, and dissolved oxygen (D.O.) were taken after each well volume was purged to ensure that the groundwater quality had stabilized before sampling. These measurements were recorded in a field logbook and are provided on Table 2-4 for the temporary monitoring wells and on Table 2-5 for the permanent monitoring wells. Purge water was containerized and managed as described in Section 2.7.

During the groundwater sampling events, a low flow well purging and sampling technique was employed. The sampling methodology in accordance with USEPA Region IV SOPs. A peristaltic pump (GeoPump®) was used to purge and sample the wells. A flow rate of less than 0.3 gallons per minute (gpm) was maintained during purging and sampling of groundwater from each of the monitoring wells. The average flow rate for monitoring well purging and sampling was approximately 0.17 gpm. The groundwater samples were collected directly from the pump discharge. Dedicated sections of polyethylene tubing and silicon pump-head tubing were used during purging and sampling activities at each well.

Groundwater sampling documentation included specific sample information such as well number, sample identification, time and date of sample collection, sampling team, and analytical parameters. These items were recorded in a field logbook and on the sample labels.

2.3.6 On-Site Laboratory Analysis

During both phases of the investigation, on-site laboratory analysis was performed on groundwater samples that were collected from each temporary monitoring well. These samples were analyzed for VOCs in accordance with EPA Method 8240 and were collected in order to define the extent of VOC groundwater contamination. During Phase I of the investigation, a total of 23 groundwater samples were collected from Site 88 temporary monitoring wells and subjected to on-site laboratory analysis of VOCs. Nine additional samples were collected for analysis by the fixed based laboratory to ensure that the on-site analysis provided accurate results. During Phase II of the investigation, a total of 19 groundwater samples were collected from additional temporary monitoring wells at Site 88 and analyzed by the on-site laboratory. These samples were used to further define the limits of the VOC contamination in groundwater and aid in the placement of the permanent monitoring wells.

A summary of the on-site groundwater analysis program for Site 88 is presented on Table 2-6. The results of the laboratory analyses as well as the nature and extent of site contamination is discussed in Section 4.0.

2.3.7 Fixed-Base Laboratory Analysis

During Phase II of the investigation, groundwater samples which were collected from permanent monitoring wells were submitted for fixed-base laboratory analysis of one or more of the following laboratory analyses:

Parameter	Number of Samples
TCL volatiles	21
Engineering parameters including:	
▸ total suspended solids (TSS)	10
▸ total dissolved solids (TDS)	10
▸ biochemical oxygen demand (BOD)	10
▸ chemical oxygen demand (COD)	10
Natural attenuation parameters including:	
▸ nitrate	10
▸ nitrite	10
▸ sulfate	10
▸ chloride	10
▸ Iron^{+2}	10
▸ sulfide	10
▸ methane	10

The TCL analysis was performed to characterize the nature and extent of contamination in groundwater which is discussed in Section 4.0. Groundwater samples were shipped to the laboratory overnight via Federal Express for analysis. Sample tracking forms were updated by Baker throughout the investigation. Chain-of-custody forms were included with each shipping cooler that was sent to the laboratory. Internal sample tracking forms and chain-of-custody forms are included in Appendix C. The engineering and natural attenuation parameters are to be used for the assessment and development of remedial alternatives. The natural attenuation and engineering parameter results for groundwater are presented in Appendix E.

During the Phase II investigation, 21 groundwater samples were collected from Site 88 (not including QA/QC samples). Table 2-7 present a summary of the fixed-base laboratory sampling program for Site 88. The summary includes sample identification, analyzed parameters duplicate samples and matrix spike/matrix spike duplicate (MS/MSD) samples. Analytical results are discussed in Section 4.0. Field quality assurance/quality control (QA/QC) samples are discussed in Section 2.4.

2.3.8 In Situ Hydraulic Conductivity (Slug) Tests

The shallow aquifer and upper portion of the Castle Hayne aquifer were characterized by performing in situ rising and falling head slug tests in select shallow, intermediate, and deep permanent monitoring wells. The tests were performed on May 18 and May 19, 1997. A solid Teflon™ slug was quickly inserted into, or removed from, the well to displace the water in that well. An electronic data logger (In Situ Hermit Model SE2000) and pressure transducer assembly were used to record the recovery of water in the monitoring wells to static level. All data was recorded on logarithmic scale to more closely monitor the initial changes in groundwater elevation. The data resulting from the slug tests were converted into time (in minutes) and the corresponding change in water level displacement (in feet). Results from the rising head tests were analyzed using Geraghty & Miller's AQTESOLV computer program for performing quantitative groundwater assessments. The shallow monitoring wells were only analyzed for rising head tests due to the fact that groundwater levels within these monitoring wells were below the top of the sand packs, making falling head tests invalid at these locations. Both rising and falling head tests were completed for the intermediate and deep monitoring wells.

Following is a tabulation of the monitoring wells for which slug tests were performed:

- Monitoring well 88-MW02 (rising head)
- Monitoring well 88-MW03IW (rising and falling head)
- Monitoring well 88-MW03DW (rising and falling head)
- Monitoring well 88-MW04 (rising head)
- Monitoring well 88-MW04IW (rising and falling head)
- Monitoring well 88-MW05 (rising head)
- Monitoring well 88-MW07 (rising head)
- Monitoring well 88-MW07IW (rising and falling head)
- Monitoring well 88-MW09 (rising head)
- Monitoring well 88-MW09IW (rising and falling head)

The Bouwer and Rice solution for slug tests in unconfined aquifers was used to evaluate all test data. The results of the *in situ* slug tests and hydrogeologic conditions at Site 88 are discussed in Section 3.0.

2.3.9 Temporary Monitoring Well Abandonment

Temporary monitoring wells installed during both the Phase I and Phase II investigations were abandoned following sampling and surveying activities. Abandonment was accomplished by manually removing the PVC pipe from the bore hole using pipe wrenches for leverage. The bore holes were then filled with soil cuttings to the surface.

2.4 Field Quality Assurance Quality Control Samples

Field QA/QC samples were collected at Site 88 during the Phase II investigation according to the procedures outlined in the USEPA Region IV standard operating procedures (SOPs). These samples were obtained to 1) ensure that decontamination procedures were effective (equipment rinsate samples); 2) evaluate field methodologies (duplicate samples); 3) establish field background conditions (field blanks); 4) evaluate whether cross-contamination occurred during sampling and shipping (trip blanks); and 5) evaluate laboratory analytical processes (MS/MSDs).

Data Quality Objectives (DQOs) for the fixed-base laboratory and QA/QC samples were implemented in accordance with DQO Level IV as defined in the Environmental Compliance Branch Standard Operating Procedures (SOPs) and Quality Assurance Manual, USEPA Region IV (USEPA, 1991). This DQO level is equivalent to the Naval Facilities Engineering Service Center (NFESC) DQO Level D, as specified in the "Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Programs" document (NEESA, 1988). The DQOs for the on-site mobile laboratory were implemented in accordance with DQO Level III (which corresponds to NFESC DQO Level C).

Data submitted for fixed-base confirmation was conducted in accordance with CLP DQO Level IV (NFESC DQO Level D). Fixed-base laboratory data was used to confirm the representativeness of the mobile laboratory analysis. Permenant wells were located inside and outside the plume of groundwater contamination to confirm the presence or absence of groundwater contamination as identified by the temporary wells (mobile laboratory analysis). Laboratory analysis for these samples was conducted in accordance with CLP DQO Level IV (NFESC DQO Level D). Thus, critical analysis of the nature and extent of contamination was based on CLP DQO Level IV (NFESC DQO Level D) data.

The definition of each type of QA/QC sample is provided in the Environmental Compliance Branch SOPs and Quality Assurance Manual, USEPA Region IV (USEPA, 1991). A brief summary of the QA/QC samples collected during this investigation is provided below:

- Duplicate Samples: Duplicates were collected at frequencies equal to or greater than ten percent of the total number of samples collected. The duplicate samples were collected at the same time, using the same techniques as the planned original environmental samples. A total of two duplicate soil samples and three duplicate groundwater samples were collected during the Phase II investigation

- Equipment Rinsate Blanks: Equipment Rinsate blanks were prepared for sampling equipment used to collect environmental samples. Rinsate samples were analyzed for parameters associated with the sampling event. A total of seven rinsate blank samples were collected during the Phase II investigation. This included, five rinsate blanks for soil borings, and two rinsate blanks for groundwater.

- Field Blanks: Field blanks were collected to provide analytical data on the water used in the field for decontamination purposes. Three field blank samples were collected during the Phase II investigation.

- Trip Blanks: Trip blanks were prepared by the analytical laboratory prior to the sampling event, and stored with the investigative samples throughout the sampling event. A total of 6 trip blanks were analyzed during the Phase II investigation.

- Matrix Spike/Matrix Spike Duplicates: MS/MSDs were collected at a frequency equal to or greater than five percent of the total number of environmental samples collected during the study. One MS/MSD soil sample and two MS/MSD groundwater samples were collected and analyzed during the Phase II investigation.

A summary of field QA/QC samples is included as Table 2-8. This table presents the sample identification and date, analytical parameters, and additional information pertinent to the field QA/QC samples. MS/MSD samples are indicated on the sample summary tables that are presented earlier in this section.

2.5 Decontamination Procedures

All reusable sampling equipment that was used during the investigation was decontaminated after each use to prevent cross-contamination of samples. Disposable sampling equipment was not decontaminated, but rather was discarded subsequent to use. Disposable equipment included polyethylene and silicon tubing used for groundwater sampling. The drill rig and associated down-hole tools were steam cleaned prior to initiating drilling activities and also between borings. Meters and instruments used for measuring water quality parameters were thoroughly rinsed with distilled water after each use.

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: drill rigs, hollow-stem augers, drill and sampling rods. Routine sample collection equipment included: split spoons, stainless steel spoons, and bowls.

For heavy equipment, the following procedures were implemented:

- Removal of caked-on soil by hand
- 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 with isopropyl alcohol
- Rinse thoroughly with organic/analyte-free water
- Air dry
- Wrap in aluminum foil, if tool not planned for immediate use

Temporary decontamination pads, constructed of a wooden frame and a plastic liner, were used to prevent spillage onto the ground surface. Decontamination fluids generated during the field program were containerized and handled according to the procedures outlined in Section 2.6 below.

2.6 Investigation Derived Waste Management

Field investigation activities at Site 88 resulted in the generation of various investigation derived waste (IDW). The IDW included soil cuttings, purge and development water, drilling fluids (mud) and solutions used to decontaminate non-disposable sampling equipment. Solid IDW was stored in three 10 cubic yard roll-off boxes, and liquid IDW was stored in a 5,000 gallon tank trailer. The general management techniques used for the IDW were:

- Collection and containerization of IDW material
- Temporary storage of IDW while awaiting confirmatory analytical data
- 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 (USEPA, 1992). Both the IDW soils and water at Site 88 were determined to be nonhazardous. All soils were transported to Lot 203 and disposed of in an area which contains other non-hazardous fill material. The liquid IDW was transported to the Groundwater Treatment Facility located at Lot 203 where proper treatment and disposal procedures were completed. A complete summary of the IDW management is contained in Appendix F.

2.7 **References**

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SECTION 2.0 TABLES

TABLE 2-1
SOIL SAMPLING SUMMARY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample ID	Sample Interval (ft bgs)	TCL Volatiles	TOC	Bulk Density	Grain Size	Vertical Permeability	Duplicate Sample	MS/MSD
Phase II Soil Samples								
IR88-MW02-02	2.0-4.0			X	X	X		
IR88-MW02DW-04	9.0-11.0	X						
IR88-MW02DW-05	11.0-13.0	X						
IR88-MW03DW-02	3.0-5.0	X						
IR88-MW03DW-04	7.0-9.0	X	X					
IR88-MW04IW-08	16.0-18.0			X	X	X		
IR88-MW04DW-06	11.0-13.0	X						
IR88-MW04DW-07	13.0-15.0	X						
IR88-MW05DW-05	9.0-11.0	X						
IR88-MW05DW-06	11.0-13.0	X						
IR88-MW06IW-06	11.0-13.0	X					X	
IR88-MW06IW-07	13.0-15.0	X						
IR88-MW07IW-09	14.0-16.0		X					
IR88-MW07IW-22	40.0-42.0		X					
IR88-MW08IW-08	15.0-17.0		X	X	X			
IR88-MW08IW-22	45.0-47.0		X	X	X			
IR88-SB01-02	3.0-5.0	X						
IR88-SB02-04	7.0-9.0	X					X	
IR88-SB02-05	9.0-11.0	X						
IR88-SB03-02	3.0-5.0	X						
IR88-SB04-04	7.0-9.0	X		X	X			
IR88-SB04-05	9.0-11.0	X						
IR88-SB04-11	20.0-22.0					X		
IR88-SB05-05	9.0-11.0	X						X
IR88-SB05-06	11.0-13.0	X						
IR88-SB06-04	7.0-9.0	X						
IR88-SB06-05	9.0-11.0	X						

NOTES: TCL = Target Compound List
TOC = Total Organic Carbon
MS/MSD = Matrix Spike/Matrix Spike Duplicate
ft = feet
bgs = below ground surface
X = Sample analyzed for indicated parameter

TABLE 2-2
SUMMARY OF TEMPORARY MONITORING WELL CONSTRUCTION DATA
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID	Date Installed	Top of Casing Elevation (ft above msl)	Ground Surface Elevation (ft above msl)	Boring Depth (ft bgs)	Well Depth (ft bgs)	Screen Interval Depth (ft bgs)
Phase I Temporary Monitoring Wells						
IR88-TW04IW	8/16/96	28.55	26.46	56.0	50.0	45.0 - 50.0
IR88-TW05	8/16/96	28.18	25.73	15.0	15.0	5.0 - 15.0
IR88-TW05IW	8/18/96	27.89	26.02	57.0	50.0	45.0 - 50.0
IR88-TW06	8/16/96	25.64	25.62	15.0	15.0	5.0 - 15.0
IR88-TW07	8/16/96	28.60	26.50	15.0	15.0	5.0 - 15.0
IR88-TW08	8/16/96	26.80	24.71	15.0	15.0	5.0 - 15.0
IR88-TW08IW	8/18/96	25.63	24.71	47.0	44.0	39.0 - 44.0
IR88-TW09	8/16/96	27.89	25.73	18.0	18.0	8.0 - 18.0
IR88-TW10	8/17/96	--	--	15.0	15.0	5.0 - 15.0
IR88-TW11	8/17/96	28.22	26.08	15.0	15.0	5.0 - 15.0
IR88-TW12	8/17/96	27.18	26.62	20.0	20.0	10.0 - 20.0
IR88-TW13	8/17/96	26.06	25.16	19.0	19.0	9.0 - 19.0
IR88-TW14	8/17/96	29.06	26.06	15.0	15.0	5.0 - 15.0
IR88-TW15	8/17/96	27.08	24.67	18.0	18.0	8.0 - 18.0
IR88-TW16	8/18/96	27.26	23.87	17.0	17.0	7.0 - 17.0
IR88-TW17	8/18/96	26.02	25.02	19.0	19.0	9.0 - 19.0
IR88-TW18	8/19/96	24.38	22.26	16.0	16.0	6.0 - 16.0
IR88-TW19	8/20/97	24.90	23.24	18.0	18.0	8.0 - 18.0
IR88-TW19IW	8/19/96	25.87	23.24	50.0	50.0	45.0 - 50.0
Phase II Temporary Monitoring Wells						
IR88-TW20	4/14/97	24.73	23.03	25.0	25.0	10.0 - 25.0
IR88-TW20IW	4/14/97	24.34	23.04	50.0	50.0	45.0 - 50.0
IR88-TW21	4/15/97	25.56	23.82	25.0	25.0	10.0 - 25.0
IR88-TW21IW	4/15/97	25.23	23.85	50.0	50.0	45.0 - 50.0
IR88-TW22	4/15/97	24.46	23.36	25.0	25.0	10.0 - 25.0
IR88-TW22IW	4/15/97	25.76	23.34	50.0	50.0	45.0 - 50.0
IR88-TW23	4/16/97	25.21	23.97	25.0	25.0	10.0 - 25.0
IR88-TW23IW	4/16/97	24.86	23.99	50.0	50.0	45.0 - 50.0
IR88-TW24	4/16/97	25.82	24.32	25.0	25.0	10.0 - 25.0
IR88-TW24IW	4/16/97	25.82	24.17	50.0	50.0	45.0 - 50.0
IR88-TW25	4/17/97	26.51	24.68	25.0	25.0	10.0 - 25.0
IR88-TW25IW	4/17/97	25.80	24.66	50.0	50.0	45.0 - 50.0
IR88-TW26	4/17/97	27.40	25.79	25.0	25.0	10.0 - 25.0
IR88-TW26IW	4/17/97	27.82	25.78	50.0	50.0	45.0 - 50.0
IR88-TW27	4/29/97	23.96	22.60	25.0	25.0	10.0 - 25.0
IR88-TW27IW	4/29/97	24.26	22.68	50.0	50.0	45.0 - 50.0
IR88-TW28	4/29/97	25.35	24.35	25.0	25.0	10.0 - 25.0
IR88-TW28IW	4/29/97	27.05	24.63	50.0	50.0	45.0 - 50.0

NOTES: ft = feet
msl = mean sea level
bgs = below ground surface
"--" = Data not available

TABLE 2-3
SUMMARY OF PERMANENT MONITORING WELL CONSTRUCTION DATA
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID	Date Installed	Top of Casing Elevation (ft above msl)	Ground Surface Elevation (ft above msl)	Boring Depth (ft bgs)	Well Depth (ft bgs)	Screen Interval Depth (ft bgs)	Sand Pack Interval Depth (ft bgs)	Bentonite Interval Depth (ft bgs)
Phase II Permanent Monitoring Wells (1)								
IR88-MW01	5/1/97	26.07	26.50	22.0	22.0	7.0 - 22.0	5.0 - 22.0	2.0 - 5.0
IR88-MW02	5/2/97	25.11	26.60	23.0	23.0	8.0 - 23.0	6.0 - 23.0	3.5 - 6.0
IR88-MW02IW	5/3/97	25.11	26.57	50.0	50.0	45.0 - 50.0	40.0 - 50.0	34.5 - 40.0
IR88-MW02DW	4/20/97	25.14	26.58	100.0	97.0	92.0 - 97.0	87.0 - 97.0	82.0 - 87.0
IR88-MW03	5/1/97	25.38	25.88	16.0	15.0	5.0 - 15.0	4.0 - 15.0	2.0 - 4.0
IR88-MW03IW	5/1/97	25.62	25.89	50.5	50.0	45.0 - 50.0	40.0 - 50.0	35.0 - 40.0
IR88-MW03DW	4/30/97	25.32	25.89	85.0	85.0	80.0 - 85.0	75.0 - 85.0	70.0 - 75.0
IR88-MW04	5/2/97	24.54	24.91	25.0	25.0	10.0 - 25.0	8.0 - 25.0	5.0 - 8.0
IR88-MW04IW	5/2/97	24.60	24.98	50.0	50.0	45.0 - 50.0	39.5 - 50.0	34.0 - 39.5
IR88-MW04DW	4/18/97	24.61	24.95	85.0	85.0	80.0 - 85.0	76.0 - 85.0	73.0 - 76.0
IR88-MW05	5/3/97	23.97	24.58	23.0	23.0	8.0 - 23.0	6.0 - 23.0	3.0 - 6.0
IR88-MW05IW	5/3/97	24.45	24.68	50.0	50.0	45.0 - 50.0	40.0 - 50.0	35.0 - 40.0
IR88-MW05DW	4/22/97	24.33	24.74	87.0	85.0	80.0 - 85.0	75.0 - 85.0	70.0 - 75.0
IR88-MW06	5/4/97	23.13	24.60	23.0	23.0	8.0 - 23.0	6.0 - 23.0	3.0 - 6.0
IR88-MW06IW	5/4/97	23.04	24.59	50.0	50.0	45.0 - 50.0	32.5 - 50.0	26.0 - 32.5
IR88-MW07	5/6/97	23.37	23.63	22.0	22.0	7.0 - 22.0	5.0 - 7.0	2.0 - 5.0
IR88-MW07IW	5/5/97	23.38	23.67	50.0	50.0	45.0 - 50.0	40.0 - 50.0	35.0 - 40.0
IR88-MW08	5/7/97	22.98	23.21	20.0	20.0	5.0 - 20.0	4.0 - 20.0	2.0 - 4.0
IR88-MW08IW	5/7/97	22.91	23.05	50.0	50.0	45.0 - 50.0	39.5 - 50.0	34.0 - 39.5
IR88-MW09	5/5/97	21.83	22.13	21.0	21.0	6.0 - 21.0	4.0 - 21.0	2.0 - 4.0
IR88-MW09IW	5/5/97	21.74	22.00	50.0	50.0	45.0 - 50.0	40.0 - 50.0	34.0 - 40.0

NOTES: (1) = No permanent monitoring wells were installed during the Phase I Investigation
ft = feet
msl = mean sea level
bgs = below ground surface

TABLE 2-4
SUMMARY OF TEMPORARY MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
Phase I Temporary Monitoring Wells								
88-TW04IW	1400	1	3	461	26.1	7.02	48.5	1.6
08/15/96	1428	2	6	460	25.9	7.02	85	1.6
0.11 gpm	1455	3	9	450	26.0	7.09	25	1.7
	1535	1	1	--	--	--	50	--
	1545	--	--	--	--	--	70	--
	1555	--	--	--	--	--	42.5	--
88-TW05(3)	1545	--	--	--	--	--	--	--
08/16/96	1630	--	--	--	--	--	70	--
	1640	--	--	--	--	--	33	--
	1650	--	--	--	--	--	12	--
	1700	--	--	--	--	--	8	--
88-TW06	0812	1	0.7	225	28.1	6.42	13	4.0
08/17/96	0900	2	1.4	217	18.5	6.25	34	3.4
0.02 gpm	0933	3	2.1	213	29.0	6.21	12	3.8
	0957	1	0.7	201	25.0	5.53	24	2.6
88-TW07	1008	2	1.4	203	24.6	5.46	16	2.5
08/17/96	1015	3	2.1	225	24.0	4.87	95	2.0
0.08 gpm	1025	4	3.0	221	24.3	4.81	195	1.8
	1030	--	--	--	--	--	10	--
	1057	1	0.5	149	26.4	4.51	--	2.8
	1100	2	1.0	104	26.5	4.34	--	2.0
	1120	3	1.5	885	25.7	4.70	--	1.9
88-TW08	1116	4	2.0	87	25.7	4.64	20	2.0
08/17/96	1130	6	3.0	885	26.1	4.89	--	2.0
0.08 gpm	1220	--	--	--	--	--	68	--
	1225	--	--	--	--	--	60	--
	1230	--	--	--	--	--	44	--
	1240	--	--	--	--	--	30	--
	1245	--	--	--	--	--	22	--
88-TW08IW	1445	1	2.4	359	26.7	6.73	93	1.2
08/18/96	1502	2	5.0	378	25.3	6.83	17	1.6
0.13 gpm	1525	3	7.5	404	24.9	6.8	4	1.4
88-TW09	1305	1	0.5	133	28.2	5.39	50	3.8
08/17/96	1313	2	1.0	101	26.6	5.26	35	3.8
0.07 gpm	1320	3	1.5	100.5	25.9	5.11	25	4.0
88-TW10	1350	1	0.7	127	28.5	5.69	10	3.8
0.06 gpm	1402	2	1.4	720	28.7	5.75	3.0	3.6
	1413	3	2.1	118	28.2	5.72	2.5	4.0

TABLE 2-4 (Continued)
SUMMARY OF TEMPORARY MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
88-TW11 08/17/96 0.12 gpm	1434	1	0.7	139	23.4	4.36	158	1.2
	1439	2	1.4	137	23.1	4.14	128	1.4
	1446	3	2.1	136	23.1	4.19	50	1.6
	1450	4	3.0	--	--	--	19	--
	1458	5	3.5	--	--	--	7	--
88-TW12 08/17/96 0.03 gpm	1525	1	0.4	158	23.9	5.04	11.5	3.8
	1535	2	0.8	140	23.7	5.16	2.7	4.0
	1600	3	1.5	140	23.3	5.32	1.0	4.0
88-TW13 08/17/96 0.02 gpm	1623	1	0.6	99	26.4	4.47	101	3.2
	1629	2	1.2	995	27.0	4.62	38	3.0
	1635	3	2.0	99	26.4	4.63	160	3.0
	1338	--	--	--	--	--	120	--
	1642	--	--	--	--	--	94	--
	1648	--	--	--	--	--	26	--
	1651	--	--	--	--	--	17	--
	1655	--	--	--	--	--	13.5	--
88-TW14 08/18/96 0.08 gpm	0742	1	0.7	226	22.9	4.51	55	3.0
	0755	2	1.5	224	23.0	4.48	1.0	3.4
	0806	3	2.5	225	23.1	4.37	1.0	3.0
88-TW15 08/18/96 0.17 gpm	0828	1	1.2	202	31.6	4.21	87	3.0
	0835	2	2.0	181	32.1	4.23	5.0	2.8
	0842	3	3.6	166	32.0	4.17	2.2	2.4
88-TW16 08/18/96 0.08 gpm	1620	1	0.7	121	27.0	5.19	31	2.4
	1632	2	1.5	109	25.9	5.11	15	2.4
	1643	3	2.5	105	25.8	5.30	2.3	2.4
88-TW17 08/20/96	0822	1	1.0	76	26.4	4.71	1.1	2.4
	0832	2	1.5	70	26.6	4.57	1.5	3.0
	0842	3	2.0	69	26.7	4.53	7.0	3.0
88-TW18 08/20/96 0.05 gpm	0914	1	0.6	155	23.1	5.96	>200	4.0
	0926	2	1.5	166	23.1	6.03	>200	4.0
	0937	3	2.2	171	23.2	6.09	195	4.0
	0945	--	--	--	--	--	99	--
	0955	--	--	--	--	--	48	--
	1005	--	--	--	--	--	32	--
88-TW19 08/20/96 0.15 gpm	1537	1	0.9	113	23.2	4.44	21	2.1
	1548	2	1.8	112	23.0	4.33	26	2.2
	1549	3	2.7	113	23.2	4.36	48	2.2
	1555	--	--	--	--	--	24	--
	1605	--	--	--	--	--	5	--

TABLE 2-4 (Continued)
SUMMARY OF TEMPORARY MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
88-TW19IW	1204	1	3	141	24.2	6.00	194	4.6
08/20/96	1341	2	6	122	23.8	5.79	7	5.0
0.03 gpm	1513	3	9	105	23.8	5.61	9	5.0
Phase II Temporary Monitoring Wells								
IR88-TW20	1330	1	1	85.5	18.5	4.29	147.6	4.0
4/22/97	1338	2	2	84.8	18.5	4.41	32.6	4.0
0.17 gpm	1345	3	3	84.6	18.6	4.48	22.5	3.3
	1353	4	4	85.5	18.4	4.53	5.5	4.0
IR88-TW20IW	1340	1	3	99.5	20.5	4.96	29.8	2.0
4/22/97	1350	2	6	97.5	20.5	4.95	11.6	2.0
0.25 gpm	1404	3	9	96.6	20.9	4.99	3.7	2.0
IR88-TW21	1025	1	1	85.7	19.0	5.30	153.3	4.5
4/22/97	1035	2	2	80.5	19.1	5.10	24.6	4.4
0.1 gpm	1045	3	3	79.9	19.5	5.05	1.2	4.0
IR88-TW21IW	1043	1	3	126.8	20.6	5.39	147.2	2.8
4/22/97	1100	2	6	127.5	20.6	5.20	102.8	3.0
0.1 gpm	1113	3	9	128.1	20.8	--	7.7	3.5
IR-88-TW22		1	1	--	--	--	--	--
4/22/97	0836	2	2	179	18.9	5.63	12.2	3.5
0.2 gpm	0841	3	3	175	18.8	5.61	5.5	3.5
IR88-TW22IW	0903	1	3	725	19.9	6.69	156	2.3
4/22/97	0916	2	6	714	19.9	6.94	80.3	3.3
0.19 gpm	0930	3	9	684	20.0	6.93	33.2	2.8
	0950	4	12	663	20.0	6.92	22.1	2.6
IR88-TW23	1411	1	1	144.8	19.5	5.48	21.7	3.8
4/21/97	1426	2	2	142.8	19.6	5.22	1.4	3.3
0.1 gpm	1432	3	3	139.9	19.3	4.92	0.9	3.5
IR88-TW23IW	1420	1	3	499.5	20.5	7.08	25.5	2.5
4/21/97	1438	2	6	481.8	20.4	7.04	7.3	2.0
0.17 gpm	1455	3	9	481.2	20.7	7.37	4.1	2.5
IR88-TW24	1710	1	1	92.9	18	5.16	>200	1.6
4/21/97	1718	2	2	93.9	17.8	5.25	113.6	1.6
0.1 gpm	1722	3	3	92.9	17.7	5.16	111	2.3
	1740	4	4	94.7	17.9	5.25	78.5	2.3
IR88-TW24IW	1728	1	3	156.4	18.7	6.54	75.3	1.8
4/21/97	--	2	6	158.9	18.6	6.69	--	1.8
0.19 gpm	1800	3	9	161	18.7	6.87	--	2

TABLE 2-4 (Continued)
SUMMARY OF TEMPORARY MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
IR88-TW25	1544	1	1	72.8	19.2	5.38	84	4.5
4/21/97	1551	2	2	69.2	19.4	5.22	1.5	4.8
0.13 gpm	1600	3	3	70.4	19.1	5.44	0.5	4.5
IR88-TW25IW	1540	1	3	582	20.0	7.04	9.2	2.8
4/21/97	1556	2	6	545	20.0	7.17	3.0	3.1
0.17 gpm	1615	3	9	536	19.9	7.19	1.6	3.1
IR88-TW26	1100	1	1	440.9	21.8	6.45	50.5	4.5
4/21/97	1120	2	2	445.2	21.1	6.52	17.6	4.5
0.04 gpm	1145	3	3	449.8	21.7	6.48	6.6	4.5
	0821	1	2	482.0	21.5	7.32	130.3	1.36
	0835	2	4	456.4	21.4	7.40	78.9	1.5
IR88-TW26IW	0852	3	6	436.3	21.7	7.32	105.6	1.2
4/21/97	0915	4	8	430.0	21.7	7.34	133.6	1.5
0.12 gpm	0930	5	10	422.9	21.9	7.34	27.0	1.3
	0940	6	12	422.5	21.7	7.35	15.5	1.5
	1000	7	14	419.6	21.9	7.45	9.6	1.5
IR88-TW27	0915	1	2.5	65	18	4.07	25	--
4/30/97	0930	2	5.0	65	18	4.27	5.8	--
0.17 gpm	0944	3	7.5	65	17	4.23	4.0	--
IR88-TW27IW	0927	1	6.5	100	19.0	5.66	>200	--
4/30/97	1000	2	13.0	60	20.0	4.66	>200	--
0.22 gpm	1028	3	19.5	65	20.5	5.07	61	--
	1057	4	26.0	65	20.0	4.97	23	--
IR88-TW28	1318	1	2.5	65	22	4.8	154	--
4/30/97	1335	2	5.0	65	19	4.83	22	--
0.15 gpm	1351	3	7.5	65	18.5	4.83	10	--
IR88-TW28IW	1323	1	6	75	20	5.54	>200	--
4/30/97	1400	2	12	70	20	5.59	36	--
0.18 gpm	1430	3	18	80	22	5.66	33	--

NOTES: (1) = Specific Conductance - micro ohms per centimeter
(2) = Dissolved Oxygen - milligrams per liter
(3) = Insufficient well yield to collected water for field measurements
gpm = gallon per minute
°C = degrees centigrade
SU = standard units
Dashes indicate that data was not collected for that time.

