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FINAL ACTION MEMORANDUM FOR SITE 89 OPERABLE UNIT 16 (OU 16) MCB CAMP LEJEUNE NC

04/01/2008

AGVIQ/CH2M HILL

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Action Memorandum
Site 89, Operable Unit No. 16

Marine Corps Base
Camp Lejeune, North Carolina

Prepared for

NAVFAC
Naval Facilities Engineering Command

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

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Prepared by

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Final

Site 89
Action Memorandum
Operable Unit 16

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Attachment A - Final EE/CA for Site 89 at MCB Camp Lejeune

Acronyms and Abbreviations

ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-Dichloroethene
DLA	Defense Logistics Agency
DoN	Department of the Navy
DRMO	Defense Reutilization and Marketing Office
EE/CA	Engineering Evaluation/Cost Analysis
ERH	electrical resistive heating
FFA	Federal Facilities Agreement
IR	Installation Restoration
LTTD	low temperature thermal desorption
MCB	Marine Corps Base
MEK	methyl-ethyl-ketone
NCDENR	North Carolina Department of Environment and Natural Resources
NCP	National Oil & Hazardous Substances Pollution Contingency Plan
NFESC	Naval Facilities Engineering Service Center
NPL	National Priority List
NTCRA	Non-Time-Critical Removal Action
OHM	OHM Remediation Service Corporation
OU	Operable Unit
PCA	1,1,2,2-tetrachloroethane
RAB	Restoration Advisory Board
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
TCE	Trichloroethene
TCRA	time-critical removal action
trans-1,2-DCE	trans-1,2-Dichloroethene
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

I. Purpose

This Action Memorandum describes the source area non-time-critical removal action (NTCRA) for Operable Unit (OU) 16, Site 89 at Marine Corps Base (MCB) Camp Lejeune, in Onslow County, North Carolina. An Engineering Evaluation/Cost Analysis (EE/CA) was prepared for the NTCRA and is included in this Action Memorandum as **Attachment A**. This Action Memorandum serves as the Decision Document to conduct the proposed work.

This Action Memorandum was prepared in accordance with the remedial program requirements defined by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended, the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and the U.S. Environmental Protection Agency's (USEPA) Superfund Removal Procedures Action Memorandum Guidance (USEPA, 1990).

The Department of the Navy (DoN) has broad authority under CERCLA Section 104 and Executive Order 12580 to carry out remedial actions when the release is on, or the sole source release is from a DoN installation. The Navy/Marine Corps Installation Restoration (IR) Program was initiated to identify, assess, characterize, and clean up or control contamination from past hazardous waste disposal operations and hazardous material spills at Navy and Marine Corps activities. This Action Memorandum follows the guidelines published in the March 2001 *Navy/Marine Corps IR Manual* (Naval Facilities Engineering Services Center [NFESC], 2001) and the USEPA *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993). This Action Memorandum addresses a NTCRA for conducting a removal action to address contaminants at Site 89 that have been identified, through previous investigations, as potentially posing a risk at MCB Camp Lejeune to human health and the environment.

II. Site Conditions and Background

This section describes MCB Camp Lejeune and Site 89, documented releases, and current National Priorities List (NPL) status. This section also reviews any previous and current actions conducted by the Navy at Site 89 and discusses anticipated future actions at the state and local levels.

A. Site Description

MCB Camp Lejeune is a training base for the United States Marine Corps located on the coastal plain in Onslow County, North Carolina and covers approximately 236 square miles, including 14 miles of coastline (**Figure 1-1**; **Attachment A**). The New River flows southeast, bisecting the Base, and forms a large estuary before entering the Atlantic Ocean. The Base is bounded on the southeast by the Atlantic Ocean, on the west by U.S. Route 17, and on the northeast by State Highway 24. The City of Jacksonville, North Carolina is located north of the Base.

Site 89 includes the Former Defense Reutilization and Marketing Office (DRMO), a larger, wooded area to the east and the south of the DRMO, and a portion of Camp Geiger to the

west. The site is located on the New River Air Station side of the Base (**Figure 1-2; Attachment A**), southeast of the intersection of G Street and 8th Street. The target area for the NTCRA (shown on **Figure 2-15**; **Attachment A**) is located in the southern portion of the former DRMO (the former vehicle maintenance and storage area).

The NTCRA target area has not been used since the DRMO relocated in 2000. The former DRMO area is surrounded by a fence with an access gate. The NTCRA target area is grass-covered and generally flat. Stormwater runoff at Site 89 drains into Edwards Creek.

B. Site History

The DRMO was operated by the Defense Logistics Agency (DLA) and, until 2000, was used as a storage yard for miscellaneous items such as scrap and surplus metal, electronic equipment, vehicles, rubber tires, fuel bladders (mobile storage tanks), and other material that would be sent offsite.

Historical records indicate that the Base Motor Pool operated on the site until approximately 1988. The Base Motor Pool was then relocated to its current location, an asphalt paved area immediately north of the DRMO facility. The Base Motor Pool reportedly used various solvents, such as acetone, TCE, and 2-butanone (methyl-ethyl-ketone [MEK]), for cleaning parts and equipment. Historical records also indicate that a 550-gallon underground storage tank (UST), identified as UST STC-868, was installed at the site in 1983 and used to store waste oil. The UST was removed in 1993.

In the early 1990s, fuel bladders were placed onsite. The bladders ranged in size from 600 to 20,000 gallons and were used in training exercises for helicopter refueling. Base personnel reported that the bladders were emptied on the ground, cleaned with solvents, re-emptied on the ground, and capped prior to storage at the DRMO. The bladders were stored for 3 to 4 years in a pile approximately 75 feet in diameter by 25 feet high. A shredder was brought onsite and located immediately north of the bladder pile. The bladders were shredded into small cubes and placed into roll-off boxes.

The primary chlorinated volatile organic compounds (VOCs) reported in groundwater at Site 89 are 1,1,2,2-tetrachloroethane (PCA) and trichloroethene (TCE) and their daughter products, including cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), and vinyl chloride.

C. Previous Investigations

A complete description of historic investigation activities at Site 89 is provided in the Comprehensive Remedial Investigation (RI) Report (CH2M HILL, 2007).

Based on the chemical and physical data gathered during previous investigations at Site 89, a significant source area is in the southern portion of the site, where chlorinated solvents, including some in the form of DNAPL, have been detected in the soil and groundwater. Dissolved concentrations of chlorinated VOCs in groundwater at approximately one to ten percent of a compound's solubility may suggest the presence of DNAPL in the subsurface. The source area identified for treatment under this NTCRA (shown on **Figure 2-15, Attachment A)** is based on dissolved concentrations in exceedance of five percent of a

compound's solubility. The source area is approximately 38,000 square feet to a depth of 25 feet. The volume of soil within the source area is estimated to be 35,000 cubic yards.

D. Release or Threatened Release Into the Environment of a Hazardous Substance, Pollutant, or Contaminant

The presence of a DNAPL plume and VOC-contaminated soils in the southern portion of Site 89 was determined to pose a potential risk to human health and environment, because it serves as a continuing source of groundwater contamination.

E. National Priority List Status

MCB Camp Lejeune was placed on the CERCLA NPL effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the USEPA Region IV, North Carolina Department of Environment and Natural Resource (NCDENR), the DoN, and the Marine Corps entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune to address environmental concerns present at the Base. The IR program is responsible for addressing these concerns and managing responses as appropriate to CERCLA and the Resource Conservation and Recovery Act (RCRA).

F. Maps, Pictures, and Other Graphic Representation

Several maps and figures are included in the EE/CA (**Attachment A**). **Figure 1-1** of the EE/CA presents a location map of MCB Camp Lejeune and Figure 2-1 presents a map of Site 89. **Figures 2-3** through **2-14** depict site characteristics of Site 89, areas involved in previous investigations, and results from previous investigations. **Figure 2-15** illustrates the NTCRA target area.

G. Other Actions to Date

1. Low Temperature Thermal Desorption

As part of a time-critical removal action (TCRA), low temperature thermal desorption (LTTD) operations were conducted by OHM Remediation Service Corporation (OHM) in the target area at Site 89 in October 2000. The LTTD effort was conducted to remediate the most contaminated soil to a PCA cleanup goal of 1 mg/kg. The top five feet of soil was treated. The final volume of soil treated during the TCRA activities was approximately 23,788 cubic yards (35,682 tons). The treated soil was placed back into the excavation area and compacted. **Figure 2-11** in **Attachment A** shows the excavation limits.

2. Electrical Resistive Heating

From September 2003 to May 2004, an electrical resistive heating (ERH) pilot study was conducted by Shaw Environmental Infrastructure as a remedial action for the target area at Site 89. The system consisted of 43 deep heating electrodes installed to a depth of 26 feet bgs and 48 shallow electrodes installed to a depth of 19 feet bgs (**Figure 2-12, Attachment A**). The total area of treatment was approximately 15,900 square feet. Approximately 50% of the

electrodes were slotted and used for vacuum extraction of volatile vapors from the subsurface. The ERH system was turned off and disassembled in May 2004. An estimated 48,000 pounds of VOCs were removed from the subsurface during this remedial action. In addition, an estimated 428 pounds of chlorinated compounds were recovered from the groundwater during the pilot test. Analytical results indicated that contaminant concentrations in soil were reduced by 97% to 99% at most locations. Contaminant concentrations in groundwater within the treatment area were reduced by 99%.

H. State and Local Authorities' Roles

The USEPA and NCDENR have been involved in planning and reviewing site investigation reports, the EE/CA and this Action Memorandum. At the local level, the general public is also involved via the Restoration Advisory Board (RAB) and publicly available site information. A public meeting discussing the EE/CA was held on July 10, 2007. Comments on this Draft Action Memorandum will be solicited from the USEPA, NCDENR, and MCB Camp Lejeune. Involvement by all parties in the planning process will continue throughout the removal activities through meetings and correspondence.

III. Threats to Public Health, Welfare or the Environment, and Statutory and Regulatory Authorities

Section 300.415 of the NCP lists the factors to be considered in determining the appropriateness of a NTCRA. Paragraph (b)(2) of Section 300.415 applies to the conditions at Site 89 as follows:

Section 300.415(b)(2)(i):	*"Actual or potential exposures to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants"*
Section 300.415(b)(2)(ii):	*"Actual or potential contamination of drinking water supplies or sensitive ecosystems"*
Section 300.415(b)(2)(iv):	*"High levels of hazardous substances or pollutants or contaminants in soils largely near the surface, that may migrate"*

DNAPL in the subsurface is a continuing source of contamination in the groundwater at Site 89. By reducing the contaminant mass, the continuing contaminant source will be reduced or eliminated and the threat to human populations, animals, or the food chain will be reduced or eliminated.

The removal action described in this Action Memorandum only addresses the source area. Significant contaminant reduction (i.e., greater than 90%) will still leave contaminant concentrations several orders of magnitude above regulatory standards. This removal action does not address groundwater dissolved contamination outside the identified source area, which will remain at the site and will be addressed separately by a final remedy.

IV. Endangerment Determination

Actual or threatened adverse impacts from the DNAPL source area, if not addressed by implementing the response action discussed in this Action Memorandum, may present an endangerment to public health, welfare, or the environment.

V. Proposed Actions and Estimated Costs

A. Proposed Action

1. Proposed Action Description

The proposed removal action is shallow soil mixing with clay-zero valent iron addition. Shallow soil mixing will be implemented in the DNAPL source area using 8.5-foot diameter augers constructing an approximate total of 550 soil mixing columns to 25 feet below ground surface (bgs).

Before mixing is started, monitoring wells and any utilities will be removed and the top five feet of clean fill material will be stripped off to provide enough "free board" for injection of materials and mixing operations. This clean excavated material, estimated to be approximately 7,037 cubic yards, will be stored at the site and used for site restoration.

A mix design of 1.5% ZVI and 1% bentonite was assumed for this alternative. However, a bench scale study will be performed to determine the appropriate amounts of materials to be injected and mixed in each soil column.

To perform mixing, the soil mix rig will be tracked into position over a pre-calculated/surveyed grid point. A baseline for the grid system will be staked out by a surveyor, and would include enough points that every column can be located off of the stakes. Mixing is performed by overlapping columns to ensure the entire volume is mixed (treated). Center-to-center distance between the columns will be spaced to account for overlap of adjacent columns. This overlap between columns (typically 25% to 35%) allows for complete mixing. The conceptual soil mixing column layout is shown in **Figure 4-3, Attachment 1**.

This action was selected based on comparative analysis of effectiveness, implementability, and cost of alternatives. The effectiveness evaluation included reviewing the protectiveness of the alternative; compliance with Applicable or Relevant and Appropriate Requirements (ARARs) to the extent practical; long-term effectiveness and performance; reduction in toxicity, mobility, or volume; short-term effectiveness; and ability to meet Remedial Action Objectives (RAOs). The RAOs for Site 89 are to remove mobile DNAPL accumulations, to the extent practicable, from the identified source area at Site 89, reduce exposure and risk to human and ecological receptors, and reduce the potential for contaminant mass flux from the source zone to groundwater. Implementability included consideration of technical feasibility, availability, administrative feasibility, support agency acceptance, and community acceptance of the alternatives. The evaluation of cost included an estimate of capital cost. Shallow soil mixing with clay-zero valent iron addition effectively meets the goals of the removal action, while satisfying implementability and cost requirements.

Records and documents concerning the use of chlorinated solvents have been reviewed and it has been determined that after this good faith effort, documentation regarding the source of contamination or waste is inconclusive and any waste removed from the site would not contain a listed waste [Management of Remediation Waste, USEPA, EPA350-F-98-026, October 1998]. Characterization/classification of any waste removed from this site will be determined based on sampling and analysis results as compared to 40 CFR Part 261 Subpart C criteria.

Personal protective equipment (PPE) and decontamination water and purge water from monitoring activities are expected to be generated and removed from the site for disposal at an off-site treatment and disposal facility. All wastes removed from the site will be sampled, analyzed and characterized in accordance with 40 CFR Part 261 Subpart C and disposed of accordingly (hazardous waste to a Subtitle C facility or non-hazardous waste to a Subtitle D facility).

2. Contribution to Remedial Performance

Shallow soil mixing with clay-zero valent iron addition is intended to be a removal action to achieve the RAOs; however, the removal action is not intended to achieve final cleanup levels for groundwater. The removal action is a source control action that seeks to reduce contaminant mass and mobility to the extent practicable, reduce exposure and risk to human and ecological receptors, and reduce the potential for contaminant mass flux from the source zone to groundwater.

This removal action does not address groundwater dissolved contamination outside the identified source area, which will remain at the site and will be addressed separately by a final remedy.

3. Description of Alternative Technologies

The EE/CA evaluated five alternatives. The alternatives were assessed for removing or treating the DNAPL source area at Site 89 and compared for effectiveness, implementability, and cost. The preferred removal action for Site 89 (shallow soil mixing) is readily implementable, cost-effective, and will minimize the risks to human health and the environment. Other alternative technologies evaluated for the source area included: excavation, electrical resistive heating, in situ thermal desorption, and air sparging. The EE/CA (**Attachment A**) describes the alternatives considered for the removal actions at Site 89 in greater depth, and the process by which the alternatives were evaluated, compared, and selected.

4. Engineering Evaluation/Cost Analysis

As described above, an EE/CA was completed to address the DNAPL source area at Site 89. The EE/CA supports a NTCRA for Site 89 at MCB Camp Lejeune. The EE/CA was presented during a public meeting on July 10, 2007. No comments were received from the public during the comment period, which ended on August 9, 2007.

5. Applicable or Relevant and Appropriate Requirements

The NCP requires that removal actions attain ARARs, with limited exception, to the extent practicable. ARARs are divided into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs apply to individual contaminants. Location-specific ARARs depend upon the location of the contamination and potential restrictions on activities conducted in these areas (i.e., wetlands, flood plains, etc.). Action-specific ARARs govern the removal action and are usually technology– or activity-based directions or limitations that control actions taken at CERCLA sites.

Analysis of the removal alternatives is presented in the EE/CA (**Attachment A**). The removal action set forth in this Action Memorandum will comply with all ARARs for human health and environment. Chemical-, location-, and action-specific ARARs specific to soil mixing with clay-zero valent iron addition at Site 89 are listed in **Tables 1, 2,** and **3,** respectively.

6. Project Schedule

The proposed phased schedule is:

Action Memorandum Released	April 2008
Preparation of Work Plan/Subcontracting	February – March 2008
Removal Action	April – August 2008
Groundwater Monitoring	September 2008 – August 2009

Factors that may affect the schedule primarily relate to seasonal restrictions. For example, inclement weather (storms or hurricanes) can delay construction and implementation of remedial systems.

B. Estimated Costs

The NCP 40 Code of Federal Regulation (CFR) Part 300.415 dictates statutory limits of $2 million and 12 months for USEPA fund-financed removal actions, with statutory exemption for emergencies and actions consistent with the removal action to be taken. The removal action at Site 89 described in this Action Memorandum will not be USEPA fund-financed. The Navy/Marine Corps IR Manual does not limit the cost or duration of the removal action. However, cost-effectiveness is a recommended criterion for evaluation of the removal action.

The Navy will contract with environmental remediation contractors to perform the required work associated with Site 89 at MCB Camp Lejeune. The cost estimate presented in the EE/CA is $4,500,000. The estimated costs are itemized in **Attachment A**.

VI. Estimated Change in the Situation Should Action Be Delayed or Not Taken

If no action is taken or the action is delayed, the DNAPL source area will continue to dissolve into the groundwater and migrate toward Edwards Creek.

VII. Outstanding Policy Issues

As noted herein, both Federal (USEPA) and state (NCDENR) agencies are currently involved in environmental planning for Site 89. The general public is also involved via the RAB, the announcement of available site-related information, and the published request for public comment. A public meeting was held on July 10, 2007 and the proposed removal action at this site was presented. All the agency and public comments received in relation to this Action Memorandum will be taken into consideration prior to the start of removal action at Site 89.

VIII. Enforcement

The DoN can and will perform the proposed response action promptly and properly.

IX. Recommendation

This Decision Document represents the selected removal action for the DNAPL source area at Site 89 at MCB Camp Lejeune developed in accordance with CERCLA as amended, and is consistent with the NCP.

Conditions at the site meet the NCP Section 300.415(b)(2) criteria for removal action. The Naval Facilities Engineering Command, in cooperation with USEPA and NCDENR, recommends approval of the proposed removal action. Response actions should commence as soon as practical due to the potential threat to human health and the environment.

X. References

CH2M HILL, 2007. *Draft Final Comprehensive Remedial Investigation, Site 89 – Operable Unit No. 16 Former Defense Reauthorization and Marketing Office (DRMO)*. Marine Corps Base Camp Lejeune, North Carolina. August 2007.

U.S. Environmental Protection Agency, 1993. *Guidance on Conducting Non-Time Critical Removal Actions under CERCLA*. EPA/540-R-93-057, OERR, USEPA, August 1993.

Tables

TABLE 1
Chemical-Specific ARARs
Site 89 Action Memorandum
MCB Camp Lejeune, North Carolina

Federal and State Chemical-Specific ARARs

Media	Requirement	Prerequisite	Citation	ARAR Determination	Comments
NC Groundwater Standards					
Groundwater	Establishes groundwater classification and groundwater quality standards, etc.	Standards are used to protect the public health or welfare and enhance water quality	15A NCAC 2L .0201 and .0202	**Relevant and Appropriate**	Soil mixing at Site 89 is not intended to achieve NC Groundwater Standards. However, groundwater standards are to be considered in ability to remove contaminant mass. Shallow groundwater not a drinking water source.

TABLE 2
Location-Specific ARARs
Site 89 Action Memorandum
MCB Camp Lejeune, North Carolina

Federal and State Location-Specific ARARs					
Location	**Requirement**	**Prerequisite**	**Citation**	**ARAR Determination**	**Comments**
Fish and Wildlife Coordination Act					
Floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood prone areas.	*Fish and Wildlife Coordination Act* , 16 USC 661 et. seq.; Executive Order 11988; 44 CFR 9, Appendix A; 40 CFR 6.302	**Applicable.**	Site 89 is within the 500-year floodplain. Measures taken to mitigate adverse effects include minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically sensitive areas.

TABLE 3
Action-Specific ARARs
Site 89 Action Memorandum
MCB Camp Lejeune, North Carolina

Federal and State Action-Specific ARARs

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Clean Air Act					
Air	NAAQS specify the maximum concentration of each criteria pollutant (carbon monoxide lead, nitrogen dioxide, particulate matter, ozone, sulfur dioxide) which is to be permitted in the ambient air, as averaged over a period of time. Requirements differ for new sources of air pollutant emissions and existing sources. Requirements also differ based on the air quality designation of the site's location (i.e., attainment, non-attainment, unclassified, or transport) (see Federal Location-Specific ARARs).	Emissions of criteria pollutants during the response action, or during the operation and maintenance of the response action. NAAQSs are not enforceable in and of themselves. Any substantive standards contained within the State Implementation Plan are, however, federally enforceable.	40 CFR 50.4 to 50.12	**Applicable.**	Criteria pollutants, including NOx and particulates, will be emitted durin use of soil mixing equipment. Emissions will be collected by a vapor hood collection system and treated prior to discharge to the atmosphere.
Air	Site remediations are required to control emissions of organic HAP by meeting emissions limitiations and work practice standards reflecting the application of maximur achievable control technology. Period inspections of equipment and continuous monitoring are required for the life of the remediation.	Emissions of hazardous air pollutants from site remediations.	40 CFR 63 Subpart GGGGG, NESHAPS for Site Remediation	**Relevant and Appropriate**	Non-time critical removal actions conducted under CERCLA are specifically exempted from this regulation (see 40 CFR 63.7881[b][2]). However, VOC emissions will be collected and treated with granular activated carbon prior to discharge to atmosphere.
Clean Water Act					
Indirect discharges	Discharge must comply with local POTW/FOTW pretreatment program, including POTW/FOTW-specific pollutants, spill prevention program requirements, and reporting and monitoring requirements.	Indirect discharges of wastewater to a POTW/FOTW through performance and technology-based pretreatment standards.	*Clean Water Act*, §307(b), 40 CFR 403 as adopted by 15A NCAC 02H	**Applicable.**	Surface runoff and displaced groundwater will be treated with granular activated carbon and sampled prior to discharge to the Base sanitary sewer system.
Safe Drinking Water Act					
Underground injection	Regulates the subsurface emplacement of liquids through the Underground Injection Control program, which governs the design and operation of five classes of injection wells in order to prevent contamination of underground sources of drinking water. The Underground Injection Control program regulates well construction, well operation, and monitoring.	Underground injection of wastes and treated groundwater.	40 CFR 144 to 148 as adopted by 15A NCAC 02H 40 CFR 268.2 as adopted by 15A NCAC 13A.0112 15A NCAC 02D.0400 and 02C.0200	**Relevant and Appropriate.**	The removal action mixes a ZVI and bentonite slurry with soil. There is not a direct injection of material and no injection of waste.
Resource Conservation and Recovery Act Subtitle C					
Generation of hazardous waste	Land disposal restrictions and standards for hazardous wastes placed on land. Treatment standards vary depending on the type of hazardous waste being treated and are concentration- and technology-based designed to reduce the mobility and toxicity o hazardous constituents present in hazardous wastes.	Placement of restricted hazardous wastes moved or treated outside the area of contamination.	40 CFR 268.49 as adopted by 15A NCAC 13A.0112	**Applicable, if hazardous contaminated soils are managed ex-situ.**	Hazardous waste soils are not anticipated to be excavated and generated.
Staging piles	Design and operating requirements for an accumulation of solid, non-flowing remediation waste. Must be designed to minimize the release of hazardous constituents from the pile (liners, covers), cannot operate for more than 2 years, must facilitate a remedy, must be closed by removing all contaminated materials.	Stockpiling of solid, non-flowing remediation wastes that are considered hazardous waste.	40 CFR 264.554 as adopted by 15A NCAC 13A.0109	**Relevant and appropriate, if contamination is detected in overburden.**	Site 89 removal action will manage hazardous waste contaminated soils ex-situ. Clean overburden will be stored in stockpiles. This clean overburden is not remediation waste, so the stockpiles will not be remediation waste staging piles. Further, clean overburden will be used to cover the site after mixing. Overburden that is suspected to be contaminated based on field screening will be returned to the treatmen area to be incorporated during the soil mixing activities or sampled and managed appropriately.
Off-site transport of hazardous wastes	Each hazardous waste generator must designate, manage, and dispose of hazardous waste properly.	Off-site transport of hazardous wastes.	40 CFR 262.10 through .58 as adopted by 15A NCAC 13A.0107	**Applicable, if hazardous waste is generated and taken off-site for treatment and disposal.**	Any hazardous waste generated will be disposed off-site. None anticipated.
Solid Waste Disposal Act					
Solid waste	Characterization of wastes generated during a remedial action would be conducted to determine if such wastes are hazardous (e.g. contaminated PPE, equipment, wastewater) or excluded under 40 CFR 261.4. Determines if the waste is listed hazardous under HAR 11-261. Determine if the waste is hazardous by testing using prescribed methods or by applying generator knowledge based on information regarding material or processes used. If waste is hazardous, it must be managed in accordance with the hazardous waste regulations.	Generation of solid wastes as defined in 40 CFR 261.2	40 CFR 262.11 as adopted by 15A NCAC 13A.0107	**Applicable.**	Depending on the waste constituents
Hazardous waste	Establishes standards for generators managing hazardous waste. Establishes specific criteria, which include: marked with "hazardous waste" or other words identifying contents., labeled with the date accumulation began, have training, have emergency response procedures in place. In accordance with state regulations.	Generation of solid waste that is determined to be hazardous waste.	40 CFR 262.11 as adopted by 15A NCAC 13A.0107	**Applicable.**	If hazardous waste is generated, labeling and management requirements will be met
NC Sediment and Erosion Control					
Sediment and erosion	Guidance on sediment and erosion control measures	Land disturbing activities which could result in the unreasonable degradation of properties, stream channels, waters, and other natural resources	15A NCAC .04B	**Applicable.**	Measures taken will include minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically sensitive areas.
Stormwater runoff	Implement good construction management techniques, sediment and erosion controls, storm water management measures, and housekeeping best management practices to ensure stormwater discharges are in compliance.	Construction activities disturbing more than 1 acre of land.	15A NCAC 2H .1000 and .1006; North Carolina General Permit CNCG 0100000	**Relevant and Appropriate.**	Less than 1 acre will be disturbed. However, silt fencing, berms, and stormwater controls and practices will be implemented.
NC Air Pollution Control Regulations					
Air	Install and operate reasonable available control technology to limit emissions of VOCs	Air emission of VOCs from miscellaneous sources.	15A NCAC 2D .0900 and .0951	**Relevant and Appropriate**	Vapors collected will be treated with granular activated carbon prior to discharge to atmosphere.