TABLE 2-5
SUMMARY OF PERMANENT MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
IR88-MW01	1731	1	2.5	313	24.4	4.10	4.5	3.9
5/15/97	1741	2	5	328	25.1	4.27	0.8	4.1
0.2 gpm	1750	3	7.5	328	24.6	4.32	0.5	3.7
	1800	4	10	319	24.1	4.36	0.5	3.4
IR88-MW02	0930	1	2.5	109	25.4	5.49	9.1	2.0
5/15/97	0947	2	4.6	103	26.1	5.30	4.9	2.0
0.04 gpm	1018	3	7	101	26.5	5.33	2.0	2.4
	0922	1	5.3	409	25.7	7.17	147	2.4
IR88-MW02IW	1025	2	10.5	376	26.0	6.88	81	2.4
5/15/97	1137	3	16	353	27.0	7.12	40	2.5
0.1 gpm	1158	4	21	323	28.4	6.86	40	1.4
	1230	5	26.5	315	27.6	6.84	32	1.4
IR88-MW02DW	0925	1	13	573	24.6	7.20	2.6	1.8
5/15/97	1035	2	26	566	26.1	7.01	4.5	1.8
0.22 gpm	1131	3	36.5	575	27.3	7.24	3.9	1.1
IR88-MW03	1415	1	1.3	106	25.0	5.31	3.1	2.2
5/14/97	1428	2	2.6	128	24.9	5.40	2.8	2.6
0.13 gpm	1438	3	4.0	124	24.7	5.27	2.5	1.8
IR88-MW03IW	1441	1	5.5	480	25.2	7.11	2.9	2.5
5/14/97	1520	2	11	484	25.9	7.38	1	1.4
0.3 gpm	1559	3	16.5	483	25.1	7.40	0.8	1.6
IR88-MW03DW	1431	1	10	496	25.2	10.26	6.5	2.4
5/14/97	1512	2	20	344	25.5	9.14	4.6	2.0
0.24 gpm	1555	3	30	335	24.5	8.89	4.3	1.5
	1636	4	40	328	24.3	8.65	4.4	1.7
IR88-MW04	0905	1	2	319	19.8	4.54	10.4	3.5
5/14/97	0919	2	4	318	19.7	4.48	1.8	3.0
0.15 gpm	0931	3	6	320	19.5	4.47	0.8	3.0
IR88-MW04IW	0916	1	5	264	21.3	6.18	96	2.5
5/14/97	0942	2	9	228	21.3	6.16	18.7	1.8
0.21 gpm	1005	3	14	206	20.9	6.02	10.5	2.1
	1029	4	18.5	184	21.9	6.08	3.3	2.1
IR88-MW04DW	0931	1	12	333	21.0	6.87	1.8	1.3
5/14/97	1021	2	24	337	21.8	7.01	1.4	1.2
0.3 gpm	1058	3	35	339	22.0	7.09	1.9	1.3
IR88-MW05	1505	1	2.5	139	22.6	5.22	2.1	4.9
5/13/97	1522	2	5.0	145	21.7	5.51	1.4	4.4
0.13 gpm	1548	3	7.5	143	22.2	5.61	1.9	4.3

TABLE 2-5 (Contimued)
SUMMARY OF PERMANENT MONITORING WELL WATER QUALITY PARAMETERS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID Date Sampled Approx. Flow Rate	Time	Well Volume	Purge Volume (Gal.)	Water Quality Parameters				
				Cond(1) (umhos/cm)	Temp. (°C)	pH (S.U.)	Turbidity (N.T.U.)	D.O.(2) (mg/L)
IR88-MW05IW	1519	1	6	465	23.0	7.91	8.1	2.0
5/13/97	1552	2	12	430	25.4	7.13	4.9	2.1
0.18 gpm	1631	3	18	445	23.3	7.15	3.1	2.3
IR88-MW05IW	1636	1	11.5	490	22.9	7.30	84	2.4
5/13/97	1739	2	23	486	23.0	7.19	45	2
0.2 gpm	1839	3	35	478	22.4	7.17	16	1.8
IR88-MW06	1454	1	1.8	198	24.0	6.51	3.1	5.6
5/15/97	1508	2	4.0	196	24.5	6.50	3.6	6.0
0.17 gpm	1522	3	6.0	197	23.9	6.51	5.8	5.6
IR88-MW06IW	1450	1	6	139	21.1	5.20	39	2.4
5/15/97	1518	2	12	132	25.6	5.09	76	2.4
0.14 gpm	1602	3	18	132	25.9	5.09	16.3	2.2
	1638	4	23	--	--	--	17	--
IR88-MW07	0842	1	2.5	106	18.6	5.17	6.7	2.9
5/18/97	0859	2	5.0	104	18.6	5.16	2.6	2.3
0.15 gpm	0916	3	7.5	101	18.4	5.17	1.0	2.3
	0932	4	10.0	99	18.6	5.18	0.7	2.3
IR88-MW07IW	0855	1	6	801	19.7	11.14	104	1.8
5/18/97	0927	2	12	357	19.8	8.95	64	1.3
0.22 gpm	1004	3	18	274	20.3	6.89	23.7	1.6
	1039	4	24	228	20.8	6.41	10.6	1.4
	1110	5	30	208	21.3	6.47	8.2	1.7
IR88-MW08	1321	1	2	108	26.5	4.81	2.9	2.7
5/16/97	1335	2	4	108	24.6	4.83	1	2.5
0.17 gpm	1346	3	6	109	22.5	4.80	0.6	2.6
IR88-MW08IW	1338	1	6	483	24.3	6.34	20	1.7
5/16/97	1409	2	12	256	25.2	6.06	8.3	1.5
0.19 gpm	1438	3	18	176	25.3	6.06	8.0	1.4
	1455	3.5	21.5	167	25.9	6.06	8.3	1.3
IR88-MW09	0841	1	2.1	56	17.9	4.01	0.5	7.7
5/16/97	0854	2	4.2	52	17.7	4.15	0.4	7.8
0.19 gpm	0906	3	6.3	53	17.9	4.19	0.4	7.5
	0901	1	6	98	19.5	4.64	153	2.4
IR88-MW09IW	0933	2	12	95	20.0	4.68	43	1.7
5/16/97	1005	3	18	94	21.8	4.91	26	1.7
0.19 gpm	1035	4	24	101	23.2	5.16	21	1.7
	1105	5	30	103	25.5	5.31	20	1.4

NOTES: (1) = Specific Conductance - micro ohms per centimeter
(2) = Dissolved Oxygen - milligrams per liter
gpm = gallon per minute
°C = degrees centigrade
SU = standard units
Dashes indicate that data was not collected for that time.

TABLE 2-6
ON-SITE GROUNDWATER SAMPLING SUMMARY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Identification	Analytical Parameters	
	On-Site Volatile Analysis EPA 8240(1)	Fixed-Based CLP TCL VOA(2)
Phase I Temporary Monitoring Wells		
IR88-TW04IW	X	
IR88-TW05	X	X
IR88-TW05IW	X	X
IR88-TW06	X	
IR88-TW07	X	X
IR88-TW08	X	X
IR88-TW08IW	X	X
IR88-TW09	X	X
IR88-TW10	X	
IR88-TW11	X	
IR88-TW12	X	
IR88-TW13	X	
IR88-TW14	X	
IR88-TW15	X	X
IR88-TW16	X	
IR88-TW17	X	
IR88-TW18	X	
IR88-TW19	X	X
IR88-TW19IW	X	X
Total Phase I	19	9
Phase II Temporary Monitoring Wells		
IR88-TW20	X	
IR88-TW20IW	X	
IR88-TW21	X	
IR88-TW21IW	X	
IR88-TW22	X	
IR88-TW22IW	X	
IR88-TW23	X	
IR88-TW23IW	X	
IR88-TW24	X	
IR88-TW24IW	X	
IR88-TW25	X	
IR88-TW25IW	X	
IR88-TW26	X	
IR88-TW26IW	X	
IR88-TW27	X	
IR88-TW27IW	X	
IR88-TW28	X	
IR88-TW28IW	X	
Total Phase II	18	0

NOTES: (1) = On-site mobile laboratory
(2) = Fixed-base laboratory
TCL = Target Compound List
VOA = Volatile Organic Analysis
X = Analyzed for indicated parameter(s)

TABLE 2-7
PERMANENT MONITORING WELL GROUNDWATER SAMPLING SUMMARY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Identification	Well Screen Interval (ft bgs)	TCL Volatiles	Natural Attenuation Parameters	TSS/TDS	BOD/COD	Chloride	Duplicate	MS/MSD
Phase II Permanent Monitoring Wells								
IR88-MW01-01	7.0 - 22.0	X	X	X	X	X		
IR88-MW02-01	8.0 - 23.0	X						
IR88-MW02IW-01	45.0 - 50.0	X					X	
IR88-MW02DW-01	92.0 - 97.0	X						
IR88-MW03-01	5.0 - 15.0	X	X	X	X	X		X
IR88-MW03IW-01	45.0 - 50.0	X	X	X	X	X		
IR88-MW03DW-01	80.0 - 85.0	X	X	X	X	X		
IR88-MW04-01	10.0 - 25.0	X						
IR88-MW04IW-01	45.0 - 50.0	X						
IR88-MW04DW-01	80.0 - 85.0	X						
IR88-MW05-01	8.0 - 23.0	X	X	X	X	X		
IR88-MW05IW-01	45.0 - 50.0	X	X	X	X	X		
IR88-MW05DW-01	80.0 - 85.0	X	X	X	X	X		
IR88-MW06-01	8.0 - 23.0	X	X	X	X	X		
IR88-MW06IW-01	45.0 - 50.0	X	X	X	X	X	X	
IR88-MW07-01	7.0 - 22.0	X						X
IR88-MW07IW-01	45.0 - 50.0	X						
IR88-MW08-01	5.0 - 20.0	X						
IR88-MW08IW-01	45.0 - 50.0	X	X	X	X	X		
IR88-MW09-01	6.0 - 21.0	X					X	
IR88-MW09IW	45.0 - 50.0	X						

NOTES:
ft bgs - feet below ground surface
TCL - Target Compound List
MS/MSD - Matrix Spike/Matrix Spike Duplicate
X - Sample analyzed for indicated parameter

Natural attenuation parameters incl.: methane, nitrate, nitrite, sulfate, sulfide, and iron^{+2}

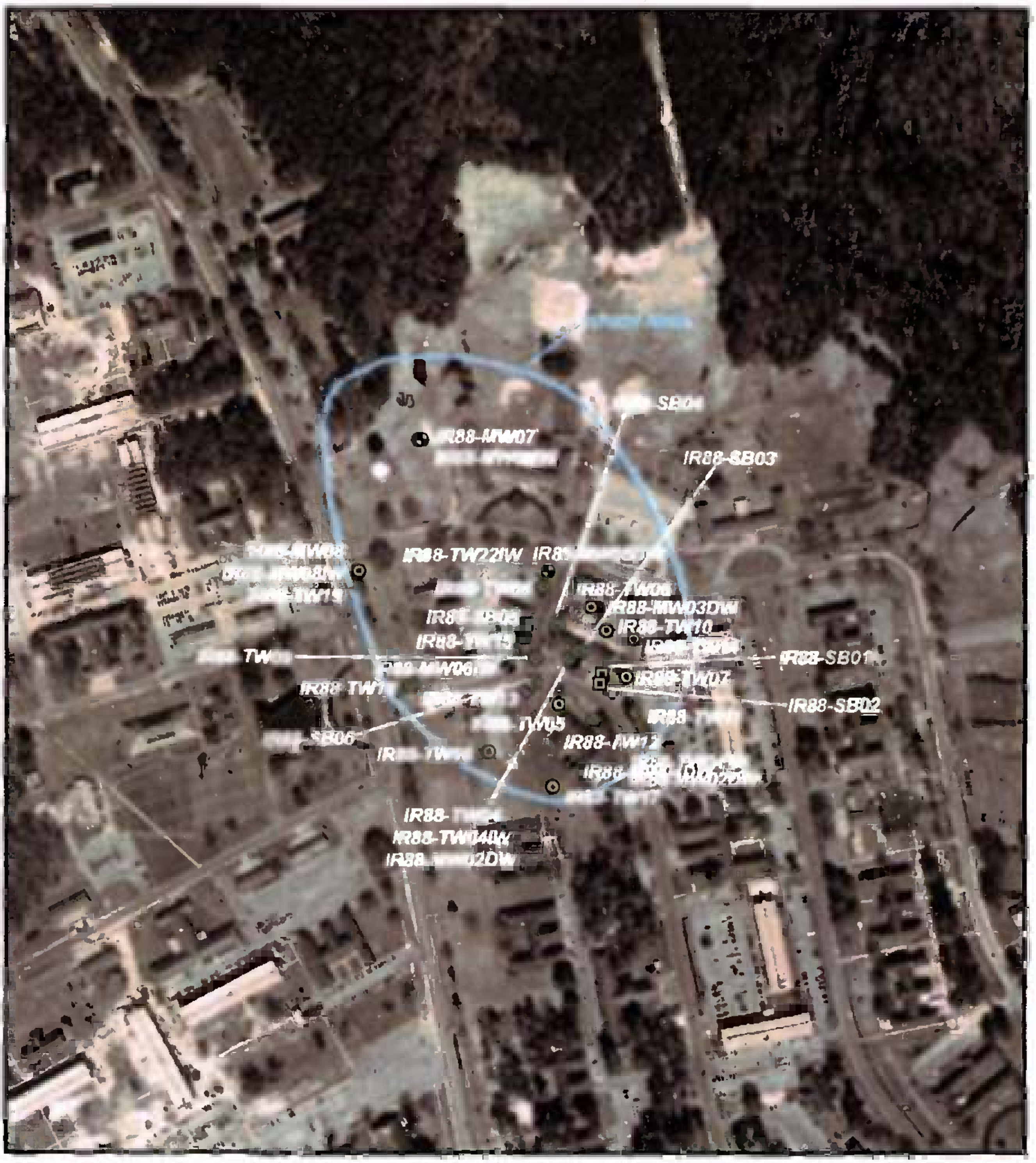
TABLE 2-8
PERMANENT MONITORING WELL GROUNDWATER SAMPLING SUMMARY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Identification	Sample Date	Analytical Parameters	Comments
Phase II QA/QC Samples			
TRIP BLANKS			
TB01	4/18/97	TCL Volatiles	Shipped with groundwater samples
TB04	4/30/97	TCL Volatiles	Shipped with groundwater samples
TB07	5/6/97	TCL Volatiles	Shipped with groundwater samples
TB08	5/7/97	TCL Volatiles	Shipped with groundwater and soil samples
TB11	5/14/97	TCL Volatiles	Shipped with groundwater samples
TB12	5/19/97	TCL Volatiles	Shipped with groundwater samples
FIELD BLANKS			
88-FB01	4/23/97	TCL Organics, TAL Metals	Sample of driller's water
88-FB02	5/7/97	TCL Organics, TAL Metals	
88-FB03	5/7/97	TCL Organics, TAL Metals	
EQUIPMENT RINSATE BLANKS			
88-RBSB05	4/21/97	TCL Organics, TAL Metals	Rinsate sample of soil sampling equipment
88-RBSB-06	4/22/97	TCL Organics, TAL Metals	Rinsate sample of soil sampling equipment
88-RBSB07	4/30/97	TCL Volatiles	Rinsate sample of soil sampling equipment
88-RBSB11	5/4/97	TCL Volatiles	Rinsate sample of soil sampling equipment
88-RBSB12	5/6/97	TCL Volatiles	Rinsate sample of soil sampling equipment
88-RBSB13	5/7/97	TCL Volatiles	Rinsate sample of soil sampling equipment
88-RBGW17	5/16/97	TCL Volatiles	Rinsate sample of groundwater sampling equipment
88-RBGW17	5/16/97	TCL Volatiles	Rinsate sample of groundwater sampling equipment
FIELD DUPLICATES			
IR88-MW06IW-06D	5/4/97	TCL Volatiles	Subsurface soil duplicate sample
IR88-SB02-04D	5/7/97	TCL Volatiles	Subsurface soil duplicate sample
IR88-MW02IW-01D	5/15/97	TCL Volatiles	Groundwater duplicate sample
IR88-MW06IW-01D	5/15/97	TCL Volatiles	Groundwater duplicate sample
IR88-MW09-01D	5/16/97	TCL Volatiles	Groundwater duplicate sample

NOTES: TCL = Target Compound List
TAL = Target Analyte List

SECTION 2.0 FIGURES

02020N03Y



LEGEND

●88-MW02DW Soil Samples Collected from Permanent Monitoring Well Locations

◉ 88-TW04 Soil Samples Collected from Temporary Monitoring Well Locations

▣ 88-SB01 Soil Boring Locations

Scale

0 400 800 Feet

N
W E
S

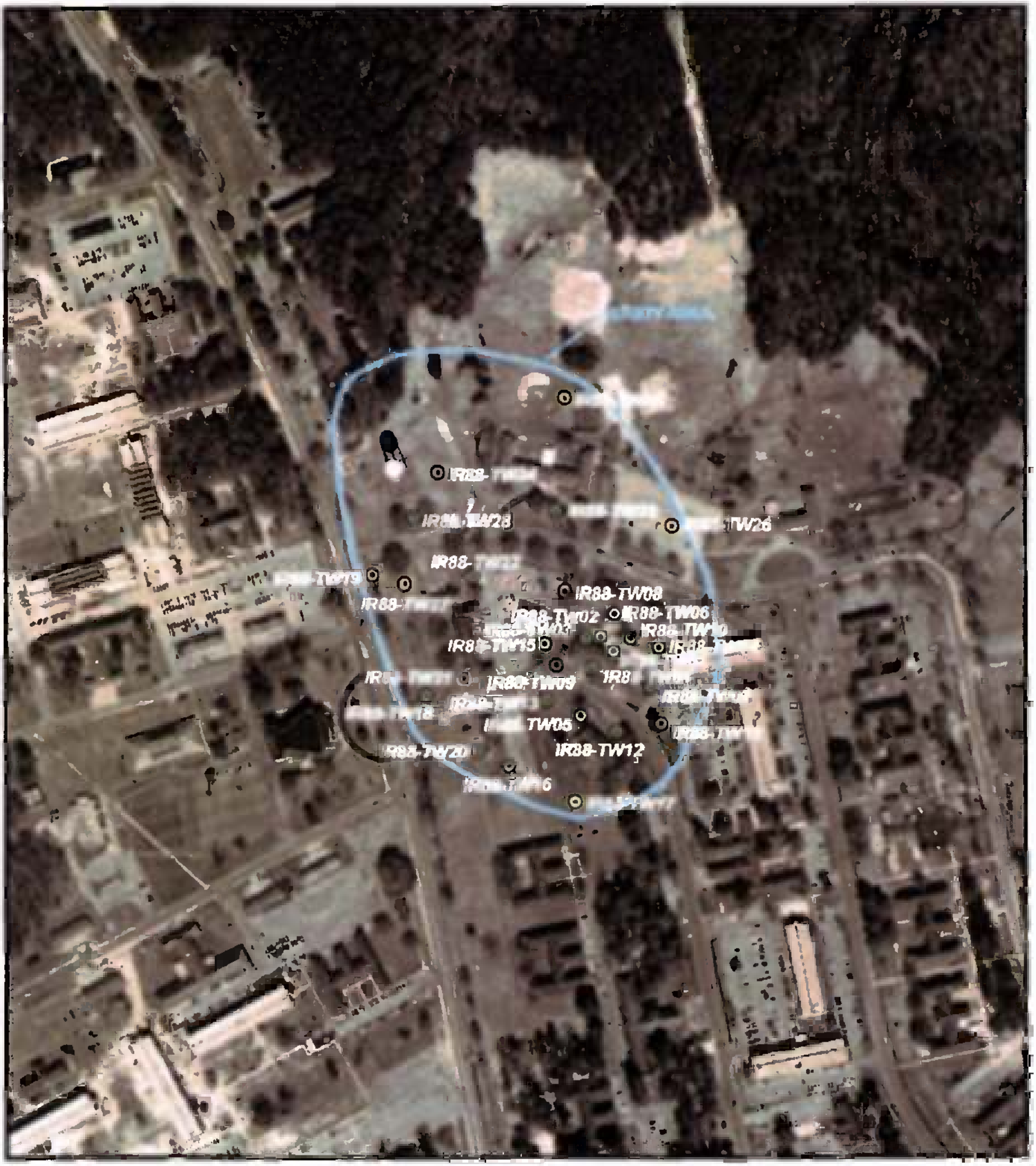
MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA

SOIL SAMPLE LOCATIONS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 2 - 1

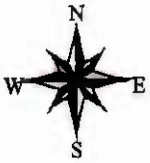
02020N04Y



LEGEND

IR88-TW01 ⊙ Shallow Temporary Monitoring Well Locations

Scale
0 400 800 Feet



**MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA**

GROUNDWATER SAMPLE LOCATIONS
(SHALLOW TEMPORARY
MONITORING WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 2 - 2

02020N05Y

LEGEND

◉ IR88-TW01IW — Intermediate Temporary Monitoring Well Locations

Scale

0 400 800 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUNDWATER SAMPLE LOCATIONS
(INTERMEDIATE TEMPORARY
MONITORING WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

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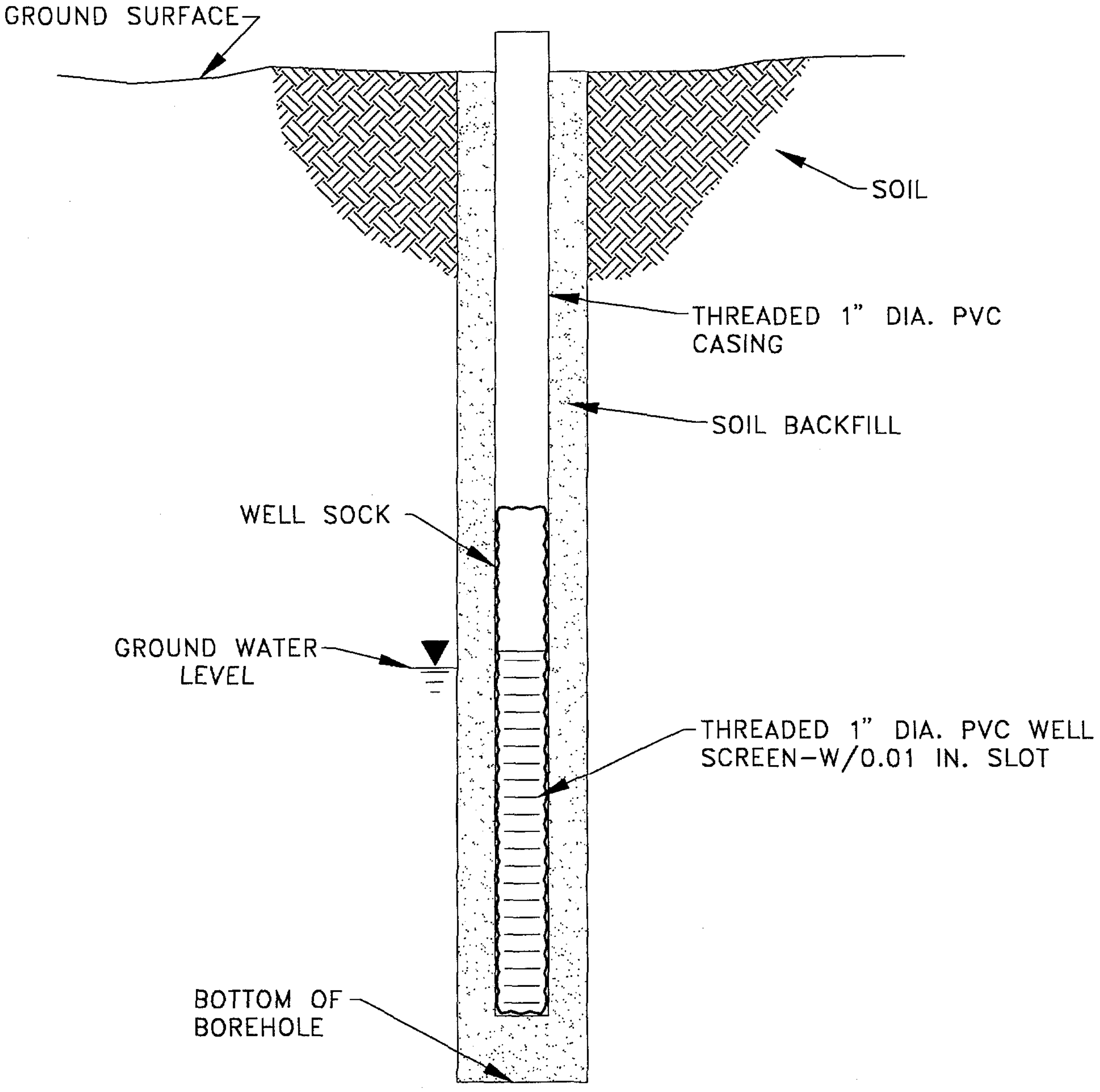
FIGURE 2 - 3



N.T.S.

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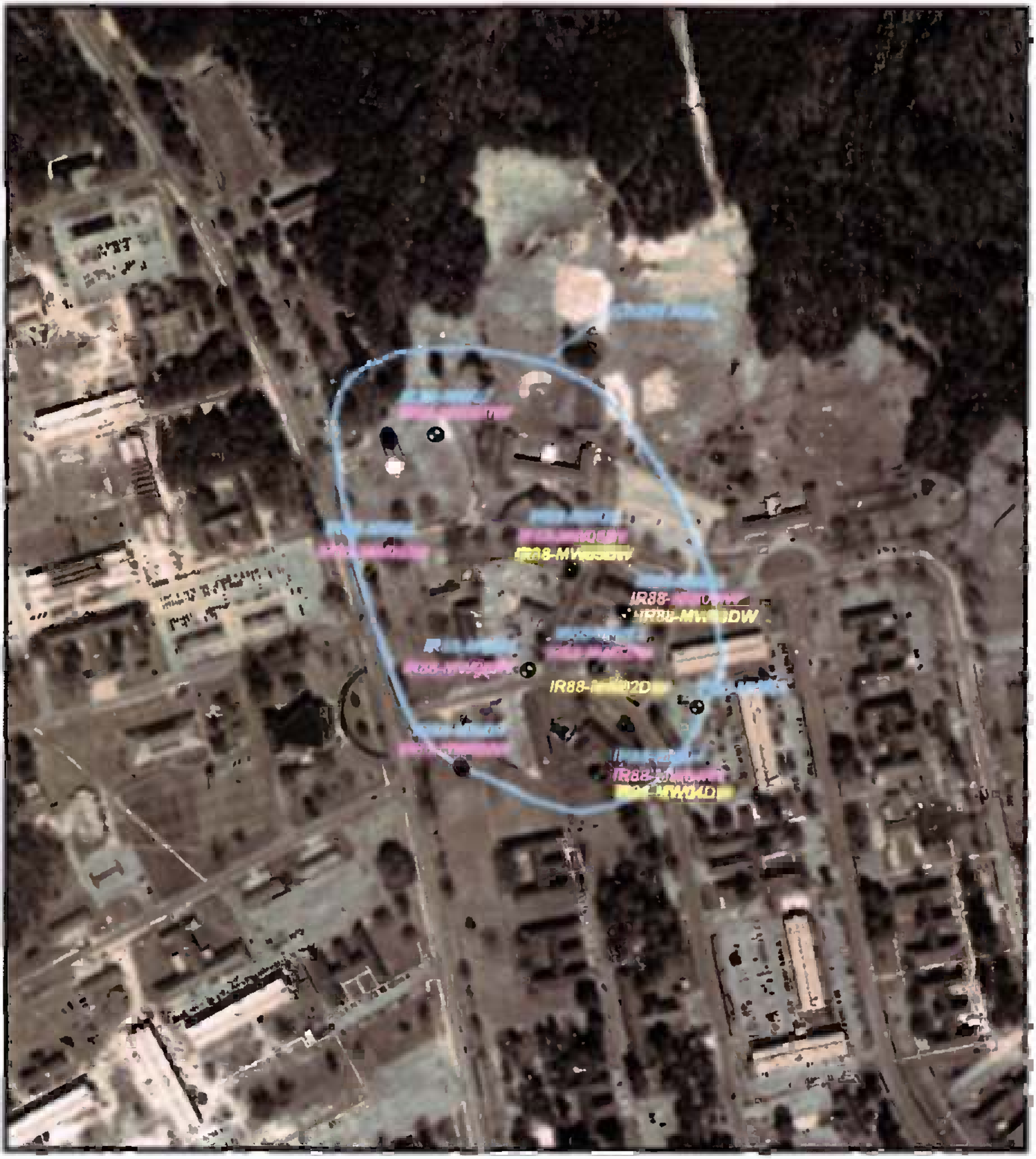
Baker Environmental, Inc.

FIGURE 2-4
TYPICAL TEMPORARY MONITORING WELL CONSTRUCTION DIAGRAM
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N06Y



LEGEND

IR88-MW01
● Shallow Permanent Monitoring Well Locations

Scale
300 0 300 600 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUNDWATER SAMPLE LOCATIONS
(PERMANENT MONITORING WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

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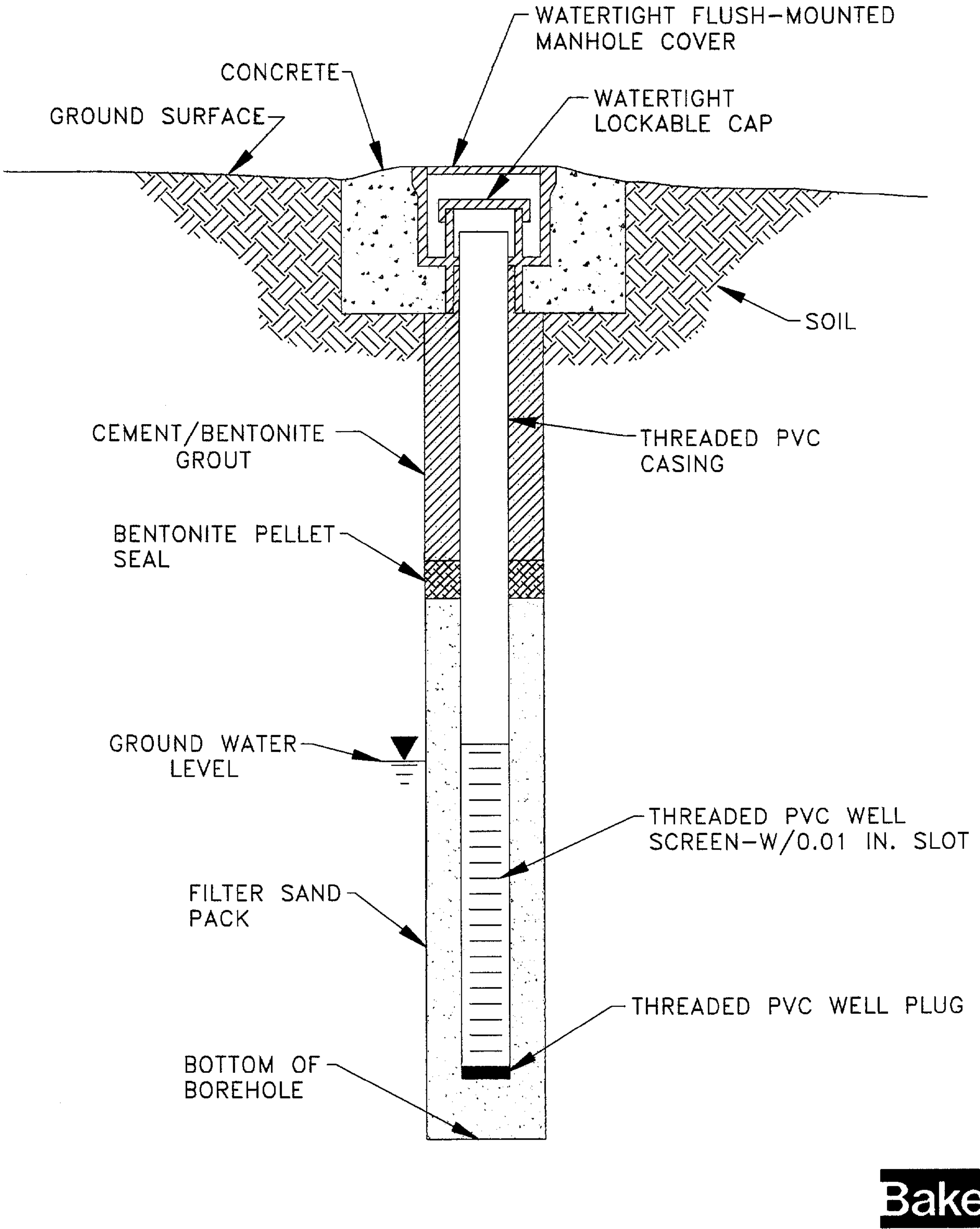
FIGURE 2 - 5

356505EE



N.T.S.