TABLE 3
Action-Specific ARARs
Site 89 Action Memorandum
MCB Camp Lejeune, North Carolina

Federal and State Action-Specific ARARs

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comments
NC Hazardous Waste Management Rules					
Waste / soil / water	Defines those solid wastes which are subject to regulation as hazardous wastes. Determines potential waste classification and applicability of land disposal restrictions and other solid and hazardous waste rules.	Treatment, storage, and/or disposal of wastes/media containing hazardous waste (i.e., soil, water, solid waste) that exhibits the characteristics of ignitability, corrosivity, reactivity, or toxicity, or if it is listed as a hazardous waste.	40 CFR 261 Subpart C and Subpart D, 40 CFR 268.45, as adopted by 15A NCAC 13A.0106	**Applicable.**	Waste generated during soil mixing at Site 89 must be characterized and managed in accordance with RCRA requirements. No listed wastes are known to be present at Site 89. Wastes to be managed must be sampled for TCLP analyses to determine the appropriate waste characterization. Some soil constituents may exceed TCLP limits when excavated, including: PCE - 0.7 mg/L (D039), TCE - 0.5 mg/L (D040), vinyl chloride - 0.2 mg/L (D043). Only potential waste would be PPE, soil cuttings, and well development water from monitoring well installation.
Soil	Soils contaminated by hazardous waste must be treated until the hazardous constituents are either: 1. 90% of the initial concentration, or 2. 10x the UTS for nonwastewaters. The soils must be treated to the higher of these two standards.	Disposal of soils containing hazardous waste	40 CFR 268.49, as adopted by 15A NCAC 13A.0112	**Applicable.**	If waste is removed from site is characterized as hazardous. Soil concentrations may exceed hazardous limits when overburden is excavated, including: PCA - 60 mg/kg, TCE - 60 mg/kg, 1,2-DCE - 60 mg/kg, vinyl chloride - 60 mg/kg
NC Surface Water Quality Standards					
Surface water	Establishes water quality standards for surface water including surface water criteria to protect human health from carcinogens (toxics) through consumption of fish and shellfish.	Direct or indirect discharge, such as storm water runoff that contains pollutants (e.g. VOCs from groundwater or suspended solids), enters waters classified for Tidal Salterwater (SC).	15A NCAC 2B .0208 and .0220	**Relevant and Appropriate**	These standards will be applied to site runoff considered and surface water monitored in the event of discharge to Edwards Creek
NC Solid Waste Management Act					
Solid waste	Solid waste shall be stored, collected, transported, separated, and disposed of in a manner consisten with these rules.	Management of wastes that meet the definition of solid waste	15A NCAC 13B.0103 and .0106	**Applicable if contaminated soils that are not hazardous are managed ex-situ and require disposal.**	Site activities include in-situ treatment to remove site contamination. Reuse of materials will be conducted when appropriate.
Pre-Treatment Program (POTW)					
Discharged water	Provides procedures for approval of pre-treatment programs for discharge to local POTWs	Pre-treatment of a waste stream prior to discharge to local POTWs.	15A NCAC 2H .0900	**Applicable.**	Stormwater and displaced groundwater will be treated with granular activated carbon prior to discharge to the Base sanitary sewer.
Well Construction & Injection Standards					
Groundwater	Criteria and standards applicable to well construction and underground injection control (UIC)	Construction of wells or the introduction of a material into the subsurface	15A NCAC 2C .0100 and .0200	**Applicable.**	New monitoring wells will be constructed and soil mixing will be performed in accordance with regulations.
Air Quality Emission Control Standards					
Air	Requires plan outlining actions to control fugitive dust emissions from the site that could travel beyond the site boundary	Fugitive dust emissions that cause or contribute to substantive complaints	15A NCAC 2D .0540(c) through (f)	**Relevant and Appropriate.**	Soil mixing activities are not expected to result in fugitive dust emissions; actions such as wetting dry soils will be implemented as necessary.

Attachment A

Final EE/CA for Site 89 at MCB Camp Lejeune

FINAL

Engineering Evaluation/Cost Analysis
Operable Unit No. 16 Site 89
Source Removal

Marine Corps Base
Camp Lejeune, North Carolina

Prepared for

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

Contract No. N62470-03-D-4401
Task Order-080

July 2007

Prepared by

AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

FINAL

Engineering Evaluation/Cost Analysis

Operable Unit No. 16 Site 89
Source Removal

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July 2007

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Acronyms and Abbreviations

AC	Alternating Current
ARARs	Applicable, Relevant, or Appropriate Requirements
Baker	Baker Environmental, Inc.
Bgs	Below Ground Surface
°C	Degree Celsius
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CVOC	Chlorinated Volatile Organic Compound
CLEAN	Comprehensive Long-Term Environmental Action Navy
1,2-DCE	1,2-Dichloroethene, 1,2-Dichloroethylene
DNAPL	Dense Non-Aqueous Phase Liquid
DoN	Department of the Navy
DOT	Department of Transportation
DPE	Dual Phase Extraction
DW	Deep Well
ECD	Electron Capture Detector
EE/CA	Engineering Evaluation/Cost Assessment
ERD	Enhanced Reductive Dechlorination
ERH	Electrical Resistance Heating
°F	Degrees Fahrenheit
FFA	Federal Facilities Agreement
ft	Feet or Foot
ft/day	Feet per Day
ft/ft	Feet Per Foot
gpm	Gallons per minute
i	Horizontal Hydraulic Gradient
in. Hg	Inches of Mercury
IW	Intermediate Well
K_h	Horizontal Hydraulic Conductivity
LTM	Long Term Monitoring
MCB	Marine Corps Base
Mg/kg	Milligram per Kilogram

MIP	Membrane Interface Probe
MSL	Mean Sea Level
MW	Monitoring Well
µg/L	micrograms per liter
n	Effective Porosity
NAPL	Non-Aqueous Phase Liquid
NAPLANAL	Modeling Program Developed by Duke to Estimate DNAPL
NAVFAC	Naval Facilities Engineering Command
NCDENR	North Carolina Department of Environment and Natural Resources
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NTCRA	Non-Time-Critical Removal Action
OHM	OHM Remediation Services Corporation
OSHA	Occupational Safety and Health Administration
PCE	Tetrachloroethylene, perchloroethene, perchlorethylene, perc
PID	Photo-Ionization Detector
PITT	Partitioning Interwell Tracer Test
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goals
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act of 1986
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TW	Temporary Monitoring Wells
USDoD	United States Department of Defense
USEPA	United States Environmental Protection Agency
USTs	Underground Storage Tanks
VC	Vinyl Chloride
VER	Vacuum Enhanced Recovery
v_h	Groundwater Seepage Velocity
VOC	Volatile Organic Compound
ZVI	Zero Valent Iron

Executive Summary

This report presents an engineering evaluation and cost analysis (EE/CA) for a non-time-critical removal action (NTCRA) for the dense non-aqueous phase liquid (DNAPL) source area at Operable Unit No. 16, Site 89 at Marine Corps Base (MCB) Camp Lejeune, Onslow County, North Carolina. Site 89 includes the Former Defense Reutilization and Marketing Office (DRMO), a larger, wooded area to the east and the south of the DRMO, and a portion of Camp Geiger to the west. The site is located on the New River Air Station side of the Base, southeast of the intersection of G Street and 8th Street. The DRMO was operated by the Defense Logistics Agency (DLA) and was used until 2000 as a storage yard for items such as scrap and surplus metal, electronic equipment, vehicles, rubber tires, and fuel bladders (mobile storage tanks).

Of the volatile organic compounds (VOCs) detected at Site 89, 1,1,2,2-tetrachloroethane (PCA) and trichloroethene (TCE) are the most prevalent and found at the highest concentrations. Other solvents, such as TCE daughter products 1,2-dichloroethene (1,2-DCE) and vinyl chloride (VC), have also been detected. Analytical data indicate the presence of a DNAPL source in the southern portion of the former DRMO. The source area is approximately 38,000 square feet with an estimated volume of 35,000 cubic yards. **Figure E-1** shows the footprint of the source area.

The purpose of this EECA is to analyze removal or treatment action alternatives for contaminant mass removal or treatment at the identified source area within the former DRMO. Five alternatives were evaluated to remediate the DNAPL impacted area: (1) excavation; (2) electrical resistive heating (ERH); (3) shallow soil mixing; (4) in-situ thermal desorption (ISTD); and (5) air sparge.

Each technology was evaluated based on effectiveness, implementability, and cost, as summarized in Table E-1. The technology to be implemented for the Site 89 NTCRA will be chosen by the Partnering Team, based on information presented in this EE/CA. The Partnering Team is comprised of representatives from MCB Camp Lejeune, US Environmental Protection Agency (EPA), North Carolina Department of Environment and Natural Resources (NC DENR), Shaw Group, and CH2M HILL.

TABLE E-1
Summary of Alternative Comparison

Evaluation Criteria	Alternative 1 Excavation	Alternative 2 Electrical Resistive Heating	Alternative 3 Shallow Soil Mixing	Alternative 4 In Situ Thermal Desorption	Alternative 5 Air Sparging
EFFECTIVENESS					
Overall Protection of Human Health and the Environment	Meets RAO through removal.	Meets RAOs through mass transfer to the vapor phase followed by treatment.	Meets RAO through treatment (contaminant degradation).	Meets RAOs through mass transfer to the vapor phase followed by treatment	Has potential to meet RAOs through mass transfer to the vapor phase followed by treatment, but may not be suitable for bulk DNAPL removal.
Compliance with ARARs	Complies with ARARs.	Complies with ARARs.	Complies with ARARs.	Complies with ARARs	Complies with ARARs.
Long-term effectiveness and permanence	All associated material is removed. Contamination is not destroyed, just transported offsite, which could result in future liability issues.	Risk reduction is provided through mass transfer and extraction. Contaminant flux is reduced.	Risk reduction is provided through contaminant degradation. Contaminant flux is reduced.	Risk reduction is provided through mass transfer and extraction. Contaminant flux is reduced.	Risk reduction is provided through mass transfer and extraction.
Reduction of Toxicity, Mobility or Volume through Treatment	Reduces toxicity, mobility and volume at the site through physical removal Contamination is not destroyed, but rather moved to a permitted facility.	Reduces toxicity, mobility and volume through heating, extraction, and hydrolysis. Treatment is irreversible.	Reduces toxicity, mobility, and volume through contaminant iron treatment. Reduces mobility of dissolved plume with addition of clay. Treatment is irreversible.	Reduces toxicity, mobility, and volume through heating, extraction, and hydrolysis. Treatment is irreversible.	Has potential to reduce toxicity, mobility, and volume through long term volatilization, extraction, and treatment. May not be suitable for bulk DNAPL removal and could result in significant residuals remaining after treatment.
Short-Term Effectiveness	Not effective in the short-term. Largest concern of this alternative is worker and surrounding community health and safety issues due to the possible creation of a hazardous atmosphere due to high contaminant concentrations. Encapsulation of the entire excavation area may be required with a substantial air handling system to vent and treat the enclosure, as well as Level C or B PPE. Excavation is considered one of the most dangerous construction activities with risks to workers such as cave-ins, falling, and falling loads requiring benching, trenching, shoring, bracing, underpinning, or shields. The open excavation will need to be barricaded to prevent non-workers from entering the site. Large increase of truck traffic around site and Base. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	Unpaved areas in thesource area could pose a possible risk of fugitive vapor migration to surrounding buildings. A temporary cover, such as a geo-synthetic liner, could be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Short term increase in air emissions. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	There is a potential of releasing air emissions to the atmosphere. A removable hood used on the mixing augers will capture these emissions and vapor treatment systems could treat these emissions. The treatment zone could be messy During mixing and addition, swells could be formed which could result in the spread of contaminants to clean areas. To capture these swells, excavations could be performed prior to implementation. Non-hazardous soil would be excavated, stockpiled, and reused to provide a final grade over the site. Excavation activities will pose hazards as associated with Alternative 1. Worker safety is an issue when working around the large equipment and near the soil slurry. A high visibility safety fence with appropriate warning signs would surround soil mixing activities. Noise may be an issue depending on the equipment used. However, operation would only be during standard working daytime hours. Potential to achieve RAOs within one year Significant management of groundwater and liquids	Unpaved areas in thesource area could pose a possible risk of fugitive vapor migration to surrounding buildings. A temporary cover, such as a geo-synthetic liner, could be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Short term increase in air emissions. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	There is a potential of releasing air emissions to the atmosphere. There is potential for sparge air "short-circuiting" around low permeability zones, which may leave localized untreated areas. Pneumatic fracturing would be recommended to enhance secondary permeability and DNAPL mass removal. During pneumatic fracturing, DNAPL could be released to underlying soils. A gravel layer immediately above grade would be utilized to collect soil vapor, due to the shallow depth to water at the site. Worker safety is an issue when installing sparge wells. The time frame to complete remedial action is conservatively estimated to be five years. A review of the alternative would be conducted at least once during that time period.
IMPLEMENTABILITY					
Technical Feasibility	Feasible. Excavation is known to be a reliable technology. Future remedial actions would not be required at the site.	ERH is much less restricted by heterogeneous subsurface conditions. However, the shallow water table could hinder the efficiency of SVE vapor captor units. Air emissions and water extracted during operation of the technology would require treatment. ERH has been proven to be a reliable technology at Site 89.	Insufficient delivery of reductive compounds to the subsurface could result in the ineffective treatment of the source area. The site is unoccupied, allowing for easy implementation of soil mixing (site is large enough to accommodate crane, infrastructure is limited, etc.) Vapor treatment may be required. Shallow soil mixing has been proven to be a reliable technology at Site 88.	ISTD is much less restricted by heterogeneous subsurface conditions. However, the shallow water table could hinder the efficiency of SVE vapor captor units. Air emissions and water extracted during operation of the technology would require treatment. ISTD offers flexibility in the orientation of heaters and can achieve higher temperatures than ERH, with more uniform heating. ISTD is a reliable technology, but has not been implemented at MCB Camp Lejeune.	Insufficient distribution of sparge air could result in untreated DNAPL in localized areas. Because the site is vacant and there are no plans to develop the property in the near future, long term operation is considered feasible. Because of the relatively low permeability of the Surficial Aquifer, sparging would require a longer period of time to achieve significant mass removal. Air sparging has been proven to be a reliable technology at Site 89 and Site 86; however, neither system was associated with source areas. Few case studies exist regarding air sparging source areas.
Administrative Feasibility	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required. Hazardous landfill may require pre-treatment.	Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air discharge permits may be required.
Availability of Services and Materials	Services and materials are available.	Services and materials are available. However, there are a limited number of suppliers to perform this work.	Services and materials are available.	Services and materials are available. However, there are a limited number of suppliers to perform this work.	Services and materials are readily available.
State and Community Acceptance	To be determined	To be determined	To be determined	To be determined	To be determined
COST					
Capital Cost (Direct and Indirect)	$25,300,000 - $54,200,000	$4,900,000 - $10,600,000	$3,000,000 - $6,500,000	$5,500,000 - $11,800,000	$1,600,000 - $3,300,000
Total O&M Cost	$0	$0	$0	$0	$600,000 - $1,400,000
Present Worth	$25,300,000 - $54,200,000	$4,900,000 - $10,600,000	$3,000,000 - $6,500,000	$5,500,000 - $11,800,000	$2,200,000 - $4,700,000

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- DNAPL Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure E-1
Footprint of DNAPL Source Area
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIO CH2M HILL

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1.0 Introduction

This report presents an Engineering Evaluation/Cost Analysis for a NTCRA for Operable Unit No. 16, Site 89 at MCB Camp Lejeune in Onslow County, North Carolina **(Figure 1-1)**. Site 89 includes the Former Defense Reutilization and Marketing Office (DRMO), a larger, wooded area to the east and the south of the DRMO, and a portion of Camp Geiger to the west. The site is located on the New River Air Station side of the Base (**Figure 1-2**), southeast of the intersection of G Street and 8th Street. The DRMO was operated by the Defense Logistics Agency (DLA) and was used until 2000 as a storage yard for items such as scrap and surplus metal, electronic equipment, vehicles, rubber tires, and fuel bladders (mobile storage tanks).

Site investigations over time indicate the occurrence of dense non-aqueous phase liquid (DNAPL) at Site 89. Previous removal actions were intended to address the source area; however, the Comprehensive Remedial Investigation conducted by CH2M HILL indicates that significant DNAPL still exists in the subsurface. As a result, the Camp Lejeune Partnering Team requested the EE/CA to focus on source removal.

This EE/CA is prepared by AGVIQ-CH2M HILL Joint Venture I (JV I) under the Naval Facilities Engineering Command (NAVFAC) – Mid-Atlantic Division, JV I Contract N62470-03-D-4401, Task Order (TO) 080.

The remedial alternatives presented and evaluated are designed to address the identified source area only. The actions are intended to remove or treat as much DNAPL from the source area as is practical and cost efficient. DNAPL removal is complex and current technologies used to address "free phase" dense liquids are limited. Treatment of the dissolved plume is not addressed in this EE/CA.

1.1 Regulatory Background

This document is issued by the United States Department of the Navy (DoN), lead agency responsible for remediation of Site 89, with the assistance of the United States Environmental Protection Agency (USEPA) Region 4 and the North Carolina Department of Environment and Natural Resources (NCDENR), under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA).

A removal action is being considered for the portion of Site 89 where DNAPL source area has been identified. This removal action is not time-critical. NTCRAs are defined in 40 CFR Section 300.415(b)(4) as actions pertaining to a less imminent threat to human health and the environment and that have planning periods of six months or more. For time-critical removal actions, activities shall begin as soon as possible to "abate, prevent, minimize, stabilize, mitigate, or eliminate the threat to public health or welfare of the United States or the environment" (40 CFR Section 300.415(b)(3)).

According to 40 CFR Section 300.415, the lead agency is required to conduct an EE/CA when an NTCRA is planned for a site. The goals of an EE/CA are to identify the objectives of the removal action and to analyze the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives. An EE/CA documents the removal action alternatives and selection process. NTCRAs also allow for the expedited cleanup of sites where the extent of the contamination is well defined.

1.2 Purpose of the EE/CA

According to the USEPA *Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA* (USEPA, 1993), "an EE/CA is a flexible document tailored to the scope, goals, and objectives of the non-time-critical removal action. It should contain only those data necessary to support the selection of a response alternative, and rely upon existing documentation whenever possible." The goals of an EE/CA are:

- Satisfy environmental review requirements for removal actions,
- Satisfy administrative record requirements for improved documentation of removal action selection, and
- Provide a framework for evaluating and selecting alternative technologies.

The guidance further notes the following:

- A separate risk assessment is not necessary,
- Data collection to characterize the nature and extent of contamination should be limited to those needed to support the specific objectives of the non-time-critical removal action, and
- Only a few viable alternatives relevant to the EE/CA objectives should be identified and analyzed.

An EE/CA must be completed for all non-time critical removal actions under CERCLA, as required by section 300.415(b)(4)(i) of the NCP. An EE/CA serves an analogous function to the RI/FS conducted for remedial actions, but is more focused and streamlined.

1.3 Organization of the EE/CA

The following information is presented in this EE/CA:

- Section 2 Site Characterization
- Section 3 Identification of Remedial Action Objectives
- Section 4 Remedial Action Alternatives
- Section 5 Detailed Analysis of Remedial Action Alternatives
- Section 6 Comparative Analysis of Remedial Action Alternatives
- Section 7 References

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Legend
- Cities
- Limited Access Highway
- Highway
- Local Roads
- Installation Area

N

0 10 Miles

Figure 1-1
Base Location Map
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

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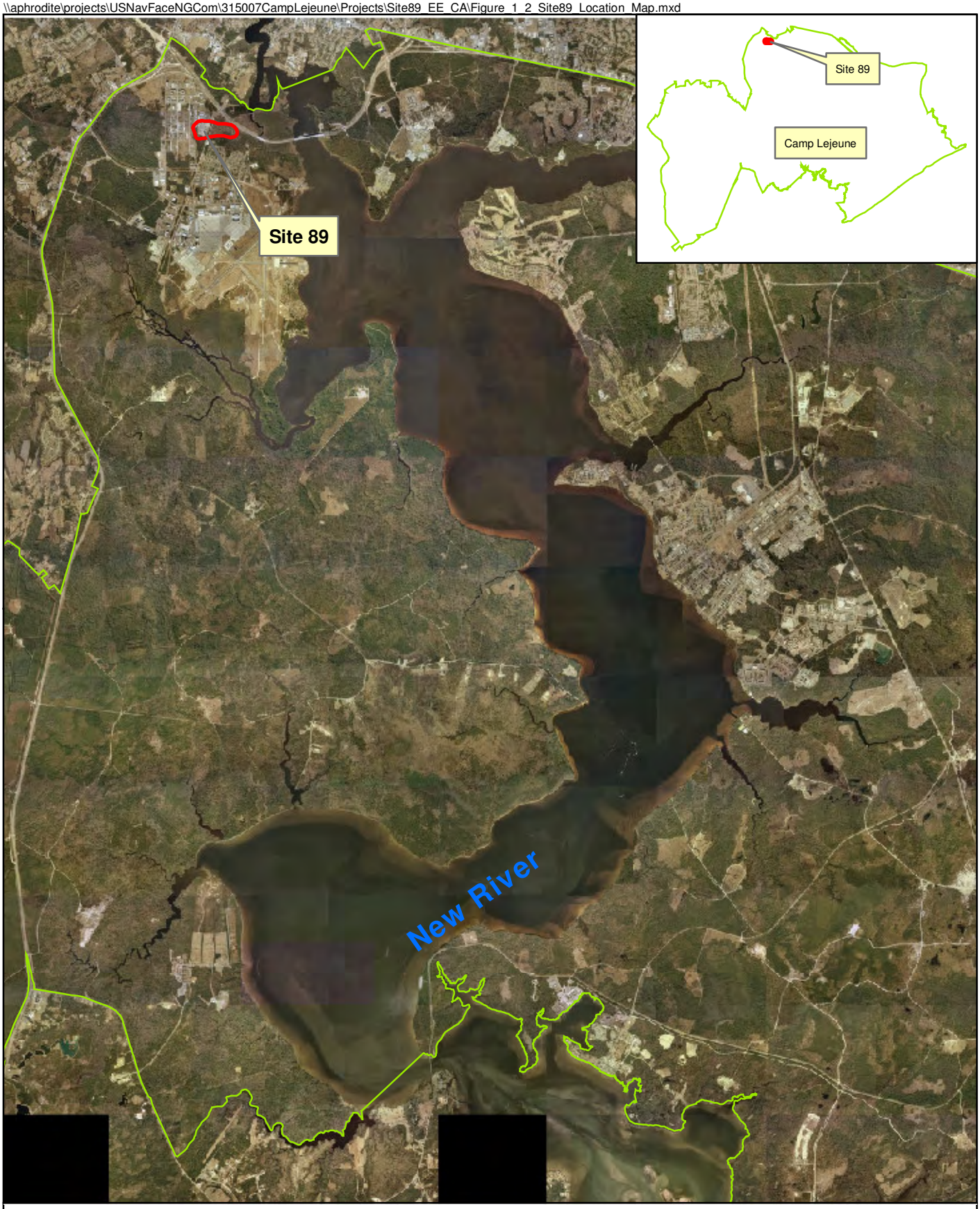


Legend

Environmental Restoration Area

Installation Area

N

0 4,000 8,000 Feet

Aerial Photograph taken Feb. 2004

Figure 1-2

Site 89 Location Map

Operable Unit No. 16 Site 89

MCB Camp Lejeune, North Carolina

AGVIO

CH2M HILL

2.0 Site Characterization

This section contains site characterization information including site description and background, nature and extent of contamination, and a streamlined risk evaluation.

2.1 Facility and Site Description

MCB Camp Lejeune is located in Onslow County, North Carolina. The Base covers approximately 236 square miles and is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The southeastern border of the Base is the Atlantic Ocean shoreline (**Figure 1-1**, Camp Lejeune Site Location Map). The western and northeastern boundaries are U.S. Route 17 and State Route 24, respectively. The City of Jacksonville, North Carolina borders the Base to the north.

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), although the elevation of the majority of the Base lies between 20 and 40 feet above msl.

2.1.1 Facility and Site Physical Setting

The general location of Site 89 is shown on **Figure 1-2**. Site 89 is located to the west of the New River, on Camp Geiger near the intersection of G and 8th Street**.** The Site 89 investigative area includes the woods to the east and the south of the DRMO and a portion of Camp Geiger to the west.

The majority of the ground surface of the former DRMO area is covered with asphalt; however, the areas immediately east of the former UST STC-868 and south of Building TC952 are grass covered, as shown on **Figure 2-1.** The area east of the former DRMO and north of Edwards Creek is a wooded area that is also included in Site 89. The areas north and west of Site 89 are generally developed, covered with buildings, asphalt, and grass. The former DRMO area is surrounded by a fence with an access gate located near Building TC864.

Figure 2-2 shows the location of Site 89 relative to its topography and hydrologic features. The areas surrounding Site 89 to the north and west drain into stormwater ditches. Many of the stormwater ditches north and west of Site 89 flow and discharge into the source of Edwards Creek near the intersection of 8th and G Streets. The former DRMO of Site 89 drains into Edwards Creek and the drainage ditch along the east side of the site. Ground surface elevations are approximately 5 to 20 feet above msl. Underground utilities are shown in **Figure 2-3.**

2.1.2 Site History

The DRMO was operated by the Defense Logistics Agency (DLA) and, until 2000, was used as a storage yard for miscellaneous items such as scrap and surplus metal, electronic equipment, vehicles, rubber tires, fuel bladders (mobile storage tanks), and other material that would be sent offsite.

Historical records indicate that the Base Motor Pool operated on the site until approximately 1988. The Base Motor Pool was then relocated to its current location, an asphalt paved area immediately north of the DRMO facility. The Base Motor Pool reportedly used various solvents, such as acetone, TCE, and 2-butanone (methyl-ethyl-ketone [MEK]), for cleaning parts and equipment. Historical records also indicate that a 550-gallon underground storage tank (UST), identified as UST STC-868, was installed at the site in 1983 and used to store waste oil. The UST was removed in 1993.

In the early 1990s, fuel bladders were placed onsite. The bladders ranged in size from 600 to 20,000 gallons and were used in training exercises for helicopter refueling. Base personnel reported that the bladders were emptied on the ground, cleaned with solvents, re-emptied on the ground, and capped prior to storage at the DRMO. The bladders were stored for 3 to 4 years in a pile approximately 75 feet in diameter by 25 feet high. The pile was located west of the oil changing area, as shown on **Figure 2-1**. A shredder was brought onsite and located immediately north of the bladder pile. The bladders were shredded into small cubes and placed into roll-off boxes. During shredding operations, liquids were reportedly observed escaping from the bladders. These liquids were not contained or removed.

The site has not been used since the DRMO relocated in 2000. The only site activity since that time has been related to environmental investigations.

2.1.3 Soil and Lithologic Information

A detailed discussion of the soil and lithologies at Site 89 is presented in the Draft Comprehensive RI Report (CH2M HILL, 2005). Information pertinent to the source area is summarized herein.

The location of the A-A′ and B-B′ geologic cross-section is shown on **Figure 2-5** and cross-sections are shown on **Figures 2-6** and **2-7**, respectively. Cross-section A-A′ trends west-east and passes through the south side of Site 89. The section includes the stratigraphic sequence of the undifferentiated and River Bend Formations described above.

The undifferentiated formation varies in depth across the A-A′ cross-section, varying from approximately 18 feet deep near the Site 93 monitoring well 93-MW03 to approximately 8 feet deep near the Site 89 monitoring well 89-MW04 to approximately 16 feet deep near the Site 89 monitoring well 89-MW08. The east side of the A-A′ cross-section contains mostly fine sand with a thinning of the partially cemented sand layer and the olive to greenish gray, fine sand layer. The partially cemented sands in the upper portion of the River Bend formation, observed between 20 to 40 ft bgs, were discontinuous across the A-A′ cross section. An olive to greenish gray, fine sand layer, approximately 5 to 10 feet thick, was continuous at 40 to 50 ft bgs throughout the A-A′ section.

2.1.4 Hydrologic and Hydrogeologic Information

A detailed discussion of the hydrologic and hydrogeologic characteristics at Site 89 is presented in the Draft Comprehensive RI Report (CH2M HILL, 2005). Information pertinent to the source area is summarized herein.

The hydrogeologic setting at Site 89 is that of a three aquifer system: the surficial aquifer, the Upper Castle Hayne aquifer, and the Castle Hayne aquifer. Groundwater potentiometric surface maps for Site 89 were produced for each aquifer. The water level elevations used to produce these maps were measured in November 2005.

The static water level elevations of the unconfined surficial aquifer ranged from 12.1 ft msl to 5.8 ft msl in November 2005. Groundwater flow within the unconfined surficial aquifer at Site 89 is influenced by Edwards Creek, generally to the south/southeast. A groundwater contour map of the surficial aquifer, based on data collected during November 2005, is shown on **Figure 2-8**. The fine silty and clayey sand of the Belgrade formation is laterally discontinuous at Site 89 and therefore only provides semi-confining conditions to the Upper Castle Hayne aquifer below. The horizontal hydraulic gradient in December 2005 within the surficial aquifer averaged approximately 0.010 ft/ft.

Static water level elevations within the Upper Castle Hayne aquifer ranged from 11.0 ft msl to 4.5 ft msl in November 2005. Groundwater within the Upper Castle Hayne aquifer generally flows southeast toward the New River. The horizontal hydraulic gradient in November 2005 within the Upper Castle Hayne aquifer averaged approximately 0.003 ft/ft. A groundwater contour map of the Upper Castle Hayne aquifer is shown on **Figure 2-9**.

The static water level elevations within the Castle Hayne aquifer ranged from 11.4 ft msl to 5.8 ft msl in November 2005. Groundwater within the Castle Hayne aquifer generally flows southeast toward the New River, as shown on **Figure 2-10**. The horizontal hydraulic gradient in November 2005 within the Castle Hayne aquifer averaged approximately 0.003 ft/ft.

Based on the November 2005 water-level data, slight downward gradients exist between well pairs 89-MW03/89-MW03IW and 89-MW04/89-MW04IW of 0.003 ft/ft and 0.027 ft/ft, respectively.

2.1.5 Aquifer Testing

Hydraulic conductivity values were determined for the surficial aquifer and Upper Castle Hayne aquifer units using slug tests (Baker, 2000). The average hydraulic conductivity value for the surficial aquifer unit (comprised of silty sands) was approximately 8.4 feet per day (ft/day), while the average hydraulic conductivity for the Upper castle Hayne aquifer was approximately 64.6 ft/day. CH2M HILL performed slug tests in the shallow aquifer on January 26, 2006, which indicated consistent hydraulic conductivity values ranging from 3.9 ft/day to 6.3 ft/day

2.1.6 Seepage Velocities

Groundwater flow velocities can be calculated using the hydraulic conductivity data along with the hydraulic gradient and an estimated porosity. Velocities were calculated using Darcy's equation.

Using,

$$v_h = \frac{K_h}{n} i$$

where,

v_h - groundwater seepage velocity (ft/day)

K_h - horizontal hydraulic conductivity (ft/day)

n - effective porosity (dimensionless)

i - horizontal hydraulic gradient

Using effective porosity values for silts and sands in the range of 25 to 50 percent (Freeze and Cherry, 1979), a seepage velocity within the surficial aquifer at Site 89 was determined in the range from 0.078 to 0.252 ft/day (28 to 92 feet per year [ft/year]), based on the slug tests conducted by CH2M HILL. The extent of shells within the lithology of the Upper Castle Hayne aquifer appears to provide a more conductive zone for groundwater movement as compared to the silty sand lithology of the surficial aquifer. Using effective porosity values for silts and sands in the range of 25 to 50 percent (Freeze and Cherry, 1979), a seepage velocity within the more conductive Upper Castle Hayne aquifer at Site 89 was determined in the range from 0.39 to 0.78 ft/day (141 to 284 ft/year), based on the slug tests conducted by Baker Environmental, Inc. (Baker). Assuming a saturated thickness of 45 feet (depth from water table down to greenish gray fine sand semi-confining layer), the transmissivity value for the Upper Castle Hayne aquifer is approximately 2,910 ft^2/day.

2.1.7 Surrounding Land Use and Populations

The majority of the ground surface at Site 89 is covered with asphalt; however, the areas immediately east of the former UST STC-868 and south of Building TC952 are grass covered and/or wooded (**Figure 2-1**). Access to most of Site 89 is restricted. Several vacant buildings are located within the restricted area. The unrestricted area is currently in use by the Camp Geiger School of Infantry, where one building on the northern part of the site (TC864) is used for check-in one day each week. All buildings on-site are marked for demolition at an undetermined date. Building TC860, located immediately west of Site 89, is permanently occupied by School of Infantry administration.

Based on the information provided in the Wellhead Protection Plan – 2002 Update (AH Environmental Consultants, 2002), there are no water supply wells within 1,500 feet of Site 89. Wells TC-1251 and TC-1253 are located 2,300 and 2,600 feet southeast of Site 89, respectively. TC-1251 is screened from 120 to 135 ft bgs and TC-1253 is screened from 120 to 170 ft bgs.

Potable water to MCB Camp Lejeune and the surrounding residential area is provided by water supply wells that pump groundwater from the Castle Hayne aquifer. Although freshwater is present within the surficial, Castle Hayne, Beaufort, and Peedee aquifers, all of which are located below MCB Camp Lejeune, only the Castle Hayne aquifer is used by MCB Camp Lejeune as a water supply source (Cardinell, et al., 1993). No wells between Site 89 and groundwater discharge points reportedly utilize the Castle Hayne Aquifer for domestic

potable supply or any other uses. MCB Camp Lejeune controls all the land between Site 89 and associated groundwater discharge points.

2.1.8 Sensitive Ecosystems

A detailed Ecological Risk Assessment (ERA) is presented in the Draft Comprehensive RI Report (CH2M HILL, 2005). Pertinent information regarding Edwards Creek and site wetlands is summarized herein.

The results of the risk assessment indicated that the western wetland adjacent to Edwards Creek contains levels of PAHs and pesticides (DDTr) that pose a risk to receptors exposed directly to wetland sediment. The risk identified was to the benthic invertebrate community. Other communities living within the wetland may also be at risk as the wetland serves as a spawning ground for amphibians which are most sensitive during their juvenile life stages in the aquatic environment.

The comparison of site-specific benthic macroinvertebrate data collected in the stream and reference locations was used to evaluate risk in Edwards Creek. Analysis suggested that the poor condition of the benthic community is most likely related to poor quality habitat and not constituent releases from Site 89. Overall, evidence suggests minimal potential for ecological risk within the sediments of Edwards Creek.

The comparison of chemical concentrations in surface water to ecological benchmarks suggests there is no unacceptable risk; average concentrations do not exceed ecological benchmarks for fish. The finding of a poor quality fisheries community at the site and at the unimpacted reference station also suggests, as was the case for benthic macroinvertebrates, that the quality of the fish community in Edwards Creek at Site 89 is more likely related to habitat quality than releases at Site 89.

2.1.9 Meteorology

Mild winters and hot humid summers characterize the MCB Camp Lejeune area climate. Winters are usually short and mild with occasional and short duration cold periods. Summers are long, hot, and humid. Average annual net precipitation is approximately 50 inches. Ambient air temperatures generally range from 33 to 53 degrees Fahrenheit (°F) in the winter months, and 71°F to 88°F during the summer months. Winds are generally south-southwesterly in the summer, and north-northwesterly in the winter (Water and Air Research, 1983).

2.2 Previous Investigations

A complete review of historic investigation activities at Site 89 is provided in the Draft Comprehensive RI (CH2M HILL, 2005).

Investigations at Site 89 have historically been focused on a small area within the DRMO that formerly contained a 550-gallon steel UST used to store waste oil. The UST, identified as UST STC-868, was reportedly removed in 1993. The initial UST investigation detected chlorinated solvents in the groundwater, which led to the inclusion of the site into the Camp Lejeune Installation Restoration (IR) Program. Several investigations followed to determine the source, nature, and extent of contamination.

2.2.1 Phase I and II Focused Remedial Investigations

A Focused RI was done in two phases to further assess the extent of contamination. Phase I was completed in August 1996 and Phase II in May 1997. The investigations included sampling soil and groundwater from locations around the former DRMO as well as in the area east of the former DRMO. Permanent and temporary monitoring wells were installed and sampled. In addition, surface water and sediment samples were collected from Edwards Creek. Samples were analyzed for VOCs, SVOCs, metals, and pesticides/polychlorinated biphenyls (PCBs).

Among the VOCs detected in subsurface soil samples, PCA was reported in subsurface soils as high as 98 mg/kg in boring 89-MW03DW, while TCE was reported as high as 110 mg/kg in boring 89-MW05DW.

VOCs were reported in the groundwater samples, with the highest VOC concentrations identified in the shallow zone. Concentrations of TCE above regulatory levels were found in the shallow zone (approximately 15 feet below ground surface [ft bgs]) as high as 744 µg/L and in the intermediate zone (approximately 40 ft bgs), downgradient of the former UST area, at 510 µg/L in well 89-MW04IW. No VOCs were reported in the deep wells (approximately 70 ft bgs) during the Phase I and II RI.

Surface water and sediment samples were collected at 10 locations along Edwards Creek. TCE was reported as high as 26 µg/L, while PCA was reported as high as 150 µg/L in surface water. TCE and PCA were reported at concentrations as high as 2.4 mg/kg and 1.7 mg/kg, respectively, in sediment. Surface water and sediment sampling locations with these detections were all located south and downgradient of the former UST area.

2.2.2 Long-Term Monitoring Program

Groundwater and surface water samples were collected at Site 89 on a semi-annual basis from April 1999 to December 2003 by Baker as part of the Base-wide long-term monitoring (LTM) program at MCB Camp Lejeune. The monitoring program at Site 89 was intended to detect changes in groundwater contaminant concentrations and monitor contaminant migration. In addition, the program provided data used in evaluating natural attenuation processes.

2.2.3 Immediate Response Field Efforts (1999)

In October and December 1999, additional investigations were conducted by Baker to further delineate potential vadose zone source soils and characterize groundwater, surface water, and sediment.

October 1999 Event

The maximum PCA, TCE, and vinyl chloride concentrations detected in surface water samples collected during October 1999 were 2,500 µg/L, 730 µg/L, and 100 J µg/L, respectively. These maximum detections were identified in DSW-14, collected from the drainage ditch.

The maximum PCA, TCE, and vinyl chloride concentrations detected in groundwater samples collected during October 1999 were 26,000 µg/L (89-MW02), 60,000 µg/L (89-MW09), and 740 µg/L (89-MW13).

Multiple VOCs were detected above their applicable residential and/or industrial RBCs in surface and subsurface soils collected during the October 1999 event. The maximum concentrations of PCA, PCE, and TCE were 18,000 mg/kg (IR89-SB05, 3-5 ft), 29 mg/kg (IR89-SB05, 1-3 ft), and 210 mg/kg (IR89-SB33, 3-5ft), respectively.

Six VOCs (acetone, 2-butanone, vinyl chloride, 1,2-DCE, TCE, and PCA) were detected in sediment samples collected in October 1999. The maximum concentration of PCA was 4 mg/kg detected in a sample from the drainage ditch located on the eastern portion of the site (DSD-14).

December 1999 Event

In December 1999, VOCs were detected in surface and subsurface soil samples. TCA, TCE, and vinyl chloride were detected at 1.50 mg/kg (89-TW108-6-7), 190 mg/kg (89-TW109-7-8), and 2.2 mg/kg (89-TW106-4-5), respectively.

2.2.4 Supplemental Site Investigations

Two additional sampling events were conducted by Baker in March and April of 2000 to better define two areas prior to soil excavation for a Time Critical Removal Action (TCRA).

In March 2000, surface and subsurface soils were collected from six boring locations placed in and around the TCRA excavation area. The maximum PCA, PCE, and TCE concentrations were 84,000 mg/kg (89-SB69-3-4), 160 mg/kg (89-SB69-24-26), and 4,600 mg/kg (89-SB-69-24-26). Based on these data, the horizontal extent of the source areas to be excavated was estimated.

Four permanent monitoring wells were installed south of Edwards Creek to determine if Edwards Creek was functioning as a hydraulic barrier. No VOCs were detected in these wells at this time. In addition, three temporary shallow monitoring wells were installed inside the DRMO and around the proposed excavation area. The maximum PCA, TCE, and vinyl chloride concentrations detected in the groundwater samples collected from the temporary monitoring wells were 1,800,000 µg/L, 360,000 µg/L, and 1,200 µg/L, respectively.

Baker conducted a Supplemental Investigation (SI) in an area south of the former DRMO during June 2001. The SI included the advancement of membrane interface probe (MIP) borings and confirmatory soil borings; the installation of four permanent monitoring wells (two shallow and two intermediate depth wells); and six Ribbon NAPL Samplers. The presence of DNAPL was discovered in monitoring well 89-MW17 during the investigation. The SI identified two separate DNAPL plumes on the southern portion of the site.

2.2.5 Comprehensive Remedial Investigation

After a series of removal actions (described in the following section), CH2M HILL was tasked to perform a comprehensive RI of Site 89, beginning in late 2003 and concluding late 2005. The objectives of the Comprehensive RI were to update and expand the existing

database of information concerning the nature and extent of contamination, including potential DNAPL areas. The scope of work for the Comprehensive RI included completion of membrane interface probe (MIP) profiling, direct push groundwater sampling, installation new monitoring wells, sampling of groundwater from all site monitoring wells, and sampling of surface water, sediment, sediment pore-water, and vapor. Chlorinated volatile organic compounds (CVOCs), including TCE and 1,1,2,2 PCA, were reported in soil, groundwater, surface water, and sediment samples. PCE and degradation products of TCE and PCA have also been detected at Site 89.

The nature and extent of contamination at Site 89 presented in Section 2.4 is based primarily on data collected during the Comprehensive RI, although historical data from all phases of work was reviewed.

2.3 Previous Removal Actions

2.3.1 Low Temperature Thermal Desorption Operations

As part of a TCRA, low temperature thermal desorption (LTTD) operations were conducted by OHM Remediation Service Corporation (OHM) in the southern portion of the DRMO area in October 2000. The LTTD effort was conducted to remediate the most contaminated soil to a cleanup goal of PCA at 1 mg/kg. The top five feet of soil was removed. The final volume of soil treated during the TCRA activities was approximately 23,788 cubic yards (35,682 tons). The treated soil was placed back into the excavation area and compacted. **Figure 2-11** shows the excavation limits.

2.3.2 Electrical Resistive Heating Operations

From September 2003 to May 2004, an electrical resistive heating (ERH) pilot study was conducted by Shaw Environmental Infrastructure as a remedial action for one of the DNAPL plumes identified in the SI. The system consisted of 43 deep heating electrodes installed to a depth of 26 feet bgs and 48 shallow electrodes installed to a depth of 19 feet bgs, as shown on **Figure 2-12**. The total area of treatment was approximately 15,900 square feet. Approximately 50% of the electrodes were slotted and used for vacuum extraction of volatile vapors from the subsurface. The ERH system was turned off and disassembled in May 2004. An estimated 48,000 pounds of VOCs were removed from the subsurface during this remedial action. In addition, an estimated 428 pounds of chlorinated compounds were recovered from the groundwater during the pilot test. Analytical results indicated that contaminant concentrations in soil were reduced by 97% to 99% at most locations. Contaminant concentrations in groundwater within the treatment area were reduced by 99%

2.4 Nature and Extent of Contamination

A detailed discussion of the nature and extent of contamination is presented in the Draft Comprehensive RI Report (CH2M HILL, 2005). Investigative activities conducted in association with the Comprehensive RI included MIP profiling, direct push technology (DPT) groundwater sampling, monitoring well groundwater sampling, and surface water and sediment sampling. The following briefly summarizes the results of each activity.

MIP Profiling

The MIP investigation focused on the vicinity of UST STC-868, around Building TC952, and along the north area of the former DRMO. The ECD detector reached a maximum response of 1,200,000 µV from 1.5 to 8 ft bgs and 11 to 25 ft bgs at MIP location 89-MP03 in the vicinity of former UST STC-868. The ECD detector reached a maximum response of 1,200,000 µV from 16 to 18 ft bgs at MIP location 89-MP27 within former DRMO area.

DPT Groundwater Sampling

TCE was the most prevalent VOC compound detected during the DPT groundwater investigation. The highest concentrations of TCE were generally within the shallow aquifer zone (approximately 15 to 20 ft bgs) and in the vicinity of the former UST STC-868 at the DRMO, with a maximum concentration of 23,000 µg/L detected from 89-SB54. Elevated concentrations of TCE were also reported in the shallow aquifer near Building TC952 and Building TC864.

Monitoring Well Groundwater Sampling

Groundwater samples were collected from a total of 58 monitoring wells in April 2004 and 76 monitoring wells in November – December 2005. TCE was again the most prevalent VOC compound detected. TCE was detected in the surficial aquifer and Upper Castle Hayne aquifer, but was not detected in the Castle Hayne aquifer. Results from the November – December 2005 sampling event indicate that the highest concentrations of TCE were generally within the shallow aquifer in the vicinity of the former vehicle maintenance and storage area and in the vicinity of the former UST STC-868 at the DRMO. The distribution of TCE detected in the surficial and Upper Castle Hayne aquifers during the November – December 2005 event are presented as isoconcentration maps on **Figures 2-13** and **2-14**. PCA, PCE, cis-1,2-DCE, and vinyl chloride were also detected in groundwater at concentrations exceeding the North Carolina 2L Groundwater Standards during the Comprehensive RI.

Surface Water and Sediment Sampling

VOCs were detected at all six surface water sampling locations within Edwards Creek during the April 2004 sampling event. Maximum concentrations of 1,1,2,2-PCA (180 µg/L), TCE (260 µg/L), cis-1,2-DCE (2,300 µg/L), and vinyl chloride (480 µg/L) were all reported at sample location 89-SG06 located within the drainage ditch east of the former DRMO. Only 1,1,2,2-PCA and TCE exceeded the North Carolina 2B Surface Water Quality Standards. Based on the results of the April 2004 surface water sampling, the above locations were re-sampled with two additional downstream locations in December 2005. Concentrations of 1,1,2,2-PCA exceeded the 2B Surface Water Standard at all locations except upstream 89-SG01. The sample collected from the drainage ditch (89-SG06) indicated a TCE surface water concentration of 400 µg/L in December 2005.

VOCs were detected at all six sediment sampling locations within Edwards Creek during the April 2004 field activities. Maximum concentrations of 1,1,2,2-PCA (.007 mg/kg), 1,1-DCE (0.280 mg/kg), PCE (0.041 mg/kg) TCE (2.4 mg/kg), cis-1,2-DCE (1.7 mg/kg), and vinyl chloride (0.290 mg/kg) were all reported at sample location 89-SG06 located within the drainage ditch east of the former DRMO. Based on the results of the April 2004 sediment sampling, the above locations were re-sampled along with two additional locations in December 2005. Maximum concentrations of each VOC were again reported at sample

location 89-SG06. VOCs were not detected in the two additional downstream sediment samples; thereby fully delineating the extent of VOCs in sediment.

2.5 Source Area

Based on the chemical and physical data gathered during investigations at Site 89, a significant source area is in the southern portion of the former DRMO (the former vehicle maintenance and storage area), where substantial chlorinated solvents, including some in the form of DNAPL, have been detected in the soil and groundwater. Dissolved concentrations of VOCs in groundwater at approximately one to ten percent of a compound's solubility may suggest the presence of DNAPL in the subsurface. The source area identified for treatment under this NTCRA, as shown on **Figure 2-15,** is based on dissolved concentrations in exceedance of five percent of a compound's solubility. The source area is approximately 38,000 square feet to a depth of 25 feet. The volume of soil within the source area is estimated to be 35,000 cubic yards. Assuming a pore space of 25%, the treatment area also contains approximately 1.8 million gallons of groundwater. Based on the maximum TCE concentrations detected within the source area during the Comprehensive RI, an estimated 37,000 pounds of contamination is present in the subsurface. This value is a gross estimate and does not account for the mass of DNAPL that is known to exist. The actual contaminant mass is most likely one to three times greater due to the presence of DNAPL and the heterogenity of the site. During implementation of the action, additional sampling will be performed to help assist in documenting baseline conditions. All wells in the source area and 89-MW40, which has historically shown concentrations at approximately 2% of TCE solubility, will be sampled during preparation of the NTCRA Work Plan to verify the limits of the source treatment.

2.6 Streamlined Risk Evaluation

According to USEPA *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*, (1993), "…[for the EE/CA, the streamlined risk evaluation should focus on the specific problem that the removal action is intended to address. If the action is intended to address a particular source of contamination, the risk evaluation should address the risks related only to that source of contamination." Since this EE/CA addresses only the removal or treatment of DNAPL as a source of further contamination in groundwater at the site, the risk evaluation is limited to DNAPL only.

The primary risk is the continuing source of contamination to groundwater from the DNAPL. By removing the contaminant mass, the continuing contaminant source will be minimized. Due to technology limitations, it may not be possible to completely remove all DNAPL. Significant contaminant reduction (i.e., greater than 90%) will still leave contaminant concentrations several orders of magnitude above regulatory standards. Additionally, these removal actions do not address groundwater dissolved contamination outside the identified source area, which will remain at the site and will be addressed separately by a final remedy.

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_1_Site89_Map.mxd

Legend

- Shallow Groundwater Monitoring Well
- Intermediate Groundwater Monitoring Well
- Deep Groundwater Monitoring Well
- Water Bodies
- Site 89 Boundary
- Surface Water Flow Direction

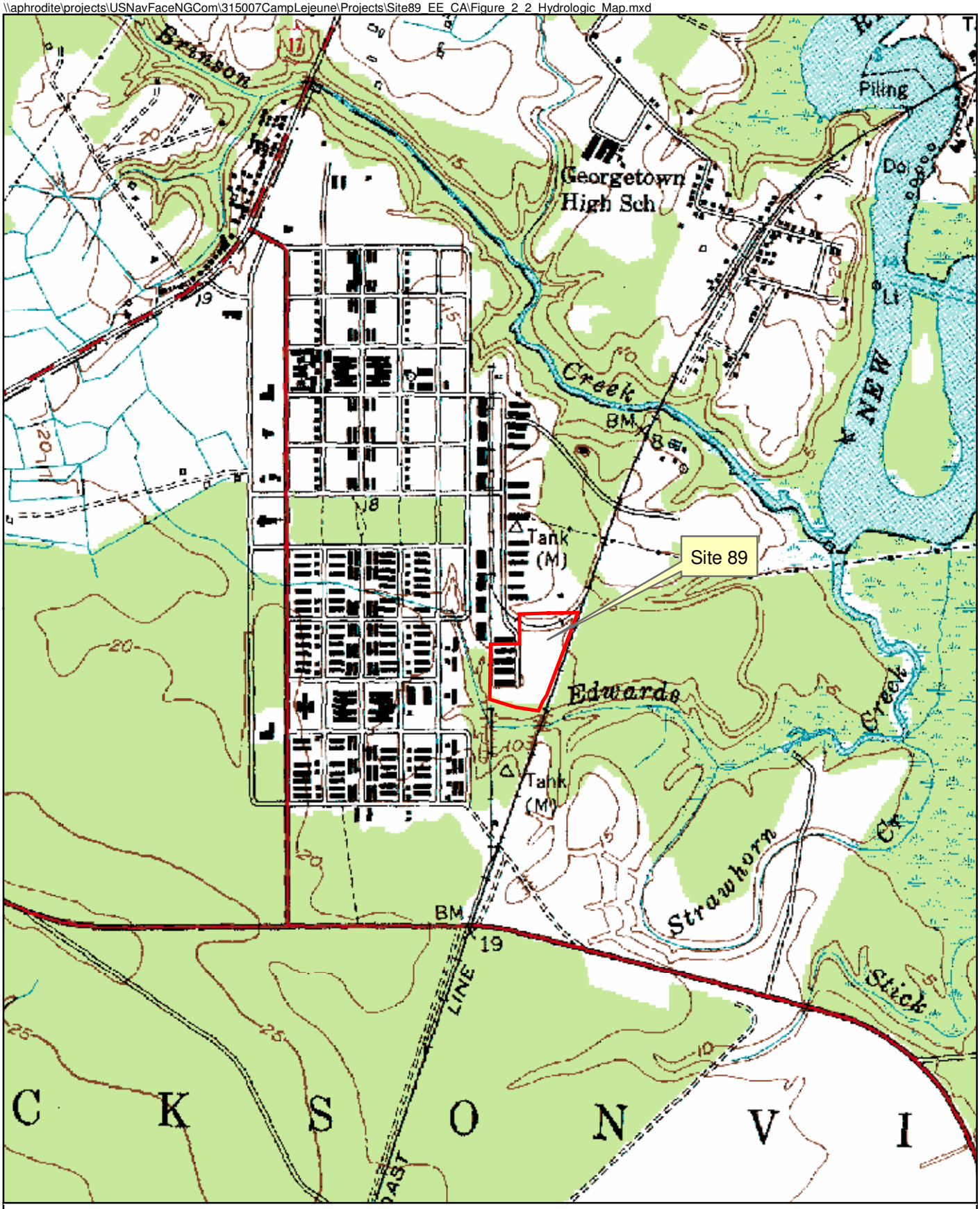
N

0 125 250 Feet

Aerial Photograph taken Feb. 2004

Figure 2-1
Site Map
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL



Source: USGS Jacksonville South, NC, quad

N

0 625 1,250
Feet

Figure 2-2
Site 89 Camp Lejeune Hydrologic Features
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ
CH2M HILL

Legend

- Wastewater network junctions
- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- Water fire connection point
- Wastewater septic tank point
- Wasterwater oil water separator point
- MANHOLE
- VALVE BOX
- Wastewater network junctions
- SWPPP GPS INLET
- Storm sewer outfall point
- Storm sewer pipe end point
- Storm sewer line
- Storm sewer open drainage line
- FMAIN
- GMAIN

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 2-3
Underground Utility Map
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_2_3_Underground_Utility_Map.mxd

FIGURE 2-4
Hydrostratigraphic Units of the North Carolina Coastal Plain
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

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

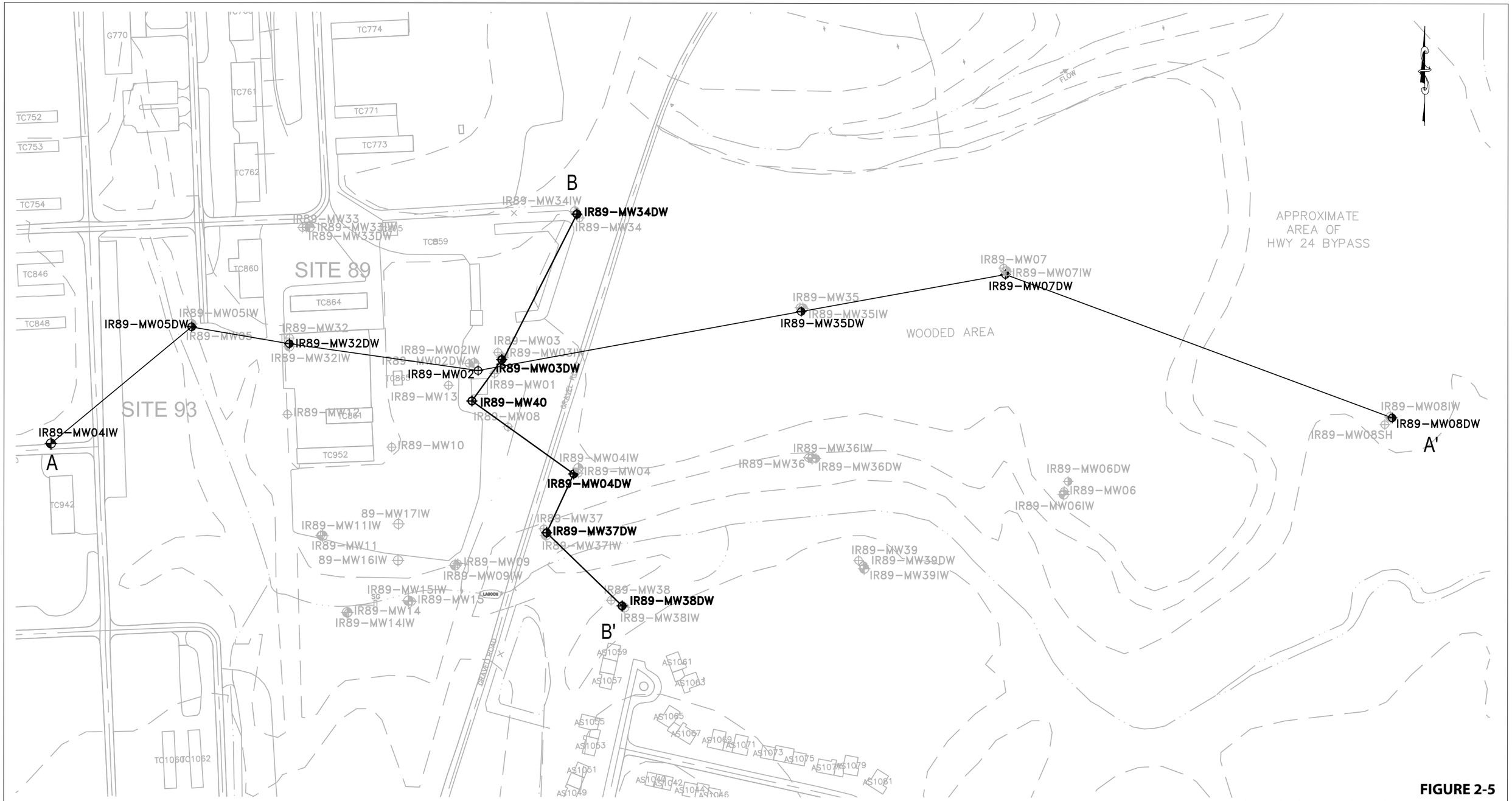
Notes:

[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.