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FIGURE 2-6
TYPICAL SHALLOW BELOW GRADE TYPE II GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION CTO - 0356
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N07Y

LEGEND

IR88-MW02DW ●	Deep Permanent Monitoring Well Locations

Scale

300 0 300 600 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUNDWATER SAMPLE LOCATIONS
(DEEP PERMANENT
MONITORING WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

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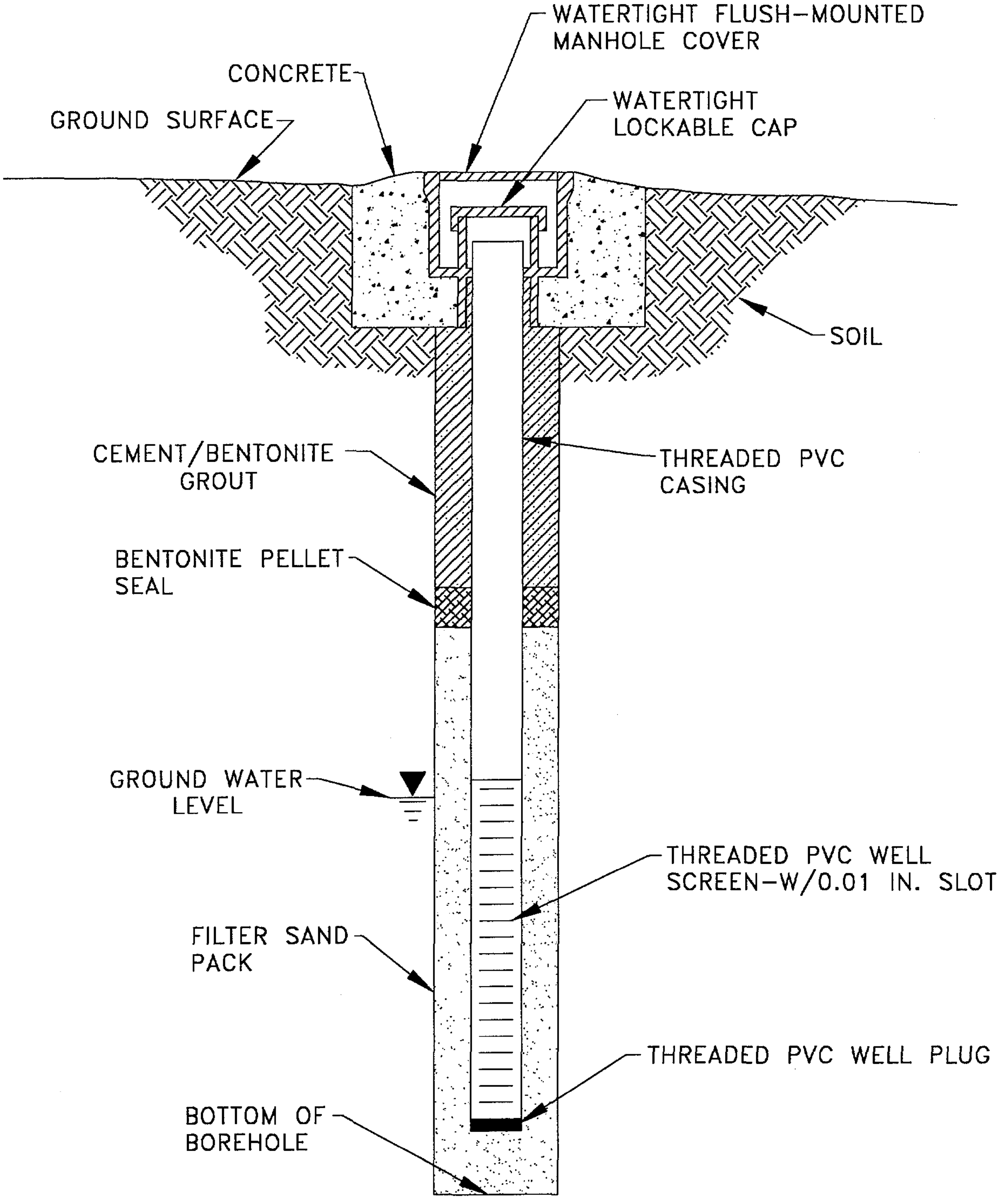
FIGURE 2 - 7

356505EE



N.T.S.

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FIGURE 2-8
TYPICAL SHALLOW BELOW GRADE TYPE II GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION CTO - 0356
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

3.0 REGIONAL AND SITE CHARACTERISTICS

This section describes the regional and site-specific environmental settings. A discussion of topography, surface hydrology and drainage, geology, hydrogeology, land use and demographics, climate/meteorology, and water supplies is presented for MCB, Camp Lejeune and OU No. 15 (Site 88). The tables and figures for Section 3.0 are presented at the end of the section.

3.1 Topography and Surface Features

The generally flat topography of MCB, Camp Lejeune is typical of the seaward portions of the North Carolina coastal plain. Elevations at the base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of MCB, Camp Lejeune is between 20 and 40 feet above msl. MCB, Camp Lejeune is dissected by the New River and its system of tributaries. The relief between the stream valleys and the flat interstream areas generally ranges from 20 to 30 feet. This is true of the area in which Site 88 is situated. Site 88 and the immediately surrounding area exhibits only slight changes in the topographic elevation (Figure 3-1). Generally, the land surface slopes downward to the west (toward the New River) on a grade of approximately 0.5 %. A slight rise is evident northwest of the site, in the area of the water tower.

Site 88 is located within a heavily developed area of MCB, Camp Lejeune. As such, it is surrounded by other buildings, parking areas, streets, and sidewalks (Figure 1-2). The Chaplin's Office and parking area is situated immediately to the north of Building 25. A Marine personnel quarters is situated immediately to the east. A printing shop is situated across Post Lane Road, and to the south. A former snack shop is situated across Post Lane Road, and to the southwest. The Post Marshall (Military Police) Headquarters and a cobbler shop is situated to the west of the site.

3.2 Surface Hydrology

The following subsections present discussions of the regional and site-specific surface hydrology.

3.2.1 Regional

The paragraphs which follow provide a summary of surface water hydrology that was originally presented in the Initial Assessment Study (IAS) report (Water and Air Research, 1983).

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

Water quality criteria for surface waters in North Carolina have been published under Title 15A of the North Carolina Administrative Code. At MCB, Camp Lejeune, the New River falls into two classifications: SC (aquatic life propagation and survival, fishing, wildlife, and secondary recreation) and SA (shell fishing for market purposes and any other usage specified by the "SB"and "SC"classification). The northern area of the New River near Montford Point at MCB, Camp Lejeune falls into the SA classification.

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

The U.S. Corps of Engineers has mapped the limits of the 100-year floodplain at Camp Lejeune at 7 feet above msl in the upper reaches of the New River.

3.2.2 Site-Specific

Storm water runoff from building roofs, roads, parking areas, and sidewalks within the study area is collected by storm sewers. Because of the relatively flat topography, storm water falling in grassy or bare areas tends to pond. This ponded water will evaporate, be taken up by vegetation root systems, or infiltrate through the vadose zone to the water table. During the time of the investigation, water was observed to be discharging from Building 25 to the ground on the north side of the building and ponding.

No surface water bodies are located on, or are adjacent to Site 88. The nearest surface water body, Beaverdam Creek, is located approximately 1,500 feet to the northeast. Beaverdam Creek flows to the northwest and discharges to Wallace Creek. Wallace Creek flows to the southwest and discharges to the New River. The New River is located approximately 3,000 feet to the west of the site.

3.3 Geology

The following subsections present discussions of the regional and site-specific geology.

3.3.1 Regional

MCB, Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments lay in interfingering beds and lenses that gently dip and thicken to the southeast (ESE, 1990). These sediments were deposited in marine and near-marine environments and range in age from early Cretaceous to Quaternary time and overlie igneous and metamorphic basement rocks of pre-Cretaceous age. Table 3-1 presents a generalized stratigraphic column for this area (ESE, 1990).

United States Geological Survey (USGS) studies (Harned, et al., 1989 and Cardinell, et al., 1993) conducted at MCB, Camp Lejeune indicate that the base is underlain by seven sand and limestone aquifers separated by confining/semiconfining units which are comprised primarily of silt and clay. These include the water table (i.e., surficial, water-bearing layer), Castle Hayne, Beaufort, Peedee, Black Creek, and the upper and lower Cape Fear aquifers. The combined thickness of these sediments is approximately 1500 feet. Less permeable clay and silt beds function as confining units or semiconfining units which separate the aquifers and impede the flow of groundwater between aquifers. For further information regarding the regional hydrogeologic conditions the reader is referred to the original USGS reports which are referenced above. These documents contain a series of hydrogeologic cross-sections illustrating the relationship between the aquifers and confining units in the vicinity of MCB, Camp Lejeune. The regional hydrogeology is discussed further in Section 3.4.1.

3.3.2 Site-Specific

In this section, the site specific geology is discussed based on information obtained in the Phase I and II Investigations. The site geology is also placed in context of the regional geology, as described in the Cardinell, et al. report of 1993.

A fairly consistent depositional sequence was observed in the borings throughout Site 88. This observed sequence is similar to the generalized North Carolina coastal plain sequence shown in Table 3-1. Table 3-1 shows that the Yorktown, Eastover, and Pungo River Formations lies between the undifferentiated and Belgrade Formation. However, the Yorktown, Eastover, and Pungo River Formations have not been identified at Camp Lejeune by Cardinell, or in the Baker investigations.

The observed lithologic sequence at Site 88 also appears to be reasonably consistent with that described by Cardinell. Cardinell described the uppermost formation, or the undifferentiated formation, as beds of sand, clay, sandy clay, and silt of Quaternary and Miocene ages. Cardinell also suggested that this formation may contain peat and shells. According to Cardinell, the River Bend Formation is below the undifferentiated formation. Cardinell described the River Bend Formation as sand, shell rock, and limestone. A confining unit may or may not be present between the undifferentiated and River Bend formations. According to Cardinell, the New River and its major tributaries have eroded this confining unit in places. This appears to be the case at Site 88. Some silt/clay layers have been observed at Site 88, however they do not appear to be confining, nor are they located between the contact of the undifferentiated and River Bend formations.

Based on information from the cross sections presented below, a generalized lithology under Site 88 can be described. The uppermost formation (the undifferentiated formation) consists of fine sand with a lesser amount of silt. Thin, discontinuous layers and lenses of silt, clay and/or peat are scattered throughout the sand. Underlying the undifferentiated formation is the River Bend Formation, beginning at a depth of 40 to 60 feet below ground surface (bgs). At this depth shell fragments appear, but sand still predominates.

Four cross sections were constructed to aid in the characterization of the geology and hydrogeology of Site 88. These cross sections were constructed based log records from well installation activities and may be found in Appendix A. The locations of these cross sections are presented on Figure 3-2. The paragraphs which follow, detail each cross section constructed for the site.

Cross-Section A-A' (Figure 3-3) trends north-south and passes through the Building 25. This section illustrates the lithologic sequence described above. Fine sand predominates in this section. A silt/clay layer is present at a depth of approximately 15 feet bgs beginning at the south end of the section (88-MW04DW). This layer extends northward to 88-TW23IW, where it appears to pinch out. This silt/clay layer is five to ten feet thick, and was observed to be saturated through its entire thickness. The top of the River Bend Formation (as determined by the appearance of shell fragments) appears to be mounded, with a peak at 88-MW05DW.

Cross-Section B-B' (Figure 3-4) trends north-south and along the western portion of Site 88. Like Section A-A', fine sand predominates in Section B-B'. A few thin lenses of silt and clay occur at

88-TW21IW and 88-MW09IW. A more substantial sequence of peat and clay is apparent at the north end of the section (88-TW24IW and 88-MW07). This sequence may have been deposited in an ancient stream flood plain environment.

Cross-Section C-C' (Figure 3-5) trends west-east and connects Sections A-A' and B-B' northwest of Building 25. Again, fine sand predominates in this section. This section shows that the silt/clay layer observed in Section A-A' (88-MW05DW) does not extent westward very far. This silt/clay layer pinches out between 88-MW05DW and 88-TW22IW. This section also shows that the top of the River Bend Formation decreases in elevation in a westerly direction.

Cross-Section D-D' (Figure 3-5) parallels, and lies southwest of Building 25. This section also shows that the silt/clay layer observed in Section A-A' (88-MW02DW) does not extent westward very far. This silt/clay layer pinches out between 88-MW02DW and 88-MW06IW. Similar to Section C-C', the elevation of the top of the River Bend Formation in Section D-D' decreases westward .

3.4 Hydrogeology

The subsections which follow present discussions of the regional and site-specific surface hydrogeology. The regional hydrogeology was originally presented in Harned, et al. (1989) and re-evaluated by Cardinell, et al. (1993). The site-specific hydrogeology is based on information obtained during this RI.

3.4.1 Regional

The two most important aquifers relative to this RI include the surficial aquifer and the Castle Hayne Aquifer. The surficial (water table) aquifer consists of a series of sediments, primarily sand and clay, which commonly extend to depths of 75 feet. This unit is not used as a water supply on the Base. The principal water supply for the base is found in the series of sand and limestone beds that occur between 50 and 300 feet bgs. This series of sediments generally is known as the Castle Hayne Formation, associated with the Castle Hayne Aquifer. This aquifer is about 150 to 450 feet thick in the area and is the most productive aquifer in North Carolina.

Clay layers occur in both of the aquifers. However, the layers are thin and discontinuous in most of the area, and no continuous clay layer separates the surficial aquifer from the Castle Hayne Aquifer. The clay layers range from 10 to 15 feet thick and comprise between 15 and 24 percent of the combined thickness of the two aquifers. The clay layers appear to be thicker and more continuous in the northwest part of the Base, particularly in the area of the MCAS. It is inferred from their generally thin and discontinuous nature that considerable leakage of groundwater occurs across and around the clay layers, particularly in the upper portion of the Castle Hayne Aquifer.

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

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

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

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

According to the North Carolina Administrative Code, Title 15A, Subchapter 2L, "Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina", the surficial water table aquifer and the Castle Hayne Aquifer are classified as GA - for existing or potential sources of drinking water supplies for humans with a chloride concentration equal to or less than 250 milligrams per liter (mg/L). This groundwater classification is for waters which are considered suitable for drinking in their natural state.

3.4.2 Site-Specific

As discussed above, there are several aquifers and intervening confining units underlying MCB, Camp Lejeune. According to Cardinell, the surficial aquifer occurs within the sediments of the undifferentiated formation. The upper portion of the Castle Hayne Aquifer occurs within the sediments of the River Bend Formation.

The surficial and Castle Hayne Aquifers were encountered during this investigation. The surficial aquifer was generally encountered at depths of 6 to 15 feet bgs. The top of the Castle Hayne Aquifer was found at a depth of 40 to 60 feet bgs. A continuous hydraulically confining unit was not observed during the investigation. The maximum boring depth was 100 feet bgs. The surficial and Castle Hayne Aquifers would be expected to be hydraulically connected in the absence of a confining unit. According to information presented in Cardinell, the combined thickness of the surficial and Castle Hayne Aquifers could be approximately 350 feet in the vicinity of Hadnot Point (in the absence of any locally confining layers).

Hydrogeologic conditions were evaluated by installing a network of 29 shallow and intermediate temporary monitoring wells, and 21 shallow, intermediate, and deep permanent monitoring wells. The sections which follow discuss data and information obtained from these wells.

3.4.2.1 Groundwater Elevation Data

Static water levels have been measured in shallow, intermediate, and deep monitoring wells, both temporary and permanent. Static water levels were measured on five separate occasions over the period of approximately one year. These data are presented on Tables 3-2, 3-3, and 3-4. Static water levels were measured in both temporary and permanent wells on May 19 and 31, 1997. Static water levels were measured only in the permanent wells on July 24, 1997, March 21, 1998, and April

6, 1998 because the temporary wells had been abandoned. Tables 3-2, 3-3, and 3-4 also present static water elevations based on the static water levels.

Groundwater elevation time trends have been evaluated using data from the permanent wells. These data are plotted on Figures 3-6A through 3-6E. These time trend plots show a consistent decrease in elevation between May and July of 1997 in all the wells plotted. The decrease in groundwater elevations between the May 19 and 31 measurements is attributable to the relatively little rain that fell during that period (Refer to Section 3.7, and Table 3-9). The groundwater elevation decrease observed between May 31 and July 24 is consistent with historical trends. As discussed in Section 3.4.1, groundwater recharge is less in the summer months due to increased evaporation and vegetation transpiration. These time trend plots also show an increase between the summer of 1997 (July 24) and the winter of 1998 (March 21) at all wells plotted. This trend is consistent with historical trends; groundwater recharge is greater in the fall and winter months because evaporation and vegetation transpiration is less. The time trend plots show a decrease occurred between March 21, 1998 and April 6, 1998 at all but one well plotted. This decrease is consistent with that observed in the spring of 1997 and may represent an annual trend. A groundwater elevation increase was observed in at 88-MW06IW between the March and April measurements. This may be an anomalous data point due to a possible measurement error. At no other time during the measurement period has this kind of counter trend occurred.

These time trend plots also show that the slopes of the lines for the shallow, intermediate, and deep monitoring wells are similar. This indicates that hydraulic changes are influencing the shallow, intermediate, and deep zones equally. This in turn, suggests that the surficial and Castle Hayne Aquifer are hydraulically connected.

Groundwater elevation differences within wells clusters were also evaluated using data from the permanent monitoring wells (Figures 3-6A through 3-6E). These plots indicate a substantial elevation difference between the shallow and intermediate wells at clusters 88-MW02, 88-MW03, and 88-MW05 through 88-MW09. These differences range from less than 1 foot at 88-MW04 to nearly 8 feet at 88-MW03. These elevation differences at suggest that there is a downward component of groundwater flow between the shallow and intermediate wells (the surficial aquifer). A downward component to flow is typical of groundwater recharge areas. According to Cardinell, 1993, the interstream areas within MCB Camp Lejeune are groundwater recharge areas. Figures 3-6A through 3-6D also indicate small elevation differences between the intermediate and deep wells (less than 0.2 feet). These small differences suggest that there is a relatively small downward component of groundwater flow between the intermediate and deep wells (the Castle Hayne Aquifer). In fact, a very slight upward potential is apparent at cluster 88-MW03 in March of 1998.

These elevation differences generally change little over time as shown on the time trend plots. One exception is at 88-MW04 where relatively larger differences between the shallow and intermediate and the intermediate and deep occur in beginning in March of 1998.

The large elevation difference observed in some wells may be due to a relatively strong recharge and the presence of the silt/clay layer. The clay layer may be inhibiting downward migration, causing a local groundwater mound. The silt/clay is present at well clusters 88-MW02, 88-MW03, 88-MW04, and 88-MW05. The elevation difference at these well clusters ranges from approximately 0.2 to 8 feet. The silt/clay layer is not present at well clusters 88-MW06, 88-MW07, 88-MW08 and 88-MW09. The elevation difference at these well clusters ranges from approximately

2 to 6 feet. With the exception of cluster 88-MW04, the elevation difference at clusters where the silt/clay layer is present is greater than at clusters where the silt/clay layer is not present. The elevation difference between the shallow and intermediate wells at 88-MW04 is significantly less (approximately 0.2 to 1 foot) than other "silt/clay layer" wells. This exception is due to the fact that this cluster may be located near the edge of the silt/clay layer.

3.4.2.2 Groundwater Potentiometric Surface Maps

Static water levels and elevations referenced in Section 3.4.2.1 have also been used to generate groundwater potentiometric surface maps. Potentiometric surface maps provide an indication of groundwater flow direction and gradient. These figures (Figures 3-7, 3-8, and 3-9) show groundwater flow for shallow, intermediate, and deep wells, respectively.

Maps were generated for the three measurement events, and for three depth intervals based on well depth; shallow, intermediate, and deep. A comparison of the three measurement events showed similar trends between May and July of 1997 at all three depth intervals. Because the trends are similar, and for simplicity purposes, only the May 19, 1997 data has been presented on potentiometric surface maps.

The shallow well potentiometric surface map shows fairly complex groundwater flow pattern (Figure 3-7). A mound is evident between Building 25 and Chaplin's office (a diagonally oriented "U" on Figure 3-7). This represents a recharge area. From this area, groundwater flows north-northeast (under the Chaplin's office) on a gradient of approximately 0.03 feet/foot. Groundwater also flows to the southwest (under Building 25) on a gradient of approximately 0.03 feet/foot. Groundwater also flows to the northwest (under the police parking lot) on a gradient of approximately 0.01 feet/foot. Another recharge area is apparent in the vicinity of the water tower. From this area, groundwater flows east (under the EMD building) on a gradient of 0.02 feet/foot, and south (under the military police building) on a gradient of 0.01 feet/foot. A groundwater discharge area is apparent in the vicinity of clusters 88-MW06 and 88-MW04. Groundwater flows from the southeast and from the northwest to this area.

The intermediate well potentiometric surface map also shows fairly complex groundwater flow pattern (Figure 3-8). The flow pattern on the figure somewhat mimics that of the shallow wells, but on a much flatter gradient. The flow gradient ranges from 0.002 feet/foot to 0.008 feet/foot. Wells 88-MW02IW and 88-MW09IW 88-MW02DW has been excluded from this map. Because these well's respective screened intervals were at different elevations than the other wells in a flow field with a downward component to flow, the static water elevations are significantly different. Presenting a map with these data points would result in nonrepresentative flow patterns.

The deep well potentiometric surface map indicates that groundwater flows to the north (Figure 3-9). The gradient is very shallow, on the order of 0.0005 feet/foot. It appears that groundwater is flowing toward the nearest body of water, Beaverdam Creek (a tributary to Wallace Creek). Well 88-MW02DW has been excluded from this map, because it is nearly 15 feet deeper than the other wells. Because well 88-MW02DW is deeper than the other wells in a flow field with a downward component to flow, the static water elevation is comparatively less. Including this well in a deep groundwater potentiometric surface analysis would result in nonrepresentative a flow pattern.

To better understand vertical groundwater flow patterns, groundwater potentiometric surfaces were also superimposed on the four cross sections (Figures 3-10 through 3-12). These four figures clearly illustrate several phenomena previously described. These include; the strong downward groundwater flow component, the large elevation differences between shallow and intermediate wells, and the depression in the shallow and intermediate groundwater potentiometric surface maps.

The strong downward groundwater flow component is clearly shown in two of the cross sections. Figure 3-11 shows the groundwater flow patterns on Cross Section B-B'. Figure 3-12 shows the groundwater flow patterns on Cross Section C-C'. This downward flow is typified at well cluster 88-TW24 on Cross Section B-B' and 88-TW22 on Cross Section C-C'.

As indicated in Section 3.4.2, the large elevation differences between shallow and intermediate wells is due to groundwater recharge and the presence of the silt/clay layer. The effects of this silt/clay is illustrated on Figure 3-10. Figure 3-10 (Cross Section A-A') shows a mounding of the shallow groundwater potentiometric surface over the silt/clay layer. The elevation of this potentiometric surface decreases toward the edges of the silt/clay layer (88-TW23). This mounding is likely caused by the very low vertical hydraulic conductivity of the silt/clay layer. As recharging groundwater flow downward, it encounters the low hydraulic conductivity of the silt/clay layer and the velocity slows (velocity is directly proportional to hydraulic conductivity). Groundwater "backs up", or mounds above the silt/clay layer. This mound changes the equilibrium of the groundwater flow system. This change is relieved by lateral flow of groundwater across the silt/clay layer. This flow pattern can be seen on Figure 3-10 (between wells 88-MW02 and 88-MW04, and 88-MW05 and 88-TW23.

The effects of the edges of the silt/clay layer on lateral groundwater flow across the layer can been seen on Figure 3-12 (Cross Section D-D'). Based on the well construction and boring log records, the clay layer extends east to well 88-MW01 and south to well cluster 88-MW04. This silt/clay does not extend very far west beyond Building 25 as seen on the cross section. This cross section illustrates the lateral flow of groundwater across the silt/clay layer (flow between wells 88-MW02 and 88-MW06). When groundwater encounters the edge of the silt/clay layer (between wells 88-MW06 and 88-TW21) groundwater flow becomes predominantly vertical.

The groundwater depression located southwest of Building 25 shown on Figure 3-7 can be explained by vertical groundwater flow patterns. In Figure 3-10, groundwater in the intermediate and deep monitoring well zones appears to converge downward, toward 88-MW02. A downward convergence zone is also apparent in the vicinity of well cluster 88-TW21 on Cross Section B-B' (Figure 3-11). These downward convergence zones are represented in plan view (Figure 3-7) by the depression mentioned above. At the convergence zone show on Figure 3-10 groundwater also flows out of the page. At the convergence zone show on Figure 3-11 groundwater also flows into the page.

3.4.2.3 Hydraulic Properties

In-situ hydraulic conductivity (slug) tests were conducted at select wells at Site 88 to provide an estimate of hydraulic conductivity of the aquifer system. A rising head slug test was conducted at five shallow wells. Falling head tests were not conducted because these tests are not valid where the static water level is within the screened interval. This is the case with the shallow wells at Site 88. Both rising and falling head tests were conducted at four intermediate wells and one deep well. A summary of the slug test results are presented on Table 3-5, and the slug test solutions are included as Appendix G.

One general pattern is evident in the hydraulic conductivity data. There appears to be a zone of higher hydraulic conductivity at the intermediate well depth (the lower portion of the surficial aquifer). The hydraulic conductivity values estimated for the upper portion of the surficial aquifer ranged from 0.4 feet/day at well 88-MW09 to 29.7 feet/day at well 88-MW07. The hydraulic conductivity values estimated for the lower portion of the surficial aquifer ranged from 56.4 feet/day at well 88-MW07IW to 85.5 feet/day at well 88-MW09IW. The hydraulic conductivity values estimated for the upper portion of the Castle Hayne Aquifer 5.1 feet/day at well 88-MW03DW.

The intermediate well hydraulic conductivity values presented above are the average of the rising and falling head tests. With the exception of well 88-MW03IW, the rising and falling head test results were consistent. This is an indication of a reasonable estimation of aquifer conditions. The large difference between the rising and falling head tests at well 88-MW03IW is an indication that the estimation may not be reasonable.

The vertical permeability (hydraulic conductivity) of selected lithologic layers was estimated through laboratory analysis. Two undisturbed Shelby tube samples were collected from the silt/clay layer show in Cross Section A-A', and one Shelby tube sample was collected from a silty sand in the vadose zone. This data is summarized on Table 3-6, while complete analytical results are included as Appendix B. The vertical conductivity of the silt/clay layer are very low (on the order of 1.0×10^{-4} feet/day). The vertical conductivity of the vadose zone sample is 1.76 feet/day.

3.4.2.4 Groundwater Flow Velocities

Groundwater flow velocity can be estimated using a variation of Darcy's equation:

$$V = Ki/n_e$$

where:

V = groundwater velocity (feet/day)
K = hydraulic conductivity (feet/day)
I = horizontal gradient (feet/foot)
n_e = effective porosity

Velocity calculations are presented in Appendix G. Hydraulic conductivity values were determined from slug tests conducted at selected wells at the site. The horizontal gradient was estimated from the potentiometric surface map contour spacing. An effective porosity of 20 percent was used (Table C.3.2 Wiedemeier, 1996).

Groundwater flow velocities in the upper surficial aquifer vary by two orders of magnitude. Velocities ranged from 0.02 feet/day at well 88-MW09 to 3.0 feet/day at well 88-MW07. Because the horizontal gradient was fairly consistent, the wide variation of velocities is related to the variation in the hydraulic conductivity.

Groundwater velocities in the lower portion of the surficial aquifer are similar to the velocities in the upper portion of the aquifer. Velocities ranged from 0.6 feet/day at well 88-MW07IW to 1.3 feet/day at well 88-MW09IW. The hydraulic conductivity of the lower surficial aquifer was an order of magnitude greater than the upper aquifer. However, the horizontal gradient in the lower surficial aquifer was an order of magnitude less than the upper portion of the aquifer.

The groundwater velocity in the upper portion of the Castle Hayne Aquifer was estimated to be 0.0005 feet/day. This low velocity is primarily attributable to the very shallow horizontal gradient.

3.4.2.5 General Groundwater Flow Patterns

General groundwater flow patterns are discussed in this section based on the information presented in above sections of 3.4.2. The purpose of this is two fold: To provide a summary of the hydrogeologic information presented herein, and; To present a framework to understand the nature and extent of contamination and to develop a site-specific fate and transport model.

Groundwater flow at Site 88 exhibits a horizontal and vertical component. Horizontal groundwater flow is complicated by the presence of two recharge areas. Groundwater recharge is apparent in the grassy area north and east of Building 25 and in the vicinity of the water tower. Surficial aquifer horizontal groundwater flow is multi-directional at velocities varying by two orders of magnitude, ranging from 0.02 to 3.0 feet/day. A strong vertical flow component is apparent between the shallow and intermediate monitoring wells. However, this vertical component of flow appears to be controlled by the presence of a silt/clay layer. Because of the apparent relative vertical hydraulic conductivity differences between the fine sand aquifer (approximately 2 feet/day) verses the silt/clay layer (approximately 1.0×10^{-4} feet/day), mounding occurs over the silt/clay layer with groundwater flowing laterally along the interface. Groundwater continues a downward flow at the edge of this silt/clay layer (in the vicinity of well clusters 88-MW04 and MW06).

Groundwater flow in the upper portion of the Castle Hayne Aquifer flows to the north at a very low velocity (0.0005 feet/day). The vertical component to groundwater flow in the Castle Hayne Aquifer is relatively weak compared to that in the surficial aquifer.

3.5 Land Use Demographics

The following subsections present discussions of the regional and site-specific surface hydrology.

3.5.1 Base-Wide

MCB, Camp Lejeune presently covers approximately 236 square miles. Present military population of MCB, Camp Lejeune is approximately 41,000 active duty personnel. The military dependent community is in excess of 32,000. About 36,100 military personnel and dependents reside in Base housing units. The remaining personnel and dependents live off base and have dramatic effects on the surrounding area. An additional 4,412 civilian employees perform facilities management and support functions. The population of Onslow County has grown from 17,739 in 1940, prior to the formation of the base, to its present population of 121,350 (Master Plan, Camp Lejeune Complex, North Carolina, 1988). During World War II, MCB, Camp Lejeune was used as a training area to prepare Marines for combat. This has been a continuing function of the facility during the Korean and Vietnam conflicts, and the recent Gulf War. Toward the end of World War II, the camp was designated as a home base for the Second Marine Division. Since that time, Fleet Marine Force (FMF) units also have been stationed here as tenant commands. The existing land use pattern for the various developed geographic areas within the MCB are listed, per geographic area, on Table 3-7.

In addition, the number of acres comprising each land use category has been estimated and provided on the table.