LEGEND

- INTERMEDIATE GROUNDWATER MONITORING WELL
- SHALLOW GROUNDWATER MONITORING WELL
- DEEP GROUNDWATER MONITORING WELL

250 0 125 250

1 inch = 250 ft.

FIGURE 2-5

GEOLOGIC CROSS SECTION LOCATION MAP

OPERABLE UNIT NO. 16 SITE 89

MCB CAMP LEJEUNE,

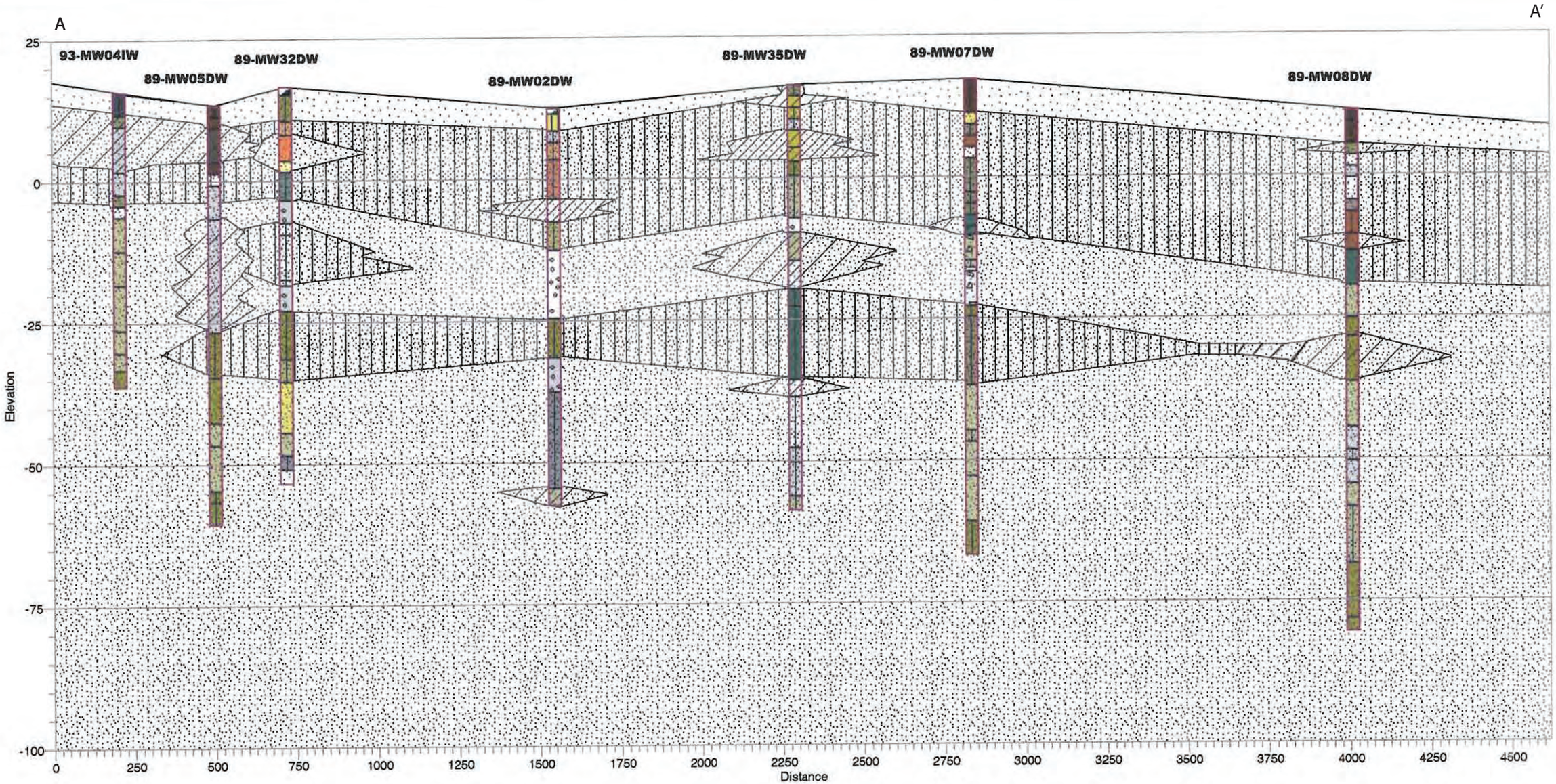
NORTH CAROLINA

AGVIQ ENVIRONMENTAL SERVICES

CH2M HILL JOINT VENTURE

EBL\NAVY CLEAN\CAMPLEJCADD\SITE 89\EECA\CAD\Figure 2-5.dwg

SOURCE: MCB, CAMP LEJEUNE, MARCH 2000



AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

Figure 2-6
Cross Section A-A'
Site 89 EE/CA
MCB Camp Lejeune, North Carolina

Legend

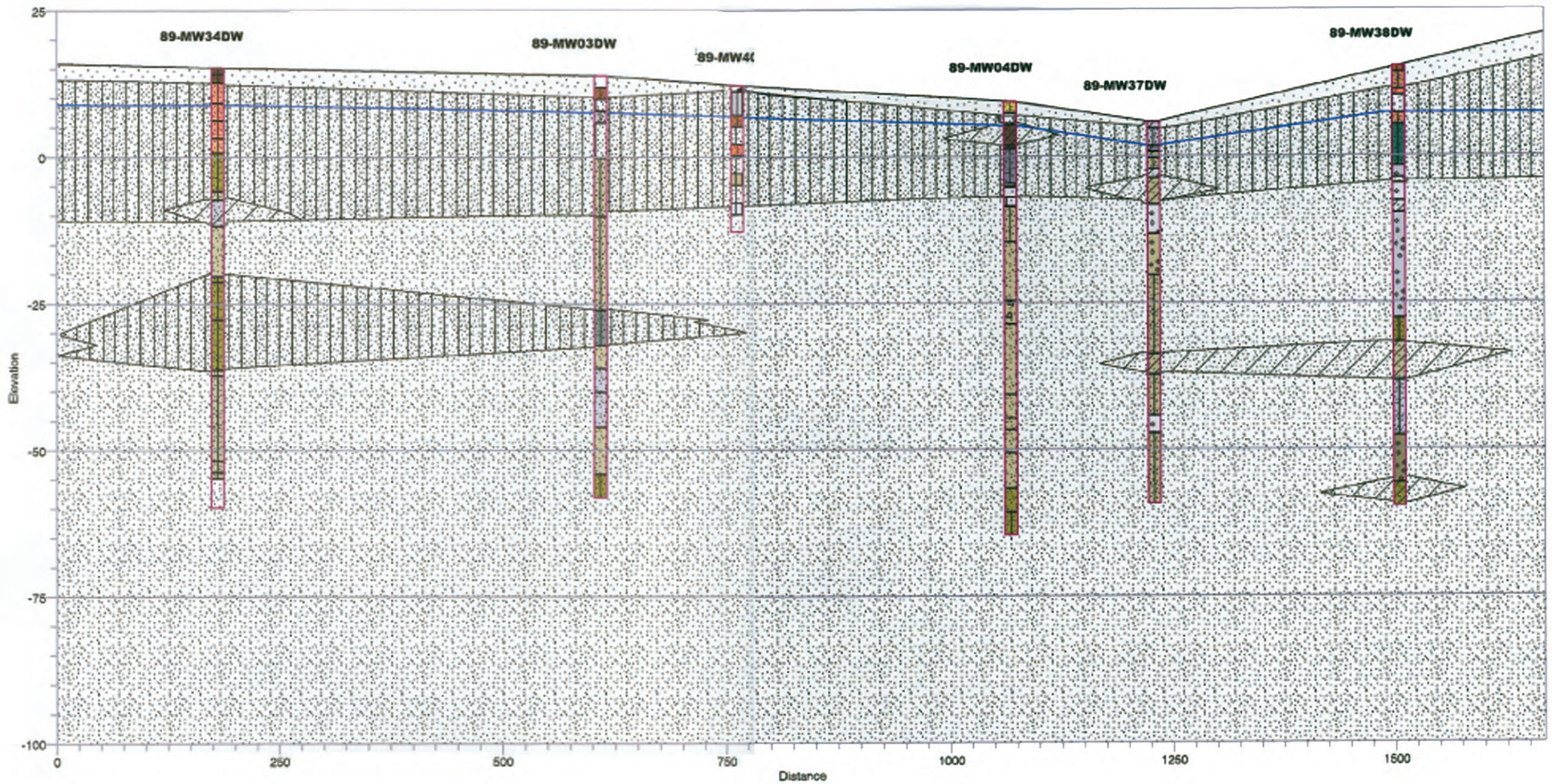
Overburden
Silty, fine to medium sands and organic soils, loose, dry to damp

Silty Sand
Silty, fine to medium sands, trace clay, shell fragments in lenses of sand unit, dense, damp to wet

Sand
Fine to coarse sands, some cementation, silt and clay lenses, loose to medium dense, wet

Clayey Silty Sand
Non-continuous, clayey silty sand, shell fragments in lenses of sand unit, dense, damp to moist

*This soil boring information is considered to be representative of the subsurface conditions at the respective soil boring locations. Subsurface conditions interpolated between borings are estimated based on geologic judgment.



AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

Figure 2-7
Cross Section B-B'
Site 89 EE/CA
MCB Camp Lejeune, North Carolina

Legend

Overburden
Silty, fine to medium sands and organic soils, loose, dry to damp

Silty Sand
Silty, fine to medium sands, trace clay, shell fragments in lenses of sand unit, dense, damp to wet

Sand
Fine to coarse sands, some cementation, silt and clay lenses, loose to medium dense, wet

Clayey Silty Sand
Non-continuous, clayey silty sand, shell fragments in lenses of sand unit, dense, damp to moist

*This soil boring information is considered to be representative of the subsurface conditions at the respective soil boring locations. Subsurface conditions interpolated between borings are estimated based on geologic judgment.

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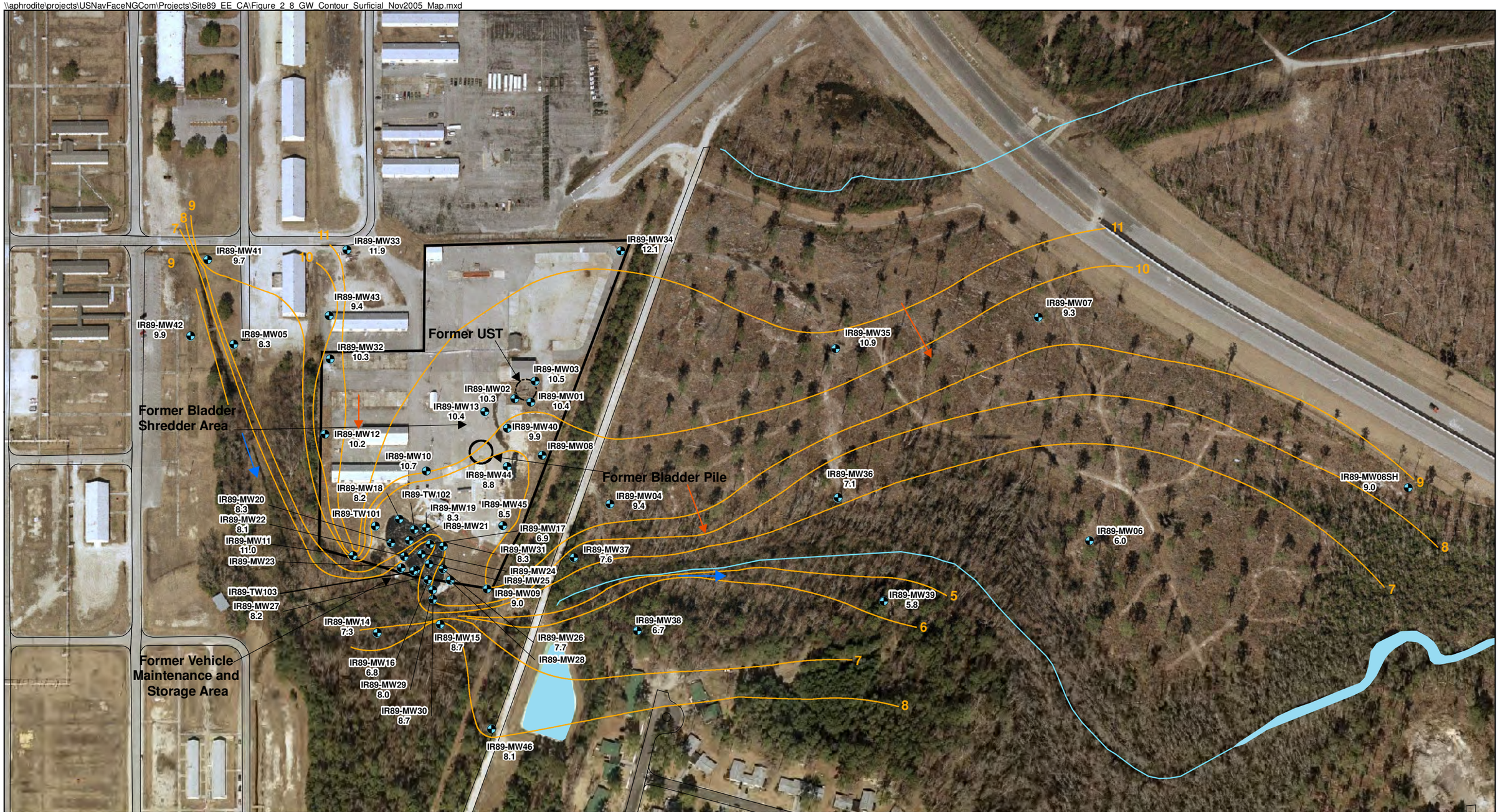


Legend

- Shallow Groundwater Monitoring Well
- Site 89 Boundary
- Water Bodies
- Surface Water Flow Direction
- Groundwater Flow Direction
- 8 Groundwater Elevation Contour

Note: All data reported in ft msl

N

0 125 250 Feet

Aerial Photograph taken Feb. 2004

Figure 2-8

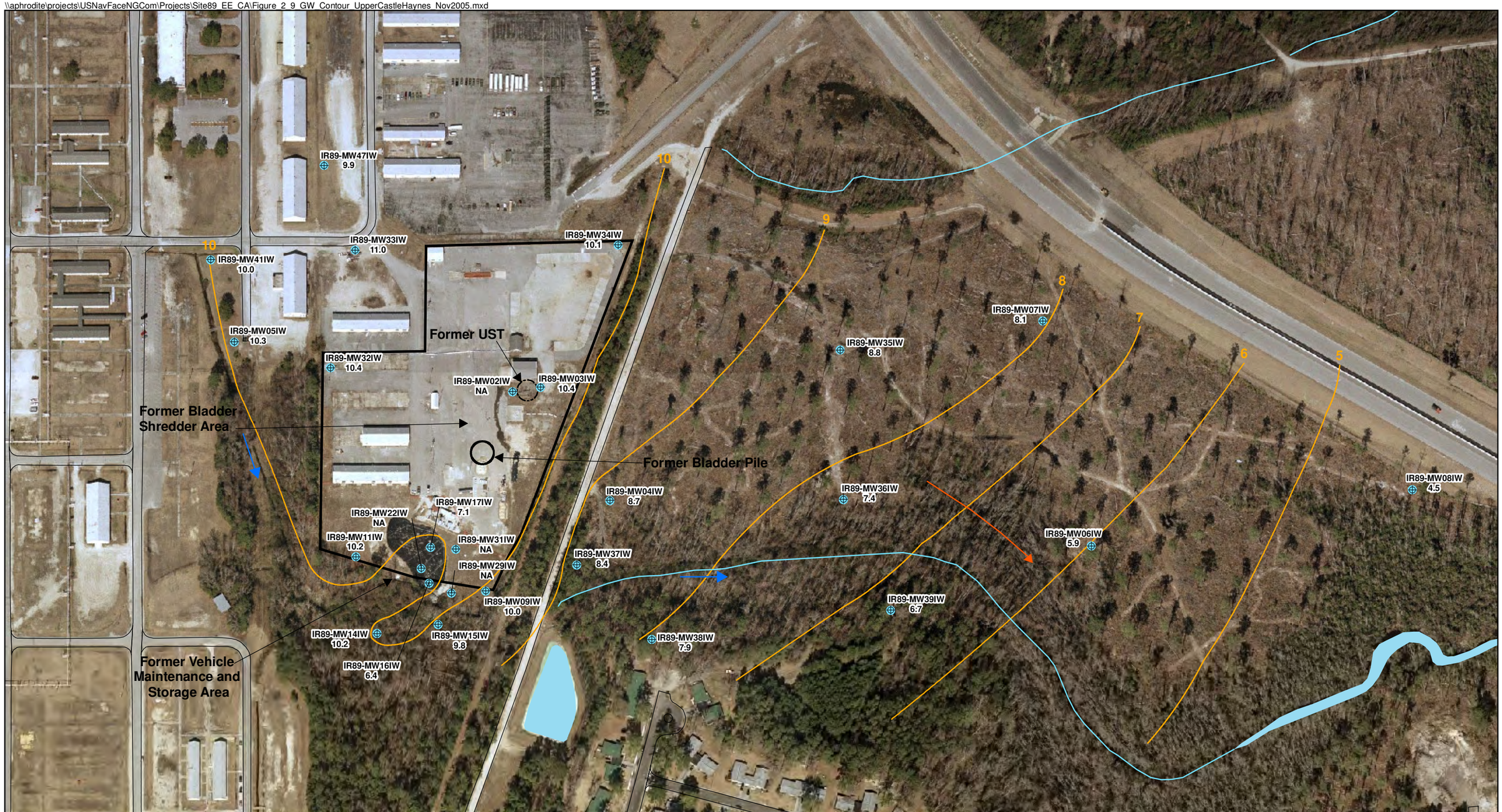
Groundwater Contour Map of the Surficial Aquifer, November 2005

Operable Unit No. 16 Site 89

MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_9_GW_Contour_UpperCastleHaynes_Nov2005.mxd



Legend

- Intermediate Groundwater Monitoring Well
- Site 89 Boundary
- Water Bodies
- Surface Water Flow Direction
- Groundwater Flow Direction
- 8 Groundwater Elevation Contour

Note: All data reported in ft msl

N

0 125 250

Feet

Aerial Photograph taken Feb. 2004

Figure 2-9

Groundwater Contour Map of the Upper Castle Hayne Aquifer, November 2005

Operable Unit No. 16 Site 89

MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_10_GW_Contours_CastleHayne_Nov2005.mxd

Legend

- Deep Groundwater Monitoring Well
- Site 89 Boundary
- Water Bodies
- Surface Water Flow Direction
- Groundwater Flow Direction
- 8 Groundwater Elevation Contour

Note: All data reported in ft msl

N

0 125 250 Feet

Aerial Photograph taken Feb. 2004

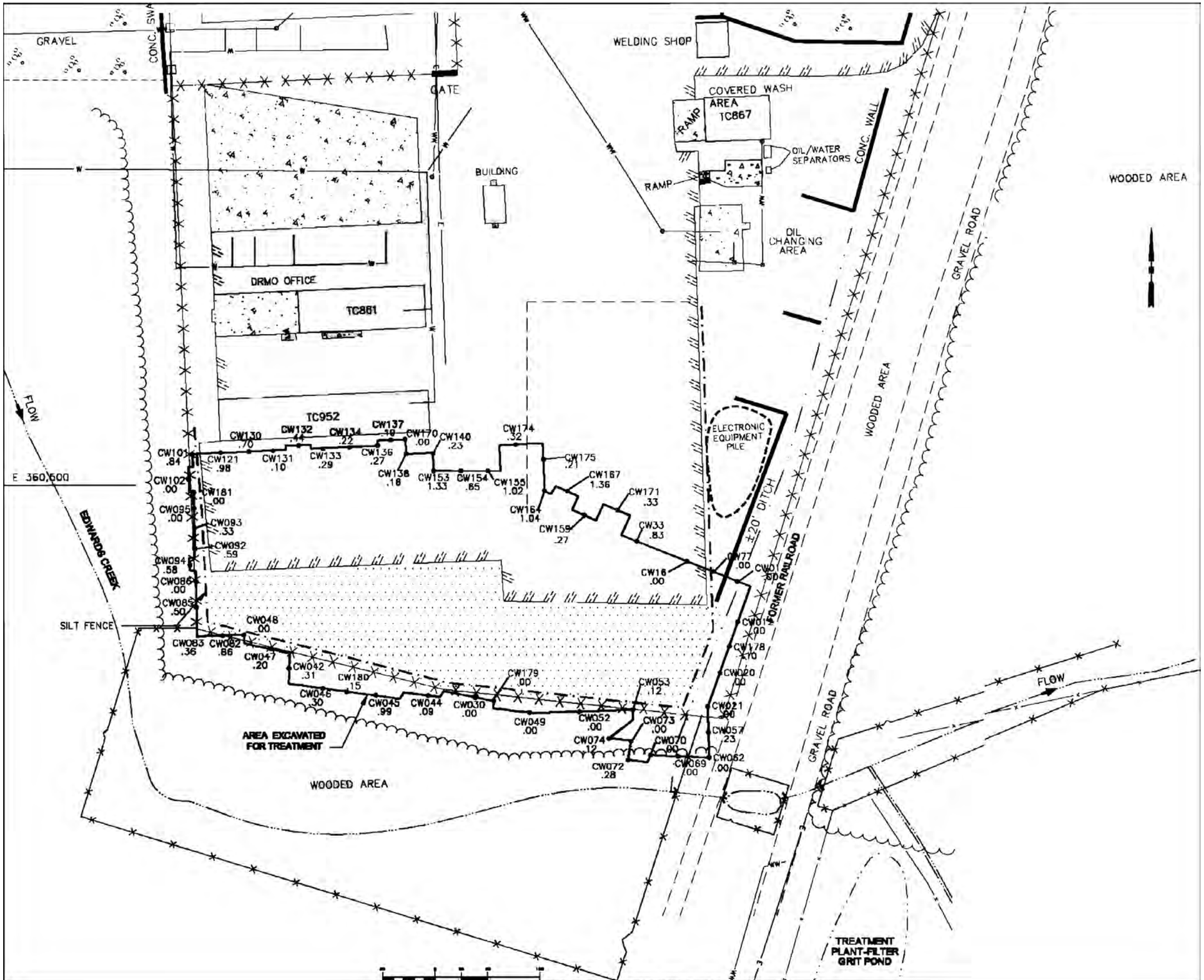
Figure 2-10

Groundwater Contour Map of the Castle Hayne Aquifer, November 2005

Operable Unit No. 16 Site 89

MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL



SOURCE: MCB CAMP LEJEUNE, 2000.

LEGEND

	Excavation Limit
CW33 .83	Sidewall Sample PPM PCM
	DRMO Existing Fence Line
	Proposed Fence
	Edge of Existing Pavement

Note: Areas to be excavated for treatment have contaminant concentrations greater than industrial RBCs.

1,1,2,2-PCA	28,000 µg/L
Vinyl Chloride	3,000 µg/L

UTILITIES

SS	Storm Sewer Line
WW	Wastewater Line
O	Wastewater Manhole
E	Electric Line
W	Water Line

Note: Contractor to verify utility locations prior to excavaction.

FIGURE 2-11
LOW TEMPERATURE THERMAL DESORPTION EXCAVATION LIMITS
OPERABLE UNIT NO. 16, SITE 89 EE/CA
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_12_Electrodes_MW_ERH_PilotStudy_2003.mxd

Legend

- Monitoring Well Locations
- Shallow Electrode
- Deep Electrode

N

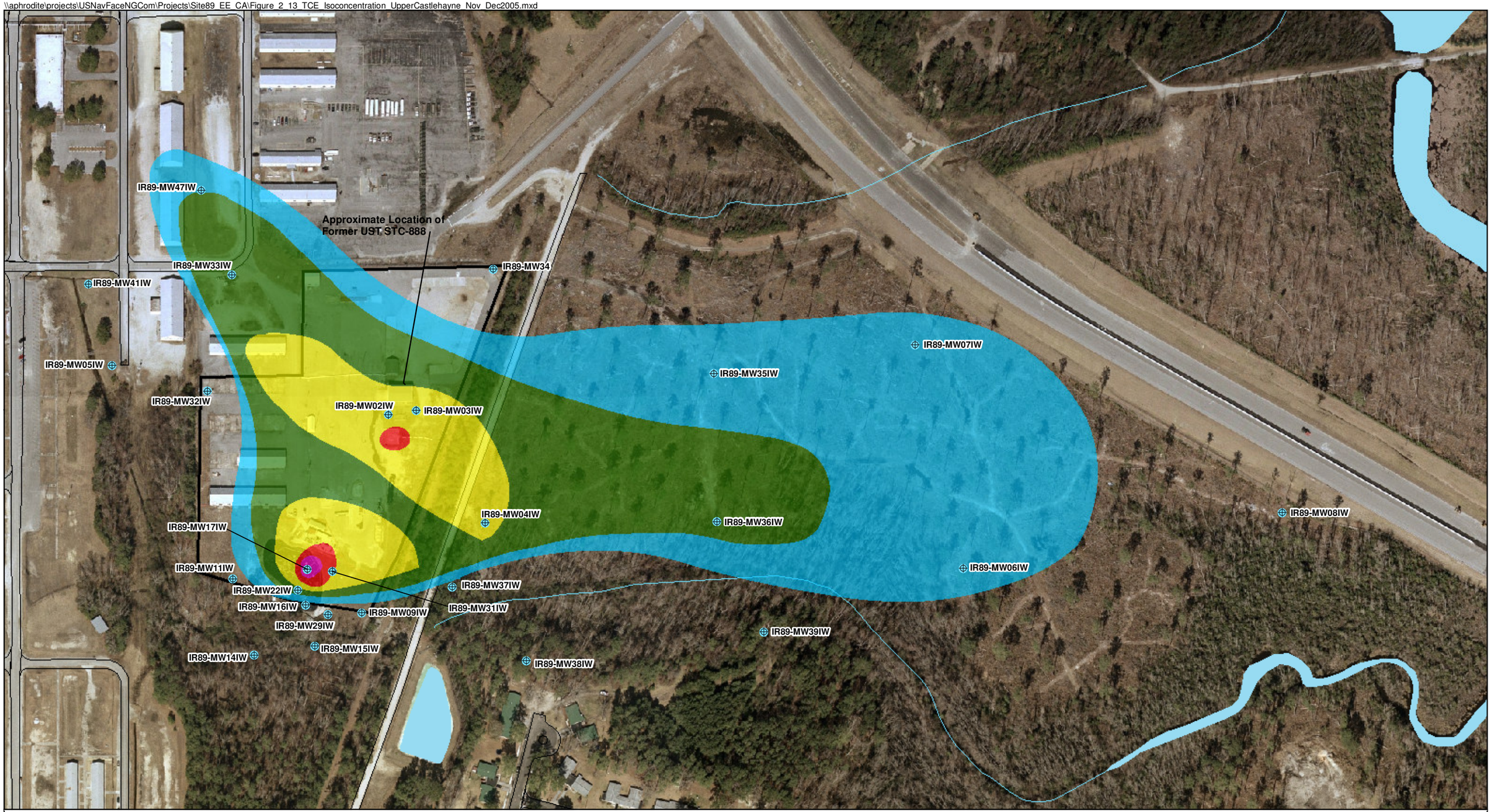
0 25 50 Feet

Aerial Photograph taken Feb. 2004

Figure 2-12
Electrodes and Monitoring Wells Installed
for the ERH Pilot Study, 2003
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIO
CH2M HILL

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_13_TCE_Isoconcentration_UpperCastlehayne_Nov_Dec2005.mxd



Legend

- Intermediate Groundwater Monitoring Well
- Site 89 Boundary
- Water Bodies

TCE Isoconcentrations of the Upper Castle Hayne Aquifer

- > 10,000 ppb
- 1,000 < x < 10,000 ppb
- 100 < x < 1,000 ppb
- 10 < x < 100 ppb
- 1 < x < 10 ppb

N

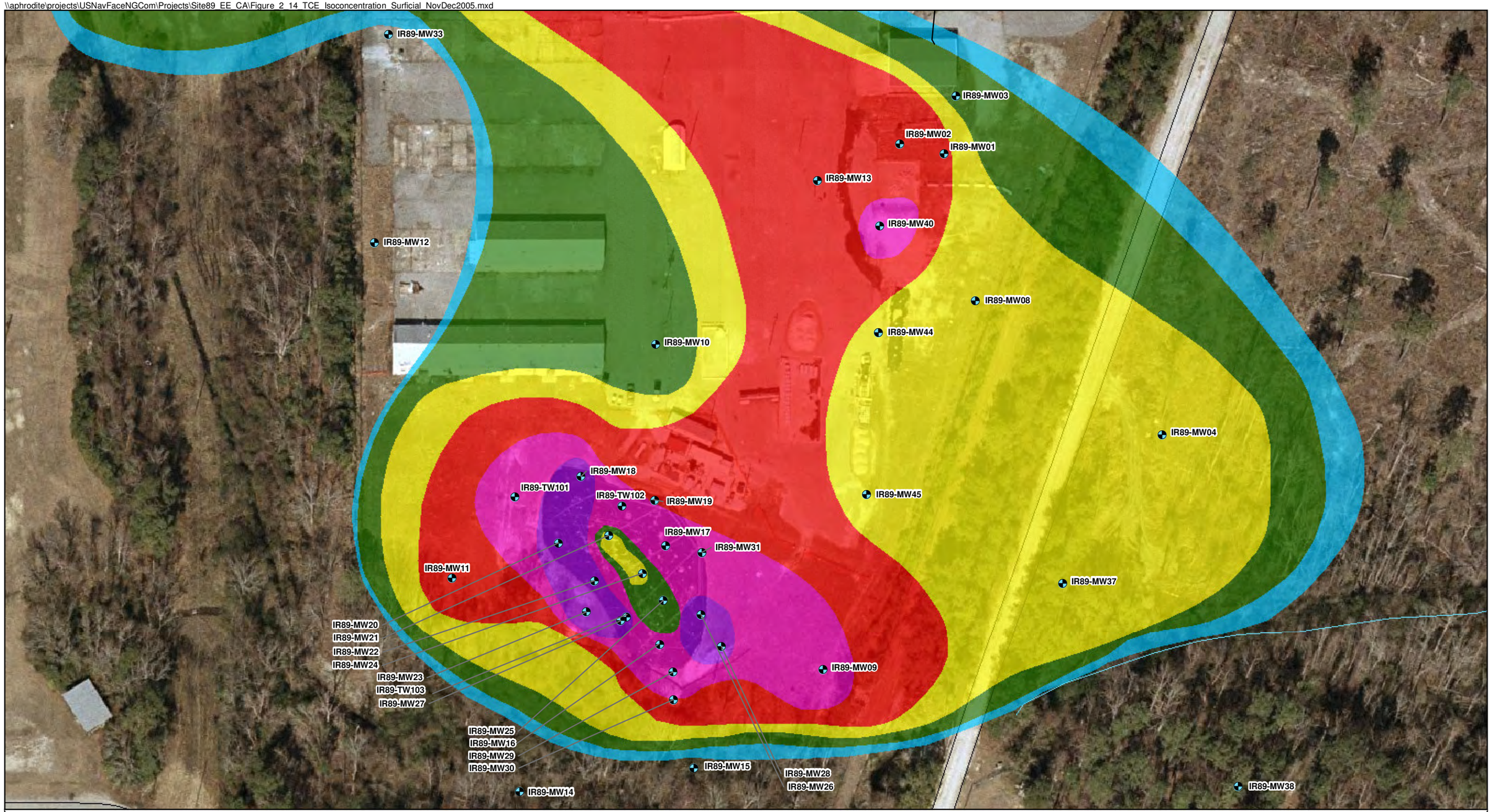
0 125 250 Feet

Aerial Photograph taken Feb. 2004

Figure 2-13
TCE Isoconcentration Contour Map of the Upper Castle Hayne Aquifer, November/December, 2005
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

\\aphrodite\projects\USNavFaceNGCom\Projects\Site89_EE_CA\Figure_2_14_TCE_Isoconcentration_Surficial_NovDec2005.mxd



Legend

- Site 89 Wells
- Water Bodies

TCE Iscoconcentration Contours of the Surfical Aquifer

- > 55,000 ppb
- 10,000 < x < 55,000 ppb
- 1,000 < x < 10,000 ppb
- 100 < x < 1,000 ppb
- 10 < x < 100 ppb
- 1 < x < 10 ppb

N

0 45 90 180 Feet

Aerial Photograph taken Feb. 2004

Figure 2-14
TCE Isoconcentration Contour Map of the Surficial Aquifer, November/December, 2005
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIO
CH2M HILL

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- DNAPL Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 2-15
Source Area Identified for Treatment
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_2_15_Source_Area_Treatment.mxd

3.0 Identification of Removal Action Objectives

This section identifies the objectives of the NTCRA at Site 89. Based on information presented in Section 2.0, conditions at Site 89 warrant the evaluation of RAOs for the protection of human health and the environment. The RAOs for the proposed interim corrective action are based upon the threat to groundwater posed by the presence of DNAPL in the surficial aquifer at Site 89.

The RAOs for Site 89 are:

- Remove mobile DNAPL accumulations, to the extent practicable, from the identified source area at Site 89.
- Reduce exposure and risk to human and ecological receptors.
- Reduce the potential for contaminant mass flux from the source zone to groundwater.

3.1 Statutory Limits on Removal Actions

Non time-critical removal actions funded by EPA have a $2 million and a 12-month statutory limit pursuant to Section 104(c)(1) CERCLA. This remedial action will not be USEPA funded-financed. The Navy/Marine Corps IR Manual does not limit the cost or duration of the remedial action. However, cost effectiveness is a recommended criterion for evaluation of the removal action alternatives.

3.2 Determination of Removal Action Scope

The selected removal action is intended to be an interim corrective action implemented at Site 89 to achieve the identified RAOs. The remedial action is intended to reduce the amount of contaminant mass present at the site as a way of minimizing, to the extent possible, the migration of contaminants from the source zone.

3.3 Determination of Removal Action Schedule

Implementation of alternative activities is anticipated to require 3 to 8 months based on the recommended remedy. The time frame of the alternatives evaluated range from several months to upwards of five years. System operation may last for a few months or several years depending on the alternative selected.

Each alternative will have different implementation timeframes. Factors that may affect the remedial action schedule primarily relate to site conditions, requirements of the removal technologies, availability of vendors and supplies, Camp Lejeune mission requirements, and inclement weather.

4.0 Identification of Remedial Action Alternatives

General response actions that may be used to satisfy the RAOs include institutional controls, removal, containment, treatment, and disposal. In accordance with the EPA *Guidance On Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA, 1993), treatment technologies were selected in favor of purely containment. Technologies selected for interim remedy evaluation must be capable of removal, rapid extraction, and/or destruction of DNAPL mass, in order to prevent delay of final remedy implementation and project closure. Technologies with demonstrated effectiveness in significantly reducing DNAPL mass are few, particularly at low permeability sites, such as Site 89.

In order to streamline the evaluation, the Camp Lejeune Partnering Team chose to evaluate the following technologies:

- Excavation
- Electrical Resistive Heating
- Shallow Soil Mixing with ZVI-Clay Addition
- In Situ Thermal Desorption
- Air Sparging

4.1 Technology Descriptions

The following is a list and a short description of the technologies considered for further evaluation.

Excavation

This alternative is excavation of the source area using conventional earth moving equipment. Excavation of soil at Site 89 was reviewed as a "benchmark" for comparison to in-situ technologies. It was assumed that the soils are sufficiently permeable to require sheet pile installation and dewatering activity, before work begins.

The level of contamination within the source area is so significant that much of the area would likely fail the Toxicity Characteristic Leaching Procedure (TCLP) test and be considered a hazardous waste. All excavated soils would require sampling in accordance with RCRA disposal requirements. The results of this sampling would determine the final designation of the excavated soil as hazardous or not depending on the concentration of the contaminants of concern. Non-hazardous soil would be stockpiled and reused to provide a final grade over the site. Soil determined to be hazardous would be transported to the hazardous waste landfill in Emelle, Alabama for disposal.

Subsurface utilities in the excavation area would be removed and re-routed. Additionally, the area around the excavation would be barricaded to discourage non-workers from wondering onto the excavation site.

Appropriate erosion and sediment controls (silt fences and berms) would be used to prevent contaminants from leaving the site. The sides of the excavation would need to be benched, trenched, supported, or a shield would need to be placed between the side of the excavation and the work area to prevent cave-ins and help protect workers. Excavation is not expected to compromise the stability of supporting structures. However, if needed, support systems such as shoring, bracing, or underpinning would be provided to ensure that adjacent structures such as buildings, sidewalks, walls, or pavement remain stable.

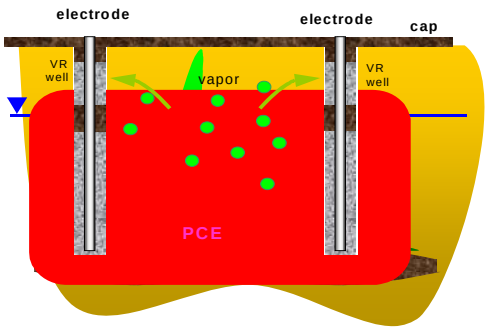
Due to the high groundwater table, significant groundwater dewatering would be required. This groundwater would be highly contaminated, requiring treatment prior to discharge.

Excavation at Site 89 would create a hazardous environment for site workers. Site workers would have to work in Level C or B personal protective equipment (PPE) to prevent exposure to site contaminants. Monitoring during construction would occur. All PPE would be disposed of with the excavated material. Additional measures that would need to be taken to protect the community and environment during implementation include dust suppression, enforcement of erosion and sedimentation controls, and enforcement of Department of Transportation (DOT) regulations.

All equipment used to excavate and transport DNAPL would have to be decontaminated prior to leaving the site by brushing, scraping, and pressure washing. The excavated area would be backfilled and restored to its original condition.

Electrical Resistive Heating

ERH is an in-situ technology used in combination with soil vapor extraction (SVE), which uses electricity applied to the subsurface through electrodes to heat the soil and thereby enhance the recovery of subsurface contaminants. ERH assists SVE by raising subsurface temperatures and inducing volatilization. In addition, an in-situ source of steam that strips contaminants from soils is created as groundwater is heated.



Resistive heating occurs more rapidly in soils of high porosity and low permeability (silts/clays). Heat is produced directly in the treatment zone by the passage of an alternating current (AC) through the soil matrix. The process works by gradually and uniformly heating the treatment zone to 60 to 100 degrees Celsius (°C). As the soil is heated vapor pressure and volatility of the mobile DNAPL are increased, while the viscosity of residual adsorbed DNAPL is decreased, improving mobility and thus enabling removal. Steam, laden with DNAPL vapor, is withdrawn by SVE and treated above ground.

As described in Section 2.3.2, an ERH pilot study was completed at Site 89 to evaluate the performance of the technology (Shaw, 2005). Installation of the pilot test ERH system began

in April 2003. The system consisted of 43 deep heating electrodes installed to a depth of 26 feet bgs and 48 shallow heating electrodes installed to a depth of 19 feet bgs. The total treatment area was approximately 15,900 square feet.

The pilot system was brought on-line in September 2003 and was operated until the beginning of May 2004. Minor downtime periods ranging from one day to a few days duration occurred as a result of excessive groundwater entrainment, minor equipment repairs, routine maintenance, and groundwater sampling events. The remedial system was in operation a total of 173 days for an operational efficiency of 75%. On-site system monitoring was conducted daily during this period to observe measurements and conditions and maintain the system's operation.

Throughout the pilot test, elevated groundwater elevations contributed to increased groundwater entrainment that necessitated additional groundwater management. Approximately 10,000 gallons of groundwater were recovered per day and stored in an above ground tank. The water in the tank was continuously re-circulated through spray nozzles to reduce VOC concentrations. Approximately 500 gallons per day of water was returned to the electrodes to maintain proper conductivity. The excess recovered groundwater was routinely removed from the storage tank using a vacuum truck and transported to the water treatment facility at Lot 203. A total of 1,730,000 gallons was managed and treated in the Lot 203 treatment facility.

During the pilot study, approximately 50% of the electrodes were slotted and used for vacuum extraction of volatile vapors from the subsurface. Vapor recovery was augmented by an overlying horizontal vacuum extraction system installed on the existing ground surface under an insulating cap. A thermal vapor treatment system including a catalytic oxidizer and wet scrubber tower was used to destroy recovered volatile vapors prior to discharge to the atmosphere. Vapor monitoring was conducted weekly from the influent and effluent recovered vapor stream for VOC analysis. Chlorinated hydrocarbon recovery, discharge, and destruction efficiency from the system was calculated from operational parameters such as organic concentrations (summa canister results), exhaust stack pressure, vapor velocity and temperature. Based on these parameters, approximately 48,000 pounds of chlorinated hydrocarbons were recovered from the subsurface during implementation of the ERH pilot test.

A catalytic oxidation unit was selected as the most cost effective treatment alternative for the contaminants at the site. The unit was equipped with a catalyst bed that was designed to thermally and chemically destroy the chlorinated contaminants at the site. The destruction process produces hydrochloric acid as a byproduct; therefore, a sodium hydroxide wet scrubber was required for neutralization prior to discharge to the atmosphere. As the pilot test progressed, the destruction efficiency of the catalytic oxidation unit decreased. Replacement of the catalyst bed resulted in an increase in destruction efficiency, again followed by a decreasing trend. It was determined that the catalyst was being poisoned, possibly by sodium and other metals present in the site groundwater. A traditional thermal oxidizer unit would have eliminated the catalyst bed fouling.

Prior to ERH pilot test implementation, soil samples were collected during installation of select electrodes and monitoring wells. Analytical results indicated two compounds (PCA and TCE) at concentrations above the North Carolina Industrial Soil Cleanup Goals (SCGs).

PCA concentrations ranged from less than 3.23 mg/kg to 5,170 mg/kg. TCE concentrations ranged from less than 1 mg/kg to 4,570 mg/kg. At the conclusions of pilot test operations, confirmation soil samples were collected from the same locations. PCA concentrations ranged from less than 0.0051 mg/kg to 676 mg/kg. TCE concentrations ranged from 0.0027 mg/kg to 107 mg/kg.

Soil analytical results from the electrode installation and monitoring well installation indicated a greater than 99% reduction in contaminant concentrations from initial conditions, with several locations achieving only 60 to 90% reduction in the TCE concentration.

Analytical results from the monitoring well installation locations at the perimeter of the treatment zone (i.e., adjacent to the hot wall) indicated a greater than 97% reduction in contaminant concentrations from initial conditions.

Prior to ERH pilot test implementation, groundwater samples were collected from the monitoring wells, identifying the following compounds at concentrations above the North Carolina Industrial Gross Contamination Levels (GCLs): cis-1,1-DCE, trans-1,2-DCE, 1,1,2,2,-PCA, 1,1,2-TCA, PCE, TCE, and vinyl chloride. Groundwater samples collected following the operation of the ERH pilot system indicate that ERH was effective in removing greater than 99% of the contaminants of concern in monitoring wells from inside the treatment zone. Groundwater samples collected from outside the treatment zone indicated operation of the ERH system did not cause contaminant migration away from the treatment zone.

During implementation, DNAPL was mobilized in the treatment area and migrated to shallow monitoring wells 89-MW17, 89-MW18, 89-MW21, and 89-MW24 when groundwater reached a temperature of 60ºC. The DNAPL persisted in these monitoring wells through the next groundwater sampling event when groundwater in the treatment zone reached a temperature of 100 ºC. The DNAPL was not observed during the week one post-pilot test operation or any subsequent groundwater sampling event.

At the conclusion of the pilot test, groundwater samples collected from shallow monitoring wells located within the treatment zone did not contain detectable concentrations of contaminants of concern, with the exception of 89-MW17. Shallow groundwater samples collected from outside the treatment zone remained relatively unchanged.

At the conclusion of the pilot test, groundwater samples collected from intermediate depth monitoring wells located within the treatment zone did not contain detectable concentrations of contaminants of concern, with the exception of 89-MW17IW. Intermediate groundwater samples collected from outside the treatment zone remained relatively unchanged.

The pilot study was completed with a total project cost of $2,100,000. Based on the removal of 48,000 pounds of contamination, the remediation cost per pound was $44.

During implementation of the pilot test, continuous monitoring of the treatment compound and surrounding project fence line was required to ensure protection of site workers, visitors, and Base residents. No health and safety incidents or injuries were reported during the project.

Shallow Soil Mixing with Clay-Zero Valent Iron Addition

Shallow soil mixing is an in-situ technology that uses a large auger system, equipped with nozzles, to add a clay-granular zero valent iron (ZVI) slurry into the soil while mechanically breaking up and mixing the soil. Shallow soil mixing converts the DNAPL source zone into a homogenous mixture of soil, clay, iron, and target contaminants by turning the auger while repeatedly cycling up and down throughout the mixing column. The iron degrades the chlorinated VOCs through a combination of chemical and biological reduction. The clay promotes uniform distribution of the iron during the mixing process. It also reduces the hydraulic conductivity of the source zone, so that contaminant discharge is reduced.

Shallow soil mixing with clay-ZVI was shown to be effective at MCB Camp Lejeune Site 88 Building 25, located at the intersection of Post Lane Road and McHugh Boulevard. The source area around Building 25 was approximately 10,000 square feet with treatment volume of approximately 7,000 cubic yards. The depth of contamination extended into to the silty clay layer for a total depth of approximately 20 ft bgs.

As a first step, soil cores and DNAPL samples were collected from the treatment area at Site 88 and shipped to Colorado State University (CSU) for inclusion in laboratory studies. CSU evaluated ZVI-clay efficacy for treatment of PCE (and associated compounds) in the site soils.

Results of the treatability study indicated an approximate 75% decrease in PCE over the 59-day study. Half-life estimates were approximately 30 days for the DNAPL spiked soil compared to approximately 20 days in the unspiked soils. The optimum mixing blend to be injected into the DNAPL source area was determined to be a grout containing 2% ZVI-clay and 1% bentonite.

In addition, two column mix studies were conducted. In the first, pure PCE was injected into the midpoint of three soil columns. Simultaneous mixing and injection of ZVI-Clay dispersed the DNAPL without affecting apparent adverse downward DNAPL migration. In the second set of column studies, addition of ZVI-Clay with and without hot air injection was compared. No significant improvement in performance was observed with hot air injection. Analysis of soils from both sets of column studies verifies the apparent rate of PCE treatment seen in the ZVI-Clay efficacy studies. Observed expansion of soil through treatment in these studies was 12-15%. Theoretical calculation using conservative assumptions indicates expansion could be 25%.

Following the treatability study, utilities within the treatment area at Site 88 were abandoned or removed, monitoring wells were abandoned, and site debris was disposed of. Approximately 10 to 20% of the treatment area was removed to account for the volume increase due to fluff, as indicated by the treatability study. The soil was screened with a PID air monitoring device during the excavation. If screening indicated potential VOCs, the soil was not removed, but moved within the treatment area. Approximately 1,600 tons of soil and debris were disposed of at the Base landfill during January 2005.

Soil mixing activities were conducted from February 11, 2005, until February 28, 2005. Shallow soil mixing was performed using a 10-foot diameter auger, constructing an approximate total of 146 soil mixing columns. A 150-ton Manitowoc 4000 W series crane,

and a 300,000 foot-pound rotary torque drill rig were used to mix the soil. The centers of the columns were positioned in the treatment area so the columns overlapped to treat 100% of the area. Approximately 7050 cubic yards of impacted soil was treated. The slurry was injected through the augers as the augers rotated and mixed with the soil.

A soil vapor extraction system was installed onsite to capture volatized contaminants that escaped through emissions during the mixing around the auger. The system consisted of a 14 ft diameter shroud that covered the area of the mixing column. Negative pressure was kept on the headspace of the hood using a 1,800 cubic feet per meter variable speed vacuum unit, pulling any vapors and dust to a vapor treatment system. Components of the vapor treatment system include a high efficiency particulate air (HEPA) filter for dust particle removal, a 3,000 lb. granular activated carbon filter, and a discharge stack.

Upon completion of the shallow soil mixing activities, stabilization of the soil was required in order to proceed with construction of a parking lot. Stabilization activities took place from April 25 through the end of May 2005. Stabilization was performed by mixing 5% Portland cement mix into the top 5 to 10 feet of the treatment area. Mixing was conducted by adding one ton of cement to a 10 ft by 10 ft area, over the entire treatment area. After stabilization, a significant portion of the treatment area was stable with this cement ratio and at this depth, while the center of the treatment area was still soft. The center of the treatment area was then divided into a grid pattern, with twenty eight 15 ft by 15 ft grids. Each grid was then stabilized to 10 ft bgs with 6% Portland cement. In total, 190 tons of cement was used to stabilize the treatment area.

Monitoring at Site 88 included soil gas, soil, and groundwater sampling both pre- and post-treatment, as well as aquifer testing. Within the treatment area PCE concentrations within the soil were significantly reduced after one year. The weighted average of contaminant reduction was 91%. The median concentration was reduced by 99.9%. The area of a former surfactant test had lower reduction, possibly due to the revenants of the surfactant.

Soil gas analysis indicates a reduction of PCE concentration within the treatment area - an average reduction of 99% seven months after mixing. Prior to treatment, groundwater in the target area had a PCE concentration of 64 mg/L. This did not represent monitoring wells with product. Groundwater samples collected by direct push methods after six months had PCE concentrations from 1.5 to 160 mg/L. Groundwater samples collected nine months after mixing, from MW-30 and MW-31, indicate PCE concentrations of below detection limit and 120 mg/L respectively. After one year, the PCE concentration in MW-30 was still below detection limits, while the PCE concentration in MW-31 was 15 mg/L, representing a 91% reduction of PCE. The concentration of DCE increased to 390 mg/L after one year in MW-31, indicating abiotic degradation is taking place. MW-31 is located where product was observed.

Downgradient water quality was not adversely impacted by mixing or the treatment process. There were some increase in several constituents, but the concentrations decreased over time to a level below initial concentrations. PCE reduction of 90% and 67% were observed.

The action was effective at reducing contaminant mobility. Hydraulic conductivity within the treatment area (MW-30) was reduced 50 to 400 times (one to two orders of magnitude).

There were no air emissions during the treatment process. Contaminant vapors were easily captured and treated in an onsite carbon system.

The total cost of the Site 88 Building 25 source removal was $1,962,000.