3.5.2 Site-Specific

Operable Unit No. 15 is located within the Hadnot Point area which comprises an area of 1,080 acres. Hadnot Point consists of a wide variety of land uses. The majority, of this area is taken up by troop housing, recreation, administrative and service buildings. Site 88 is surrounded by troop housing and service buildings.

3.6 Climate and Meteorology

MCB, Camp Lejeune experiences mild winters, and hot and humid summers. The average yearly rainfall is greater than 50 inches, and the potential evapotranspiration in the region varies from 34 to 36 inches of rainfall equivalent per year. The winter and summer seasons usually receive the most precipitation. Temperature ranges are reported to be 33 to 53 degrees Fahrenheit (°F) in the winter (i.e., January) and 71 to 88 °F in the summer (i.e., July). Winds are generally south-southwesterly in the summer, and north-northwesterly in the winter (Water and Air Research, 1983). Table 3-8 presents a summary of climatic data readings from the Marine Corps Air Station (MCAS) at New River. These measurements were collected between January 1955 and December 1990. Additionally, 1997 temperature and rainfall data were obtained from the National Oceanic and Atmospheric Administration's National Climatic Data Center in Ashville, North Carolina. Data were available from January through June, 1997 and are presented in Table 3-9.

3.7 Water Supply

MCB, Camp Lejeune water is supplied entirely from groundwater. Groundwater is obtained from approximately 90 water supply wells, and treated. There are eight water treatment plants with a total capacity of 15.821 million gallons per day (mgd). Groundwater usage is estimated at over 7 mgd (Harned, et al., 1989).

All of the water supply wells on Base use the Castle Hayne Aquifer as a source of water. The Castle Hayne Aquifer is a highly permeable, locally semiconfined aquifer that is capable of yielding several hundred to 1,000 gallons per minute (gpm) in municipal and industrial wells in the MCB, Camp Lejeune Area. The water retrieved is typically hard, calcium bicarbonate type.

Water supply wells within a one-mile radius of the sites were identified by reviewing base information. One supply well was identified to be within a one-mile radius of Site 88. Well PSWHP-603 is located approximately 2,300 feet east-southeast of Site 88. The location of the well relative to the site is shown on Figure 3-13. Table 3-13 provides detailed information concerning each of these wells including total depth, well screen interval, and whether the well is active or inactive.

This well has been closed and abandoned since the release of the Greenhorne & O'Mara, 1992 and the Geophex, Ltd., 1992 reports regarding supply well management. Thus, there are not active supply wells in the vicinity of Site 88.

One water storage tower is located near Site 88 (Figure 1-2). The water in this tower is supplied by treated groundwater from supply wells. As show on Figure 3-13, there are no active groundwater supply wells within a one mile radius. This water tower is above ground and does not contact groundwater. Thus, site-related contaminants would have no impact on the water stored in the water tower.

3.8 References

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SECTION 3.0 TABLES

TABLE 3-1
GEOLOGIC AND HYDROGEOLOGIC UNITS OF NORTH CAROLINA'S COASTAL PLAIN
OPERABLE UNIT 15 (SITE 88)
MCB, CAMP LEJEUNE, NORTH CAROLINA

Geologic Units			Hydrogeologic Units
System	Series	Formation	Aquifer and Confining Unit
Quaternary	Holocene/Pleistocene	Undifferentiated	Surficial aquifer
Tertiary	Pliocene	Yorktown Formation(1)	Yorktown confining unit
	Miocene	Eastover Formation(1)	Yorktown Aquifer
		Pungo River Formation(1)	Pungo River confining unit
			Pungo River Aquifer
		Belgrade Formation(2)	Castle Hayne confining unit
	Oligocene	River Bend Formation	Castle Hayne Aquifer
	Eocene	Castle Hayne Formation	
			Beaufort confining unit(3)
	Paleocene	Beaufort Formation	Beaufort Aquifer
Cretaceous	Upper Cretaceous	Peedee Formation	Peedee confining unit
			Peedee Aquifer
		Black Creek and Middendorf Formations	Black Creek confining unit
			Black Creek Aquifer
		Cape Fear Formation	Upper Cape Fear confining unit
			Upper Cape Fear Aquifer
			Lower Cape Fear confining unit
			Lower Cape Fear Aquifer
	Lower Cretaceous(1)	Unnamed deposits(1)	Lower Cretaceous confining unit
			Lower Cretaceous Aquifer(1)
Pre-Cretaceous basement rocks		--	--

Notes:

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

Source: Harned et al., 1989.

TABLE 3-2
STATIC WATER ELEVATIONS
SHALLOW TEMPORARY & PERMANENT MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Well ID	RP Elev.(1)	19-May-97		31-May-97		24-Jul-97		21-Mar-97		6-Apr-97	
		SWL(2)	SWE(3)	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE
88-MW01	26.07	6.37	19.70	6.52	19.55	6.84	19.23	4.95	21.12	5.35	20.72
88-MW02	25.11	8.82	16.29	9.00	16.11	9.36	16.71	7.16	17.95	8.25	16.86
88-MW03	25.38	7.62	17.76	7.70	17.68	8.82	16.29	6.50	18.88	6.98	18.40
88-MW04	24.54	13.97	10.57	14.02	10.52	14.81	10.57	10.71	13.83	12.11	12.43
88-MW05	23.97	7.27	16.70	7.41	16.56	7.80	16.74	5.21	18.76	6.15	17.82
88-MW06	23.13	11.85	11.28	11.96	11.17	12.53	11.44	9.50	13.63	10.28	12.85
88-MW07	23.37	7.81	15.56	8.15	15.22	9.13	14.00	5.22	18.15	6.34	17.03
88-MW08	22.98	7.42	15.56	7.67	15.31	8.71	14.66	4.16	18.82	5.71	17.27
88-MW09	21.83	8.22	13.61	8.50	13.33	9.25	13.73	4.76	17.07	6.18	15.65
88-TW20	24.73	12.34	12.39	12.58	12.15	(4)	--	(4)	--	(4)	--
88-TW21	25.56	14.88	10.68	15.02	10.54	(4)	--	(4)	--	(4)	--
88-TW22	24.46	10.07	14.39	10.16	14.30	(4)	--	(4)	--	(4)	--
88-TW23	25.21	15.50	9.71	15.62	9.59	(4)	--	(4)	--	(4)	--
88-TW24	25.82	10.54	15.28	10.84	14.98	(4)	--	(4)	--	(4)	--
88-TW25	26.51	16.40	10.11	16.58	9.93	(4)	--	(4)	--	(4)	--
88-TW26	27.40	17.57	9.83	17.68	9.72	(4)	--	(4)	--	(4)	--
88-TW27	23.96	9.66	14.30	9.68	14.28	(4)	--	(4)	--	(4)	--
88-TW28	25.35	10.18	15.17	10.48	14.87	(4)	--	(4)	--	(4)	--

NOTES: (1) Elevation of the reference point (top of PVC).

(2) Static Water Level

(3) Static Water Elevation

(4) No water level measurement taken - temporary well abandoned.

Units for SWL are feet, and units for SWE are feet above mean sea level

TABLE 3-3
STATIC WATER ELEVATIONS
INTERMEDIATE TEMPORARY & PERMANENT MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

		19-May-97		31-May-97		24-Jul-97		21-Mar-97		6-Apr-97	
Well ID	RP Elev.(1)	SWL(2)	SWE(3)	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE
88-MW02IW	25.14	15.79	9.35	15.90	9.24	16.57	8.57	13.59	11.55	14.52	10.62
88-MW03IW	25.32	15.18	10.14	15.26	9.88	15.92	9.22	13.04	12.28	13.97	11.35
88-MW04IW	24.61	14.19	10.42	14.31	11.01	14.99	10.33	11.90	12.71	12.84	11.77
88-MW05IW	24.33	14.14	10.19	14.26	10.35	14.90	9.71	11.98	12.35	12.91	11.42
88-MW06IW	23.04	13.57	9.47	13.68	10.65	14.34	9.99	11.39	11.65	10.28	12.76
88-MW07IW	23.38	13.68	9.70	13.88	9.16	14.47	8.57	11.40	11.98	12.46	10.92
88-MW08IW	22.91	12.85	10.06	13.04	10.34	13.68	9.70	10.74	12.17	11.64	11.27
88-MW09IW	21.74	11.55	10.19	11.72	11.19	12.36	10.55	9.49	12.25	10.32	11.42
88-TW20IW	24.34	14.62	9.72	14.72	7.02	(4)	--	(4)	--	(4)	--
88-TW21IW	25.23	15.40	9.83	15.50	8.84	(4)	--	(4)	--	(4)	--
88-TW22IW	25.76	15.97	9.79	16.12	9.11	(4)	--	(4)	--	(4)	--
88-TW23IW	24.86	15.32	9.54	15.44	10.32	(4)	--	(4)	--	(4)	--
88-TW24IW	25.82	15.96	9.86	16.60	8.26	(4)	--	(4)	--	(4)	--
88-TW25IW	25.80	16.63	9.17	16.78	9.04	(4)	--	(4)	--	(4)	--
88-TW26IW	27.82	18.56	9.26	18.68	7.12	(4)	--	(4)	--	(4)	--
88-TW27IW	24.26	13.22	11.04	13.48	14.34	(4)	--	(4)	--	(4)	--
88-TW28IW	27.05	15.97	11.08	17.28	6.98	(4)	--	(4)	--	(4)	--

NOTES: (1) Elevation of the reference point (top of PVC).

(2) Static Water Level

(3) Static Water Elevation

(4) No water level measurement taken - temporary well abandoned.

Units for SWL are feet, and units for SWE are feet above mean sea level

TABLE 3-4
STATIC WATER ELEVATIONS
DEEP TEMPORARY AND PERMANENT MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Well ID	RP Elev.(1)	19-May-97		31-May-97		24-Jul-97		21-Mar-97		6-Apr-97	
		SWL(2)	SWE(3)	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE
88-MW02DW	25.11	15.82	9.29	15.94	9.17	16.61	8.50	13.63	11.48	15.56	9.55
88-MW03DW	25.62	15.48	10.14	15.62	10.00	16.30	9.32	13.33	12.29	14.18	11.44
88-MW04DW	24.60	14.23	10.37	14.34	10.26	15.01	9.59	13.13	11.47	(4)	--
88-MW05DW	24.45	14.28	10.17	14.40	10.05	15.04	9.41	12.68	11.77	13.06	11.39

NOTES: (1) Elevation of the reference point (top of PVC).

(2) Static Water Level

(3) Static Water Elevation

(4) No water level measurement taken.

Units for SWL are feet, and units for SWE are feet above mean sea level

TABLE 3-5
SUMMARY OF HYDRAULIC CONDUCTIVITY ESTIMATES
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well ID	Hydraulic Conductivity		Average	Velocity Estimate	Comments
	Falling Head	Rising Head			
88-MW02	--	9.2	--	1.4	Fine sand & silt
88-MW04	--	15.7	--	2.4	Fine sand, little silt
88-MW05	--	0.8	--	0.04	Silt, some fine sand
88-MW07	--	29.7	--	3.0	Fine sand, little silt
88-MW09	--	0.4	--	0.02	Fine sand, little silt
Max	--	29.7	--	3.0	
Min	--	0.4	--	0.02	
Avg.	--	11.2	--	1.4	
88-MW03IW	170.3	6.8	88.5	--	F/M sand, tr. to ltl. silt & shells
88-MW04IW	59.4	64.7	62.1	0.9	Fine sand, trace silt
88-MW07IW	51.9	60.9	56.4	0.6	Fine sand, trace silt
88-MW09IW	84.0	86.9	85.5	1.3	Fine sand, trace M/C sand & silt
Max	170.3	86.9	85.5	1.3	
Min	51.9	6.8	56.4	0.6	
Avg	91.4	54.8	68.0	0.9	
88-MW03DW	6.2	4.0	--	0.0005	Fine sand little shells/fossils

Notes: Hydraulic conductivity units are in feet/day
Velocity units are in feet/day
Well 88-MW03IW data is show above, but has been excluded from calculations

TABLE 3-6
SOIL PROPERTIES SUMMARY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Well/Boring ID	Depth (ft bgs)	Bulk Density (lbs/cuft)	Vertical Permeability (ft/day)	Description
88-MW02	2-4 ft.	73.1	1.76	Silty Sand
88-MW04IW	16-18 ft.	88.0	1.28E-04	Clay
88-SB04	20-22 ft.	85.85	1.79E-04	Clay

NOTES: ft = feet
bgs = below ground surface
cuft = cubic feet

TABLE 3-7
LAND UTILIZATION: DEVELOPED AREAS ACRES/LAND USE (PERCENT)
OPERABLE UNIT 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Geographic Area	Oper.	Training (Instruc.)	Maint.	Supply/ Storage	Medical	Admin.	Family Housing	Troop Housing	CM	CO	Recreat.	Utility	Total
Hadnot Point	31 (2.9)	15 (1.4)	154 (14.3)	157 (14.4)	10 (0.9)	122 (11.3)	22 (2.0)	196 (18.1)	115 (10.7)	36 (3.3)	182 (16.9)	40 (3.7)	1,080 (100)
Paradise Point	1 (0)		3 (0.4)	1 (0)			343 (34)	19 (1.9)	31 (3.1)		610 (60.4)	2 (0.2)	1,010 (100)
Berkeley Manor/ Watkins Village							406 (80)		41 (8.1)	1 (0.2)	57 (11.2)	2 (0.5)	507 (100)
Midway Park		1 (0.4)		2 (0.7)		2 (0.7)	248 (92.2)		8 (3.0)	3 (1.1)	4 (1.5)	1 (0.4)	269 (100)
Tarawa Terrace I and II			3 (0.5)			1 (0.3)	428 (77.4)		55 (9.9)	11 (2.0)	47 (8.5)	8 (1.4)	553 (100)
Knox Trailer							57 (100)						57 (100)
French Creek	8 (1.4)	1 (0.2)	74 (12.7)	266 (45.6)	3 (0.5)	7 (1.2)		122 (20.9)	22 (3.8)	6 (1.0)	74 (12.7)		583 (100)
Courthouse Bay		73 (28.6)	28 (10.9)	14 (5.5)		12 (4.7)	12 (4.7)	43 (16.9)	15 (5.9)	4 (1.6)	43 (16.9)	11 (4.3)	255 (100)
Onslow Beach	6 (9.8)	1 (1.6)	3 (4.8)	2 (3.2)	1 (1.6)	2 (3.2)		2 (3.2)	12 (19.3)		25 (40.3)	8 (13.0)	62 (100)
Rifle Range		1 (1.3)	1 (1.3)	7 (8.8)	1 (1.3)	5 (6.3)	7 (8.8)	30 (37.5)	5 (6.3)	1 (1.3)	9 (11.3)	13 (16.3)	80 (100)
Camp Geiger	4 (1.9)	15 (6.9)	19 (8.8)	50 (23.1)		23 (10.6)		54 (25.0)	27 (12.5)	2 (1.0)	16 (7.4)	6 (2.8)	216 (100)
Montford Point	6 (2.6)	48 (20.5)	2 (0.9)	4 (1.7)	2 (0.9)	9 (3.9)		82 (35.2)	20 (8.6)	1 (0.4)	49 (21.0)	10 (4.3)	233 (100)
Base-wide Misc.	1 (0.8)			87 (68.0)		3 (2.3)			19 (14.8)			18 (14.1)	128 (100)
TOTAL	**57 (1.1)**	**155 (3.1)**	**287 (5.7)**	**590 (11.7)**	**17 (0.38)**	**186 (3.7)**	**1,523 (30.2)**	**548 (10.8)**	**370 (7.4)**	**65 (1.3)**	**1.116 (22.2)**	**119 (2.4)**	**5,033 (100)**

Source: DON, 1988

TABLE 3-8
CLIMATIC DATA SUMMARY FOR MCAS NEW RIVER
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
OPERABLE UNIT 15 (SITE 88)
MCB CAMP LEJEUNE, NORTH CAROLINA

	Temperature (Celsius)			Relative Humidity (Percent)	Temperature (Fahrenheit)			Mean Number of Days With				
								Precipitation		Temperature		
	Maximum	Minimum	Average		Maximum	Minimum	Average	>=0.01"	>=0.5"	>=90F	>=75F	<=32F
January	7.5	1.4	4.2	76	54	34	44	11	2	0	1	14
February	7.0	1.5	3.8	74	57	36	46	9	3	0	1	11
March	8.0	0.8	3.5	78	64	42	53	10	2	0	5	7
April	6.5	0.5	3.0	79	73	51	62	8	2	--	14	--
May	8.4	1.7	4.3	86	80	60	70	10	3	2	25	0
June	11.8	2.4	5.8	85	85	67	76	11	4	6	19	0
July	14.3	4.5	8.0	85	88	72	80	14	5	12	31	0
August	12.6	1.7	6.1	87	87	71	80	12	4	11	31	0
September	12.2	1.4	4.7	87	83	66	75	9	3	3	27	0
October	6.5	0.7	2.8	82	74	54	64	7	2	--	16	--
November	5.7	0.6	2.6	80	66	44	55	7	1	0	6	4
December	6.1	0.4	4.0	77	58	37	48	9	2	0	2	11
Annual	14.3	0.4	52.8	81	72	53	63	117	33	34	188	47

-- Less than 0.5 days
Source: Naval Oceanography Command Detachment, Asheville, North Carolina. Measurements obtained from January 1955 to December 1982.

TABLE 3-9
CLIMATIC DATA SUMMARY FOR MCAS, NEW RIVER
JANUARY THROUGH JUNE 1997
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Month	Temperature (°F)			Precip.[4] (inches)	Number of Days With:				
					Precipitation		High Temperature		
	Max.[1]	Min.[2]	Avg. [3]		>=0.01"	>=0.5"	>=90°F	>=75°F	<=32°F
January	54.9	34.7	44.8	4.71	10	3	0	1	1
February	61.7	40.3	51.0	4.97	11	3	0	3	0
March	71.5	46.6	59.1	3.09	6	2	0	12	0
April	71.6	47.1	59.4	2.07	10	2	0	8	0
May	78.8	54.6	66.7	1.62	7	1	1	22	0
June	83.2	63.9	73.6	3.98	8	4	6	24	0

NOTES: (1) = Average daily maximum temperature for the month
(2) = Average daily minimum temperature for the month
(3) = Average daily mean temperature for the month
(4) = Precipitation

TABLE 3-10
WATER SUPPLY WELL INFORMATION
OPERABLE UNIT 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Well ID	Well Diameter (inches)	Casing Material	Year Installed	Status	Date Closed	Depth (ft bgs)	Srceen Interval(1)		Approximate Direction & Distance
							Top (ft bgs)	Bottom (ft bgs)	
PSWHP-603	8	Steel	1941	Closed	--	195	71	195	ESE 2,400ft

Information source: Geophex Ltd., 1992.

NOTES: (1) = Well contains 5 screened intervals begining at 71 feet bgs
ft = feet
bgs = below ground surface

SECTION 3.0 FIGURES

02020 N08Y

LEGEND

/\/ Topographic Contour

Scale
0 300 600 Feet

N
W E
S

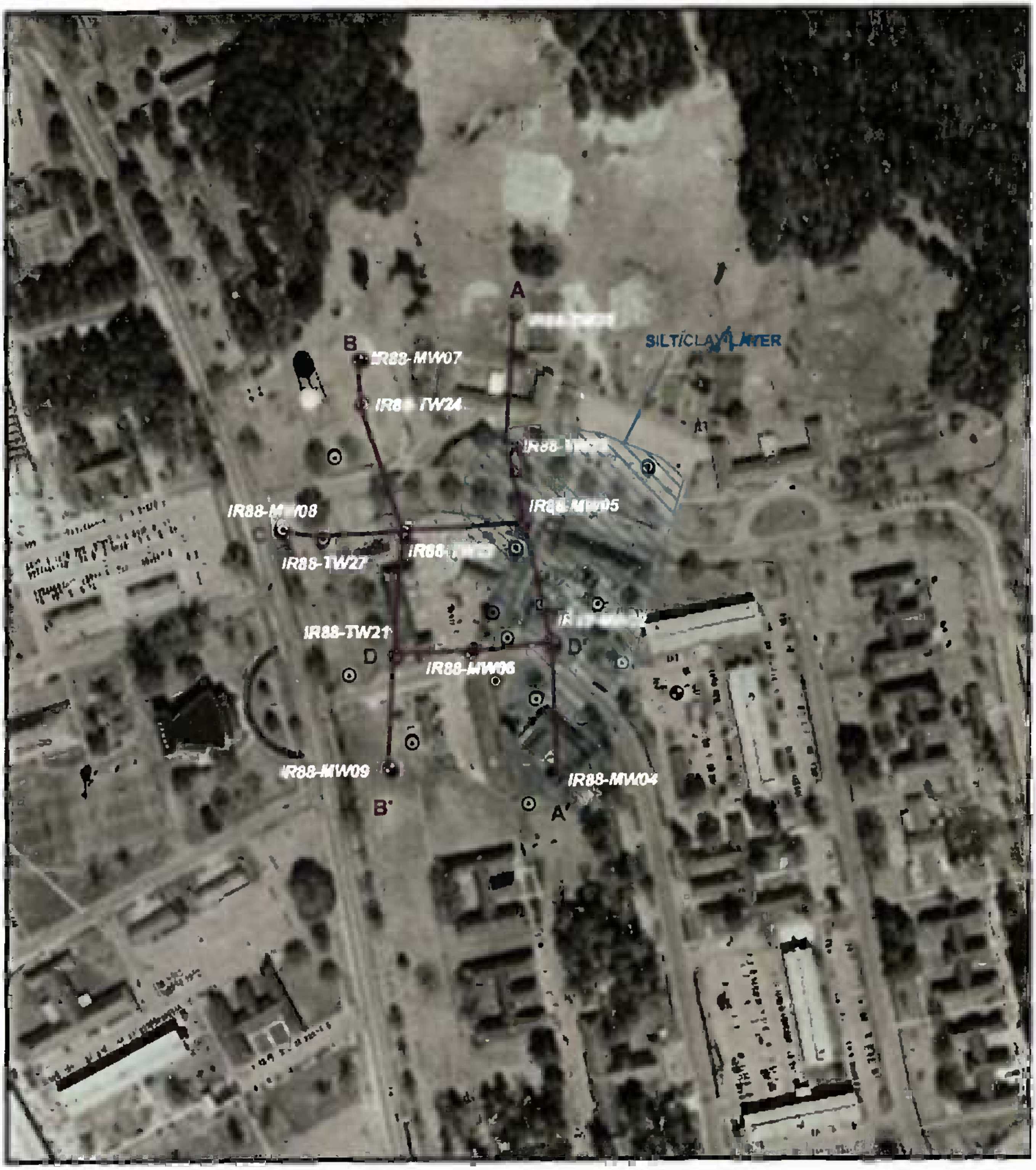
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUND SURFACE APPROXIMATION
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 3 - 1

02020N044

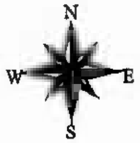


LEGEND

IR88-MW02 ●	Permanent Monitoring Well Locations
IR88-TW21 ⊙	Temporary Monitoring Well Locations
/\/	Cross Sections
▨	Silt/Clay Layer

Scale

300 0 300 600 Feet



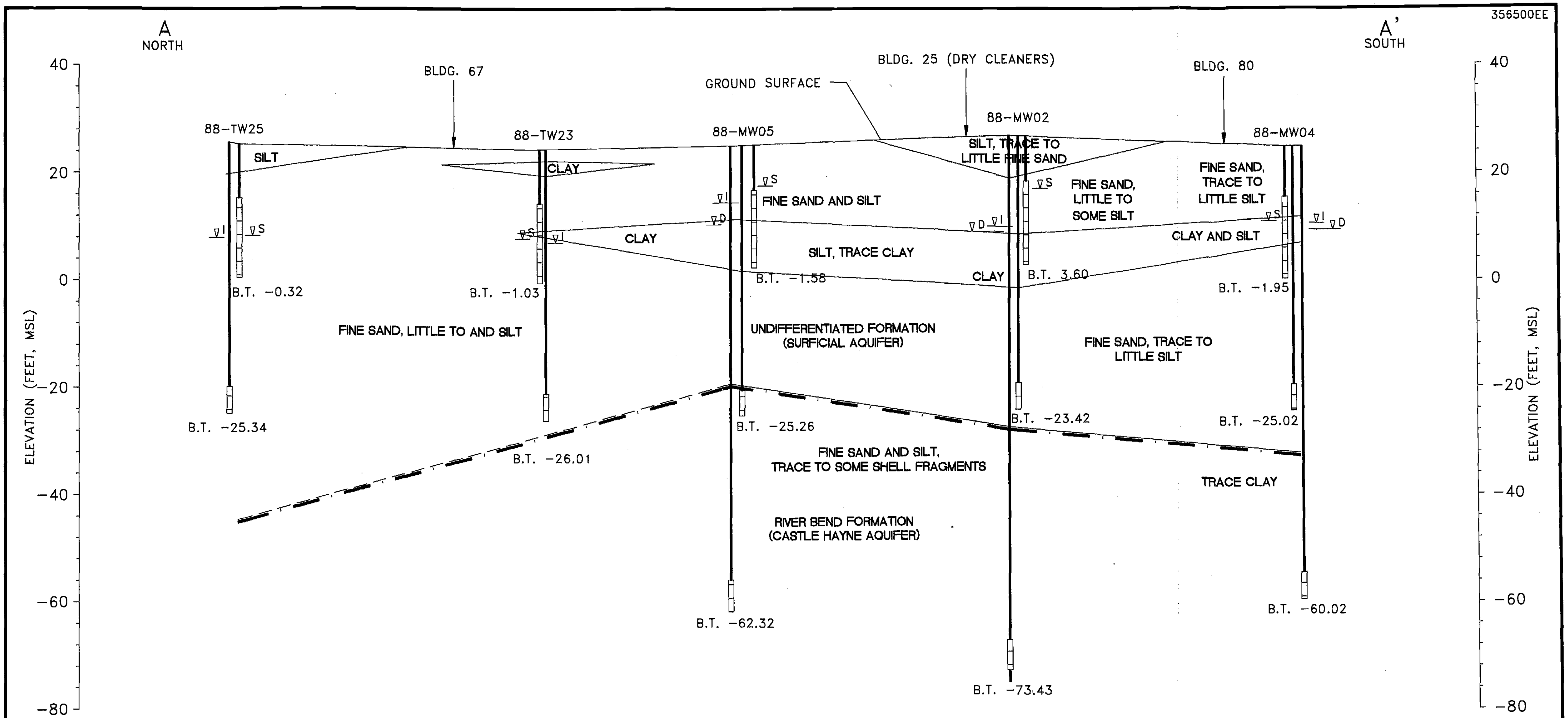
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

CROSS SECTION LOCATION MAP
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 3 - 2

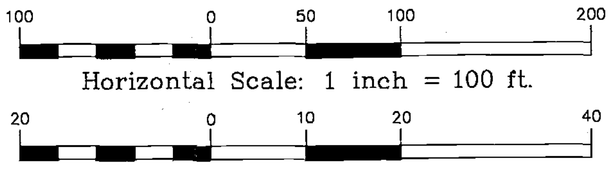
356500EE



Baker
Baker Environmental, Inc.

LEGEND

▽S	STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
▽I	STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
▽D	STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
———	ESTIMATED CONTACT
------	PROJECTED CONTACT
— · —	FORMATION/AQUIFER DIVISION LINE



Horizontal Scale: 1 inch = 100 ft.

Vertical Scale: 1 inch = 20 ft.

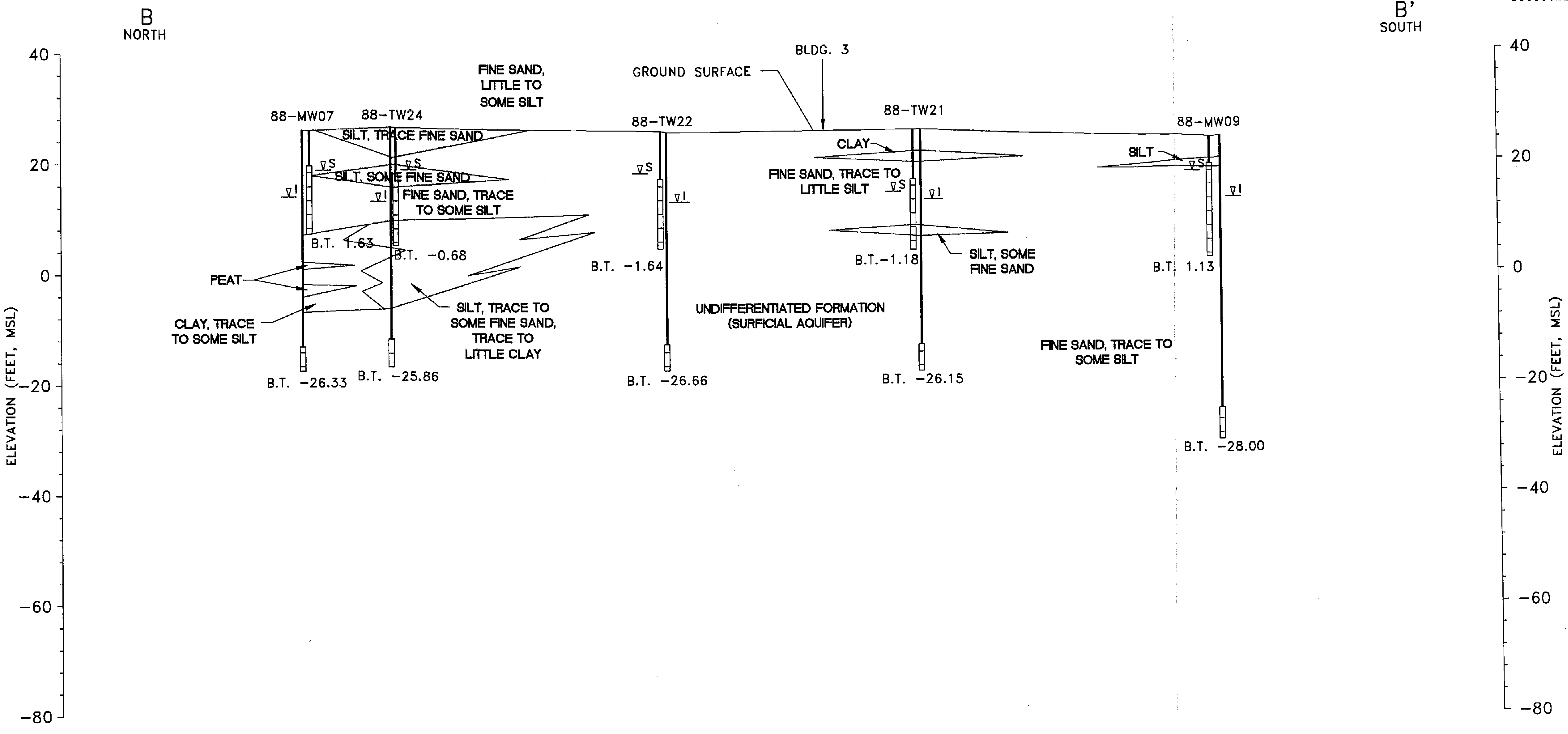
THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 3-3
HYDROGEOLOGIC CROSS-SECTION A-A'
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N102

356501EE

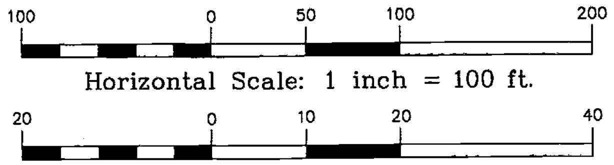


Baker

Baker Environmental, Inc.

LEGEND

∇S	STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
∇I	STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
∇D	STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
———	ESTIMATED CONTACT
- - - - - -	PROJECTED CONTACT
— · —	FORMATION/AQUIFER DIVISION LINE



Horizontal Scale: 1 inch = 100 ft.