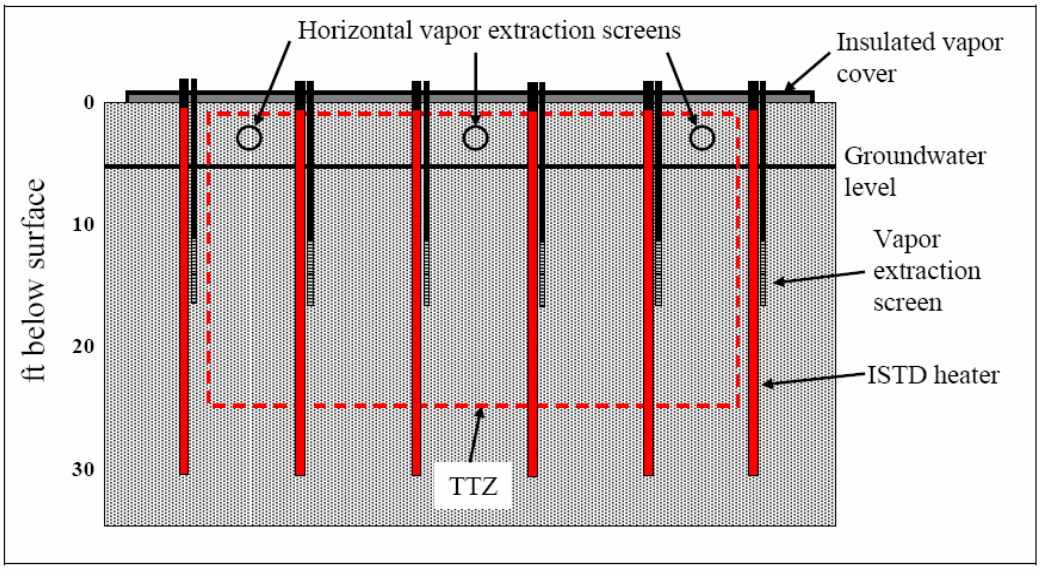
Lessons learned as documented in the Site 88 Building 25 Source Removal Non-Time Critical Removal Action Report (CH2M HILL, 2006) include:

- Design the monitoring program to collect samples immediately after mixing to obtain more accurate initial concentration
- Consistently collect more samples, both soil and water, over time at the same locations
- Plan on managing stormwater, through covering the treatment area or installing a sump with a small treatment system
- Over design/estimate the mixing depth, where possible, but cannot compromise any confining layers
- In mixing in areas with observed product, perform additional mixing and add additional ZVI as a safety factor

In Situ Thermal Desorption

In situ thermal desorption (ISTD) is a thermal technology comparable to ERH. ISTD generates heat using electrical power, based on resistive principles. The process relies on the resistive properties of a metal rod, rather than the bulk soil, as with ERH. The metal rods are analogous to the heating elements contained in an electric oven. A typical heater assembly consists of a U-shaped metal rod approximately 0.5 inches in diameter that is installed in a section of sealed well casing. Ceramic insulators are used to electrically isolate the heating element from the steel casing. The application of electric power to the element causes the steel rod to heat resistively. Heat generated by the element is adsorbed by the well casing and ultimately transferred to the subsurface formation by conduction and convection. The heating process is effective in both saturated and unsaturated zones and is well suited for applications with heterogeneous site conditions. The technology is patented with an exclusive license held by one company. Although temperatures as high as 800 ^{o}C can be achieved using ISTD, the target temperature of 100 ^{o}C is sufficient to accomplish steam distillation and effective removal of target VOCs present at the site.

ISTD systems consist of electrical power distribution equipment, vapor and groundwater extraction wells, and an aboveground treatment plant for extracted fluids. Multiple heater assemblies are placed across the treatment zone at relatively close spacing (half the distance of ERH) to ensure thorough conductive heating. Recovery wells are placed to capture groundwater and vapor mobilized during heating. A schematic diagram of a typical TCH system is shown in cross section below.



Air Sparging

Air sparging is an in situ technology involving the injection of air into the aquifer or water-bearing zone at a sufficient depth below the water table interface. Pressurized injected air rises by buoyancy through the saturated zone in a network of finger-like channels, the path of which is strongly influenced by subsurface heterogeneity. Air sparging induces mass transfer (stripping) of VOCs from groundwater and/or aerobic biological degradation.

An ongoing treatability study at Site 89 appears to indicate that air sparging is effectively reducing dissolved site contaminant concentrations. In December 2006, a directionally drilled horizontal sparge well was installed. The well is 600 feet long, with a 250 foot long slotted section, positioned at approximately 40 feet bgs. The well was constructed of four-inch diameter standard dimension ratio (SDR) 11 high-density polyethylene (HDPE). An open slot design was utilized (i.e., no sand packs, filter screens, etc.). The screen was slotted longitudinally to create a single slot zone with an open area of 0.5%. Pneumatic fracturing was completed in four borings, spaced approximately 50 feet apart along the axis of the horizontal sparge well screen to evaluate the potential for improving air sparging performance in the dense materials of the Surficial Aquifer. Fracturing was performed at 2.5 foot intervals, over a total vertical span of 12.5 feet, from 12.5 to 25 feet bgs.

Groundwater monitoring during the treatability study in the vicinity of the air sparge system has included a baseline sampling event, followed by monthly sampling events conducted during air sparge operations. At this time, conclusions have not been drawn regarding the efficacy of air sparging at Site 89; however, early results indicate that contaminant concentrations in the vicinity of the air sparge system are generally decreasing. The maximum TCE concentration was detected in 89-MW49A at 3,000 µg/L. Following two months of air sparging, TCE in 89-MW49A decreased to 310 µg/L, representing an 89.7% reduction.

Case studies involving air sparging in source areas with DNAPL are limited. One significant concern would be air emission control. As expected, during the 89 treatability study, VOC concentrations in soil gas wells greatly increased. Sparging DNAPL would have considerably higher VOC concentrations in the soil gas that would require control and treatment.

A pilot study was completed at nearby Site 86 testing the use of air sparging with ozone addition using a directionally drilled horizontal well. The pilot study began in September 2004 with the installation of a horizontal directionally drilled sparge well, followed by the installation of 12 monitoring wells. The sparge area was selected based on a minimum TCE concentration of 200 μg/L. The horizontal well was 950 feet in length, with a 350-foot section of screen, positioned at approximately 60 ft bgs. Beginning in early February 2005, an air sparge system was operated nearly continuously for approximately six months. From late July 2005 through late January 2006, a combined air and ozone sparge system was operated. The air compressor operated nearly continuously; however, due to various mechanical problems, operation of the ozone generator was intermittent, and after approximately six months of operation only 3,900 pounds of ozone had been injected. This was approximately 37 percent of the capacity of the ozone generator.

Groundwater monitoring was conducted throughout the pilot study and consisted of a baseline sampling event in October 2004, six pilot study monitoring events conducted from March 2005 to January 2006, and one rebound monitoring event conducted in May 2006. The groundwater monitoring events included collecting samples from 16 monitoring wells. As documented in the Final Pilot Study Report (CH2M HILL, 2006), observations based on the pilot study results include:

- TCE concentrations were reduced 99 percent in groundwater samples collected from monitoring wells with baseline concentrations exceeding 50 μg/L.
- Within one year, the North Carolina Groundwater Quality Standards (NCGWQS) for TCE had been achieved in 13 of the 16 monitoring wells sampled as part of the pilot study.
- Groundwater analytical data collected in May 2006, approximately three months after the system had been shut down, showed contaminant "rebound" was generally limited or non-existent, as TCE concentrations remained below the NCGWQS in 12 of the 16 monitoring wells sampled as part of the pilot study.
- Air sparging beneath a low permeability layer using a horizontal directionally drilled well resulted in extensive lateral distribution of air. The estimated distance of influence of air sparging was at least 50 feet on either side of the horizontal well.
- Assessment of ozone sparging proved inconclusive due to the low concentration of TCE after air sparging and limited period of continuous ozone generation.

4.2 Alternative Development

Five alternatives have been developed that draw on the technologies described in Section 4.1. A discussion of the advantages, limits, and implementation concerns of each alternative with respect to the DNAPL source area are provided below.

4.2.1 Alternative 1 – Excavation With Off-site Disposal

Approximately 35,000 cubic yards of material would be excavated from the DNAPL source area to an approximate depth of 25 feet. Excavation areas are shown in **Figure 4-1**. Sheet piling would be installed to surround the excavation and facilitate de-watering. Purge water from de-watering activity would be treated via an air stripper followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose. The upper five feet of soil at the site is assumed to be non-hazardous (previously treated during the TCRA) and would be stockpiled and reused to provide a final grade over the site. Soil from 5 to 25 feet bgs was assumed to be hazardous (potential waste codes include D029, D039, D040, and D043), and would be transported to the hazardous waste landfill in Emelle, Alabama for disposal.

Other components of this alternative include:

- Utility relocation and abandonment.
- Installation of site security fencing.
- Monitoring well abandonment.
- Disposal of well debris.
- Confirmation sampling.
- Site restoration.
- One groundwater monitoring event following site equilibration.

Advantages of Excavation

- Excavation is a proven and readily implementable technology that removes all contamination.

Disadvantages of Excavation

- The excavated material would require disposal as hazardous waste and would require transport to a designated waste facility.
- Approximately 2,400 truckloads would be required to remove excavated material from the site. An equivalent number would be required to bring fill onto the site.
- Utilities may be present in the DNAPL source area. These utilities would have to be removed and relocated.
- Dusts/odors may become nuisances during excavation. The application of spraying water may help control dust emissions.

- Water accumulation in excavations compromises wall stability. De-watering would need to take place during excavation below the water table. This de-watering solution would need to be treated prior to disposal. In order to avoid transporting groundwater to the Lot 203 groundwater treatment plant for disposal, purge water from de-watering activity would be treated via an air stripper followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose. Approximately 1,800,000 gallons of groundwater would have to be collected and treated.
- Excavation depths exceeding 20 feet increase costs due to the need for an appropriately sized excavator. Additionally, deep excavations result in increased risks to the site worker, as the risk for cave-in increases.

Implementation Concerns

1) Potential for Air Emissions

The biggest health and safety issue associated with excavation is due more so to the levels of contamination that would be managed, rather than the equipment, excavation shoring, and having a 25-foot deep excavation. Free product and high concentrations of contaminants exist in the soil to be removed. These very high concentrations of contaminants would be handled, transported, and managed. Once the ground is broken, VOCs will volatize to the atmosphere. Due to high concentrations of chlorinated solvents in the subsurface at Site 89, there is a risk of creating a hazardous atmosphere for workers on-site as well as the surrounding community. Engineering controls (i.e., an encapsulating unit) may be required to protect the surrounding community, as well as a substantial air handling system which would be required to vent and treat the enclosure. Workers would need to dress out in Level C or B personal protective equipment. Working in an enclosed area would be difficult and would slow workers down. In addition, dust may become a nuisance requiring the periodic spraying of water to control dust emissions.

2) Physical Hazards Associated with Excavation

Excavation is considered one of the most dangerous construction activities with risks to workers such as cave-ins, falling, and falling loads requiring benching, trenching, shoring, bracing, underpinning, or shields. A large excavation of approximately 25 feet is a hazard to the public. Much of the excavation would be in the saturated zone, resulting in less stable trench walls and exposure to contaminated groundwater. Access to Site 89 is restricted by a fence and gate; however, authorized personnel and trespassers should be considered. A barrier restricting access to the excavation would need to be constructed. Excavations can also affect the stability of surrounding buildings (TC952), although it is not expected to occur during excavation at Site 89 since preventive measures would be taken. Care must be taken to ensure the structural integrity of all of surrounding structures.

3) Transportation Issues

The removal and transportation of soil, groundwater, and the delivery of backfill material would require approximately 2,400 truckloads (4,800 trips enter and exit). These amounts include 1,920 truckloads of hazardous waste, 480 truckloads of soil, and 2,400 truckloads of backfill material. These numbers are approximate. The additional truck traffic would pose short-term safety and traffic issues at the Base.

4) Groundwater Management

This alternative will generate a significant amount of contaminated groundwater (on the order of 1,800,000 gallons). Groundwater cannot be transported to the Lot 203 groundwater treatment plant for disposal; therefore, groundwater would be treated on site with air stripping followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose.

4.2.2 Alternative 2 – Electrical Resistive Heating

The conceptual source area ERH configuration would consist of 119 electrodes, spaced at 20 foot intervals. Each electrode would be equipped with an upper and lower section separated by a fiberglass insulator, to allow focused heating of a specific depth interval. This produces heating in the target zone plus a hot floor, thereby eliminating the need for an additional borehole and electrode. SVE wells would be co-located with the electrodes. The vendor would use insulation material to create a two-zone effect. There would be separate wiring to each portion, allowing the creation of a hot floor. Current Environmental Solutions, the same vendor that performed the Site 89 pilot test in 2003, used a site model to estimate heating times, condensate production, etc. This information is contained in **Appendix A**. The conceptual layout of ERH electrodes is shown in **Figure 4-2.** Groundwater cannot be transported to the Lot 203 groundwater treatment plant for disposal; therefore, approximately 6,500,000 gallons of groundwater would be treated on site with air stripping followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose.

Other components of this alternative include:

- Installation of Site security fencing.
- Site restoration.
- Groundwater monitoring for a period of one year following remedial action.

Advantages of Electrical Resistive Heating

- ERH is an aggressive contaminant extraction method; it can be used to remove DNAPL in less than one year.
- ERH is effective in low permeability soils, where heating occurs faster in clay rich soils than sandy material. ERH has an advantage over conventional remedial methods such as air sparging or pump-and-treat, which are largely ineffective in low permeability media.
- The ERH pilot test conducted between 2003 and 2004 in the source area at Site 89 was considered a success. ERH achieved 90% to greater than 99.9% reduction in TCE in soil and groundwater sampling stations located within the treatment zone.

Disadvantages of Electrical Resistive Heating

- Capital costs can be high relative to other remedial technologies.
- Soil vapor extraction and vapor treatment (thermal oxidizer) are required to prevent fugitive steam/vapor migration and possible recontamination of the vadose zone.

Because the treatment area is unpaved, installation of a synthetic cover may be necessary. SVE vapor treatment costs are expected to be relatively high. Air discharge issues will have to be addressed.

- Due to the low permeability and shallow water table, high groundwater purge rates are expected, as demonstrated by the pilot test. Extracted groundwater would require additional treatment.
- ERH requires an extensive amount of power to operate.
- Contaminant concentrations in soil and groundwater observed six months after the pilot test indicate that movement of electrical current and heating was not completely uniform and residual impacts exceeding regulatory standards remain.
- Significant drilling is required to install the system.

Implementation Concerns

1) Potential for Air Emissions

The potential release of air emissions to the atmosphere is greater at a site where thermal technologies are being used. During the pilot study, air issues were significant. The importance of vapor capture is further accentuated by the fact that the depth to water at Site 89 is shallow, increasing the likelihood of vapor flow "short-circuiting" or fracturing during steam injection. More frequent and widespread air monitoring may be required, compared to high permeability sites with shallow contamination. Unpaved areas in the DNAPL source area may pose a possible risk of fugitive vapor migration. In this area, a temporary cover, such as a geo-synthetic liner can be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Air discharge permitting would be required.

2) Physical Hazards Associated with Electricity

Physical safety associated with electricity would be a major concern. Hazards associated with working with electricity would require the use of barriers around the site and a proactive operation and maintenance program.

3) Limited Number of Vendors

There are a limited number of vendors capable of providing ERH. A limited number of vendors can result in higher project costs and lengthen the time to complete the work, due to schedule conflicts.

4) Groundwater Management

Groundwater would be extracted in the form of steam. Groundwater cannot be transported to the Lot 203 groundwater treatment plant for disposal; therefore, approximately 6,500,000 gallons of groundwater would be treated on site using air stripping followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose.

4.2.3 Alternative 3 – Shallow Soil Mixing with Clay-Zero Valent Iron Addition

Shallow soil mixing would be implemented in the DNAPL source area using 8.5-foot diameter augers constructing an approximate total of 550 soil mixing columns to 25 feet bgs. Before mixing is started the top five feet of clean fill material would be stripped off to

remove minor utilities and to provide enough "free board" for injection of materials and mixing operations. This clean excavated material, estimated to be approximately 7,037 cubic yards, would be stored at the site and used for site restoration.

A mix design of 1.5% ZVI and 1% bentonite was assumed for this alternative. However, a bench scale study would be performed to evaluate the effectiveness of ZVI-Clay to degrade site contaminants. Bench scale studies would determine the appropriate amounts of materials to be injected and mixed in each soil column.

To perform mixing, the soil mix rig would be tracked into position over a pre-calculated/surveyed grid point. A baseline for the grid system would be staked out by a surveyor, and would include enough points that every column can be located off of the stakes. Mixing is performed by overlapping columns to ensure the entire volume is mixed (treated). Center-to-center distance between the columns would be spaced to account for overlap of adjacent columns. This overlap between columns (typically 25% to 35%) allows for complete mixing. The conceptual soil mixing column layout is shown in **Figure 4-3**.

Colorado State University owns the patent to this technology; therefore, royalty fees would be applied.

Shallow soil mixing would be intended to treat the source area and reduce contaminant flux. The ZVI would act as a passive reactive system. The source area would be transformed into a highly reactive zone, stimulating chlorinated degradation in this area.

Other components of this alternative include:

- Utility relocation and abandonment.
- Installation of Site security fencing.
- Construction of containment berms and/or dikes.
- Site restoration.
- Soil and groundwater monitoring for a period of one year following remedial action.

Advantages of Shallow Soil Mixing

- Shallow soil mixing with ZVI-Clay slurry injection has been shown effective at Camp Lejeune Site 88. Analytical results associated with Site 88 indicate greater than 92% reduction of impacts in soil over the mixing zone.
- Reduces the permeability of the source zone, which will decrease the flux of contaminants in and out of the area; thereby reducing contaminant mobility.
- Treatment time is relatively fast and is estimated to be approximately three months, depending on site restoration requirements.
- Shallow soil mixing with ZVI-Clay injection is a more robust technology that relies on the simple physical process of mixing and iron treatment. Any heterogeneous conditions will not impact this technology.

Disadvantages of Shallow Soil Mixing

- Subsurface utilities and existing monitoring wells in the treatment area would need to be removed and relocated prior to implementation of shallow soil mixing.
- Injection of slurry and mixing can cause fluff (i.e., increases in soil volumes). Some excavation prior to mixing and injection is necessary.
- A vapor capture hood is needed to contain vapors during mixing. Additionally, due to high contaminant concentrations in the source area, a carbon vapor treatment system would be required for the captured vapors. However, the air emissions would be significantly lower than other alternatives.
- Shallow soil mixing with clay-ZVI injection can be messy and dangerous to both workers and non-workers. The treatment zone would need to be barricaded to contain solids and liquids and prevent access to non-workers.
- Water separates from treated material as the soil settles. This water requires collection and treatment. During shallow soil mixing, approximately 50,000 to 100,000 gallons of water would be contained and treated by carbon adsorption, followed by discharge to the Base sanitary sewer system. A temporary discharge permit would be obtained for this purpose.
- Injection of a slurry would change the groundwater flow dynamics near Edwards Creek. There is uncertainty about how shallow soil mixing will affect the creek and how the creek will affect soil mixing.

Implementation Concerns

1) Physical Hazards Associated with Crane and Large Equipment

Shallow soil mixing requires the use of a crane and large equipment, including, but not limited to, a drill rig and a track hoe. Physical safety associated with the use of this equipment would be a major concern. In addition, excavation would be required to contain swells. Excavation and the soil slurry resulting from the mixing are potentially dangerous to workers. Barriers around the site, clear worker communication, and a proactive operation and maintenance program would be required.

2) Water Management

This alternative will generate a significant amount of water (on the order of 50,000 to 100,000 gallons). In order to avoid transporting water to the Lot 203 groundwater treatment plant for disposal, water would be treated on site using carbon adsorption, followed by discharge to the Base sanitary sewer system. A temporary stormwater discharge permit would be obtained for this purpose. Faster site stabilization would be required with shallow soil mixing.

3) Noise

As with any heavy equipment, noise may be a concern. The equipment would only be operating during normal working hours for a short time. Older rigs are louder than the newer, modern equipment. A crane mounted rig can generate noise levels that can reach 150+dB in front of the rig for older models. For comparison, peak noise levels for standard

construction equipment are: conventional tractor backhoe 140 dB, Ford F-700 dumptruck 133 dB, D6 cat dozer 130 dB, grout batch plant (generator, pump, silo, mixers) 145 dB.

4) Proximity to Edwards Creek

Injection of a slurry would change the groundwater flow dynamics near Edwards Creek. There is uncertainty about how shallow soil mixing will affect the creek and how the creek will affect soil mixing. Flooding in this area could carry contaminated slurry into the creek. Sediment and erosion controls and berms would be implemented to prevent this. The upward gradient of groundwater flow near the creek could enter into the soil mixing area during implementation. These factors would need to be considered prior to implementation. Engineering controls would be utilized to mitigate these concerns.

4.2.4 Alternative 4 – In Situ Thermal Desorption

ISTD systems consist of electrical power distribution equipment, vapor and groundwater extraction wells, and an aboveground treatment plant for extracted fluids. Multiple heater assemblies are placed across the treatment zone at relatively close spacing (half the distance of ERH) to ensure thorough conductive heating. Recovery wells are placed to capture groundwater and vapor mobilized during heating.

The conceptual source area ISTD configuration would consist of 193 electrodes, spaced at 15 foot intervals. A total of 11 horizontal SVE wells would also be installed to capture vapor and water. The conceptual layout of ISTD electrodes is shown in **Figure 4-4.**

Other components of this alternative include:

- Installation of Site security fencing.
- Site restoration.
- Groundwater monitoring for a period of one year following remedial action.

Advantages of In Situ Thermal Desorption

- ISTD is an aggressive treatment method that can be used to remove DNAPL in less than one year.
- ISTD is highly effective in low permeability and heterogeneous conditions. This method causes evaporation of water and drying/desiccation of soils, which improves the effective permeability, and, therefore, SVE performance in low permeability soils. Additionally, this method provides uniform heating in heterogeneous conditions.
- Available case histories indicate that conductive heating can achieve superior mass removal compared to ERH in lower permeability, heterogeneous conditions. Residual PCE and TCE concentrations in soil less than 5 mg/kg and 1 mg/kg, respectively, have been reported (EPA, 2004).

Disadvantages of In Situ Thermal Desorption

- Soil vapor extraction and vapor treatment (thermal oxidizer) are required to prevent fugitive steam/vapor migration and possible recontamination of the vadose zone. Because the treatment area is unpaved, installation of a synthetic cover may be

necessary. SVE vapor treatment costs are expected to be relatively high. Air discharge issues will have to be addressed.

- Due to the low permeability and shallow water table, high groundwater purge rates are expected with SVE. Similar to ERH, approximately 6,500,000 gallons of groundwater would be treated on site using air stripping followed by activated carbon and discharged to the sanitary sewer.
- ISTD requires an extensive amount of power to operate.
- Significant drilling is required to install the system. A thermal blanket overlying the site is also required.
- Tighter spacing of thermal wells, relative to electrodes with ERH, would be required, which increases costs.

Implementation Concerns

1) Potential for Air Emissions

The potential release of air emissions to the atmosphere is greater at a site where thermal technologies are being used. The importance of vapor capture is further accentuated by the fact that the depth to water at Site 89 is shallow, increasing the likelihood of vapor flow "short-circuiting" or fracturing. More frequent and widespread air monitoring may be required, compared to high permeability sites with shallow contamination. Unpaved areas in the DNAPL source area may pose a possible risk of fugitive vapor migration. In this area, a temporary cover, such as a geo-synthetic liner can be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Air discharge permitting would be required.

2) Physical Hazards Associated with Electricity

Physical safety associated with electricity would be a major concern. Hazards associated with working with electricity would require the use of barriers around the site and a proactive operation and maintenance program.

3) Groundwater Management

High groundwater purge rates are expected with SVE. Similar to ERH, approximately 6,500,000 gallons of groundwater would be treated on site using air stripping followed by activated carbon and discharged to the sanitary sewer. A temporary stormwater discharge permit would be obtained for this purpose.

4.2.5 Alternative 5 – Air Sparging

Air sparging is included as a relatively low cost source treatment option, considered as an alternative to excavation, soil mixing, or in-situ thermal treatment. Air sparging is not expected to achieve the same level of performance as these alternatives, particularly over the near term (less than one year). However, because the site is vacant, and there are no plans to develop the property in the near future, long term operation (i.e. 3 to 5 years) of a low cost option is considered feasible.

A conceptual layout of 73 vertical sparge wells, as shown in **Figure 4-5**, would be installed within source areas, at 25 foot spacing. Sparge well depths, to be determined in the field,

are expected to be 25 feet bgs. Based on the apparent success of pneumatic fracturing associated with the Site 89 Treatability Study, pneumatic fracturing would be performed over a vertical interval of 10 to 25 feet bgs.

Vapor flow "short-circuiting" or fracturing is more likely to occur during air sparging at sites where the depth to water is shallow. This decreases the efficiency of the system. Because of the shallow depth to groundwater, conventional soil vapor extraction using vertical wells is not practical or recommended. Accordingly, installation of a high permeability gravel layer over the top of native soil was assumed. The completed soil cover would include one foot of gravel, an impermeable HDPE liner (to prevent surface water infiltration and enhance permeability of the soil), and six inches of cover soil. Horizontal SVE collection pipes, also constructed of HDPE, would be installed within the layer of gravel. Treatment of collected off-gas using a convertible thermal/catalytic oxidizer was assumed for the first year of operation, with vapor phase granular activated carbon thereafter.

Other components of this alternative include:

- Installation of site security fencing.
- Site restoration.
- Groundwater monitoring for a period of one year following remedial action.

Advantages of Air Sparging

- Air sparging with SVE is generally the low cost option relative to the other alternatives considered.
- Air sparging with SVE involves simple equipment and straightforward operation and maintenance.
- An air sparging system can be operated indefinitely until the desired results are achieved. Air sparging could also be amended with ozone or nutrient gases to advance chlorinated degradation.

Disadvantages of Air Sparging

- Case studies involving air sparging in source areas with DNAPL are limited.
- During air sparging, a significant amount of chlorinated hydrocarbons dissolved in groundwater would be transferred to soil vapor. Soil vapor extraction is required to prevent fugitive vapor migration and possible recontamination of the vadose zone. Because the treatment area is unpaved, installation of an engineered cover would be necessary. A temporary air discharge permit would be required.
- In low permeability soils, sparge air channeling will result in bypassing in some areas, with associated poor performance. Pneumatic fracturing would be recommended to increase sparge air channel density and enhance performance.
- Some degree of rebound, an increase in contaminant concentrations following system shut-off, is expected with air sparging.

- Air sparging combined with pneumatic fracturing may increase the risk of DNAPL mobilization into underlying zones, unless careful attention is paid to injection well construction and fracturing methods.

Implementation Concerns

1) Potential for Air Emissions

The potential release of air emissions to the atmosphere is greater at a site where the depth to water is shallow, increasing the likelihood of vapor flow "short-circuiting" or fracturing. More frequent and widespread air monitoring may be required, compared to high permeability sites with shallow contamination. Unpaved areas in the DNAPL source area may pose a possible risk of fugitive vapor migration. Installation of an engineered cover would be necessary. Air discharge permitting would be required.

2) Potential for DNAPL Mobilization

Air sparging in combination with pneumatic fracturing increases the potential for DNAPL to mobilize into underlying zones. Careful attention must be paid during injection well construction and fracturing to minimize this potential.

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- Footprint Source Area
- Excavation (depth = 25 ft; total perimeter = 1197 ft)

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 4-1
Source Area Treatment
Alternative 1 - Excavation
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_4_1_Source_Area_Treatment_Alternative_1_Excavation.mxd

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- Electrode Locations (119 electrodes; 20ft spacing))
- Footprint Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 4-2
Source Area Treatment
Alternative 2 - Electrical Resistance Heating
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_4_2_Source_Area_Treatment_Alternative_2_ElectricResistantHeating.mxd

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- In-Situ Soil Mixing Columns
- Footprint Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 4-3
Source Area Treatment
Alternative 3 - Shallow Soil Mixing
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_4_3_Source_Area_Treatment_Alternative_3_ShallowSoilMixing.mxd

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- In-Situ Heater Locations (193 heaters; 15ft spacing)
- Footprint Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 4-4
Source Area Treatment
Alternative 4 - In Situ Thermal Desorption
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_4_4_Source_Area_Treatment_Alternative_4_InSituThermalDesorption.mxd

Legend

- Monitoring Well Locations
- GeoProbe Soil Borings - CH2M Hill May 2002 Supplemental Investigation
- GeoProbe Soil Boring Locations -CH2M Hill 2004 Remedial Investigation
- Air Sparge Well (73 wells; 25ft spacing)
- Air Sparge Conduit Trench (Total Length = 1925 Ft)
- Sparge Compressor Building
- Footprint Source Area

N

0 50 100 Feet

Aerial Photograph taken Feb. 2004

Figure 4-5
Source Area Treatment
Alternative 5 - Air Sparging
Operable Unit No. 16 Site 89
MCB Camp Lejeune, North Carolina

AGVIQ CH2M HILL

File Path: V:\USNavFaceNGCom\315007CampLejeune\Projects\Site89_EE_CA\Figure_4_5_Source_Area_Treatment_Alternative_5_AirSparging.mxd

5.0 Detailed Analysis of Remedial Action Alternatives

The alternatives analysis uses the three main evaluation criteria of effectiveness, implementability, and cost, in accordance with the U.S. EPA's Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA (USEPA, 1993). Each evaluation criterion is described in **Table 5-1**. Anticipated ARARs are listed in **Appendix B**. **Table 5-2** summarizes the direct and indirect capital costs, as well as long-term operation and maintenance costs (as applicable) for the alternatives. **Appendix C** contains the detailed cost estimates for the five alternatives. **Table 5-3** summarizes the evaluation for each technology.

TABLE 5-1
Evaluation Criteria

Effectiveness	
Protection of human health and the environment	The assessment describes how the action achieves and maintains protection of human health and the environment and achieves site-specific objectives both during and after implementation.
Compliance with ARARs	An alternative is assessed in terms of its compliance with ARARs, or if a waiver is required, how it is justified.
Short-term effectiveness	An action is assessed in terms of its effectiveness in protecting human health and the environment during the construction and implementation of a remedy before response action objectives have been met. The duration of time until the response objectives are met is also factored into this criterion.
Long-term effectiveness and permanence	An action is assessed in terms of its long-term effectiveness in maintaining protection of human health and the environment after response action objectives have been met. The magnitude of residual risk and adequacy and reliability of post-removal site controls are taken into consideration.
Reduction of toxicity, mobility or volume through treatment	An action is assessed in terms of anticipated performance of the specific treatment technologies it employs. Factors such as volume of materials destroyed or treated, the degree of expected reductions, the degree to which treatment is irreversible, and the type and quantity of remaining residuals are taken into consideration.
Implementability	
Technical feasibility	The ability of the technology to implement the remedy is evaluated.
Administrative feasibility	The administrative feasibility factor evaluates requirements for permits, zoning variances, impacts on adjoining property, and the ability to impose institutional controls.
Availability of services and materials	The availability of offsite treatment, storage, and disposal capacity, personnel, services and materials, and other resources necessary to implement the alternative will be evaluated.
State and community acceptance	The acceptability of an alternative to the state agency and the community is evaluated.
Cost	
Direct and indirect capital costs	Includes costs for construction, equipment and materials, analytical services, engineering and design, and permit/licenses.
O and M costs	Includes ongoing monitoring and maintenance for a specific period.

5.1 Alternative 1 – Excavation with Off-site Disposal

Effectiveness

Alternative 1, excavation, has the potential to protect human health and the environment by achieving the RAOs presented in Section 3. Through physical removal, Alternative 1 is suitable for bulk DNAPL removal from the subsurface. This alternative would have to comply with ARARs, and, therefore, would be regulated by numerous transportation and disposal guidelines, pre-treatment of soil, and final disposal at the hazardous waste landfill. Additionally, Alternative 1 may require a temporary storm discharge permit.

Alternative 1 is effective in the long-term, as the source area would be physically removed. However, contaminants are not destroyed, but rather moved to a permitted facility. Alternative 1 eliminates toxicity, mobility, and volume at the site.

Alternative 1 would raise overall site risk for the period that the action took place. Risks to site workers and the nearby community will increase due to construction activity. There would be an increase in truck traffic that could cause a greater risk of injury or accidents. The health and safety issues with Alternative 1 are more so due to the levels of contamination that would have to be managed rather than with the equipment, excavation shoring, or having a 25-foot deep excavation. Free product and high concentrations of contaminants exist in the soil to be removed. These very high concentrations of contaminants would have to be handled, transported, and managed. High contaminant concentrations in the source area would create a hazardous atmosphere affecting site workers and the surrounding community. Once the ground is broken, a large percent of VOCs will volatize to the atmosphere requiring Level C or B personal protective equipment for site workers. Excavation is considered one of the most dangerous construction activities with risks to workers such as cave-ins, falling, and falling loads requiring benching, trenching, shoring, bracing, underpinning, or shields. A large excavation of approximately 25 feet deep is a hazard to the public. A barrier restricting access to the excavation would need to be constructed. Liquids would be generated that will require management and treatment. Alternative 1 has the potential to achieve RAOs within one year.

Implementability

Alternative 1, excavation, is technically feasible. Future remedial actions would not be required at the site. Subsurface utilities in the treatment area would be removed and relocated. Heavy equipment would be required to implement this alternative. Air and water discharge permits may be required. Disposal of excavated material at the hazardous waste landfill could require permitting and/or pre-treatment. Services and materials associated with implementation of Alternative 1 are readily available. State acceptance of this alternative is subject to review. Community acceptance of this alternative is unknown and would be determined during the public comment period.

Cost

Alternative 1, excavation, is estimated to cost $38,000,000 (a +50%/-30% range of $25.3MM to $54.2MM). This is equivalent to $1,100 per cubic yard.

5.2 Alternative 2 – Electrical Resistive Heating

Effectiveness

Alternative 2, ERH, has the potential to protect human health and the environment by achieving the RAOs presented in Section 3. Through mass transfer to the vapor phase with vapor capture, ERH is suitable for bulk DNAPL removal from the subsurface. Alternative 2 would have to comply with ARARs, and, therefore, ensure that applicable NIOSH and OSHA standards for VOCs in ambient are not exceeded. Additionally, Alternative 2 may require a temporary storm discharge permit.

Alternative 2 is effective in the long-term through mass transfer and extraction. DNAPL is removed from the subsurface and residual impacts are biodegraded. Some residuals may remain. Alternative 2 reduces contaminant mass, toxicity, and mobility. Thermal treatments are irreversible.

Unpaved areas in the source area may pose a possible risk of fugitive vapor migration to surrounding buildings. In this area, a temporary cover, such as a geo-synthetic liner could be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Worker concerns are air emissions and working with electricity. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Significant drilling activity would be required to install these systems. Liquids would be generated that will require management and treatment. Alternative 2 has the potential to achieve RAOs within one year.

Implementability

Alternative 2 is technically feasible and has been proven to be a reliable technology at Site 89. Air and water discharge permits may be required during implementation. Services and materials are readily available, although there are a limited number of ERH vendors. State acceptance of this alternative is subject to review. Community acceptance of this alternative is unknown and would be determined at a public meeting.

Cost

Alternative 2, ERH, is estimated to cost $7,400,000 (a +50%/-30% range of $4.9MM to $10.6MM). This is equivalent to $210 per cubic yard.

5.3 Alternative 3 – Shallow Soil Mixing with Clay-Zero Valent Iron Addition

Effectiveness

Alternative 3, shallow soil mixing with Clay-ZVI addition, has the potential to protect human health and the environment by achieving the RAOs presented in Section 3. Through in situ reduction, degradation, and containment, Alternative 3 is suitable for bulk DNAPL removal from the subsurface. This alternative would have to comply with ARARs, and, therefore, ensure that applicable NIOSH and OSHA standards for VOCs in ambient are not exceeded. Additionally, this alternative may require a temporary discharge permit.

Alternative 3 is effective in the long-term, providing risk reduction through treatment and containment and significantly reducing contaminant flux. The addition of bentonite clay in Alternative 3 significantly reduces the hydraulic conductivity of the treated columns and the introduction of elemental iron causes chemical reduction of solvents, thereby reducing toxicity.

Alternative 3, soil mixing, is moderately effective in the short-term. Air emissions will have to be considered. No significant increase of traffic would occur. During mixing and injection, the soil will fluff up and expand its volume. Swells can be formed which may result in the spread of contaminants to clean areas. To capture the fluff, excavation would be performed prior to implementation and sediment and erosion controls would be installed. Noise may be an issue depending on the equipment used. However, operation of the equipment would only be during standard working daytime hours. Additionally, worker safety is an issue when working around large equipment and near the soil slurry. A high visibility safety fence with appropriate warning signs would surround soil mixing activities. Alternative 3 has the potential to achieve RAOs within one year.

Implementability

Alternative 3 is technically feasible and has been proven to be a reliable technology at Site 88. Subsurface utilities in the treatment area would be removed and relocated. Heavy equipment would be required to implement this alternative. Air and water discharge permits may be required. Services and materials are readily available; however, there are a limited number of suppliers to perform this work. State acceptance of this alternative is subject to review. Community acceptance of this alternative is unknown and would be determined at a public meeting.

Cost

Alternative 3, soil mixing, is estimated to cost $4,500,000 (a +50%/-30% range of $3.0MM to $6.5MM). This is equivalent to $130 per cubic yard.

5.4 Alternative 4 – In Situ Thermal Desorption

Effectiveness

Alternative 4, ISTD, has the potential to protect human health and the environment by achieving the RAOs presented in Section 3. Through mass transfer to the vapor phase with vapor capture, Alternative 4 is suitable for bulk DNAPL removal from the subsurface. This alternative would have to comply with ARARs, and, therefore, ensure that applicable NIOSH and OSHA standards for VOCs in ambient are not exceeded. Additionally, this alternative may require a temporary storm discharge permit.

Alternative 4 is effective in the long-term through mass transfer and extraction. DNAPL is removed from the subsurface and residual impacts are biodegraded. Some residuals may remain. Alternative 4 reduces contaminant mass, toxicity, and mobility. Thermal treatments are irreversible.

Unpaved areas in the source area may pose a possible risk of fugitive vapor migration to surrounding buildings. In this area, a temporary cover, such as a geo-synthetic liner could

be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Worker concerns are air emissions and working with electricity. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Significant drilling activity would be required to install these systems. Liquids would be generated that will require management and treatment. Alternative 4 has the potential to achieve RAOs within one year.

Implementability

Alternative 4 is technically feasible, but has not been implemented at MCB Camp Lejeune. Air and water discharge permits may be required during implementation of Alternative 4. Services and materials are readily available; however, there are a very limited number of suppliers to perform this work. State acceptance of this alternative is subject to review. Community acceptance of this alternative is unknown and would be determined at a public meeting.

Cost

Alternative 4, ISTD, is estimated to cost $8,200,000 (a +50%/-30% range of $5.5MM to $11.8MM). This is equivalent to $240 per cubic yard.

5.5 Alternative 5 – Air Sparging

Effectiveness

Alternative 5, air sparging, has not been widely applied for bulk DNAPL removal and may not provide adequate protection of human and ecological receptors. Alternative 5 would have to comply with ARARs, and, therefore, ensure that applicable NIOSH and OSHA standards for VOCs in ambient are not exceeded.

Alternative 5 has the potential to provide long-term risk reduction through mass transfer to the vapor phase with vapor capture. Air sparging may not be suitable for bulk DNAPL removal and could result in significant residuals remaining following treatment.

Alternative 5, air sparging with SVE, is moderately effective in the short-term. Air emissions will have to be considered. Unpaved areas in the source area may pose a possible risk of fugitive vapor migration. Installation of an engineered cover would be necessary. No increase of traffic would occur. Risks to site workers include physical hazards resulting from the use of a drill rig associated with installation of sparge wells. The timeframe to achieve RAOs is conservatively estimated to be five years.

Implementability

Alternative 5 is technically feasible and has proven to be a reliable technology at Sites 86 and 89; however, few case studies exist regarding air sparging source areas. Subsurface utilities in the treatment area may require removal or relocation. Air and water discharge permits may be required. Services and materials are readily available. State acceptance of this alternative is subject to review. Community acceptance of this alternative is unknown and would be determined at a public meeting.

Cost

Capital costs associated with Alternative 5 are estimated to be $2,300,000 (a +50%/-30% range of $1.6MM to $3.3MM. The present worth of operations and maintenance is estimated to be $820,000 (a +50%/-30% range of $0.6MM to $1.4MM). The total present worth of Alternative 5, air sparging, is estimated to be $3,300,000 (a +50%/-30% range of $2.2MM to $4.7MM). This is equivalent to $90 per cubic yard.

TABLE 5-2

Cost Estimates for Source Zone Remedial Options

Alternative	Capital Cost	Present Worth of O&M Cost	Total Present Worth	Cost/ Cubic Yard
Alternative 1 - Excavation	$25,300,000 - $54,200,000	$0	$25,300,000 - $54,200,000	$720 - $1550
Alternative 2 - ERH	$4,900,000 - $10,600,000	$0	$4,900,000 - $10,600,000	$140 - $300
Alternative 3 - Shallow Soil Mixing	$3,000,000 - $6,500,000	$0	$3,000,000 - $6,500,000	$90 - $190
Alternative 4 - ISTD	$5,500,000 - $11,800,000	$0	$5,500,000 - $11,800,000	$160 - $340
Alternative 5 - Air Sparging	$1,600,000 - $3,300,000	$600,000 - $1,400,000	$2,200,000 - $4,700,000	$60 - $130

Note: Cost presented herein are for comparison purposes only and are not a guarantee of fixed costs for the specific alternative. The cost estimate is accurate to +50% -30%.

TABLE 5-3
Summary of Alternative Comparison

Evaluation Criteria	Alternative 1 Excavation	Alternative 2 Electrical Resistive Heating	Alternative 3 Shallow Soil Mixing	Alternative 4 In Situ Thermal Desorption	Alternative 5 Air Sparging
EFFECTIVENESS					
Overall Protection of Human Health and the Environment	Meets RAO through removal.	Meets RAOs through mass transfer to the vapor phase followed by treatment.	Meets RAO through treatment (contaminant degradation).	Meets RAOs through mass transfer to the vapor phase followed by treatment	Has potential to meet RAOs through mass transfer to the vapor phase followed by treatment, but may not be suitable for bulk DNAPL removal.
Compliance with ARARs	Complies with ARARs.	Complies with ARARs.	Complies with ARARs.	Complies with ARARs	Complies with ARARs.
Long-term effectiveness and permanence	All associated material is removed. Contamination is not destroyed, just transported offsite, which could result in future liability issues.	Risk reduction is provided through mass transfer and extraction. Contaminant flux is reduced.	Risk reduction is provided through contaminant degradation. Contaminant flux is reduced.	Risk reduction is provided through mass transfer and extraction. Contaminant flux is reduced.	Risk reduction is provided through mass transfer and extraction.
Reduction of Toxicity, Mobility or Volume through Treatment	Reduces toxicity, mobility and volume at the site through physical removal Contamination is not destroyed, but rather moved to a permitted facility.	Reduces toxicity, mobility and volume through heating, extraction, and hydrolysis. Treatment is irreversible.	Reduces toxicity, mobility, and volume through contaminant iron treatment. Reduces mobility of dissolved plume with addition of clay. Treatment is irreversible.	Reduces toxicity, mobility, and volume through heating, extraction, and hydrolysis. Treatment is irreversible.	Has potential to reduce toxicity, mobility, and volume through long term volatilization, extraction, and treatment. May not be suitable for bulk DNAPL removal and could result in significant residuals remaining after treatment.
Short-Term Effectiveness	Not effective in the short-term. Largest concern of this alternative is worker and surrounding community health and safety issues due to the possible creation of a hazardous atmosphere due to high contaminant concentrations. Encapsulation of the entire excavation area may be required with a substantial air handling system to vent and treat the enclosure, as well as Level C or B PPE. Excavation is considered one of the most dangerous construction activities with risks to workers such as cave-ins, falling, and falling loads requiring benching, trenching, shoring, bracing, underpinning, or shields. The open excavation will need to be barricaded to prevent non-workers from entering the site. Large increase of truck traffic around site and Base. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	Unpaved areas in thesource area could pose a possible risk of fugitive vapor migration to surrounding buildings. A temporary cover, such as a geo-synthetic liner, could be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Short term increase in air emissions. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	There is a potential of releasing air emissions to the atmosphere. A removable hood used on the mixing augers will capture these emissions and vapor treatment systems could treat these emissions. The treatment zone could be messy During mixing and addition, swells could be formed which could result in the spread of contaminants to clean areas. To capture these swells, excavations could be performed prior to implementation. Non-hazardous soil would be excavated, stockpiled, and reused to provide a final grade over the site. Excavation activities will pose hazards as associated with Alternative 1. Worker safety is an issue when working around the large equipment and near the soil slurry. A high visibility safety fence with appropriate warning signs would surround soil mixing activities. Noise may be an issue depending on the equipment used. However, operation would only be during standard working daytime hours. Potential to achieve RAOs within one year Significant management of groundwater and liquids	Unpaved areas in thesource area could pose a possible risk of fugitive vapor migration to surrounding buildings. A temporary cover, such as a geo-synthetic liner, could be installed to improve vapor capture and diminish the possible risk of fugitive vapor migration. Hazards associated with working with electricity require the use of barriers around the site and a proactive operation and maintenance program. Short term increase in air emissions. Significant management of groundwater and liquids. Potential to achieve RAOs within one year	There is a potential of releasing air emissions to the atmosphere. There is potential for sparge air "short-circuiting" around low permeability zones, which may leave localized untreated areas. Pneumatic fracturing would be recommended to enhance secondary permeability and DNAPL mass removal. During pneumatic fracturing, DNAPL could be released to underlying soils. A gravel layer immediately above grade would be utilized to collect soil vapor, due to the shallow depth to water at the site. Worker safety is an issue when installing sparge wells. The time frame to complete remedial action is conservatively estimated to be five years. A review of the alternative would be conducted at least once during that time period.
IMPLEMENTABILITY					
Technical Feasibility	Feasible. Excavation is known to be a reliable technology. Future remedial actions would not be required at the site.	ERH is much less restricted by heterogeneous subsurface conditions. However, the shallow water table could hinder the efficiency of SVE vapor captor units. Air emissions and water extracted during operation of the technology would require treatment. ERH has been proven to be a reliable technology at Site 89.	Insufficient delivery of reductive compounds to the subsurface could result in the ineffective treatment of the source area. The site is unoccupied, allowing for easy implementation of soil mixing (site is large enough to accommodate crane, infrastructure is limited, etc.) Vapor treatment may be required. Shallow soil mixing has been proven to be a reliable technology at Site 88.	ISTD is much less restricted by heterogeneous subsurface conditions. However, the shallow water table could hinder the efficiency of SVE vapor captor units. Air emissions and water extracted during operation of the technology would require treatment. ISTD offers flexibility in the orientation of heaters and can achieve higher temperatures than ERH, with more uniform heating. ISTD is a reliable technology, but has not been implemented at MCB Camp Lejeune.	Insufficient distribution of sparge air could result in untreated DNAPL in localized areas. Because the site is vacant and there are no plans to develop the property in the near future, long term operation is considered feasible. Because of the relatively low permeability of the Surficial Aquifer, sparging would require a longer period of time to achieve significant mass removal. Air sparging has been proven to be a reliable technology at Site 89 and Site 86; however, neither system was associated with source areas. Few case studies exist regarding air sparging source areas.
Administrative Feasibility	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required. Hazardous landfill may require pre-treatment.	Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air and water discharge permits may be required.	Subsurface utilities in the treatment area would be removed and relocated Air discharge permits may be required.
Availability of Services and Materials	Services and materials are available.	Services and materials are available. However, there are a limited number of suppliers to perform this work.	Services and materials are available.	Services and materials are available. However, there are a limited number of suppliers to perform this work.	Services and materials are readily available.
State and Community Acceptance	To be determined	To be determined	To be determined	To be determined	To be determined
COST					
Capital Cost (Direct and Indirect)	$25,300,000 - $54,200,000	$4,900,000 - $10,600,000	$3,000,000 - $6,500,000	$5,500,000 - $11,800,000	$1,600,000 - $3,300,000
Total O&M Cost	$0	$0	$0	$0	$600,000 - $1,400,000
Present Worth	$25,300,000 - $54,200,000	$4,900,000 - $10,600,000	$3,000,000 - $6,500,000	$5,500,000 - $11,800,000	$2,200,000 - $4,700,000

6.0 Comparative Analysis of Remedial Action Alternatives

The relative effectiveness of each of the five alternative options was compared using the three criteria summarized in Section 5: effectiveness, implementability, and cost. This evaluation is summarized in **Table 6-1**.

6.1 Effectiveness of Alternatives

6.1.1 Protection of Human Health and the Environment

All of the alternatives screened have the potential to achieve the RAOs specified in Section 3. Alternatives 2 through 4 are most protective as those technologies use mass transfer or chemical reduction and containment for treatment of the source area. Alternative 1 satisfies the RAOs through physical removal, an ex-situ process which poses risks during implementation. Alternative 5 has not been widely applied for bulk DNAPL removal and may not provide adequate protection of human and ecological receptors.

6.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

All five alternatives are expected to meet ARARs at the completion of implementation.

6.1.3 Long-Term Effectiveness and Permanence

Alternative 1 should be the most effective in removing contaminant mass since all associated material would be physically removed. Alternatives 2, 3, and 4 will provide similar effectiveness in the long-term. Alternative 5 (air sparge) is expected to be the least effective technology for treating a source area.

6.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Again, Alternative 1 (excavation) is expected to have the greatest success in reducing toxicity, mobility, and volume since the contamination would be physically removed from the site. Alternative 3 (soil mixing) is an active treatment technology, which is preferred under CERCLA, and also provides containment. Alternatives 2, 4, and 5 (ERH, ISTD, and air sparge) transfer VOCs from one medium (groundwater) to another (air) in order to reduce toxicity, mobility, and volume, which requires additional treatment to prevent discharge to the air.

6.1.5 Short-Term Effectiveness

Short-term effectiveness in terms of risks to workers, the community, and the environment is minimized for Alternative 3 (soil mixing) through use of PPE, a vapor capture hood, and site controls. Worker exposure to heavy equipment and soil slurry is a concern, which would be addressed with site controls such as a high visibility fence and warning signs. Alternatives 2 and 4 (ERH and ISTD) pose a concern due to the electrical hazards and heat

hazards associated with these technologies. Alternative 1 presents the greatest risk to workers and the surrounding community due to volatilized contamination; in addition, highly contaminated soil and groundwater would have to be transported and disposed of off-site. Alternatives 1 through 4 have the shortest time required to achieve RAOs, as these technologies should see a relatively rapid reduction in contaminant concentrations. Alternative 5 (air sparge) would be slower than these technologies.

6.2 Implementability of Alternatives

Alternative 3, shallow soil mixing, is the most implementable technology, as it was proven reliable in a source area at Site 88. Alternative 2, ERH, is the next most implementable technology, which was proven reliable at Site 89, but has a limited number of vendors. Alternative 4, ISTD, is considered moderately implementable, in that it can be a reliable technology, but has not been proven at MCB Camp Lejeune and has a limited number of vendors. Alternative 5, air sparge, follows. Air sparging was proven reliable at Sites 86 and 89; however, few case studies support this treatment in DNAPL source areas. Alternative 1, excavation, has significant risks and issues associated with it and is not considered very implementable.

6.3 Cost of Alternatives

As presented in **Table 5-2**, Alternative 5, air sparging, has the lowest cost at $60 to $130 per cubic yard, followed closely by Alternative 3, shallow soil mixing, with a cost of $90 to $190 per cubic yard. Alternatives 2 and 4 (ERH and ISTD) have similar costs, at $140 to $300 and $160 to $340 per cubic yard, respectively. Alternative 5, excavation, has the highest cost at $720 to $1550 per cubic yard.