Vertical Scale: 1 inch = 20 ft.

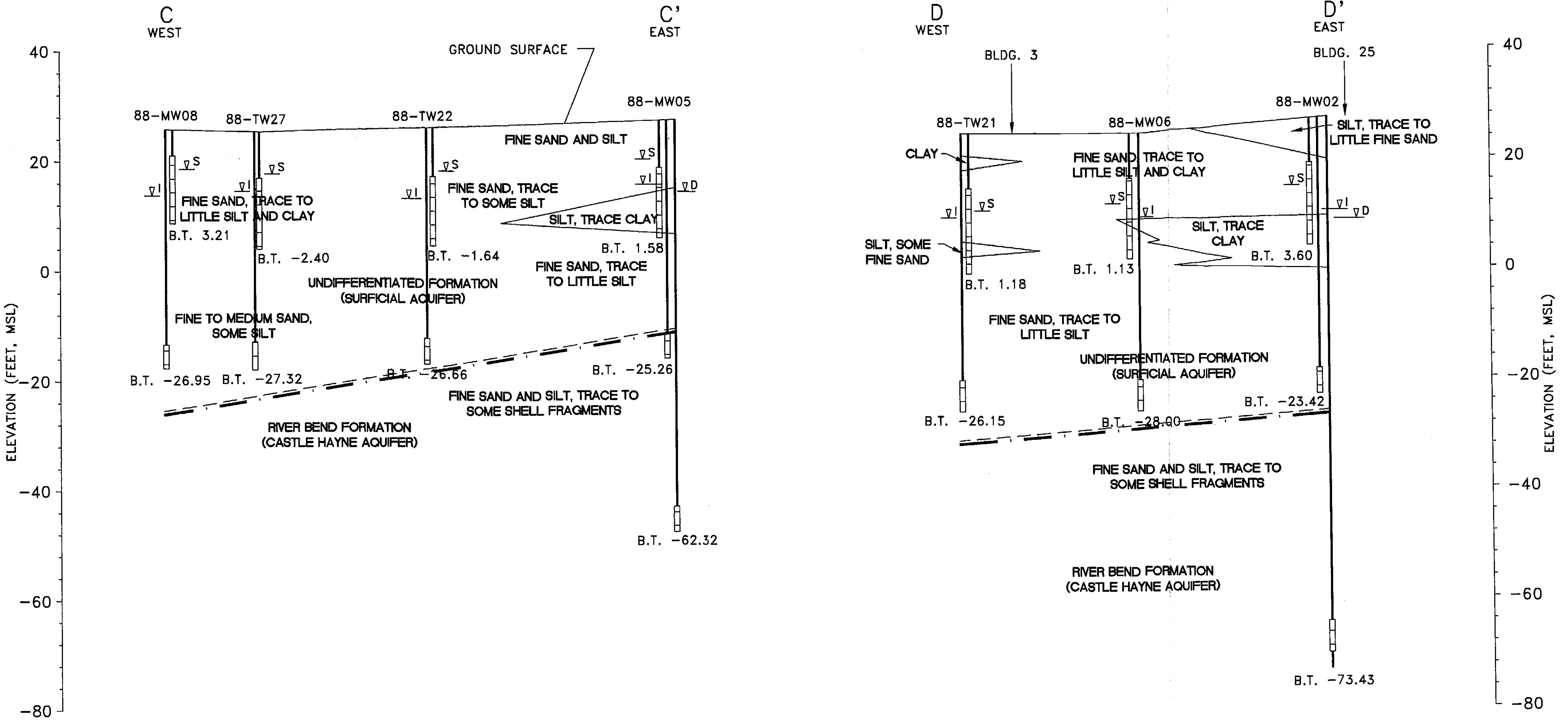
THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 3-4
HYDROGEOLOGIC CROSS-SECTION B-B'
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N112

356502EE



Baker
Baker Environmental, Inc.

LEGEND

▽S	STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
▽I	STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
▽D	STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
———	ESTIMATED CONTACT
- - - - - -	PROJECTED CONTACT
— · —	FORMATION/AQUIFER DIVISION LINE

100 0 50 100 200

Horizontal Scale: 1 inch = 100 ft.

20 0 10 20 40

Vertical Scale: 1 inch = 20 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 3-5
HYDROGEOLOGIC CROSS-SECTIONS C-C' AND D-D'
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N122

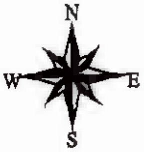
02020N134

LEGEND

∧∧	Shallow Groundwater Contour
●	Permanent Monitoring Well
⊙	Temporary Monitoring Well
➔	Groundwater Flow Direction

Scale

300 0 300 600 Feet



MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUNDWATER POTENTIOMETRIC
SURFACE MAP (MAY 19, 1997) -
SHALLOW MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 3 - 7

02020 N 149

LEGEND

Intermediate Groundwater Contour

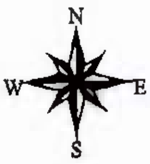
● Permanent Monitoring Well

⊙ Temporary Monitoring Well

➔ Groundwater Flow Direction

Scale

300 0 300 600 Feet



MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

GROUNDWATER POTENTIOMETRIC
SURFACE MAP (MAY 19, 1997) -
INTERMEDIATE MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 3 - 8

FIGURE 3-6A

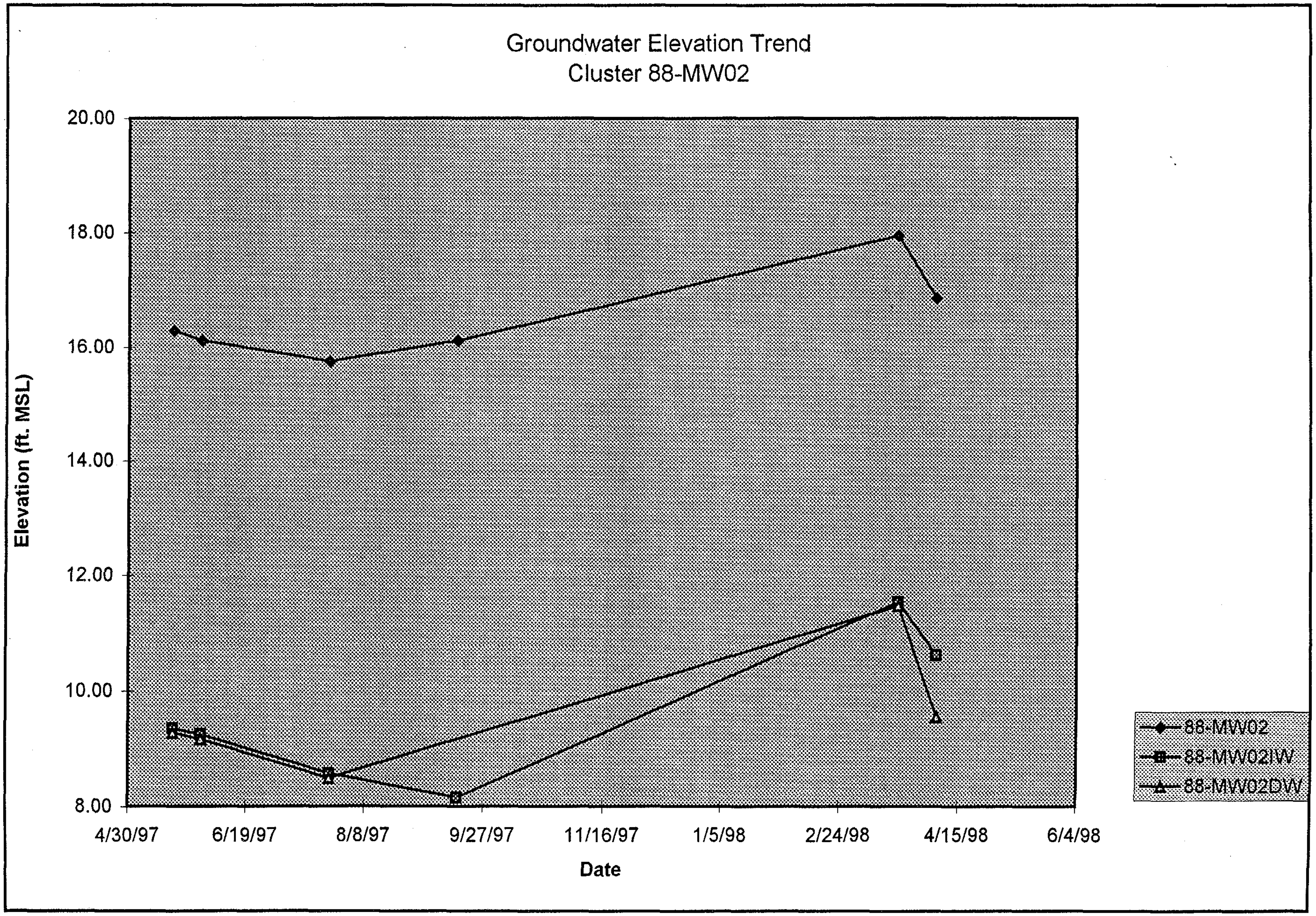

Groundwater Elevation Trend
Cluster 88-MW02
Elevation (ft. MSL)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
1/5/98
2/24/98
4/15/98
6/4/98
Date
88-MW02
88-MW02IW
88-MW02DW

FIGURE 3-6B

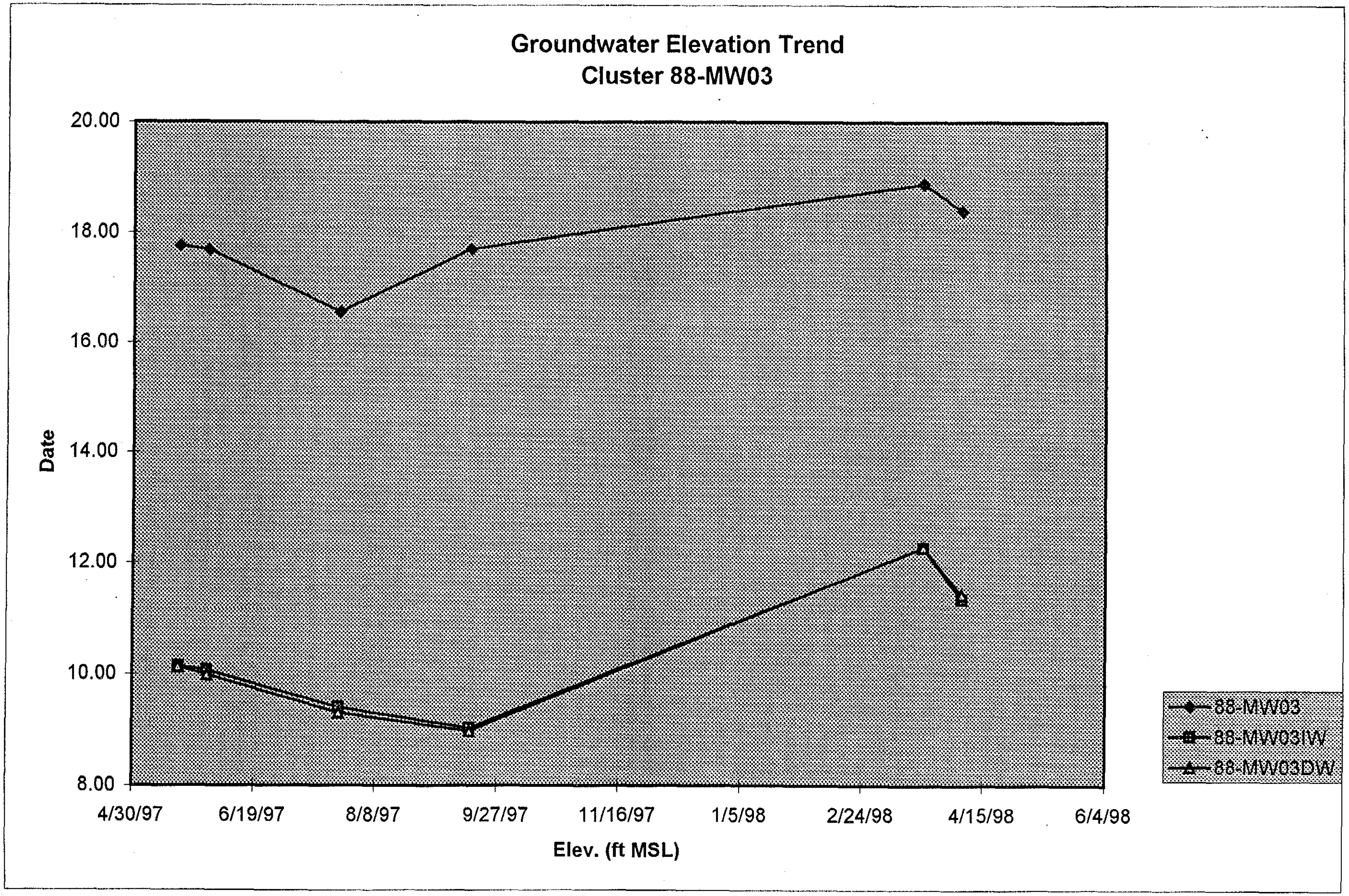

Groundwater Elevation Trend
Cluster 88-MW03
20.00
18.00
16.00
14.00
12.00
10.00
8.00
Date
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
1/5/98
2/24/98
4/15/98
6/4/98
Elev. (ft MSL)
88-MW03
88-MW03IW
88-MW03DW

FIGURE 3-6C

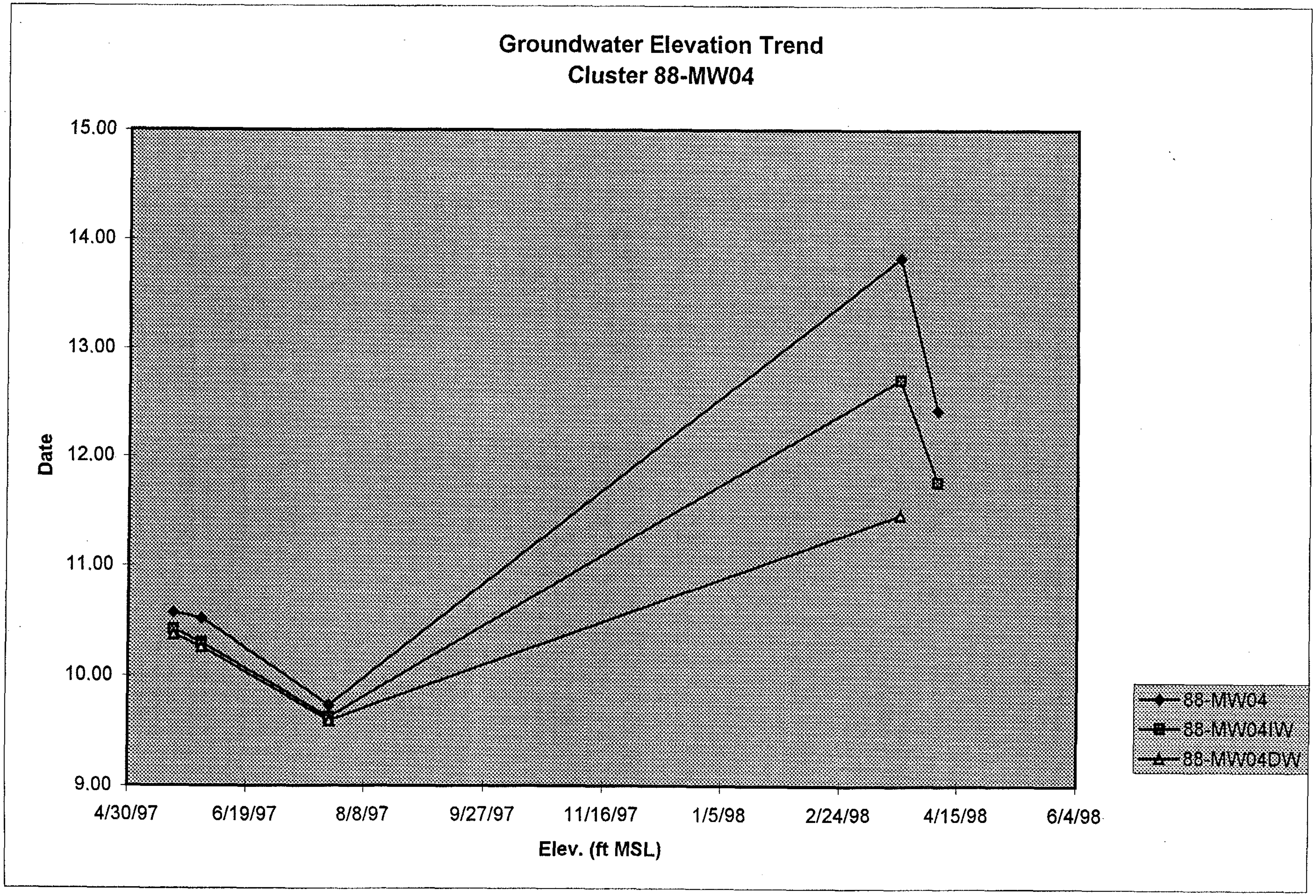

Groundwater Elevation Trend
Cluster 88-MW04
15.00
14.00
13.00
12.00
11.00
10.00
9.00
Date
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
1/5/98
2/24/98
4/15/98
6/4/98
Elev. (ft MSL)
88-MW04
88-MW04IW
88-MW04DW

FIGURE 3-6D

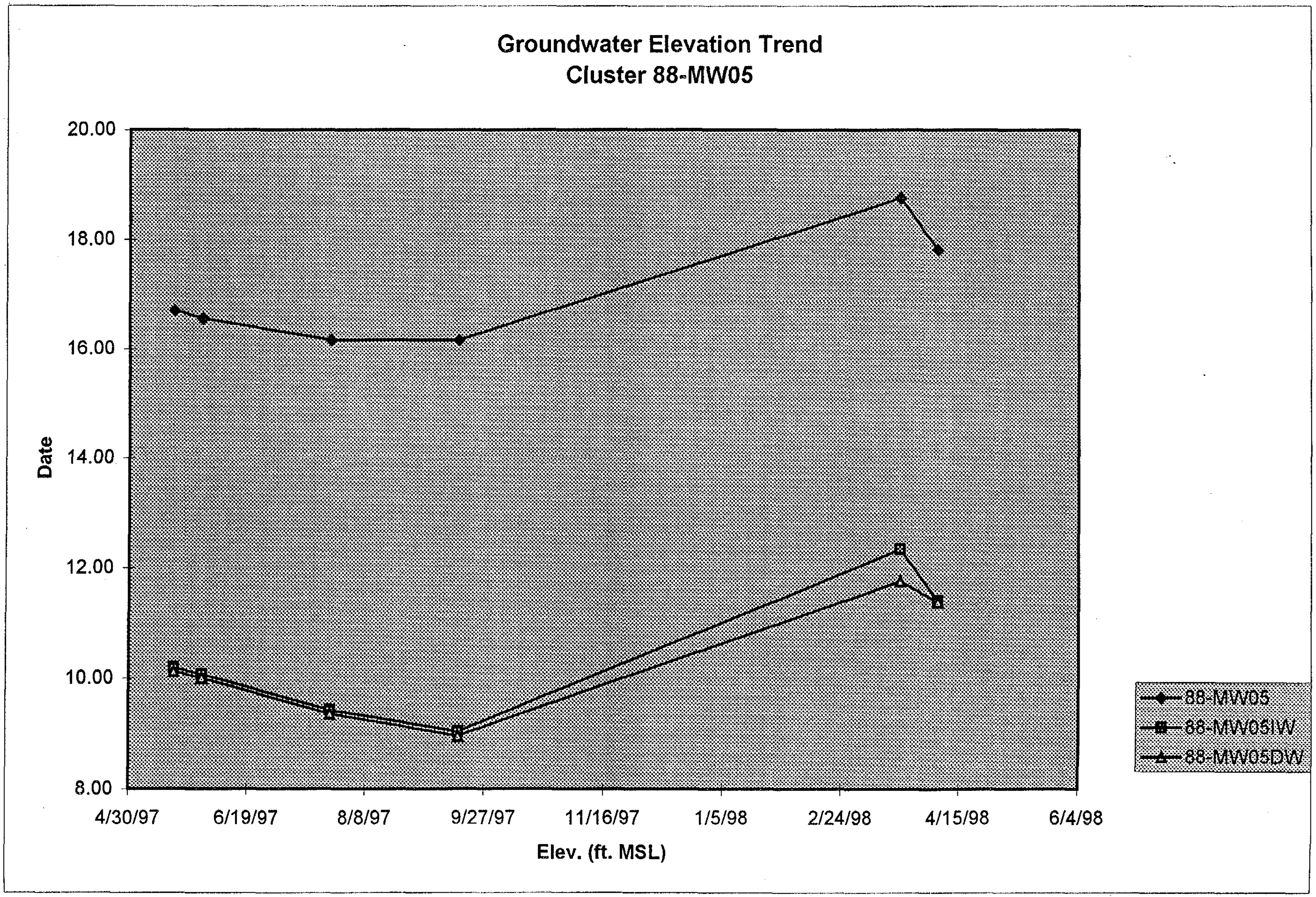
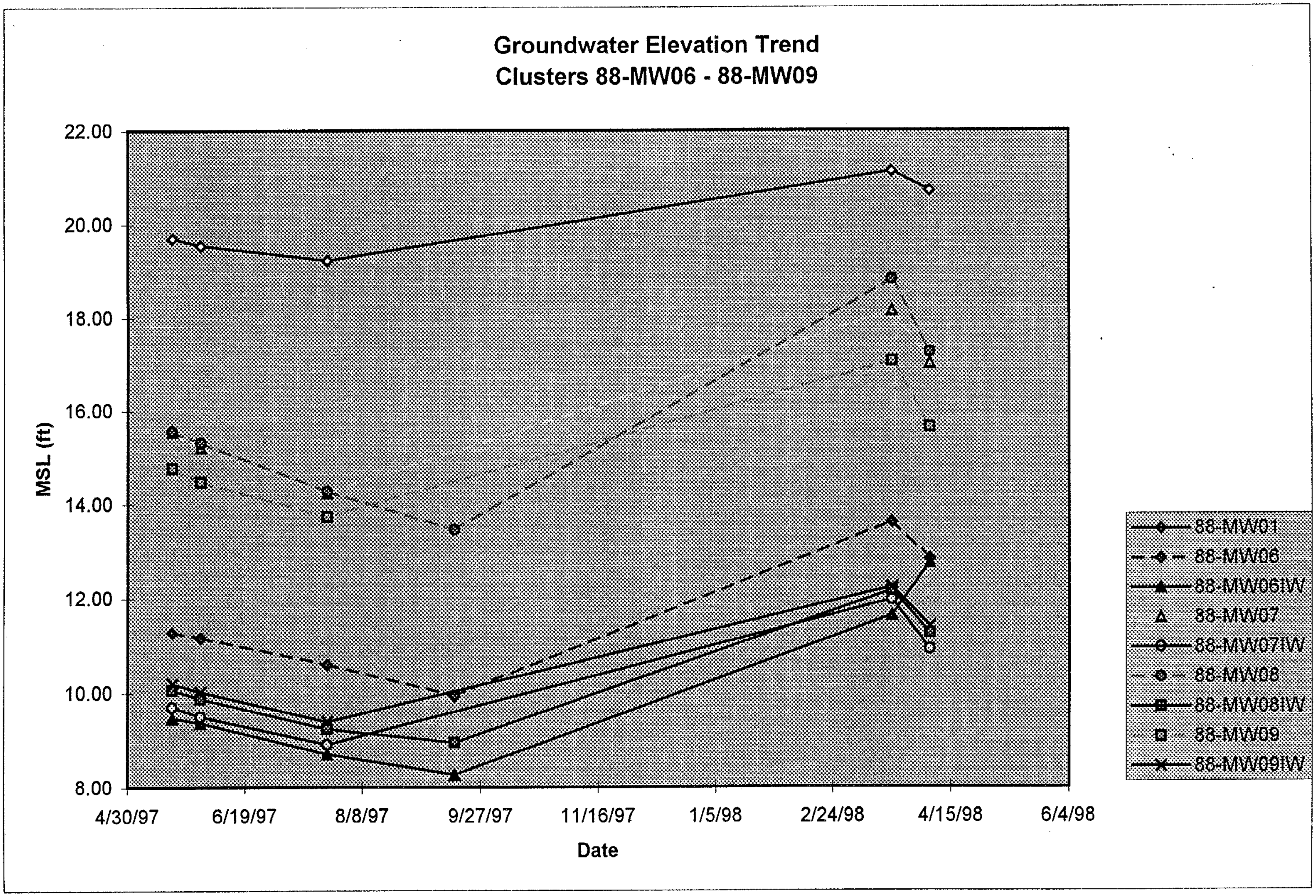

Groundwater Elevation Trend
Cluster 88-MW05
20.00
18.00
16.00
14.00
12.00
10.00
8.00
Date
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
1/5/98
2/24/98
4/15/98
6/4/98
Elev. (ft. MSL)
88-MW05
88-MW05IW
88-MW05DW

FIGURE 3-6E


Groundwater Elevation Trend
Clusters 88-MW06 - 88-MW09
MSL (ft)
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
1/5/98
2/24/98
4/15/98
6/4/98
Date
88-MW01
88-MW06
88-MW06IW
88-MW07
88-MW07IW
88-MW08
88-MW08IW
88-MW09
88-MW09IW

LEGEND

Deep Groundwater Contour

Deep Groundwater Contour Projection

Permanent Monitoring Well

→ Groundwater Flow Direction

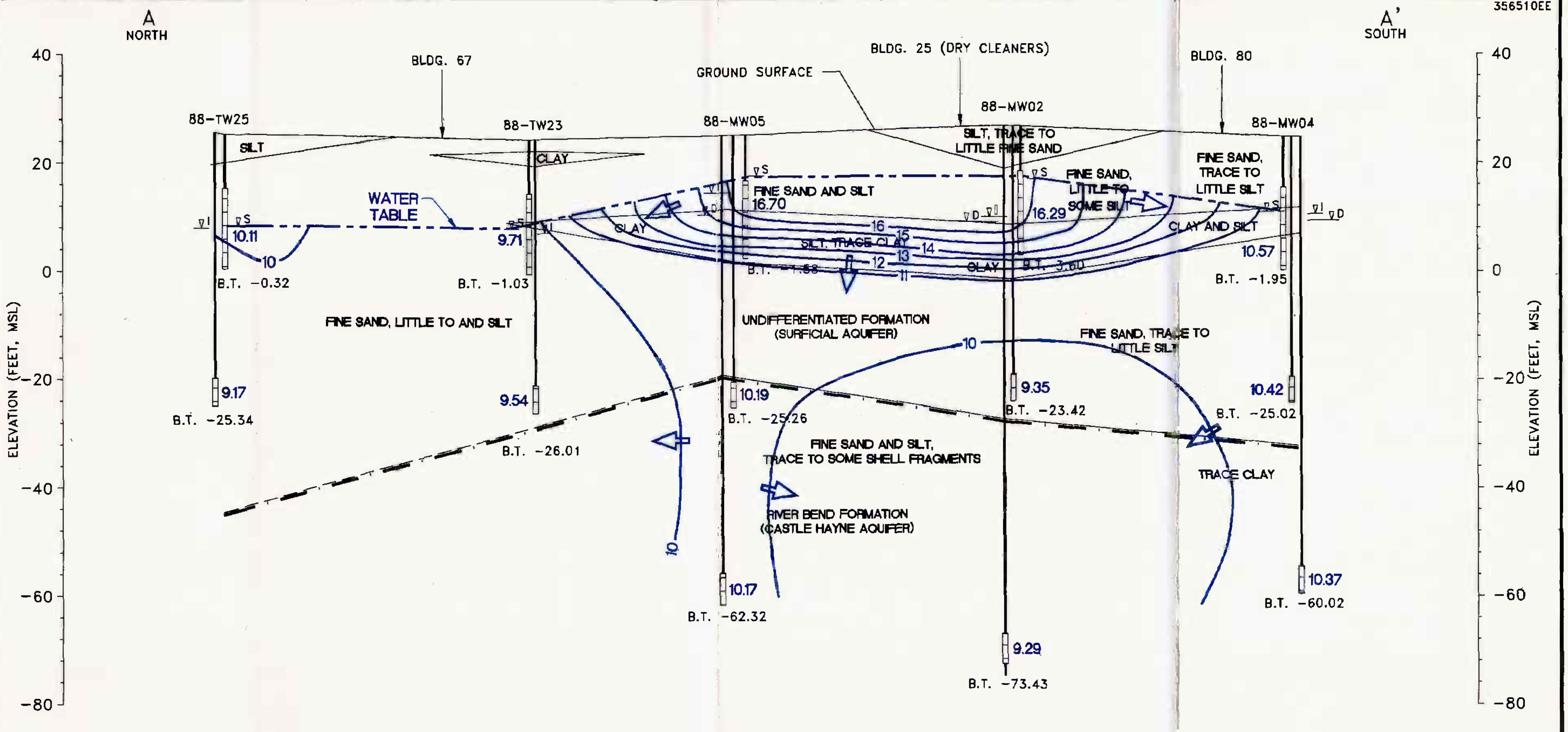
200 0 200 400 Feet Scale

MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA

GROUNDWATER POTENTIOMETRIC
SURFACE MAP (MAY 19, 1997) -
DEEP MONITORING WELLS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 3 - 9



Baker
Baker Environmental, Inc.

LEGEND

▽S	STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
▽I	STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
▽D	STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
———	ESTIMATED CONTACT
- - - - - -	PROJECTED CONTACT
— · —	FORMATION/AQUIFER DIVISION LINE
———	GROUNDWATER CONTOUR LINE
9.17	GROUNDWATER ELEVATION
⇦	GROUNDWATER FLOW DIRECTION

100 0 50 100 200

Horizontal Scale: 1 inch = 100 ft.

20 0 10 20 40

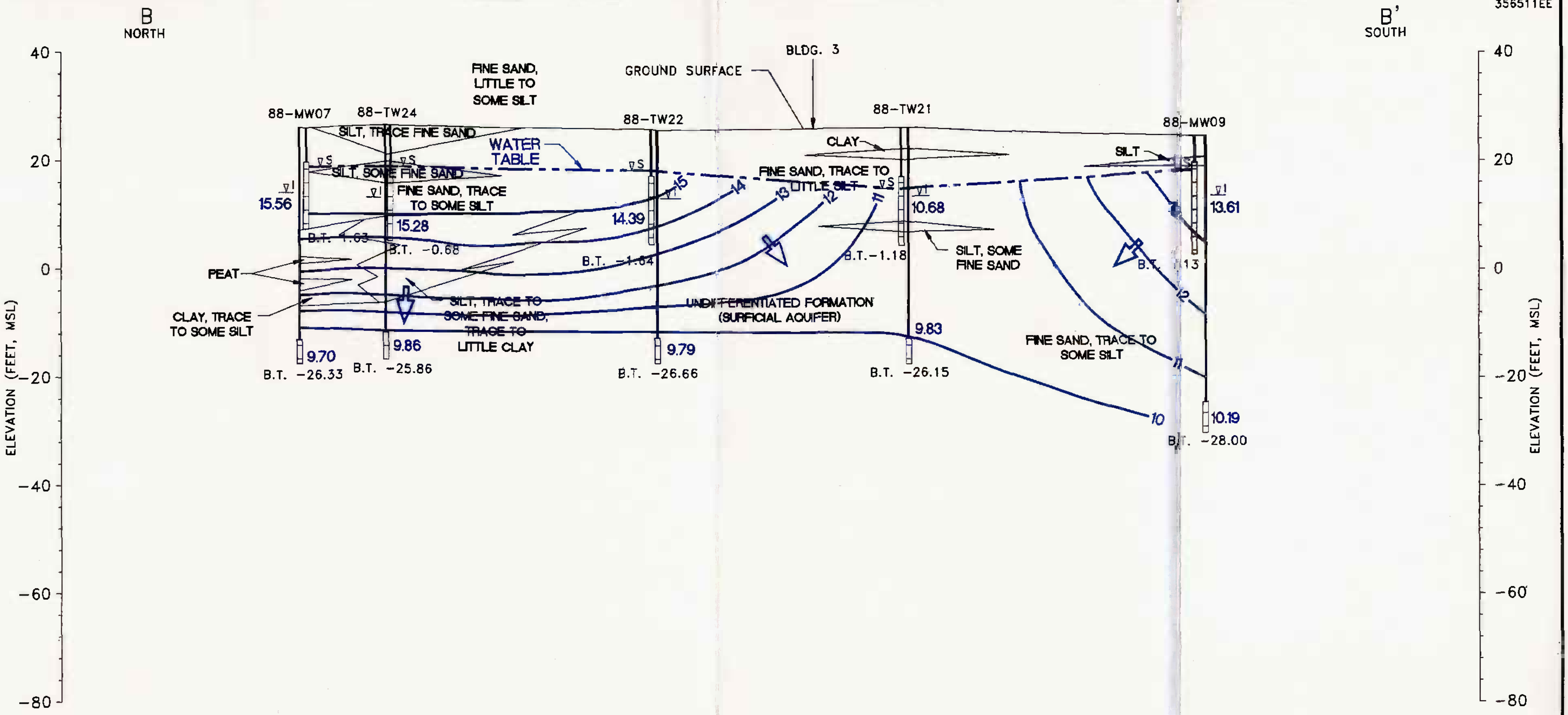
Vertical Scale: 1 inch = 20 ft.

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 3-10
HYDROGEOLOGIC CROSS-SECTION A-A'
SHOWING GROUNDWATER POTENTIOMETRIC SURFACE LINES
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

356511EE



Baker
Baker Environmental, Inc.

LEGEND

▽S STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
▽I STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
▽D STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32' BORING TERMINATED, ELEVATION MSL
▯ WELL SCREEN INTERVAL
—— ESTIMATED CONTACT
- - - - PROJECTED CONTACT
— · — FORMATION/AQUIFER DIVISION LINE
—— GROUNDWATER CONTOUR LINE
9.70 GROUNDWATER ELEVATION
⇦ GROUNDWATER FLOW DIRECTION

100 0 50 100 200
Horizontal Scale: 1 inch = 100 ft.

20 0 10 20 40
Vertical Scale: 1 inch = 20 ft.

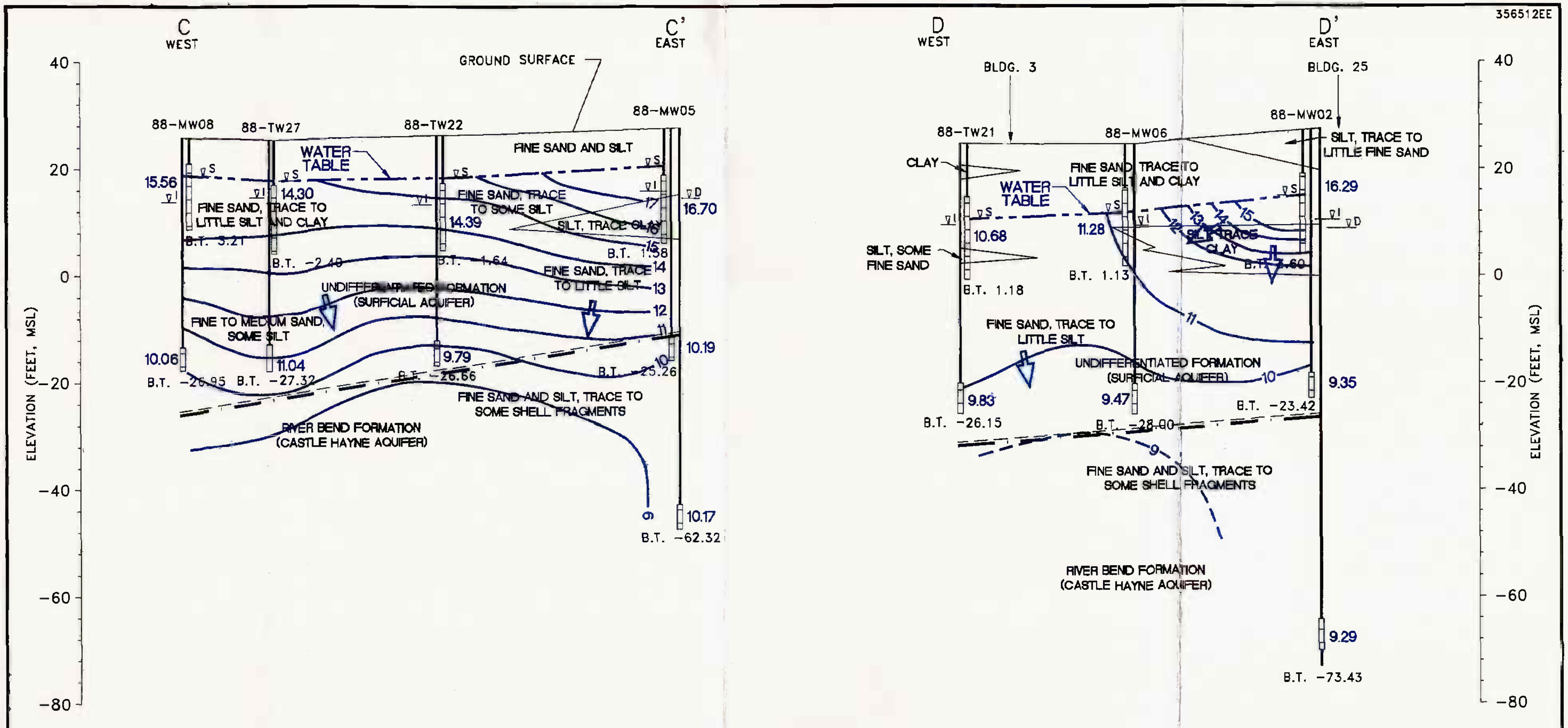
THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 3-11
HYDROGEOLOGIC CROSS-SECTION B-B'
SHOWING GROUNDWATER POTENTIOMETRIC SURFACE LINES
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N17Y

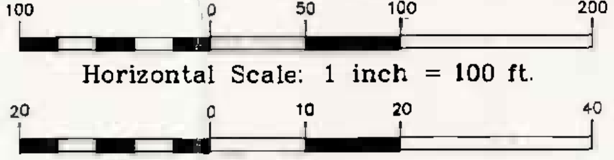
356512EE



Baker
Baker Environmental, Inc.

LEGEND

∇S	STATIC GROUNDWATER ENCOUNTERED IN SHALLOW WELL (5/31/97)
∇I	STATIC GROUNDWATER ENCOUNTERED IN INTERMEDIATE WELL (5/31/97)
∇D	STATIC GROUNDWATER ENCOUNTERED IN DEEP WELL (5/31/97)
B.T. -0.32'	BORING TERMINATED, ELEVATION MSL
▯	WELL SCREEN INTERVAL
——	ESTIMATED CONTACT
-------	PROJECTED CONTACT
— · —	FORMATION/AQUIFER DIVISION LINE
——	GROUNDWATER CONTOUR LINE
10.06	GROUNDWATER ELEVATION
⇦	GROUNDWATER FLOW DIRECTION



Horizontal Scale: 1 inch = 100 ft.

Vertical Scale: 1 inch = 20 ft.

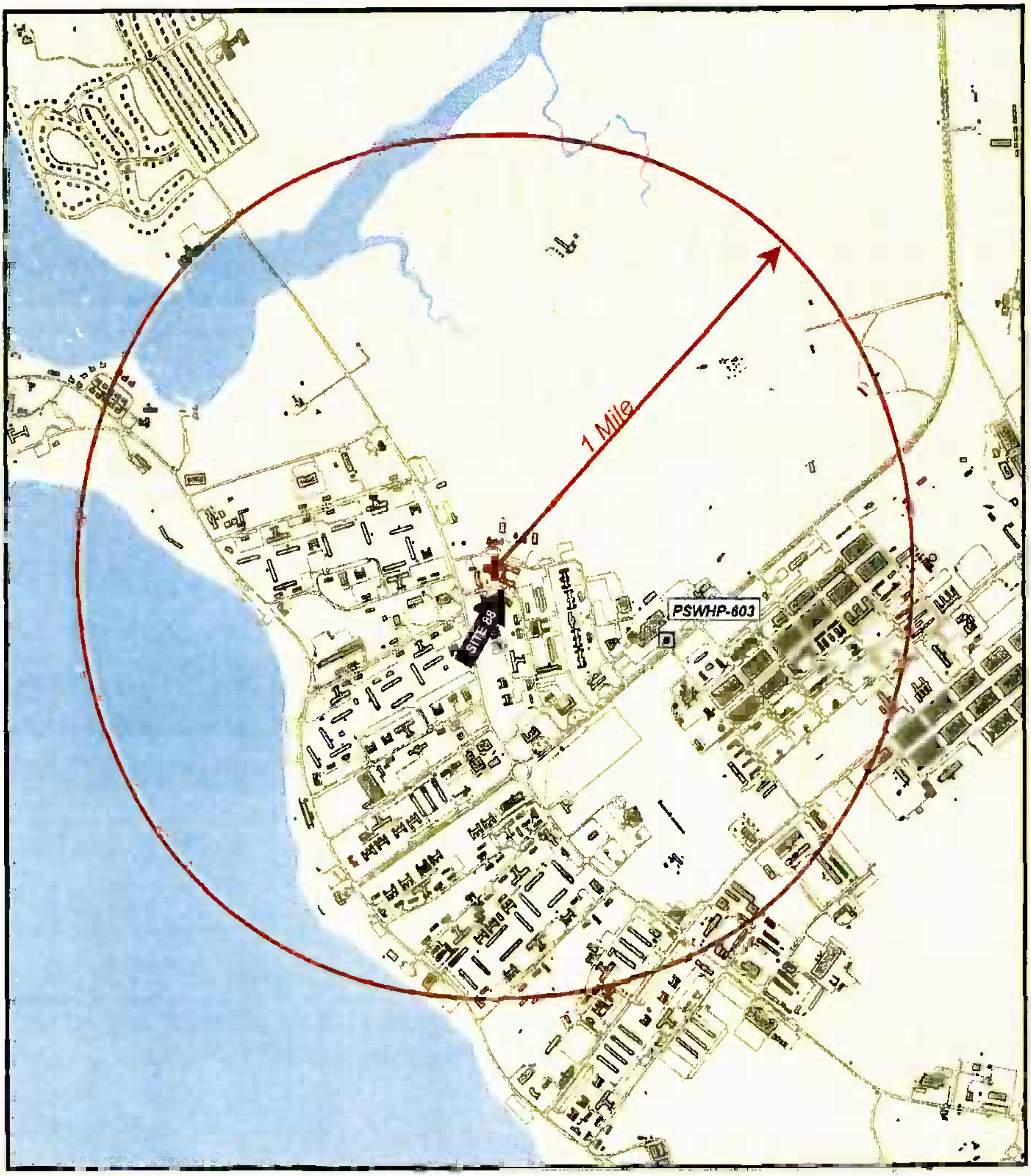
THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

FIGURE 3-12
HYDROGEOLOGIC CROSS-SECTIONS C-C' AND D-D' SHOWING GROUNDWATER POTENTIOMETRIC SURFACE LINES
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO - 0356

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02020N18Y

02020N14Y



LEGEND

● Monitoring Well Related to RI

PSWHP-603
▣ Inactive Potable Supply Well (Typical)

Scale
1000 0 1000 2000 3000 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

POTABLE SUPPLY WELLS
WITHIN 1 MILE RADIUS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO-0356

Baker

FIGURE 3 - 13

4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the results of the Remedial Investigation (RI) performed at OU No. 15 (Site 88). The objective of the section is to characterize the nature and extent of contamination at Site 88. This characterization was accomplished by specific laboratory analysis of environmental samples including subsurface soil and groundwater. The positive detection summary tables and detection figures referenced in the text are presented at the end of Section 4.0. A complete summary of the analytical data is included in Appendix H.

Presentation of the analytical data includes a comparison of site data to established standards and/or criteria. The standards and criteria chosen for evaluation are media specific and help to provide a reasonable assessment of site conditions. An explanation of each of the standards and criteria are presented in Section 4.4.

The analytical results for Quality Assurance/Quality Control (QA/QC) samples are presented in Section 4.3. The QA/QC results include duplicate samples in Appendix I and blank samples included in Appendix J.

4.1 Data Quality

The fixed-base laboratory data generated during the two investigation phases were submitted for third-party validation to determine the usability of the data. Procedures stipulated by the National Functional Guidelines for Organic Analyses (USEPA, 1991) were observed during the validation process. Validation of the analytical data serves 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 (USEPA, 1989). 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).

4.2 Data Management and Tracking

The management and tracking of environmental samples from the time of field collection to the receipt of the validated electronic analytical results is of primary importance and reflects the overall quality of the laboratory results. Field samples and their corresponding analytical tests were recorded on the chain-of-custody sheets, which are included in Appendix C. The chain-of-custody records were compared to the sampling plan to determine if all designated samples were collected for the appropriate parameters. Similarly, the validated information was compared to laboratory information as a final check. In summary, the tracking information was used to identify the following items:

- Identify sample discrepancies between the sampling 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.

4.3 Non-Site Related Analytical Results

Some of the organic compounds detected in environmental media at Site 88 may be attributable to non-site related conditions or activities. Two primary sources of non-site related analytical results include laboratory contaminants and non-site related operational activities. A discussion of non-site related analytical results for Site 88 is provided in the subsections which follow.

4.3.1 Laboratory Contaminants

Field blank trip blank and method blanks samples provide a measure of contamination that has been introduced into a sample set during the collection, transportation, preparation, or analysis of samples. To remove non-site related constituents 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 (e.g., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) were retained for use in interpreting site conditions only when observed concentrations in any environmental sample 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, its presence among the data set was attributed to laboratory contamination in that particular sample (USEPA, 1989) and excluded from further evaluation. The maximum concentrations of detected common laboratory contaminants in blanks were as follows:

• Bromodichloromethane	7 J µg/L
• bis-(2-Ethylhexyl)phthalate	4 J µg/L

Neither of these compounds was detected in samples at Site 88. Thus, the detection of these compounds in blanks did not effect the data set.

4.3.2 Non-Site Related Contaminants

Organic constituents that are not considered common laboratory contaminants (i.e., all other TCL compounds) were retained in the site analytical database only when observed concentrations exceeded five times the maximum concentration detected in any QA/QC blank (USEPA, 1989). All TCL compounds detected at less than five times the maximum level of contamination noted in any QA/QC blank were attributed to blank contamination and excluded from further evaluation. The maximum concentrations of all other detected blank contaminants were as follows:

• Pyrene	1J µg/L
• Chloroform	21 µg/L

The analytical results obtained from the QA/QC samples demonstrate that the data is reliable and useful for assessing the conditions at OU No. 17 (Site 88). However, the field blank samples collected from the potable water source used during drilling detected low concentrations of chloroform. Detections of chloroform from a potable water source are not uncommon as the compound can be introduced to the water supply as part of the chlorination process for treating potable water.

Chloroform was frequently detected in groundwater samples from the temporary monitoring wells in which the potable water source was used while drilling. Water was used to prevent loose sands from flowing into the hollow stem augers during drilling. As the chloroform was present in the potable water source used for drilling, its detection in the environmental samples was not considered to be site related.

The presence of trace amounts of chloroform (which may be indicative of the presence of potable water) may bias the analytical results low compared to actual conditions. However, VOC concentrations were typically high enough, such that the temporary monitoring wells provided sufficient information for screening purposes. It is important to note that the screening results were only intended to give preliminary estimates of the plume geometry. In addition, permanent monitoring wells were installed at the site for full characterization. The permanent monitoring wells provide accurate groundwater data, and provide fixed points from which future samples can be obtained.

4.4 State and Federal Criteria and Standards

Contaminant concentrations in groundwater can be compared to contaminant-specific established State and Federal criteria and standards. The only enforceable Federal regulatory standards for water are the Federal Maximum Contaminant Levels (MCLs). Federal Risk -Based Concentrations (RCBs) were also compared to levels of organic constituents in the groundwater water. In addition to the Federal standards, the State of North Carolina has developed the North Carolina Water Quality Standards (NCWQS) for groundwater and surface water.

In general, chemical-specific criteria and standards are not available for soil. RCBs were compared to levels of organic constituents in the subsurface soil to provide an indication of the health risks associated with the presence of organic constituents. Additionally, USEPA Soil Screening Levels were compared to levels of organic constituents in the subsurface soil to assist with the selection of contaminants of potential concern. A brief explanation of the criteria and standards used for the comparison of site analytical results is presented below.

Region III Risk -Based Concentrations (RBCs) - March, 1997 - RBC values are derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. The RBCs for potentially carcinogenic chemicals are based on a target Incremental Cancer Risk (ICR) of $1x10^{-6}$. The RBCs for noncarcinogens are based on a target hazard quotient of 1.0. In order to account for cumulative risk from multiple chemicals in a medium, it is necessary to derive the RBCs based on a target hazard quotient of 0.1. Re-derivation of the noncarcinogenic RBCs based on a target hazard quotient of 0.1, while using the most recent toxicological criteria available, results in a set of values that can be used as screening values. In order to provide the accurate screening values, the noncarcinogenic RBCs were divided by a factor of ten. For potential carcinogens, the toxicity criteria applicable to the derivation of RBC values are oral and inhalation cancer slope factors (CSFs); for noncarcinogens, they are chronic oral and inhalation reference doses (RfDs). These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of RBC values requires that the screening concentrations be updated periodically to reflect changes in the toxicity criteria. The RBC table is issued on a semi-annual basis.

USEPA Soil Screening Levels (SSLs) December 1994 - SSLs are not national cleanup standards, nor do they alone trigger the need for remedial response. Soil screening is a process of identifying areas and contaminants that do not require any further Federal action. By identifying areas where concentrations of contaminants are below levels of concern, the focus of resources can be on exposure areas, COPCs and exposure pathways (USEPA, 1994). SSLs can be generic, where no site data is available. SSLs can also be site-specific (by either a simple method or detailed approach). The simple method determines SSLs for the site using site-specific parameters such as dry bulk density, fractional organic content and percent moisture. A detailed approach involves the collection of additional data that allows the application of fate and transport models. Simple Method SSLs were used herein. The derivation of site-specific SSLs is provided in Appendix G.

North Carolina Water Quality Standards (Groundwater) NCWQS, 1994 - NCWQSs are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which otherwise render the groundwater unsuitable for its intended purpose.

Federal Maximum Contaminant Levels - February, 1996 - Federal MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act (SDWA) and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply.

4.5 Nature of Contamination

The nature of contamination focuses on VOCs detected in soil and groundwater samples at Site 88. The objective of this section is to characterize the nature of such contamination that is present as a result of past waste management activities at Building 25.

4.5.1 Soil Investigation

Chlorinated solvent compounds are the primary contaminants in subsurface soils. A total of 39 subsurface soil samples were collected in the two investigation phases. Twenty Phase I Investigation subsurface soil samples were analyzed via on-site mobile laboratory (EPA Method 8240). Nineteen Phase II Investigation subsurface soil samples were analyzed via fixed-base laboratory (CLP Methods). The two analytical methods contain slightly different sets of VOCs. For example, both methods analyze for PCE and TCE, however, only 8240 analysis includes cis-1,2-DCE and trans-1,2-DCE, while only CLP analysis includes carbon disulfide.

A summary of the positive detections of all compounds is provided on Table 4-1. The most frequently detected compound, PCE, was detected in 18 of the 29 samples. The next most-frequently detected compound was TCE, which was detected in 8 of 29 samples. Other VOCs detected include; acetone (6 of 1 samples), chloroform (2 of 29 samples), and cis-1,2-DCE (1 of 18 samples). Detections of VOCs ranged from 0.1 ppb (chloroform) to 237.6 ppb (PCE). No detected VOC exceeded the US EPA Region III Residential RBCs (risk-based concentrations). Four samples exceeded the USEPA SSLs for PCE and no samples exceeded the USEPA SSLs for TCE or DCE.

Acetone appears to be a soil contaminant, but is not likely related to activity conducted at Site 88. Acetone was detected in 9 of 20 soil samples, but was not detected in any of the field blanks. The number of detections in soil samples and that lack of detections in the field blanks suggests that acetone is not a laboratory artifact. However, information collected during the RI does not indicate that acetone is related to activities at Site 88. Acetone is not a degradation product of PCE, nor is there a history of its use at the site. Additionally, there is no pattern to the acetone concentration distribution that suggests that Building 25 might be a source. Acetone occurs in only a few locations scattered across the site. Acetone can be present in the environment due to several natural and artificial sources (Howard, 1990). Acetone has been found as naturally occurring in some plants and can be released during forest fires. Acetone may be present in stack emissions, fugitive emissions, and is a byproduct of a few manufacturing processes. Acetone is also a product of photoxidation of alkanes and alkenes found in urban air. Other sources of acetone include wood-burning fireplaces and tobacco smoke.

Chloroform is not considered to be a soil contaminant. Chloroform was detected at low, consistent levels and is believed to be a mobile laboratory contaminant.

Carbon disulfide is not considered to be a soil contaminant. Carbon disulfide was detected in only one soil sample, at an estimated value below the detection limit. Carbon disulfide can occur naturally by the action of microorganisms living in marshy environments. It is related to the natural biodegradation of organic material.

4.5.2 Groundwater Investigation

Chlorinated solvent compounds are the primary contaminants in groundwater at Site 88. A total of 62 groundwater water samples have been collected at the site from the Phase I and II Investigation and analyzed by fixed-base and mobile laboratories. Forty-one samples from the temporary monitoring wells were analyzed for select VOCs by an on-site mobile laboratory in both Phase I and Phase II activities (USEPA Method 8240). The temporary wells were used to delineate the extent of contamination. A summary of the positive detections from the temporary wells is provided on Table 4-2. Twenty-one samples from the permanent monitoring wells were analyzed for TCL VOCs by CLP methods. The permanent wells, in conjunction with the temporary wells were used to further characterize the nature of the contamination. A summary of the positive detections from all 62 samples is provided on Table 4-3.

The mobile laboratory 8240 methods from the Phase I and II Investigations contain slightly different sets of VOCs. As previously mentioned, the fixed-based laboratory CLP Methods also contain slightly different sets of VOCs as compared to the mobile laboratory.

Forty-one groundwater samples were collected from the temporary wells during the two phases of work. PCE was most frequently detected in these wells (26 of 41 samples). TCE was the next most-frequently detected compound (19 of 41 samples). Other VOC detections include chloroform (18 of 41 samples), cis-1,2-DCE (14 of 41 samples), trans-1,2-DCE (9 of 41 samples), 1,1,1-trichloroethane (4 of 41 samples), 1,1-dichloroethene (2 of 18 samples), and toluene (1 of 18 samples). The maximum concentration observed in the temporary wells was for PCE, at 54,881.7 ppb. The minimum concentration observed was for PCE and chloroform, at 0.1 ppb.

Chlorinated solvent compounds were also detected in the permanent wells, Table 4-3 includes both mobile and fixed-base laboratory results from temporary and permanent wells to provide a maximum number of data points to characterize the nature of contamination. The most frequently detected compound was PCE (33 of 62 samples), followed by TCE (28 of 62 samples), trans-1,2-DCE (18 of 62 samples), and cis-1,2-DCE (14 of 41 samples). Other VOC detections included chloroform (19 of 62 samples), 1,1-dichloroethene (4 of 39 samples), 1,1,1-trichloroethane (4 of 62 samples), toluene (1 of 39 samples), and vinyl chloride (1 of 62 samples). The maximum concentration observed in the permanent wells was for PCE, at 9,100 ppb. The minimum concentration observed was of PCE and chloroform, at 0.1 ppb.

The data from the DNAPL investigation provided relevant information regarding the nature of groundwater contamination at Site 88. Three groundwater samples were collected as a part of the DNAPL investigation. PCE and the daughter products TCE and cis-1,2-DCE were detected in all three groundwater samples. The concentration of VOCs in groundwater ranged from 1,500 ppb (cis-1,2-DCE) to 170,000 ppb (PCE).

The presence of many of the volatile organic compounds in groundwater are considered to be a result of previous site operations. However, three of the compounds detected are considered not to be related to previous site operations. These compounds include chloroform, 1,1,1-trichloroethane, and toluene. These compounds are discussed in the paragraphs which follow.

The detections of chloroform in the groundwater samples is not considered to be site related. The presence of chloroform in the groundwater samples is most likely related to contamination from the mobile laboratory used during sampling of the temporary monitoring wells.

The compounds 1,1,1-trichloroethane and toluene are not directly related to dry cleaning, but are common. 1,1,1-Trichloroethane is a common solvent found in many consumer and industrial products. Toluene is typically associated with gasoline. Such sources for these compounds are prevalent at MCB Camp Lejeune.

Many of the VOC detections were at concentrations that exceeded comparison criteria. Since the NC WQS values are equal to, or lower than, the federal MCL values, the detections are discussed herein to the NC WQS as a more conservative comparison. Of the 33 detections of PCE, 24 exceeded the NC WQS. The TCE NC WQS was exceeded in 24 of 28 detections. The cis-1,2-DCE NC WQS was exceeded in 8 of 14 detections. The trans-1,2-DCE NC WQS was exceeded in 2 of 18 detections. The vinyl chloride NC WQS was exceeded in 1 of 1 detections. The 1,1-DCE NC WQS was exceeded in 1 of 4 detections. The detections of 1,1,1-trichloroethane and toluene did not exceed their respective NC WQS values.

4.6 Extent of Contamination

The extent of contamination focuses on chlorinated solvents detected in soil and groundwater samples at Site 88. The objective of this section is to characterize the extent of such contamination that is present as a result of past waste management activities conducted at Building 25.

4.6.1 Extent of Soil Contamination

Limited subsurface soil contamination is evident at Site 88. No contaminant concentrations exceeded RBCs, however several soil borings exhibited concentrations above USEPA SSL. Figure 4-1 depicts the distribution and extent of chlorinated solvent compounds that exceed USEPA SSLs. These exceedances occur under and near Building 25 and along a line of borings that parallels an underground sewer line. Section 5.3 discusses the role of the underground sewer line as a contaminant migration pathway. (It appears that leakage of solvent-contaminated sewer water has contaminated subsurface soils near the sewer line.) Based on this pattern of detections in soil samples, it appears that the soil contamination is related to waste/product management practices at Building 25. The presence of VOCs were not evident in soil samples from borings in the vicinity of the EMD building, the water tower, or the military police building.

Free phase and residual phase DNAPL (PCE) contamination is confined to areas under, and on the north side of Building 25. This information is based on DNAPL investigations conducted by DE&S. At the current time it is believed that the silt/clay layer is a capillary barrier to the downward migration of DNAPL in the vicinity of Building 25. Results of the DNAPL investigation suggest that the clayey layer is continuous in the vicinity of the DNAPL area, and that DNAPL has accumulated on top of the clayey layer. A report detailing the nature and extent of DNAPL contamination has not yet been issued by Duke. Therefore, detailed findings are not presented herein.

4.6.2 Extent of Groundwater Contamination

Groundwater contamination is evident at Site 88. PCE, TCE, and cis-1,2-DCE were detected above NC WQS in a number of samples from shallow and intermediate monitoring wells (both permanent and temporary). Figure 4-2 depicts the distribution and extent of PCE, TCE, and cis-1,2-DCE NC WQS exceedences in shallow monitoring wells. Figure 4-3 depicts the distribution and extent of PCE, TCE, and cis-1,2-DCE NC WQS exceedences in intermediate monitoring wells.

Figure 4-2 shows the exceedences in shallow groundwater to be distributed in areas northwest and south of Building 25. The highest PCE concentrations in the data set were observed at wells 88-TW08 (15 feet bgs, per Table 2-2) and 88-TW22 (25 feet bgs), at levels around 55,000 ppb. These wells are located 200 to 400 feet northwest of the building, respectively. It should be noted that samples from wells installed close to Building 25 during the DNAPL investigation exhibited concentrations of approximately 170,000 ppb. These wells do not appear on this figure as they are a part of a separate investigation. Section 5.3 discusses source area locations and contaminant migration.

Figure 4-3 shows the exceedences in intermediate groundwater to be distributed northwest, north, and south of Building 25. The highest contaminant concentrations were generally observed in wells in the immediate vicinity of, and northwest of Building 25. For example, the highest concentration of PCE in the data set have been observed at well 88-TW22IW (50 feet bgs) and 88-MW02IW (50 feet bgs, per Table 2-3). Other wells with elevated concentrations of PCE include 88-MW03IW (50 feet bgs), 88-MW05IW (50 feet bgs), 88-TW08IW (44 feet bgs), and 88-TW05IW (50 feet bgs).

Trace levels of chlorinated solvent compounds were detected in one deep well, 88-MW05DW (85 feet bgs, per Table 2-3). These compounds include PCE (4J ug/L), trans 1,2-DCE (2J ug/L), and TCE (4J ug/L). These compounds were detected below method detection limits and the values were estimated. TCE and PCE estimated levels exceed NC WQS, but neither exceed Federal MCLs.

It is apparent that dissolved-phase chlorinated solvent compounds have traveled downward, through the silt/clay layer (where present) and impacted the intermediate well groundwater zone, and to a much lesser extent, the deep well groundwater zone. There is no evidence at this time to suggest that immiscible liquids (DNAPL) have migrated below the silt/clay layer into the Castle Hayne Aquifer. Concentrations of PCE and TCE are below 10 % of the solubility limit for each compound (an indicator of the presence of DNAPL).

4.7 Summary

The primary contaminants of concern at OU No. 15 (Site 88) are PCE and its daughter products, TCE and cis-1,2-DCE, which have impacted groundwater in the surficial aquifer and the upper portion of the Castle Hayne Aquifer. The data collected as part of the RI demonstrate that a distinct contaminant plume is present at OU No. 15. The pattern of the distribution of groundwater contamination as illustrated on Figures 4-2, and 4-3 suggest that the Building 25 area is a source area. The shallow groundwater has been impacted by VOCs in the area northwest and south of Building 25. The shallow contaminant plume has migrated approximately 700 feet west-northwest and northwest of Building 25. The shallow contaminant plume has also migrated approximately 300 feet south of Building 25.

Groundwater at the intermediate depth (approximately 50 feet bgs) has also been affected at Site 88. The contaminants in the area of Building 25 have migrated vertically and are present in the upper portions of the Castle Hayne Aquifer. A discontinuous clayey layer at approximately 20 feet bgs appears not to have limited the vertical migration of dissolved-phase contaminants. At the intermediate depth, the dissolved-phase contaminants have migrated approximately 700 feet to the northwest and 500 feet to the southwest of Building 25. Trace levels of dissolved-phase contaminants were detected in one deep monitoring well, namely 88-MW05DW.

The impact on subsurface soils is limited at Site 88. The highest levels of chlorinated solvents detected in subsurface soils occur under and near Building 25 and along an underground sewer line. The USEPA SSLs confirm that the subsurface soils in these areas warrant further consideration. The contaminants in these soils will be addressed in the qualitative risk assessment.

4.8 References

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USEPA. 1994. Soil Screening Guidance. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/R-94/101 PB95-963529. December, 1994.

SECTION 4.0 TABLES

TABLE 4-1
POSITIVE DETECTION SUMMARY
SUBSURFACE SOIL - VOLATILE ORGANICS
PHASE I - MOBILE LABORATORY
PHASE II - FIXED BASE LABORATORY
FOCUSED REMEDIAL INVESTIGATION CTO-0356
OPERABLE UNIT NO. 16 (SITE 88)
MCB CAMP LEJEUNE, NORTH CAROLINA

	Region III Residential RBCs (Risk) (ug/kg)	USEPA Soil Screening Levels (ug/kg)	Min Detect	Max Detect	Location of Maximum Detect	Detection Frequency	Region III Residential RBCs (Risk) Exceedance Count	USEPA Soil Screening Levels Exceedance Count
VOLATILES (ug/kg)								
ACETONE	780000	3608.3	12	120 J	IR88-MW06IW-06	6/11	0	0
CHLOROFORM	100000	2.2	0.1	0.1	IR88-TW14-03,IR88-TW15-04	2/29	0	0
CIS-1,2-DICHLOROETHENE	78000	66.5	21	21	IR88-TW15-04	1/18	0	0
TETRACHLOROETHENE	12000	25.9	0.1	237.6	IR88-TW08-03	18/29	0	4
TRICHLOROETHENE	58000	46.6	0.1	16	IR88-SB04-04	8/29	0	0

TABLE 4-2
POSITIVE DETECTION SUMMARY
GROUNDWATER - VOLATILE ORGANICS
PHASE I AND II MOBILE LABORATORY
FOCUSED REMEDIAL INVESTIGATION CTO-0356
OPERABLE UNIT NO. 15 (SITE 88)
MCB CAMP LEJEUNE, NORTH CAROLINA

	NC WQS (ug/L)	US - Primary MCL (ug/L)	Region III TW RBCs (Risk) (ug/L)	Min Detect	Max Detect	Location of Maximum Detect	Detection Frequency	NC WQS Exceedance Count	US - Primary MCL Exceedance Count	Region III TW TBCs (Risk) Exceedance Count
VOLATILES (ug/L)										
1,1,1-TRICHLOROETHANE	200	200	79	0.2	0.5	IR88-TW08-01	4/41	0	0	0
1,1-DICHLOROETHENE	7	7	0.044	0.3	1.9	IR88-TW28IW-01	2/18	0	0	2
CHLOROFORM	0.19	100/80	0.15	0.1	13.8	IR88-TW28IW-01	18/41	16	0	16
CIS-1,2-DICHLOROETHENE	70	70	6.1	1	3725	IR88-TW15-01	14/41	8	8	11
TETRACHLOROETHENE	0.7	5	1.1	0.1	54881.7	IR88-TW22-01	26/41	17	15	17
TOLUENE	1000	1000	75	7	7	IR88-TW22IW-01	1/18	0	0	0
TRANS-1,2-DICHLOROETHENE	70	100	12	1	38	IR88-TW15-01	9/41	0	0	1
TRICHLOROETHENE	2.8	5	1.6	0.2	3030.9	IR88-TW15-01	19/41	15	14	15

TABLE 4-3
POSITIVE DETECTION SUMMARY
GROUNDWATER - VOLATILE ORGANICS
PHASE I AND II MOBILE LABORATORY AND
PHASE II - FIXED BASE LABORATORY
FOCUSED REMEDIAL INVESTIGATION CTO-0356
OPERABLE UNIT NO. 15 (SITE 88)
MCB CAMP LEJEUNE, NORTH CAROLINA

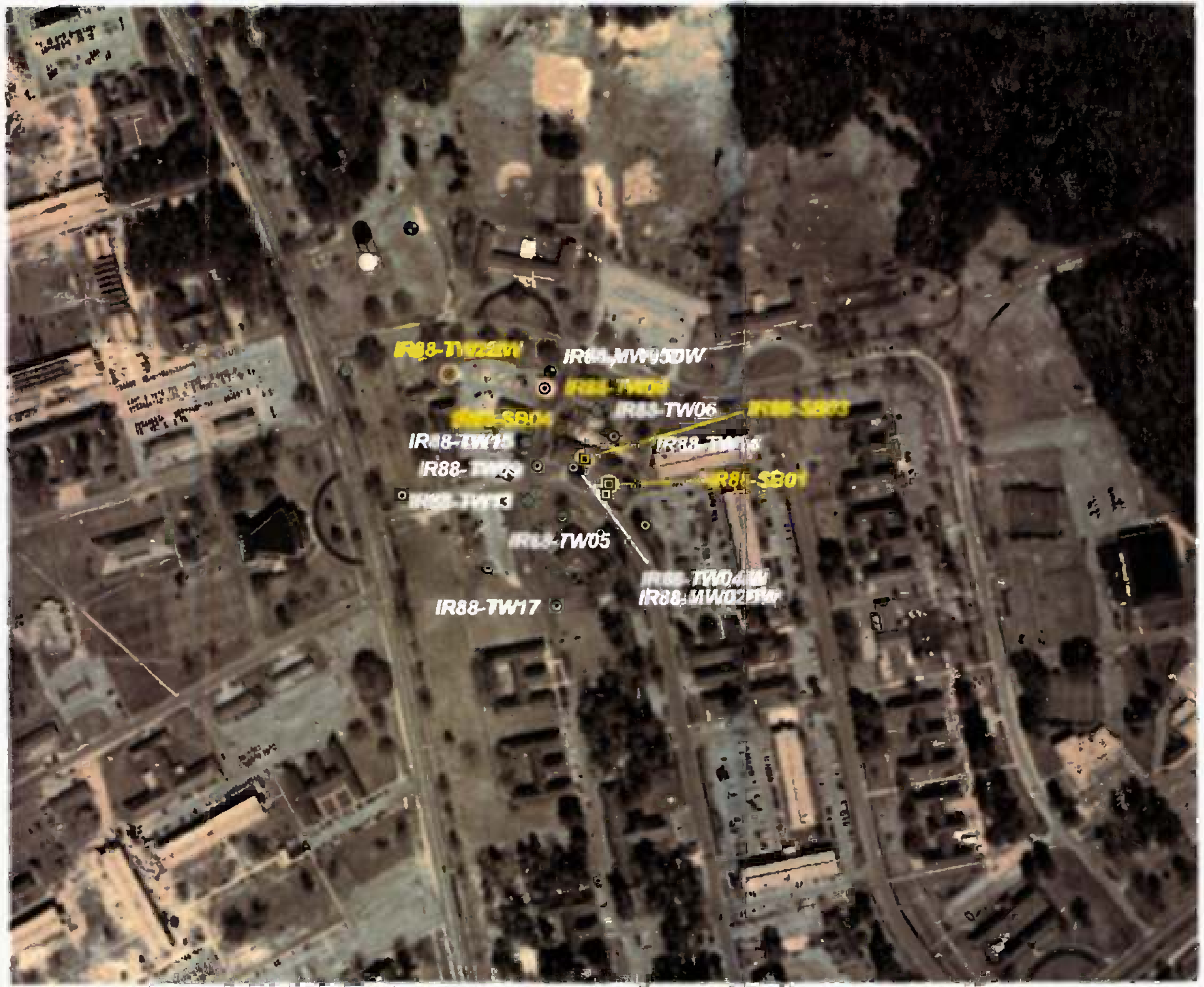
	NC WQS (ug/L)	US - Primary MCL (ug/L)	Region III TW RBCs (Risk) (ug/L)	Min Detect	Max Detect	Location of Maximum Detect	Detection Frequency	NC WQS Exceedance Count	US - Primary MCL Exceedance Count	Region III TW TBCs (Risk) Exceedance Count
VOLATILES (ug/L)										
1,1,1-TRICHLOROETHANE	200	200	79	0.2	0.5	IR88-TW08-01	4/62	0	0	0
1,1-DICHLOROETHENE	7	7	0.044	0.3	7 J	IR88-MW07IW-01	4/39	1	1	4
CHLOROFORM	0.19	100/80	0.15	0.1	13.8	IR88-TW28IW-01	19/62	17	0	17
CIS-1,2-DICHLOROETHENE	70	70	6.1	1	3725	IR88-TW15-01	14/41	8	8	11
TETRACHLOROETHENE	0.7	5	1.1	0.1	54881.7	IR88-TW22-01	33/62	24	20	24
TOLUENE	1000	1000	75	7	7	IR88-TW22IW-01	1/39	0	0	0
TRANS-1,2-DICHLOROETHENE	70	100	12	1	600	IR88-MW05IW-01	18/62	2	2	8
TRICHLOROETHENE	2.8	5	1.6	0.2	3030.9	IR88-TW15-01	28/62	24	21	24
VINYL CHLORIDE	0.015	2	0.019	4 J	4 J	IR88-MW07IW-01	1/62	1	1	1

SECTION 4.0 FIGURES

POSITIVE DETECTIONS - SITE 88 SOIL

Sample ID	Compound	Result (ug/kg)	Date_samp	Depth (ft)
IR88-MW02DW-05	TETRACHLOROETHENE	4 J	4/20/97	9-11
IR88-MW05DW-05	TETRACHLOROETHENE	7 J	4/20/97	9-11
IR88-SB01-02	TETRACHLOROETHENE	$\boxed{200}$	4/20/97	3-5
IR88-SB03-02	TETRACHLOROETHENE	$\boxed{56 J}$	4/20/97	3-5
IR88-SB03-02	TRICHLOROETHENE	3 J	4/20/97	3-5
IR88-SB04-04	TETRACHLOROETHENE	$\boxed{38}$	5/06/97	7-9
IR88-SB04-04	TRICHLOROETHENE	16	5/06/97	7-9
IR88-TW04IW-03	TETRACHLOROETHENE	14.8	8/16/96	5-7
IR88-TW04IW-03	TRICHLOROETHENE	0.2	8/16/96	5-7
IR88-TW05-04	TETRACHLOROETHENE	1.2	8/16/96	7-9
IR88-TW05-04	TRICHLOROETHENE	0.1	8/16/96	7-9
IR88-TW06-03	TETRACHLOROETHENE	0.4	8/16/96	5-7
IR88-TW07-03	TETRACHLOROETHENE	0.1	8/16/96	5-7
IR88-TW08-03	TETRACHLOROETHENE	$\boxed{237.6}$	8/16/96	5-7
IR88-TW08-03	TRICHLOROETHENE	0.8	8/16/96	5-7
IR88-TW09-04	TETRACHLOROETHENE	22.6	8/16/96	7-9
IR88-TW09-06	TETRACHLOROETHENE	3.1	8/16/96	11-13
IR88-TW09-04	TRICHLOROETHENE	3.3	8/16/96	7-9
IR88-TW09-06	TRICHLOROETHENE	0.5	8/16/96	11-13
IR88-TW13-03	TETRACHLOROETHENE	1.5	8/17/96	5-7
IR88-TW13-05	TETRACHLOROETHENE	0.9	8/17/96	9-11
IR88-TW14-03	TETRACHLOROETHENE	0.3	8/17/96	5-7
IR88-TW15-04	TETRACHLOROETHENE	11.6	8/17/96	7-9
IR88-TW15-04	TRICHLOROETHENE	8.5	8/17/96	7-9
IR88-TW15-04	CIS-1,2-DICHLOROETHENE	21	8/17/96	7-9
IR88-TW16-04	TETRACHLOROETHENE	0.2	8/18/96	7-9
IR88-TW17-04	TETRACHLOROETHENE	0.2	8/18/96	7-9
IR88-TW22IW-05	TETRACHLOROETHENE	10	4/15/97	9-11
IR88-TW22IW-06	TETRACHLOROETHENE	$\boxed{399}$	4/15/97	11-13
IR88-TW22IW-06	TRICHLOROETHENE	13	4/15/97	11-13
IR88-TW22IW-06	CIS-1,2-DICHLOROETHENE	32	4/15/97	11-13

Note: Outlined results exceed the USEPA Soil Screening Level (SSL).



Notes:

All concentrations are reported in micrograms per kilogram (ug/kg).

J = Estimated value.

LEGEND

IR88-MW02DW ●	Soil Samples Collected from Permanent Monitoring Well Locations
IR88-TW04 ◎	Soil Samples Collected fromTemporary Monitoring Well Locations
IR88-SB01 ▣	Soil Boring Location
IR88-MW02DW ●	Soil Sample Location Exceeding the USEPA SSLs

Scale 500 0 500 1000 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

VOLATILE ORGANIC COMPOUNDS
IN SUBSURFACE SOIL SAMPLES
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 4 - 1

GROUNDWATER EXCEEDANCES - SITE 88 SHALLOW WELLS

Sample ID	Compound	Result (ug/l)	Sample Date	NCWQS
IR88-MW02	TETRACHLOROETHENE	9100	5/15/97	0.70
IR88-MW02	TRICHLOROETHENE	96 J	5/15/97	2.80
IR88-MW02	1,2-DICHLOROETHENE (TOTAL)	41 J	5/15/97	
IR88-MW05	TETRACHLOROETHENE	3000	5/13/97	0.70
IR88-MW05	TRICHLOROETHENE	42	5/13/97	2.80
IR88-MW05	1,2-DICHLOROETHENE (TOTAL)	38	5/13/97	
IR88-MW07	TRICHLOROETHENE	3 J	5/18/97	2.80
IR88-MW07	1,2-DICHLOROETHENE (TOTAL)	2 J	5/18/97	
IR88-MW08	TETRACHLOROETHENE	2 J	5/16/97	0.70
IR88-TW01	TETRACHLOROETHENE	157.2	8/1/96	0.70
IR88-TW01	TRICHLOROETHENE	17.7	8/1/96	2.80
IR88-TW02	TETRACHLOROETHENE	649.1	8/1/96	0.70
IR88-TW02	TRICHLOROETHENE	81.5	8/1/96	2.80
IR88-TW02	CIS-1,2-DICHLOROETHENE	445	8/1/96	70.00
IR88-TW03	TETRACHLOROETHENE	14090	8/1/96	0.70
IR88-TW03	TRICHLOROETHENE	838.1	8/1/96	2.80
IR88-TW03	CIS-1,2-DICHLOROETHENE	1184	8/1/96	70.00
IR88-TW04	TETRACHLOROETHENE	32839.4	8/1/96	0.70
IR88-TW04	TRICHLOROETHENE	229.9	8/1/96	2.80
IR88-TW05	TETRACHLOROETHENE	1381.7	8/16/96	0.70
IR88-TW05	TRICHLOROETHENE	20.8	8/16/96	2.80
IR88-TW08	TETRACHLOROETHENE	53703.8	8/17/96	0.70
IR88-TW08	TRICHLOROETHENE	341.2	8/17/96	2.80
IR88-TW08	CIS-1,2-DICHLOROETHENE	271	8/17/96	70.00
IR88-TW09	TETRACHLOROETHENE	969.2	8/17/96	0.70
IR88-TW09	TRICHLOROETHENE	70.8	8/17/96	2.80
IR88-TW11	TETRACHLOROETHENE	1.3	8/17/96	0.70
IR88-TW12	TETRACHLOROETHENE	1.5	8/17/96	0.70
IR88-TW13	TETRACHLOROETHENE	44.3	8/17/96	0.70
IR88-TW15	TETRACHLOROETHENE	4931.8	8/18/96	0.70
IR88-TW15	TRICHLOROETHENE	3030.9	8/18/96	2.80
IR88-TW15	CIS-1,2-DICHLOROETHENE	3725	8/18/96	70.00
IR88-TW22	TETRACHLOROETHENE	54881.7	4/21/97	0.70
IR88-TW22	TRICHLOROETHENE	124.9	4/21/97	2.80
IR88-TW22	CIS-1,2-DICHLOROETHENE	126	4/21/97	70.00

Notes:

Table presents conentrations exceeding the North Carolina Water Quality Standards (NCWQSs).

All concentrations are reported in micrograms per liter (ug/l).

J = Estimated value.

LEGEND

/\/	Extent of Tetrachloroethene (PCE) Contamination	IR88-MW05 ●	Permanent Monitoring Well Location
/\/	Extent of Trichloroethene (TCE) Contamination	IR88-TW01 ⊙	Temporary Monitoring Well Location
/\/	Extent of cis-1,2-Dichloroethene (cis-1,2-DCE) Contamination	IR88-MW05 ●	Contaminant Concentrations Exceeded the NCWQS

Scale 500 0 500 1000 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

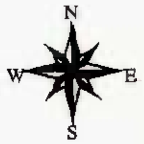
VOLATILE ORGANIC COMPOUNDS
IN GROUNDWATER (SHALLOW WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 4 - 2

GROUNDWATER EXCEEDANCES - SITE 88 INTERMEDIATE WELLS

Sample ID	Compound	Result (ug/l)	Sample Date	NCWQS
IR88-MW02IW	TETRACHLOROETHENE	3200	5/15/97	0.70
IR88-MW02IW	TETRACHLOROETHENE	3400	5/15/97	0.70
IR88-MW02IW	TRICHLOROETHENE	120 J	5/15/97	2.80
IR88-MW02IW	TRICHLOROETHENE	120 J	5/15/97	2.80
IR88-MW02IW	1,2-DICHLOROETHENE (TOTAL)	12 J	5/15/97	
IR88-MW02IW	1,2-DICHLOROETHENE (TOTAL)	12 J	5/15/97	
IR88-MW03IW	TETRACHLOROETHENE	1700	5/14/97	0.70
IR88-MW03IW	TRICHLOROETHENE	530	5/14/97	2.80
IR88-MW03IW	1,2-DICHLOROETHENE (TOTAL)	36	5/14/97	
IR88-MW05IW	TETRACHLOROETHENE	1400	5/13/97	0.70
IR88-MW05IW	TRICHLOROETHENE	910	5/13/97	2.80
IR88-MW05IW	1,2-DICHLOROETHENE (TOTAL)	600	5/13/97	
IR88-MW07IW	VINYL CHLORIDE	4 J	5/18/97	0.01
IR88-MW07IW	TRICHLOROETHENE	28	5/18/97	2.80
IR88-MW07IW	1,2-DICHLOROETHENE (TOTAL)	110	5/18/97	
IR88-MW09IW	TRICHLOROETHENE	29	5/16/97	2.80
IR88-MW09IW	1,2-DICHLOROETHENE (TOTAL)	48	5/16/97	
IR88-TW04IW	TETRACHLOROETHENE	21	8/16/96	0.70
IR88-TW04IW	TRICHLOROETHENE	5.5	8/16/96	2.80
IR88-TW05IW	TETRACHLOROETHENE	1142.7	8/18/96	0.70
IR88-TW05IW	TRICHLOROETHENE	71.2	8/18/96	2.80
IR88-TW05IW	CIS-1,2-DICHLOROETHENE	89	8/18/96	70.00
IR88-TW08IW	TETRACHLOROETHENE	1314.4	8/18/96	0.70
IR88-TW08IW	TRICHLOROETHENE	822.7	8/18/96	2.80
IR88-TW08IW	CIS-1,2-DICHLOROETHENE	883	8/18/96	70.00
IR88-TW20IW	TRICHLOROETHENE	7.1	4/21/97	2.80
IR88-TW22IW	TETRACHLOROETHENE	26592	4/21/97	0.70
IR88-TW22IW	TRICHLOROETHENE	13	4/21/97	2.80
IR88-TW22IW	CIS-1,2-DICHLOROETHENE	81	4/21/97	70.00
IR88-TW23IW	TETRACHLOROETHENE	15.8	4/21/97	0.70
IR88-TW28IW	TRICHLOROETHENE	4.1	4/30/97	2.80



Notes:

Table presents conentrations exceeding the North Carolina Water Quality Standards (NCWQSs).

All concentrations are reported in micrograms per liter (ug/l).

J = Estimated value.

LEGEND

∧/ Extent of Tetrachloroethene (PCE) Contamination	IR88-MW02IW ● Permanent Monitoring Well Location
∧/ Extent of Trichloroethene (TCE) Contamination	IR88-TW20IW ⊙ Temporary Monitoring Well Location
∧/ Extent of cis 1,2-Dichloroethene (cis-1,2-DCE) Contamination	IR88-MW02IW ● Contaminant Concentrations Exceeded the NCWQS

Scale 500 0 500 1000 Feet

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

VOLATILE ORGANIC COMPOUNDS
IN GROUNDWATER (INTERMEDIATE WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 4 - 3

5.0 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 significant contaminants in Site 88 media discussed in Section 4.5, and their fate and transport in the environment.

5.1 Chemical and Physical Properties Impacting Fate and Transport

Table 5-1 presents the physical and chemical properties associated with the organic compounds detected during these investigations. These properties determine the inherent environmental mobility and fate of a contaminant. The properties of interest include:

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

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 is generally higher than vapor pressures for polynuclear aromatic hydrocarbons (PAHs). Contaminants with higher vapor pressures (e.g., VOCs) will enter the atmosphere at a quicker rate than the contaminants with low vapor pressures (e.g., PCBs).

The rate at which a contaminant is leached from soil by infiltrating precipitation is proportional to its water solubility. More soluble contaminants are usually more readily leached than less soluble contaminants. 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 go into solution faster and possibly in greater concentrations than less soluble compounds. The solubility of a specific compound is dependent on the chemistry of the groundwater and aquifer material. Factors such as groundwater pH, Eh (redox potential), temperature, and the presence of other compounds can greatly affect the solubility.

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 coefficients 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 the organic carbon in soils. The solubility of a chemical in water is inversely proportional to the K_{oc}. Contaminants with high soil adsorption coefficients generally have low water solubilities. For example, contaminants such as PAHs are relatively immobile in the environment, are preferentially bound to the soil, and have a higher K_{oc} value. These compounds are not subject to aqueous transport to the extent of compounds with higher water solubilities. Mechanical activities (e.g., erosion) and the physical characteristics of surface soils may, however, increase the mobility of these bound soil 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 specified 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 relationship is 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 as presented by Ford and Gurba (1984) is:

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

The mobility index for each organic analyte detected at Site 88 is presented on Table 5-1.

5.2 Contaminant Transport Pathways

Based on the evaluation of existing conditions at Site 88, the following potential contaminant transport pathways have been identified.

- Leaching of soil contaminants to groundwater
- Dissolution of dense non-aqueous phase liquid (DNAPL) to groundwater
- Migration of groundwater contaminants

Contaminant concentrations may be affected by one or more mechanisms during transport. Contaminants may be physically transformed by volatilization or precipitation. Contaminants may be chemically transformed through photolysis, hydrolysis, oxidation/reduction. Contaminants may be biologically transformed by biodegradation. Additionally, contaminants may accumulate in one or more media.

The relative importance of some transport mechanisms is presented in Table 5-2. The paragraphs which follow describe the potential transport pathways listed above with respect to significant compound concentrations. Significant compound concentrations refers to those compounds discussed in Section 4.5 frequently occurring above criteria comparisons. Specific fate and transport concerns are discussed in Section 5.3.

5.2.1 Leaching of Soil Contaminants to Groundwater

Volatile organic compounds have been detected in soils generally concentrated under and around Building 25. Additionally, relatively high levels of VOCs, including free-phase product have been detected in soils in a small area on the north side of Building 25. VOCs were detected in groundwater primarily northwest and south of Building 25.

Contaminants that adhere to soil particles or have accumulated in soil pore spaces can leach and migrate vertically to the groundwater as a result of infiltration of precipitation. The rate and extent of this leaching 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.

5.2.2 Dissolution of DNAPL to Groundwater

DNAPL has been detected in the surficial aquifer, on the north side of Building 25. As groundwater passes through a DNAPL zone, the DNAPL will dissolve into the groundwater. Factors affecting the rate of dissolution include the chemical constituents of the DNAPL, the presence of organic carbon in the aquifer matrix, and the groundwater pH, Eh (redox potential), and temperature.

5.2.3 Migration of Groundwater Contaminants

Contaminants can migrate in either a dissolved phase or as an immiscible liquid. The paragraphs which follow discuss transport mechanisms of both dissolved-phase and immiscible-liquid contaminants.

A contaminant that is present in water above its solubility concentration will form an immiscible liquid. Based on the specific gravity of the contaminant, it will either float or sink in the water. In the case of chlorinated solvents (eg., PCE), the contaminant will sink in the water because it has a higher specific gravity than water. Subsurface transport of the immiscible contaminants is governed by a set of factors different from those of dissolved contaminants.

Movement of an immiscible liquid is controlled by entry conditions and flow conditions (Feenstra, et al., 1995). Entry of an immiscible liquid to a subsurface system is primarily controlled by the capillary phenomena. These phenomena arise from the fact that an interfacial tension is present between two mutually immiscible liquids (contaminant and water, or contaminant and air) in small pore space. Once in a subsurface system, the rate and direction of flow depends on the density and viscosity of the fluid, the pressure driving the fluid, the hydraulic conductivity of the formation, and the degree of saturation of the fluid in the formation (Feenstra, et al., 1995). Fluids denser than water will sink, fluids lighter than water will float. The driving pressure is related to the amount of fluid released into the environment. An immiscible liquid will flow faster where the fluid is already present in the formation. Contaminants from the immiscible liquids may then dissolve into groundwater, volatilize from groundwater to ground air, evaporate directly into ground air, or sorb from groundwater to solid surfaces.

Organics leaching from soil, or dissolving from a DNAPL source, into groundwater can migrate as dissolved constituents in groundwater in the direction of groundwater flow. Three general processes govern the migration of dissolved constituents in groundwater: advection, dispersion, and retardation. Advection is a process by which solutes are carried by groundwater movement. Dispersion is a mixing of contaminated and uncontaminated water during advection. Retardation is a slowing of contaminant migration caused by the reaction of the solute with the aquifer soil.

Advection is the process by which moving groundwater carries dissolved solutes (Fetter, 1988). Groundwater flow at Site 88 exhibits a horizontal and vertical component. Horizontal groundwater flow is complicated by the presence of two recharge areas. Groundwater recharge is apparent is the grassy area north and east of Building 25 and in the vicinity of the water tower. Surficial aquifer horizontal groundwater flow is multi-directional at velocities varying by two orders of magnitude, ranging from 0.02 to 3.0 feet/day. A strong vertical flow component is apparent between the shallow and intermediate monitoring wells. However, this vertical component of flow appears to be controlled the presence of a silt/clay layer. Because of the relative vertical hydraulic conductivity differences between the fine sand aquifer and the silt/clay layer, groundwater flows horizontally along the interface. Groundwater continues a downward flow at the edge of this silt/clay layer (in the vicinity of well clusters 88-MW04 and MW06). Groundwater flow in the upper portion of the Castle Hayne Aquifer flows to the north on a very low velocity (0.0005 feet/day). The vertical component to groundwater flow in the Castle Hayne Aquifer is relatively weak compared to that in the surficial 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 zone of lower concentration. Dispersion can occur in three directions, longitudinal (in the direction of flow), transverse (horizontally perpendicular to longitudinal), and vertical. Dispersion is largely scale dependent (i.e., the greater the area over which it is measured, the larger the dispersion value). Furthermore, longitudinal dispersion is often observed to be markedly greater than dispersion in the transverse direction of flow. It is often assumed that transverse dispersion is one-tenth longitudinal dispersion (Nichols, 1993). Lacking detailed site studies to determine dispersion, longitudinal dispersion can be estimated to be one-tenth of the length of the flow path, in the same lithologies (Fetter, 1988).

Retardation is a process whereby a solute concentration is reduced through a chemical, biological, or radioactive change. Solutes can be categorized in two broad classes: conservative and reactive. Conservative solutes do not react with aquifer groundwater and soil. Reactive solutes will interact with the aquifer soil encountered along the flow path through adsorption, partitioning, ion exchange, and other processes. A retardation factor (R) can be calculated by the following equation (Fetter, 1988):

$$R = 1 + (P_b/n)(K_d)$$

where:

P_b = dry bulk density of the soil
n = porosity of the soil
k_d = distribution coefficient for the solute with the soil (K_{oc} of the solute times the natural TOC content of the soil)

The following is a summary of estimated retardation factors for chlorinated VOCs detected in groundwater samples at Site 88:

	Solute Retardation Factor
cis-1,2-Dichloroethene (cis-1,2-DCE)	2.19
trans-1,2-Dichloroethene (trans-1,2-DCE)	2.28
Trichloroethene (TCE)	4.17
Tetrachloroethene (PCE)	9.91

The retardation factor calculations are provided in Appendix G. The lower the retardation factor, the faster the migration rate. The relative differences are useful for describing plume characteristics.

Natural biodegradation of chlorinated VOCs is slow according to U.S. Department of Health and Human Services' toxilogical profile manuals for these compounds. These manuals as well as other sources show that PCE will degrade to TCE. TCE will degrade primarily to cis-1,2-DCE, and to a lesser extent, trans-1,2-DCE. Cis-1,2-DCE will degrade to chloroethane and, to a lesser extent, vinyl chloride. Trans-1,2-DCE will degrade to vinyl chloride. This degradation process is also known as reductive dehalogenation.

5.3 Fate and Transport Summary

Volatile organic compounds, namely PCE and its daughter products TCE and cis-1,2-DCE, 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.

A DNAPL and dissolved contaminant plume are evident at Site 88. The compound PCE and its daughter products TCE and cis-1,2-DCE have been detected in wells located north, west, and south of Building 25. With the presence of a DNAPL source on the north side of Building 25, the dissolved contaminant plume in groundwater is expected to persist much longer than if a source were not present.

The exceedences of the NC WQS established for PCE, TCE, and cis-1,2-DCE in the shallow groundwater zone appears to be related to groundwater flow patterns and possibly the presence of underground sewer lines. Figure 5-1 shows the extent of groundwater exceedences superimposed on the shallow groundwater potentiometric surface map. The source area (the DNAPL area) is located on the northern side of Building 25. The extent of the contamination as shown on Figure 5-1 suggests that the dissolved chlorinated solvent contamination is migrating from the source area to the south and northwest, along groundwater flow lines. The groundwater flow direction, however, does not fully account for the northwestern migration of the dissolved contaminants. Figure 5-1 also shows the sanitary sewer layout in the vicinity of Building 25. This figure shows that the general shape of the PCE plume follows the sewer line. The figure shows that the sewer line lies on a groundwater divide, where groundwater flows generally to the north and south from the sewer line. It appears that the sewer line has enhanced the northwestward migration of contaminants from the source area. The TCE "finger" that extends north, past the water tower appears to be a result of reductive dehalogenation of PCE and lateral dispersion and is not related to the sewer line. It is apparent that flow in this portion of the sewer line is southerly.

The exceedences of the NC WQS established for PCE, TCE, and cis-1,2-DCE in the intermediate groundwater zone appears to be related to groundwater flow patterns. A strong vertical groundwater flow component is evident at Site 88 (Section 3.4.2). It appears that dissolved contaminants have migrated vertically downward to the intermediate zone and also spread laterally. It appears that the silt/clay layer has not precluded the vertical migration of dissolved constituents.

Some evidence of biodegradation is apparent. The information gathered for this RI suggests that the contaminant source is PCE. The Base Laundry has used PCE in its dry cleaning operations. There is no record of the use of TCE or cis-1,2-DCE at the site. Therefore, the presence of TCE and cis-1,2-DCE is likely as daughter products of PCE. This occurs through the reductive dehalogenation process.

The nearest downgradient receptor appears to be Beaver Dam Creek. This creek is located approximately 1,500 feet to the northeast of the site. Based on the contaminant concentration distribution, it does not appear that the contaminant plume is migrating in the direction of Beaver Dam Creek. The plume appears to be migrating towards the New River. However, the water tower groundwater recharge area is affecting the plume migration, by either deflecting it or impeding its progress.

Based on the contaminant concentration distribution, the vertical extent of the contaminant plume extends to a depth of approximately 50 feet bgs. Significant further vertical migration seems unlikely due to the small vertical component of groundwater flow between the intermediate and deep monitoring wells.

5.4 References

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SECTION 5.0 TABLES

TABLE 5-1

PHYSICAL AND CHEMICAL PROPERTIES FOR SELECT ORGANIC CHEMICALS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

Constituents	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	K_{oc}	log K_{ow}	Specific Gravity (g/cm^3)	Henry's Law Constant (atm-m^3/mole)	Mobility Index	Comments
Volatiles:								
Cis-1,2-Dichloroethene	208	3,500	35.5	1.69	--	7.58E-03	4.3	Very mobile
Trans-1,2-Dichloroethene	324	6,300	38	1.48	1.26	6.56E-03	4.7	Very mobile
Trichloroethene	57.9	1,100	94.3	2.38	1.46	9.10E-03	2.8	Very mobile
Tetrachloroethene	17.5	150,000	265	3.60	1	2.59E-02	4.0	Very mobile

Notes: -- = Value not available.

TABLE 5-2

RELATIVE IMPORTANCE OF PROCESSES INFLUENCING AQUATIC FATE OF SELECT ORGANIC CHEMICALS
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB CAMP LEJEUNE, NORTH CAROLINA

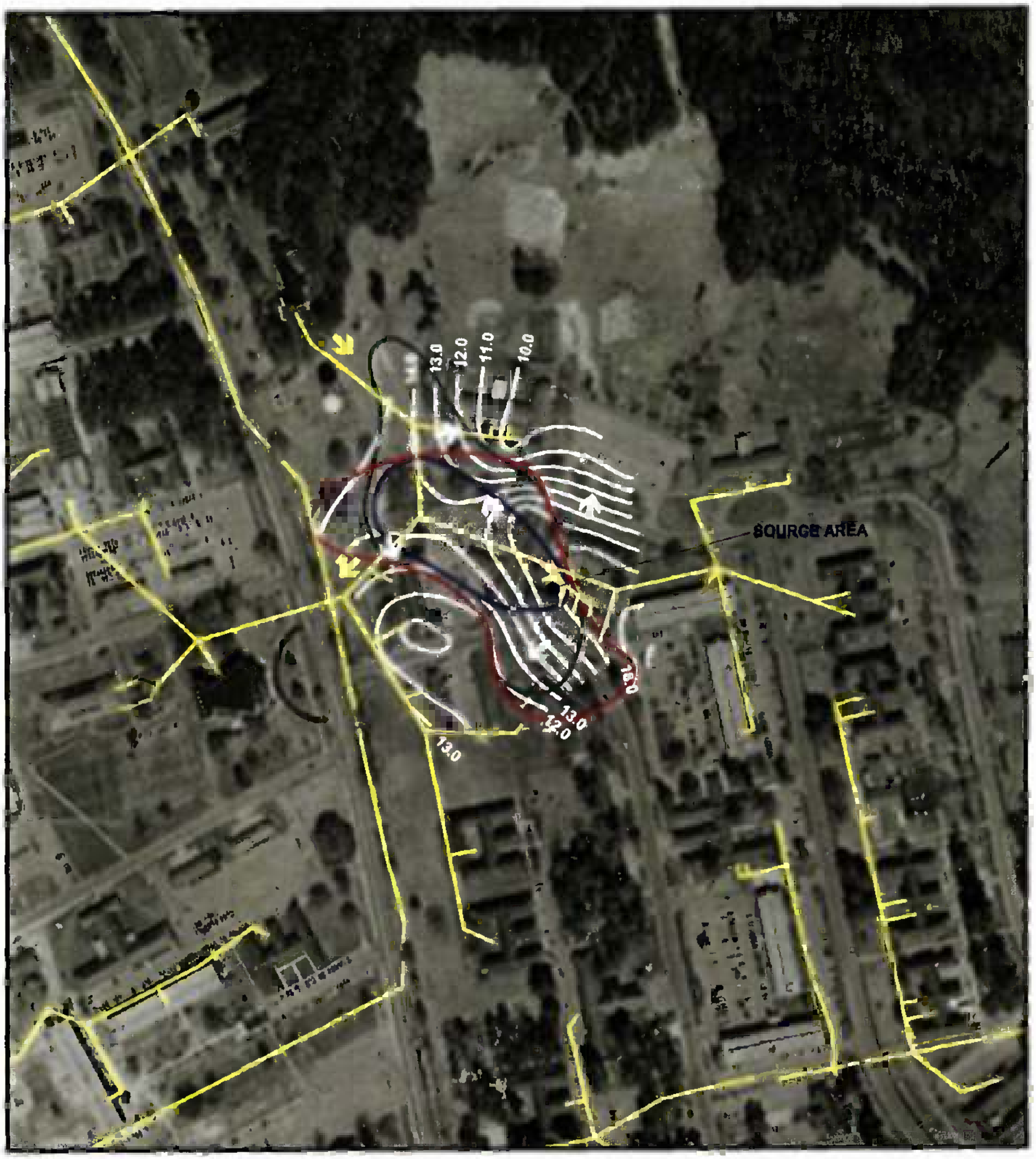
Constituents	Sorption	Volatilization	Biodegradation	Photolysis-Direct	Hydrolysis	Bioaccumulation
Volatiles: Cis-1,2-Dichloroethene	--	+	?	--	--	--
Trans-1,2-Dichloroethene	--	+	?	--	--	--
Trichloroethene	--	+	?	--	--	--
Tetrachloroethene	--	+	+	--	--	--

Key to Symbols:
+ Could be an important fate process
- Not likely to be an important process
? Importance of process uncertain or not known
NA - Information not avialable

Source: U.S. Environmental Protection Agency. September 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water - Part I. EPA/600-6-85/022a.

SECTION 5.0 FIGURES

02020N 23Y



LEGEND

Sanitary Sewer Lines

Extent of PCE Contamination

Extent of TCE Contamination

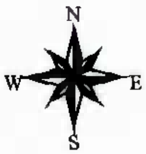
Extent of DCE Contamination

Shallow Groundwater Contour

Sewer Flow Direction

➔ Groundwater Flow Direction

300 0 Scale 300 600 Fee



MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

TRANSPORT OF VOLATILE ORGANIC
COMPOUNDS IN GROUNDWATER
(SHALLOW WELLS)
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION
CTO 0356

Baker

FIGURE 5 - 1

6.0 QUALITATIVE RISK ASSESSMENT

6.1 Introduction

This qualitative risk assessment for Operable Unit (OU) No. 15 (Site 88) evaluates the projected impact of contaminants of potential concern (COPCs) on human health and/or the environment, now and in the future, in a "no further remedial action scenario." This qualitative evaluation examines the data generated during the sampling and analytical phase of the focused RI and identifies areas of concern (AOCs) and COPCs with respect to geographical, demographic, physical and biological characteristics of the study area.

The components of this qualitative risk assessment include:

- Hazard Identification
- Qualitative evaluation of COPCs
- Uncertainty analysis
- Summary of results

The qualitative risk assessment is divided into four sections beginning with the introduction. Section 6.2 presents the Hazard Identification, which presents criteria for selecting COPCs. COPCs are chosen, for each environmental medium at each site, from an overall list of detected contaminants. Section 6.3 presents the Qualitative Evaluation of COPCs, which discusses the COPCs selected by media and any potential impacts that may exist to human health. Section 6.4 addresses sources of uncertainty in the qualitative risk assessment. Section 6.5 provides a summary of results of the qualitative risk assessment. References for the qualitative risk assessment are included in Section 6.6 of this report. Referenced tables are presented after the text portion of this section.

6.2 Hazard Identification

Data generated during the focused remedial investigation at the site were used to draw conclusions and to identify data gaps in the qualitative risk assessment. The data were evaluated to assess which data 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 determine whether further evaluation of potential human health risks is necessary.

6.2.1 Identification of Data Suitable for Use in a Qualitative Risk Assessment

To provide for accurate conclusions to be drawn from sampling results, analytical data were reviewed and evaluated. 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.

This focused RI was divided into two phases: the initial investigation, or Phase I, was completed in August of 1996, and the follow-up investigation, or Phase II, was completed in April of 1997. Two environmental media were investigated at the site during this focused RI: subsurface soils (above the water table) and groundwater. It should be noted that only the subsurface soil samples collected from above the water table were included for evaluation in this qualitative risk assessment (refer to Section 4.5.1 for further discussion). For Site 88, these media were assessed to determine if further evaluation of potential risk to human receptors was necessary.

The subsurface soil and groundwater samples collected during the focused RI sampling effort were analyzed by two separate laboratories: a mobile (on-site) laboratory and a fixed base (off-site) laboratory. In order to determine the nature and extent of volatile organic compound (VOC) contamination at Site 88, soil and groundwater samples were submitted to the mobile laboratory for VOC analysis. A percentage of these samples were sent to the fixed base laboratory for confirmation purposes and analyzed for VOCs. The mobile laboratory was used to analyze Phase I soil and Phase I and II groundwater. The fixed base laboratory was used to analyzed Phase II soil and groundwater. Analytical data from both laboratories were used in this qualitative risk assessment. For a more detailed discussion on sampling procedure, refer to Section 3.0.

The initial hazard identification step entailed the validation and evaluation of the site data to determine its usability in the risk assessment in accordance with the National Functional Guidelines (USEPA, 1991)and USEPA's Data Usability Guidance (USEPA, 1992). This process resulted in the identification of COPCs for the site. It should be noted that only the analytical data from the fixed base laboratory was validated by a third-party validator. During this validation and evaluation, data that would result in inaccurate conclusions (e.g., data that were 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. Although the analytical results from the mobile laboratory were not validated, they were included in the process of COPC selection to provide a more complete representation of the data results. A summary of analytical findings was presented in Section 4.0.

Although shallow groundwater is not utilized as a potable source at Site 88, the shallow and deep groundwater at the site were evaluated as a single exposure source since it has been shown that there is a potential interconnection between the shallow and deep aquifers. This potential interconnection is a result of the discontinuity of the Castle Hayne semi-confining unit. Section 3.4.2 details the evidence of the interconnection. Consequently, exposure to both sources of groundwater combined were evaluated as a single unit. Although the aquifer is classified as GA (i.e., existing or potential source of drinking water supply for humans), it is not used as a potable water source at MCB Camp Lejeune because of its low yielding production rates. However, there remains the possibility that upon closure of this facility, residential housing could be constructed and shallow groundwater used for potable purposes in the future. Therefore, shallow groundwater was included in this qualitative risk assessment.

Information relating to the nature and extent of contamination at the site is provided in Section 4.0 of this report. The discussion provided in Section 4.0 also was utilized in the selection of COPCs at the site. The reduced data sets for all media of concern at the site are also provided in table form in Section 4.0 of this report.

6.2.2 Criteria for Selecting Contaminants of Potential Concern

Criteria used in selecting COPCs from constituents detected during the field sampling and analytical phase of the investigation are:

- Historical information
- Comparison to USEPA Region III Risk-Based Concentrations (RBCs)
- State and federal standards and criteria
- Comparison to field and laboratory blank data

In addition, the criteria used in the qualitative analysis of COPCs selected from the media investigated during this focused RI include:

- Prevalence
- Toxicity

USEPA's Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989) as well as USEPA Region IV's Supplemental Guidance to RAGS (USEPA, 1995) provides the criteria used to establish COPCs. A brief description of the selection and comparison criteria used in choosing final COPCs is presented below. A contaminant must not necessarily fit into all of these categories to be retained as a COPC.

6.2.2.1 Historical Information

Using historical information to associate contaminants with site activities, when combined with the following selection procedures, helps determine contaminant retention for, or elimination from, evaluation in the qualitative risk assessment.

6.2.2.2 USEPA Region III RBCs

RBC values are derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. The RBCs for potentially carcinogenic chemicals are based on a target ICR of $1x10^{-6}$. The RBCs for noncarcinogens are based on a target hazard quotient of 1.0. In order to account for cumulative risk from multiple chemicals in a medium, it is necessary to derive the RBCs based on a target hazard quotient of 0.1. Re-derivation of the noncarcinogenic RBCs based on a target hazard quotient of 0.1, while using the most recent toxicological criteria available, results in a set of values that can be used as screening values. In order to provide the accurate screening values, the noncarcinogenic RBCs were divided by a factor of ten. For potential carcinogens, the toxicity criteria applicable to the derivation of RBC values are oral and inhalation cancer slope factors (CSFs); for noncarcinogens, they are chronic oral and inhalation reference doses (RfDs). These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of RBC values requires that the screening concentrations be updated periodically to reflect changes in the toxicity criteria. The RBC table is issued on a semi-annual basis. It should be noted that the most recent update was published in March of 1997.

6.2.2.3 State and Federal Criteria and Standards

Contaminant concentrations in soil can be compared to contaminant-specific state criteria. This risk assessment utilizes the Method I, Category S-1 target concentrations for soil taken from the North Carolina Risk Analysis Framework (NCDEHNR, 1996). A more detailed description is given below.

Contaminant concentrations in groundwater can be compared to contaminant-specific state and federal criteria. This risk assessment utilizes the North Carolina Risk Analysis Framework, Method I, Category G-1 target concentrations for drinking water and non-drinking water exposure. These target concentrations correspond North Carolina Water Quality Standards (NCWQS) for groundwater. The only enforceable federal regulatory standards for water are Federal Maximum Contaminant Levels (MCLs).

Regulatory guidelines are used, when necessary, to infer potential health risks and environmental impacts. An explanation of the federal and state criteria and standards used for qualitative evaluation of contaminants is presented below. It should be emphasized that COPCs were not chosen based on comparison to state and federal criteria. However, these standards and criteria were used for a qualitative analysis of the COPCs.

Method I, Category S-1 Target Concentrations, North Carolina Risk Analysis Framework - Soil - These soil concentrations were derived using standard EPA risk assessment equations for the ingestion of soil in residential exposures. These values were used in the qualitative evaluation of Site 88 subsurface soil samples.

Method II, Category S3:G1 Target Concentrations, North Carolina Risk Analysis Framework - Soil-to-Groundwater Pathway - These soil concentrations are derived using site-specific characteristics in a transport model for the protection of groundwater. This methodology is based on that found in the USEPA *Soil Screening Guidance* (USEPA, 1996a). These values were used in the qualitative evaluation of Site 88 subsurface soil samples.

Method I, Category G-1 Target Concentrations, North Carolina Risk Analysis Framework - Groundwater - These target concentrations for drinking water and non-drinking water exposures, such as swimming pools or irrigation, are the groundwater quality standards or interim standards established in 15A NCAC 2L.0202 (i.e., North Carolina Water Quality Standards described below). The groundwater standards and interim standards are developed using state and federal guidelines for the protection of human health.

North Carolina Water Quality Standards (NCWQSs) - Groundwater - NCWQSs are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which otherwise render the groundwater unsuitable for its intended purpose.

Maximum Contaminant Levels (MCLs) - Federal Groundwater Standards - 40 CFR 161 - MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply.

As stated previously, COPCs in all media of concern at the site were compared with these aforementioned criteria. The results of the standards/criteria comparison for the site are presented in Tables 6-1 and 6-2.

6.2.3.4 Contaminant Concentrations in Blanks

Associating contaminants detected in field related QA/QC samples (i.e., trip blanks, equipment rinsates and/or field blanks) or laboratory method blanks with the same contaminants detected in analytical samples can eliminate non-site-related contaminants from the list of COPCs. Blank data should be compared to sample results with which the blanks are associated; however, due to the comprehensive nature of data sets, it is difficult to associate specific blanks with specific environmental samples. Thus, in order to evaluate contaminant levels, maximum contaminant concentrations reported in a given set of blanks are applied to an entire data set for a given medium.

In accordance with the National Functional Guidelines for Organics, common laboratory contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) should be regarded as a direct result of site activities only when sample concentrations exceed 10 times the maximum blank concentration. For other contaminants not considered common in a laboratory, concentrations exceeding five times the maximum blank concentration indicate contamination resulting from site activities (USEPA, 1991).

When evaluating contaminant concentrations in soil, Contract Required Quantitation Limits (CRQLs) and percent moisture are employed, in order to correlate solid and aqueous quantitation limits. The CRQL for semivolatiles (SVOCs) in soil is 33 to 66 times that of aqueous samples, depending on the contaminant. In order to assess SVOC contaminant levels in soil using aqueous blanks, blank concentrations must be multiplied by 33 or 66 to account for variances in the CRQL. The final value is divided by the sample percent moisture, in order to account for the aqueous-to-solid blank medium adjustment.

Eliminating a sample result correlates directly to a reduction in the contaminant prevalence in that medium. Consequently, if elimination due to blank concentration reduces the prevalence of a contaminant to less than five percent, a contaminant that may have been included according to its prevalence is eliminated as a COPC. Maximum concentrations of common laboratory contaminants detected in blanks are presented in Table 2-8.

Blanks containing organic constituents that are not considered common laboratory contaminants (i.e., all other TCL compounds) are regarded as positive results only when observed concentrations exceed five times the maximum concentration detected in any blank (USEPA, 1989b). All TCL compounds at concentrations less than five times the maximum level of contamination noted in any blank are considered to be attributed to blank contamination. Maximum concentrations of other contaminants detected in blanks are presented in Table 2-8. QA/QC data summaries are presented in Appendix J.

6.2.2.5 Prevalence

The frequency of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. The judicious use of data sets limits for including infrequently detected contaminants. Chemical occurrence must be evaluated with respect to the number of samples taken in order to determine frequency criteria warranting the inclusion of a chemical as a COPC. Contaminants that are infrequently detected, (i.e., less than five percent when at least 20 samples of a medium are available) do not necessarily indicate contamination. Such detections may result from certain sampling or analytical practices.

A contaminant may not be retained for qualitative evaluation in the risk assessment if: (1) it is detected infrequently in an environmental medium; (2) it is absent or detected at low concentrations in other media; or (3) site history does not provide evidence to suggest that the contaminant should be present.

6.2.2.6 Toxicity

Contaminant toxicity assessment must be incorporated when selecting COPCs with respect to human health risk. Toxic properties to be considered in COPC selection include weight-of-evidence classification, carcinogenicity, mutagenicity, teratogenicity, systemic effects and reproductive toxicity. Bioaccumulation and bioconcentration properties may affect the severity of toxic response in an organism and/or subsequent receptors; these additional properties are evaluated if relevant data exist.

6.2.3 Selection of Contaminants of Potential Concern

The following sections present an overview of the analytical data obtained for each environmental medium during the focused RI and the subsequent retention or elimination of COPCs using the aforementioned selection criteria. The primary criterion used in selecting a chemical as a COPC at each site was comparing the maximum detected sample concentration to the Target Concentrations established in the North Carolina Risk Analysis Framework for soil and groundwater. USEPA Region III RBCs (USEPA, 1997) were also used as a secondary comparison criteria. In conjunction with the concentration comparisons to these criteria, evaluation of laboratory contaminants, chemical prevalence, and site history was conducted.

Tables 6-1 and 6-2 present the selection of COPCs for each environmental medium for both the mobile and fixed base laboratories based on a comparison of the maximum detected concentration with the USEPA Region III RBC values and other selection criteria. Information is presented in these tables only for those constituents detected at least once, in the medium of interest.

6.2.3.1 Subsurface Soil

Table 6-1 summarizes the results and COPC selection for subsurface soil analyzed by the mobile and fixed base laboratories. It should be noted that only subsurface soil samples collected from above the water table were included in this evaluation. Up to 29 subsurface soil samples (from above the water table) were analyzed for VOCs. Acetone was detected in 6 out of 11 samples at a maximum concentration of 120J µg/kg. Chloroform was detected in 2 out of 29 samples at a maximum concentration of 0.1 µg/kg. Cis-1,2-dichloroethene was detected in 1 out of 18 samples at a maximum concentration of 21 µg/kg. Tetrachloroethene was detected in 18 out of 29 samples at a maximum concentration of 237.6 µg/kg. Trichloroethene was detected in 8 out of 29 samples at a maximum concentration of 16 µg/kg. All of the above mentioned compounds were detected at maximum concentrations less than their respective Method I, Category S-1 target concentrations and residential soil RBCs. One VOC, tetrachloroethene, was detected at a maximum concentration above its Method II, Category S3:G1 target concentration. Therefore, tetrachloroethene was the only VOC retained as a COPC.

In summary, tetrachoroethene was retained as a COPC for Site 88 subsurface soil.

6.2.3.2 Groundwater

Table 6-2 summarizes the results and COPC selection for groundwater analyzed by the mobile and fixed base laboratories. Up to 62 groundwater samples were analyzed for VOCs. 1,1,1-Trichloroethane and toluene were detected at maximum concentrations less than their respective Method I, Category G-1 target concentrations, NCWQS, and tap water RBCs. Therefore, these compounds were not selected as COPCs. 1,1-Dichloroethene, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride were detected at maximum concentrations that exceeded corresponding target concentrations, NCWQS, and tap water RBCs. Therefore, these VOCs were retained as COPCs. Chloroform was detected at a maximum concentration (13.8 µg/L) that exceeded its standards and criteria but was less than the concentration detected in the Phase II blanks (17 µg/L). However, chloroform was retained as a COPC for further evaluation since it was detected in samples analyzed by the mobile laboratory in both phases, and there are chlorinated solvents present at Site 88.

In summary, the following compounds were retained as groundwater COPCs for Site 88: 1,1-dichloroethene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride.

6.3 Qualitative Evaluation of COPCs

Subsurface Soil

One VOC, tetrachloroethene, was retained as a subsurface soil COPC. It was detected in 18 out of 29 samples with 4 out of 18 positive detections exceeding the Method II, Category S3:G1 target concentration. Currently, Site 88 is the location of a dry cleaning facility. Based on this information and the elevated concentrations, it is likely that the presence of tetrachloroethene is site-related.

Groundwater

Seven VOCs, 1,1-dichloroethene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride were retained as groundwater COPCs. 1,1-Dichloroethene was detected in 4 out of 39 samples at a maximum concentration that exceeded its target concentration, NCWQS, MCL, and tap water RBC. Cis-1,2-dichloroethene was detected in 14 out of 41samples where 8 of 14 exceeded its target concentration, NCWQS, and MCL and 11 of 14 exceeded its tap water RBC. Tetrachloroethene was detected in 33 out of 62 samples at a maximum concentration of 54,882 µg/L. Several detected concentrations exceeded criteria: 24 of 33 detected concentrations exceeded the target concentration, NCWQS, and RBC, and 20 of 33 exceeded the MCL. Currently, Site 88 is the location of a dry cleaning facility. Based on this information and the elevated concentrations, it is likely that the presence of tetrachloroethene is site-related. Trans-1,2-dichloroethene was detected in 18 out of 62 samples at a maximum concentration that exceeded its target concentration, NCWQS, MCL, and tap water RBC. Trichloroethene was detected in 28 out of 62 samples where several detected concentrations exceeded criteria: 24 of 28 exceeded the target concentration, NCWQS, and RBC, and 21 of 28 exceeded the MCL. Vinyl chloride was detected at a low frequency of detection (1 out of 62 samples). However, the detected concentration of vinyl chloride exceeded its target concentration, NCWQS, MCL, and tap water RBC. In addition, vinyl chloride is classified as a Class A carcinogen.

The presence of chloroform in groundwater samples may be related to mobile laboratory contamination. Chloroform was detected in 19 out of 62 samples analyzed. Seventeen concentrations exceeded the target concentration and NCWQS, as well as the tap water RBC, for chloroform. Chloroform was detected in 18 out of 41 mobile laboratory samples. The chloroform may be related to a potable water source used by the mobile laboratory. The presence of chloroform is not uncommon as these compounds can be present in a water supply as part of the chlorination process for treating water. Detections of chloroform were consistently noted at similar concentrations in the groundwater samples analyzed by the mobile laboratory, while detections were generally absent in the fixed-based analysis of the same media. It is possible that the presence of this compound is not site-related.

6.4 Sources of Uncertainty

Uncertainties may arise during the risk assessment process. This section presents site-specific sources of uncertainty in the risk assessment.

The credibility of the risk assessment relies on the quality of 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 data (mean concentration, standard deviation, and detection frequencies) are subject to uncertainty in the ability to acquire data.

In this qualitative risk assessment, conclusions were drawn based on comparison to standards and criteria. If the maximum detected concentration of a compound exceeded its comparison criteria, it was retained as a COPC. Potential risk from exposure to a specific compound was assumed based solely on exceedence of criteria/standards, when simply exceeding criteria/standards may not necessarily mean risk to human health. There was no quantitative assessment to determine how much or little a COPC contributed to potential human health risk. In this way, the qualitative risk assessment process may overestimate the risk to human health from exposure to COPCs.

Data validation serves to reduce some of the inherent uncertainty associated with 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 risk estimation. Data can be qualified as "J" (estimated) for many reasons, including a slight exceedence of holding times, high or low surrogate recovery, or intra-sample variability. Data qualified with "J" were retained for risk assessment.

For this focused RI, the data analyzed by the fixed base laboratory was validated by a third party validator. The data analyzed by the mobile laboratory was not validated. The two data sets were combined in order to provide a more complete representation of site conditions. There is some uncertainty associated with the use of data that has not been validated in risk estimation. However, for those samples that were subjected to both mobile and fixed-base analysis, the analytical findings were in agreement. This qualitative risk assessment evaluates the potential for adverse human health effects to occur and the need for further investigation. It is unlikely that the use of mobile laboratory data significantly increased the uncertainty in this qualitative risk assessment.

6.5 Summary of Results

One VOC, tetrachloroethene, was retained as a COPC for Site 88 subsurface soil. 1,1-Dichloroethene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride were retained as Site 88 groundwater COPCs. Given the frequency of detection, the concentrations, and the current land use of the site (i.e., location of a dry cleaning facility), it is likely the presence of these compounds is site-related and could present a potential for current and/or future adverse human health effects under a no further action scenario.

6.6 References

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USEPA. 1996a. United States Environmental Protection Agency. Soil Screening Guidance: Technical Background Document. EPA/540/R-95/128.

USEPA. 1996b. United States Environmental Protection Agency. Drinking Water Regulations and Health Advisories. Office of Water. Washington, D.C. October, 1996.

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SECTION 6.0 TABLES

TABLE 6-1

SUMMARY OF DATA AND COPC SELECTION
VOLATILE ORGANICS IN SUBSURFACE SOIL
PHASE I - MOBILE LABORATORY
PHASE II - FIXED BASE LABORATORY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Constituent	Range/Frequency		Comparison to Criteria						COPC Selection[3]
	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Method I, Category S-1 Target Concentrations[1]	Positive Detects Above S-1 Target	Method II, Category S3:G1 Target Concentrations[1]	Positive Detects Above S3:G1 Target	Residential RBC Value[2]	Positive Detects Above Residential RBC Value	
Volatiles (μg/kg):									
Acetone	12 - 120J	6/11	1,560,000	0	3,608.3	0	780,000	0	No
Chloroform	0.1	2/29	100,000	0	2.2	0	100,000	0	No
Cis-1,2-Dichloroethene	21	1/18	156,000	0	66.5	0	78,000	0	No
Tetrachloroethene	0.1 - 237.6	18/29	12,000	0	25.9	4	12,000	0	Yes
Trichloroethene	0.1 - 16	8/29	58,000	0	46.6	0	58,000	0	No

Notes:

(1) North Carolina Risk Analysis Framework, (NCDEHNR, 1996).
(2) Region III Risk-Based Concentration Table (USEPA, 1997).
(3) COPC = Chemical of Potential Concern for human health risk assessment (yes/no).

J = Estimated value.

TABLE 6-2

SUMMARY OF DATA AND COPC SELECTION
VOLATILE ORGANICS IN GROUNDWATER
PHASE I AND II - MOBILE LABORATORY AND
PHASE II - FIXED BASE LABORATORY
OPERABLE UNIT NO. 15 (SITE 88)
FOCUSED REMEDIAL INVESTIGATION, CTO-0356
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Groundwater Criteria			Frequency/Range		Comparison to Criteria			COPC Selection(4)
	Method I, Category G-1 Target Concentrations(1)	MCL(2)	Region III Tap Water RBC Value(3)	No. of Positive Detects/ No. of Samples	Concentration Range	Positive Detects Above G-1 Target	Positive Detects Above MCL	Positive Detects Above RBC Value	
Volatiles (µg/L):									
1,1,1-Trichloroethane	200	200	79	4/62	0.2 - 0.5	0	0	0	No
1,1-Dichloroethene	7	7	0.044	4/39	0.3 - 7J	1	1	4	Yes
Chloroform	0.19	100	0.15	19/62	0.1 - 13.8	17	0	17	Yes
Cis-1,2-Dichloroethene	70	70	6.1	14/41	1 - 3,725	8	8	11	Yes
Tetrachloroethene	0.7	5	1.1	33/62	0.1 - 54,881.7	24	20	24	Yes
Toluene	1,000	1,000	75	1/39	7	0	0	0	No
Trans-1,2-Dichloroethene	70	100	12	18/62	1 - 600	2	2	8	Yes
Trichloroethene	2.8	5	1.6	28/62	0.2 - 3,030.9	24	21	24	Yes
Vinyl Chloride	0.015	2	0.019	1/62	4J	1	1	1	Yes

Notes:

(1) North Carolina Risk Analysis Framework (NCDEHNR, 1996), NCWQS (October, 1994).
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level (October, 1996b).
(3) Region III Risk-Based Concentration Table (USEPA, 1997).
(4) COPC = Chemical of potential concern for human health risk assessment (yes/no).

J = Estimated value.

7.0 CONCLUSIONS

The following conclusions for Operable Unit No. 15 (Site 88) are based on the results of the Remedial Investigation and the Qualitative Risk Assessment.

1. Chlorinated solvent compounds are the primary contaminants in the subsurface soil. Tetrachloroethene was the most prevalent compound detected in the soil. Trichloroethene, total-1,2-dichloroethene, cis-1,2-dichloroethene, were also detected in the subsurface soil. Chlorinated solvent contamination in the soil is generally concentrated in the area under and on the north side of Building 25. At the current time it is believed that the silt/clay layer acts as a capillary barrier to the downward migration of DNAPL in the vicinity of Building 25. Results of the DNAPL investigation suggest that the clayey layer is continuous in the vicinity of the DNAPL area, and that DNAPL has accumulated on top of the clayey layer.

2. Chlorinated compounds are the primary contaminants in the groundwater. Tetrachloroethene was the most prevalent compound detected in the groundwater. Other volatile organic compounds (VOCs) including trichloroethene, cis-1,2-dichloroethene, and trans-1,2-dichloroethene, 1,1,1-trichloroethane, 1,1-dichloroethane, and vinyl chloride were also detected in the groundwater. Concentrations of VOCs in the surfical aquifer and the upper Castle Hayne Aquifer exceed published federal standards and state standards.

3. Dissolved-phase volatile contaminants in the area of Building 25 have migrated both horizontally and vertically, and are present in the upper portions of the Castle Hayne Aquifer. Contamination in the surficial aquifer has migrated 400 feet northwest and 150 feet south of building 25. A discontinuous silt/clay layer at approximately 20 feet below ground surface appears not to have limited the vertical migration of the dissolved-phase contaminants. At the intermediate depth, dissolved contaminants have migrated approximately 700 feet to the northwest and 500 feet to the southwest of Building 25. The vertical extent of the contaminant plume extends to a depth of approximately 85 feet below ground surface at one location. Trace levels of contaminants was observed in one deep monitoring well (88-MW05DW. Significant further vertical migration seems unlikely due to the small vertical component of groundwater flow between the intermediate and deep monitoring wells.

4. The presence of VOCs in the soil and groundwater are considered to be a result of previous site operations. The pattern of the distribution of groundwater contamination suggests that Building 25 is the source area.

5. Some evidence of biodegradation is apparent. The information gathered for this Remedial Investigation suggests that the contaminant source is tetrachloroethene. The Base Laundry had used this solvent in its dry cleaning process. There is no history of the use of trichloroethene, or cis-1,2-dichloroethene. Therefore, the presence of these solvents is likely due to the dehalogenation process.

6. One VOC, tetrachloroethene, was retained as a Contaminants of Potential Concern (COPC) for the subsurface soil. 1,1-Dichloroethene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride were retained as Site 88 groundwater COPCs. Given the frequency of detection, the concentrations, current land use of the site (i.e., location of dry cleaning facility), it is likely the presence of these compounds is site-related. However, given the fact that there are no drinking water supply

wells within a one mile radius of the site, it is unlikely that the presence of volatile compounds in the groundwater, even at concentrations that exceed federal and state standards, could currently present a potential for adverse human health effects.