TABLE 6-1

Relative Comparison of Alternatives

Ranking	Protection of Human Health and Environment	Compliance with ARARs, Advisories, and Guidance	Long Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Cost per Cubic Yard
Most Preferred	*Alternative 2 - ERH* -Meets RAOs through mass transfer	*Alternative 1 - Excavation*	*Alternative 1 - Excavation* -All associated material is removed	*Alternative 1 - Excavation* -All associated material is removed	*Alternative 2 - ERH* -Increased risk to site workers -Hazards associated with electricity	*Alternative 3 - Soil Mixing* -Proven reliable at Site 88.	*Alternative 5 - Air Sparge* $60 - $130
	Alternative 3 - Soil Mixing -Meets RAOs through chemical reduction and containment	*Alternative 2 - ERH*	*Alternative 2 - ERH* -Mass transfer and extraction -Reduced contaminant flux	*Alternative 3 - Soil Mixing* -Treatment and containment -Reduced contaminant flux -Reduced mobility -Treatment is irreversible	*Alternative 3 - Soil Mixing* -Increased risk to site workers -Hazards associated with heavy equipment and soil slurry	*Alternative 2 - ERH* -Proven reliable at Site 89	*Alternative 3 - Soil Mixing* $90 - $190
	Alternative 4 - ISTD -Meets RAOs through mass transfer	*Alternative 3 - Soil Mixing*	*Alternative 3 - Soil Mixing* -Treatment and containment Reduced contaminant flux	*Alternative 2 - ERH* -Mass transfer and extraction -Reduced contaminant flux -Treatment is irreversible	*Alternative 4 - ISTD* -Increased risk to site workers -Hazards associated with electricity	*Alternative 4 - ISTD* -Reliable technology not yet applied at Camp Lejeune	*Alternative 2 - ERH* $140 - $300
	Alternative 1 - Excavation -Meets RAOs through physical removal	*Alternative 4 - ISTD*	*Alternative 4 - ISTD* -Mass transfer and extraction -Reduced contaminant flux	*Alternative 4 - ISTD* -Mass transfer and extraction -Reduced contaminant flux -Treatment is irreversible	*Alternative 5 - Air Sparge* -Longest time until RAOs are achieved -DNAPL could be released to underlying soils during pneumatic fracturing	*Alternative 4 - Air Sparge* -Proven reliable at Sites 86 and 89; however, few case studies support air sparging with DNAPL source areas	*Alternative 4 - ISTD* $160 - $340
	Alternative 5 - Air Sparge -May not be suitable for bulk DNAPL removal	*Alternative 5 - Air Sparge*	*Alternative 5 - Air Sparge* -May not be suitable for bulk DNAPL removal -May result in significant residuals	*Alternative 5 - Air Sparge* -May not be suitable for bulk DNAPL removal -May result in significant residuals	*Alternative 1 - Excavation* -Greatest overall increase in risk to workers and surrounding community	*Alternative 5 - Excavation* -Management of soil and groundwater -Disposal in hazardous landfill may require permitting	*Alternative 1 - Excavation* $720 - $1550
Least Preferred							

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Appendix A

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MCB Camp Lejune Site 89 2

Six-Phase Heating Conceptual Design

CES Proposal: P486 V2

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Site Specifics & Design Overview

State?	NC
Site Zip Code?	28217
Six Phase Heating Treatment Area (ft^2):	38,000
Shape of Treatment Area (circle, rectangle, oval):	rectangle
Treatment Area Length (ft):	200
Treatment Area Width/Diameter (ft):	190
Treatment Area Perimeter (ft):	780
Shallow Extent of Six Phase Heating (ft):	1
Deep Extent of Six Phase Heating (ft):	25
Typical Depth to Groundwater (ft):	7
Treated Volume (yd^3):	33,778
Compare to Excavation Option (tons):	47,500
Annual Rainfall (in):	42
Groundwater Flow Velocity (ft/day):	0.01
Ambient Air Temperature(˚C):	25
Ambient Groundwater Temperature (˚C):	15
Proposed Treatment Temperature (˚C):	117
Treat Sequentially as # Sections:	1
Per-cent of site under building/pavement?	50%
What per-cent of cover material is concrete?	50%
What per-cent of site is public access?	50%
Is this a single array pilot test?	no
Vapor Extraction Required?	yes
Are Vents in Same Boreholes as Electrodes?	yes
Insulating Surface Cover Required?	yes
Impermeable Surface Seal Required?	yes
Separate Electrode Interval for Saturated Zone ?	yes
Does Vadose Zone Need to be Pre-Heated?	no
Does Vadose Zone Need to be Pre-Dried?	no
Air Sparging?	no
Multiphase Extraction Required?	yes
Account for In Situ Degradation?	yes
Degradation Mechanism:	hydrolysis

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Site Hydrogeology

Layer Model	Soil Type	Top, ft bgs	Thickness, ft	Zone	Hydraulic Conduct. cm/sec
Upper Layer 1	Silt	0.0	1.0	Vadose	5.79E-04
Upper Layer 2	Silt	1.0	1.0	Vadose	5.79E-04
Heated Layer 1	Silt	2.0	4.6	Vadose	5.79E-04
Heated Layer 2	Silt	6.6	0.4	Vadose	5.79E-04
Heated Layer 3	Silt	7.0	4.6	Saturated	5.79E-04
Heated Layer 4	Silt	11.6	4.6	Saturated	5.79E-04
Heated Layer 5	Silty Clay	16.2	8.8	Saturated	3.47E-05
Lower Layer 1	Silty Clay	25.0	5.0	Saturated	3.47E-05
Lower Layer 2	Silty Clay	30.0	5.0	Saturated	3.47E-05

Layer Model	Groundwater Conductivity 25˚C (µS/cm):	Soil Resitivity (ohm-m)	Soil TOC (wt %)	Soil TPH (mg/kg)	Sorption Coefficient (Kd, L/Kg)
Upper Layer 1	118.0	361.9	0.38%	0	4.77
Upper Layer 2	118.0	347.5	0.38%	0	4.81
Heated Layer 1	118.0	295.5	0.38%	0	4.95
Heated Layer 2	118.0	221.6	0.38%	0	5.08
Heated Layer 3	118.0	216.6	0.38%	0	5.21
Heated Layer 4	118.0	223.2	0.38%	0	5.46
Heated Layer 5	118.0	71.3	0.38%	0	5.82
Lower Layer 1	118.0	71.3	0.38%	0	5.82
Lower Layer 2	118.0	71.3	0.38%	0	5.82

Layer Model	Intrinsic Permeability (cm2)	Soil Moisture Content (wt %)	Soil Total Porosity	Soil Dry Density (kg/L)	Soil Wet Density (kg/L)
Upper Layer 1	5.33E-09	20.1%	46.1%	1.43	1.79
Upper Layer 2	5.33E-09	20.9%	46.1%	1.43	1.81
Heated Layer 1	5.33E-09	24.4%	46.1%	1.43	1.90
Heated Layer 2	5.33E-09	31.5%	46.1%	1.43	2.09
Heated Layer 3	5.33E-09	32.5%	46.1%	1.43	2.12
Heated Layer 4	5.33E-09	32.5%	46.1%	1.43	2.12
Heated Layer 5	3.20E-10	21.5%	36.1%	1.70	2.17
Lower Layer 1	3.20E-10	21.5%	36.1%	1.70	2.17
Lower Layer 2	3.20E-10	21.5%	36.1%	1.70	2.17

Layer Model	Specific Yield (dimless)	Layer Transmissivity (m2/sec)	Sand Fraction (%)	Silt Fraction (%)	Clay Fraction (%)
Upper Layer 1	0.03	1.76E-06	10%	85%	5%
Upper Layer 2	0.03	1.76E-06	10%	85%	5%
Heated Layer 1	0.03	8.11E-06	10%	85%	5%
Heated Layer 2	0.03	7.06E-07	10%	85%	5%
Heated Layer 3	0.03	8.11E-06	10%	85%	5%
Heated Layer 4	0.03	8.11E-06	10%	85%	5%
Heated Layer 5	0.03	9.31E-07	6%	47%	47%
Lower Layer 1	0.03	5.29E-07	6%	47%	47%
Lower Layer 2	0.03	5.29E-07	6%	47%	47%

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Contaminant Properties

Controlling Contaminant:	PCE
Total Contaminant Mass (lb):	20,953
Total Contaminant Volume (gallons):	1,553
Contaminant CAS Number:	127-18-4
Contaminant Molecular Weight (g/mol):	165.8
Contaminant Boiling Temperature at 1 atm (°C):	121.3
Heat of Vaporization (w-hr/kg):	57.5
Contaminant K_{oc} (cm3/g, L/kg):	1380.4
Carbon Absorption (wt%):	24%

	Ambient (at 15°C)	Heated (at 117°C)
Contaminant Water Solubility (mg/l):	270.7	193.7
Contaminant Vapor Pressure (Torr):	10.7	672.4
Contaminant Henry's Constant (atm):	476	27,224
Contaminant Henry's Constant (mg/L air / mg/L aq):	0.36	15.48
Contaminant NAPL Density (kg/L):	1.629	1.460
Contaminant NAPL Dynamic Viscosity (cP):	0.939	0.393
Contaminant NAPL Kinematic Viscosity (cSt):	0.577	0.269

Contaminant Distribution and Cleanup Targets

	Heated Layer 1	Heated Layer 2	Heated Layer 3	Heated Layer 4	Heated Layer 5
Zone:	Vadose	Vadose	Saturated	Saturated	Saturated
Volume (yd^3):	6,474.1	563.0	6,474.1	6,474.1	12,385.2
Initial Soil Concentrations, Dry Basis (mg/kg)					
Peak:	500	500	500	500	500
Average:	250	250	250	250	250
Target:	3.00	3.00	3.00	3.00	3.00
Initial Groundwater Concentrations (µg/L)					
Estimated Ave:	n/a	n/a	45,215	43,236	41,430
Target:	n/a	n/a	500	500	500
Initial Mass Distribution (lb)					
NAPL present?:	no	no	no	no	no
Sorbed:	3,699.9	320.2	3,684.6	3,694.5	8,565.8
Dissolved:	180.3	19.6	227.0	217.1	311.4
Vapor:	31.6	0.3	0.2	0.2	0.2
NAPL:	0.0	0.0	0.0	0.0	0.0
Total Mass:	3,911.8	340.2	3,911.8	3,911.8	8,877.4
Initial Saturations (v/v)					
Water	34.6%	44.6%	46.0%	46.0%	36.0%
Air	11.5%	1.5%	0.1%	0.1%	0.1%
NAPL	0.0%	0.0%	0.0%	0.0%	0.0%

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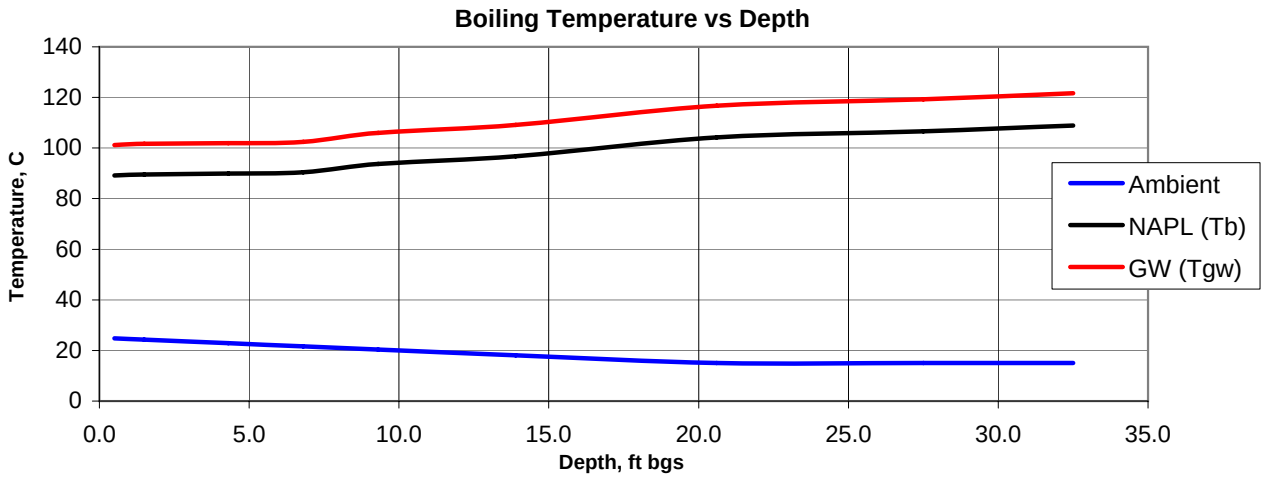
Estimated Treatment Temperatures & Pressure



	GW (˚C) Boiling Temperature	NAPL (˚C) Boiling Temperature	Ambient (˚C) Subsurface Temperature	Pressure at Boiling mm Hg	Layer Midpoint ft bgs
Upper Layer 1	101.2	89.1	24.8	792	0.5
Upper Layer 2	101.7	89.6	24.3	806	1.5
Heated Layer 1	101.9	89.9	22.9	814	4.3
Heated Layer 2	102.5	90.4	21.6	829	6.8
Heated Layer 3	106.0	93.7	20.4	936	9.3
Heated Layer 4	109.1	96.8	18.1	1,041	13.9
Heated Layer 5	116.8	104.2	15.0	1,341	20.6
Lower Layer 1	119.3	106.6	15.0	1,455	27.5
Lower Layer 2	121.7	108.9	15.0	1,568	32.5

Electrode Design Specifications

Number of Vertical Heating Intervals:	2	
Electrode and Extraction Well Terminations:	50% is below grade	
Number of Temperature Monitoring Wells:	38	
Soil Cuttings from Electrode Installation:	84.2	tons
Average Wetting Rate (all Electrodes):	0.50	gpm
Total Volume of Drip Water Added:	131,198	gallons
Total Amount of Electrolyte Required:	360	Lb

	Primary	Upper
Electrode Diameter (inches):	3.0	3.0
Borehole Diameter (inches):	12.00	12.0
Array to Electrode Ratio (D/d):	40	40.0
Distance between Electrodes (ft):	20.0	20.0
Total Number of Electrodes:	105	105.0
Depth to Top of Electrode (ft):	7.0	2.0
Total Depth of Electrode (ft):	25.0	3.0
Conductive Zone Length (ft):	18.0	1.0
Length of Electrode in Vadose Zone (ft):	0.0	1.0
Length of Electrode in Groundwater (ft):	18.0	0.0
Number of Drip Intervals per Primary Electrode:	1	1
Electrode Drill Cuttings (tons):	84.2	0.0

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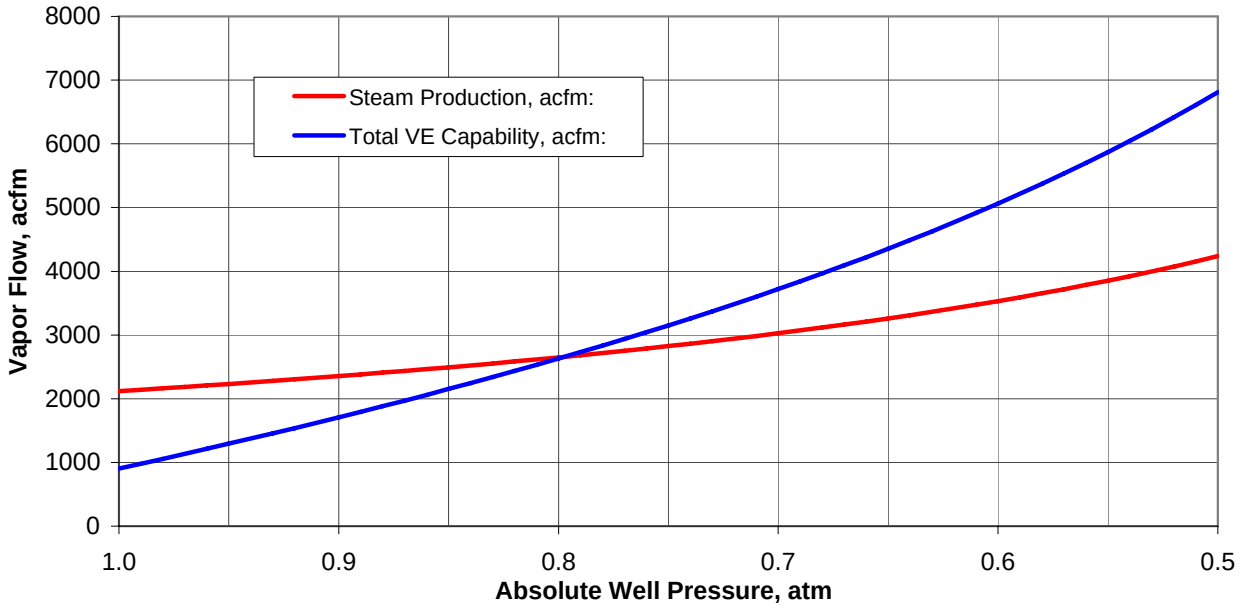
Extraction System Design

Design Extraction Vaccum:	0.80	atm
Well Vacuum:	6	in. Hg
Peak Steam Production Rate:	1,555	scfm
Peak Air Flow Rate:	431	scfm
Vapor Extraction Design Flow Rate:	1830	scfm
Recommended Blower Vacuum:	10	in. Hg
Vapor Extraction Blower:	160	hp
SVE/DVE Wells Co-Located with Electrodes?	yes	
Average Condensate Production Rate:	0.93	gpm
Total Condensate Produced:	1,547,300	gallons
Peak Vapor Extraction Rate:	2,212.2	lb/day
Peak In Situ Degradation Rate:	10.7	lb/day
Average Total Cleanup Rate:	309.7	lb/day
Final Extraction Rate:	0.2	lb/day
Soil Cuttings from VE Well Installation:	0.0	tons
Vapor Treatment Method:	catox	
Is Acid Gas Stack Scrubber Required?	no	

	Shallow/VE	Horizontal	Deep/DVE
Type of Vents Required:	yes	yes	yes
Vent Spacing (ft):	20	20	20
Number of Vents:	105	57	105
Wellbore/Trench Diameter (in.):	12.00	12.00	12.00
Screened Length per Vent (ft):	4.6	30.0	18.0
Peak Design Flow per Vent (acfm):	8.0	23.7	3.4
Wellscreen Diameter (in.):	3.0	2.0	3.0
Well Drill/Trenching Cuttings (tons):	0.0	0.0	0.0

Extraction System Design Curve



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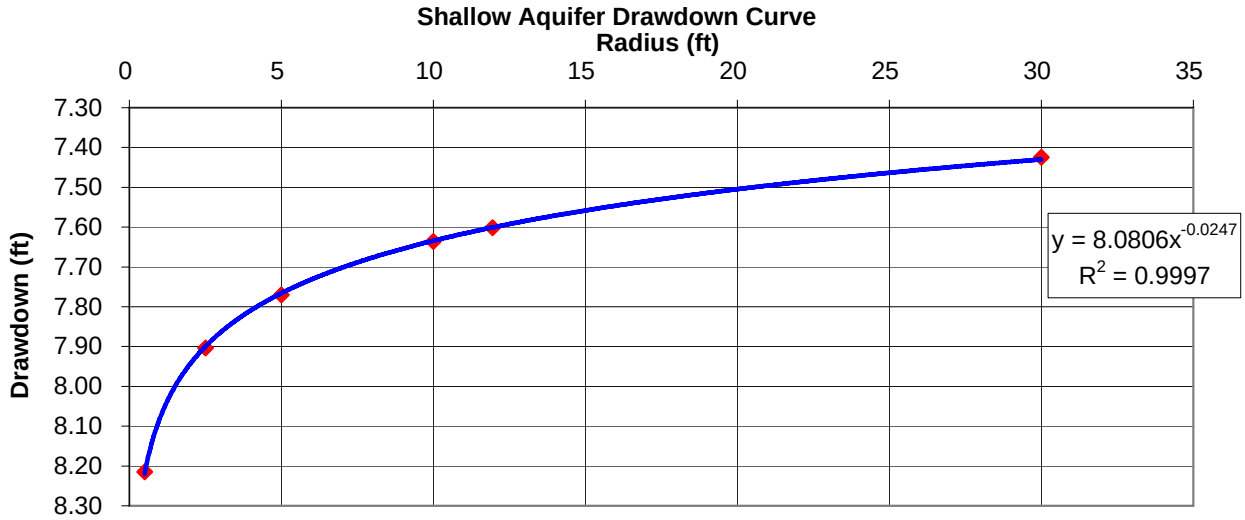
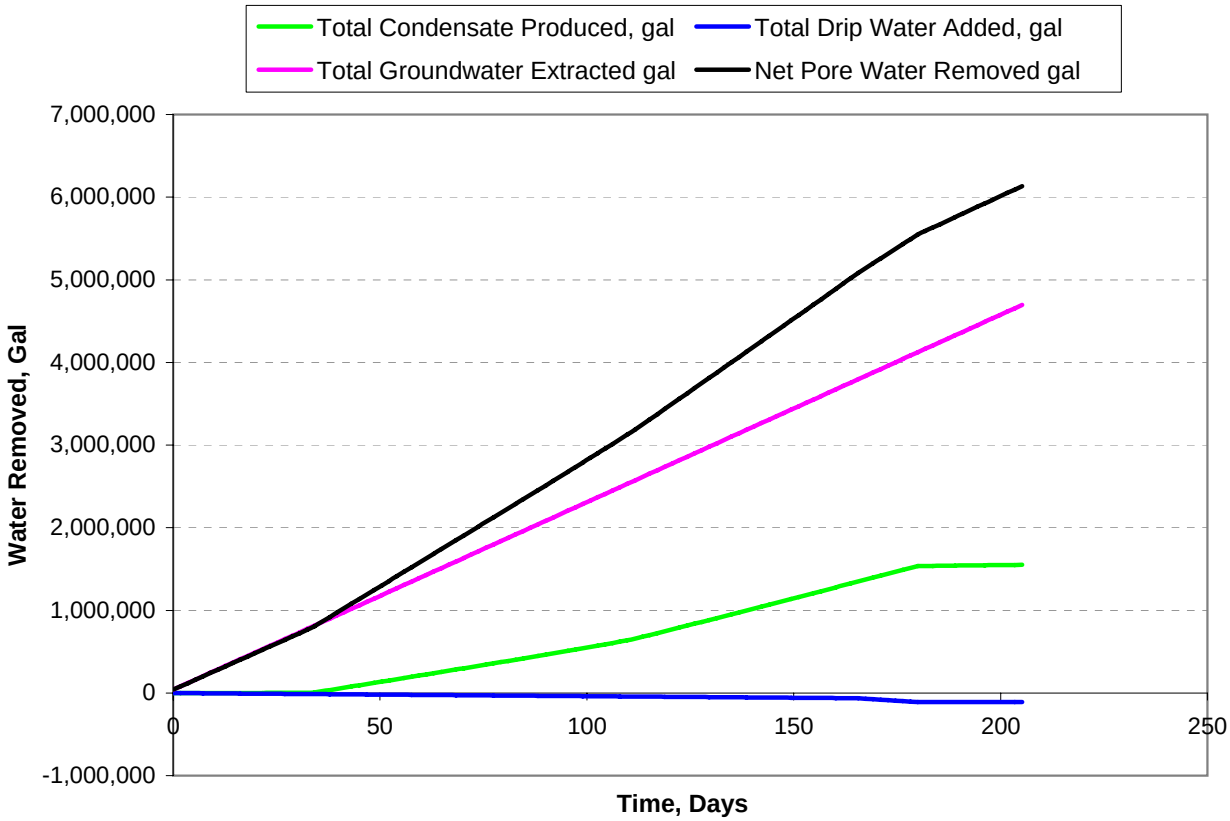
Groundwater Extraction & Overall Water Balance



Typical Depth to Groundwater: 7 ft bgs

Total Groundwater Extracted:	4,694,760	gallons
Total Condensate Produced:	1,547,300	gallons
Total Volume of Drip Water Added:	131,198	gallons
Total NAPL Extracted:	0	lb



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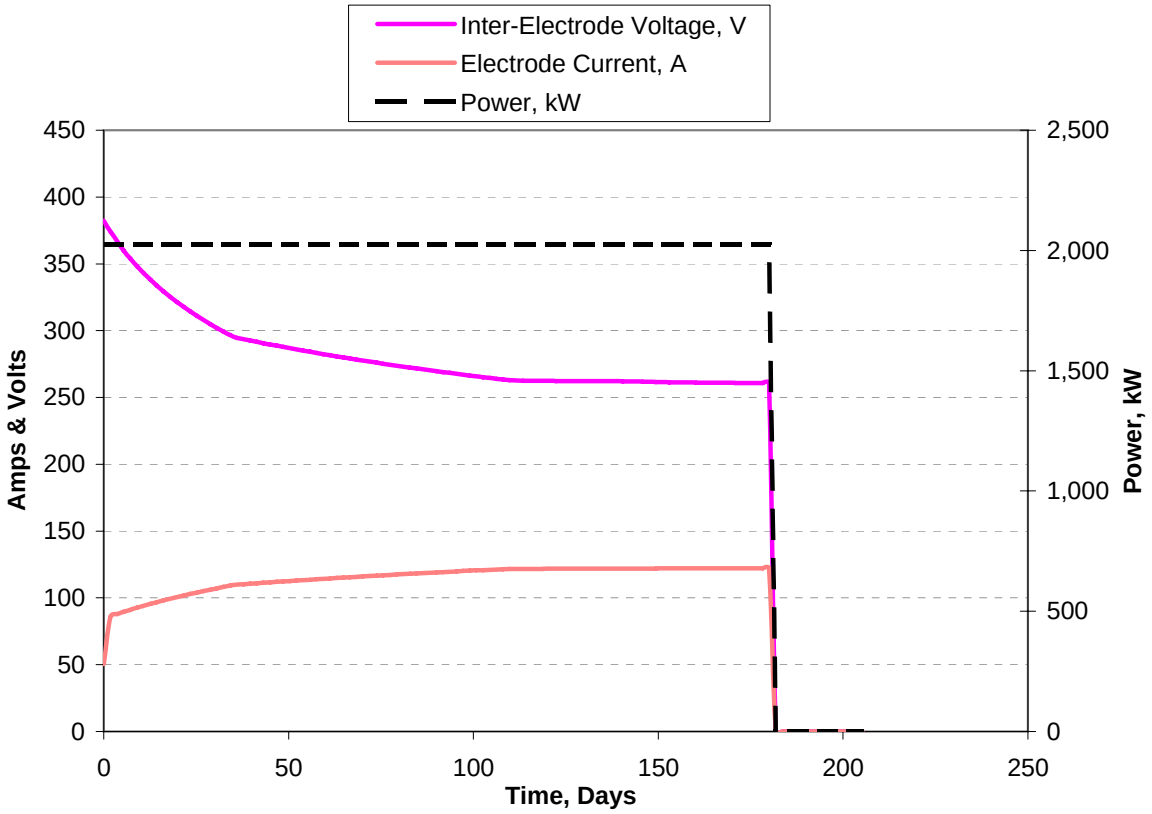
Estimated Treatment Time & Energy Requirements

Time to Pre-Heat/Dry Vadose Zone:	0	days
Time to Heat-up Site:	167	days
Time to Treat Site:	15	days
Extra Time for Multiphase Extraction:	0	days
Total Treatment Time:	181	days
Subsurface Energy Estimate:	8,835,500	kW-hr
Subsurface Energy Density:	273	kw hr/yd3
Total Energy Estimate:	9,606,162	kW-hr

Power Supply Specifications & Electrical Requirements



Site Electrical Power Requirement:	2,500	kW
Site Service Requirement at 480V, 3-Phase:	2,900	Amps
Power Supply Rating:	2250	kW
Peak Electrode Voltage:	382	Volts
Peak Phase Current:	4,484	Amps
Number of Electrode Phases:	3	

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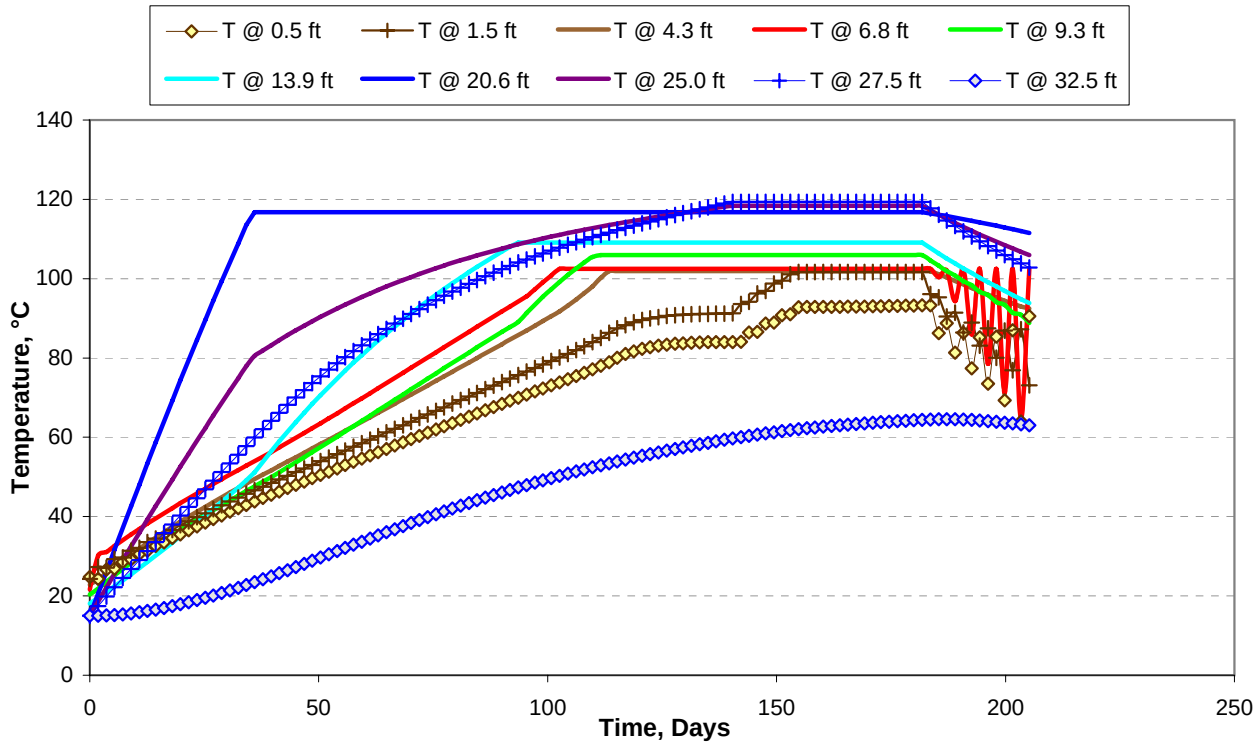
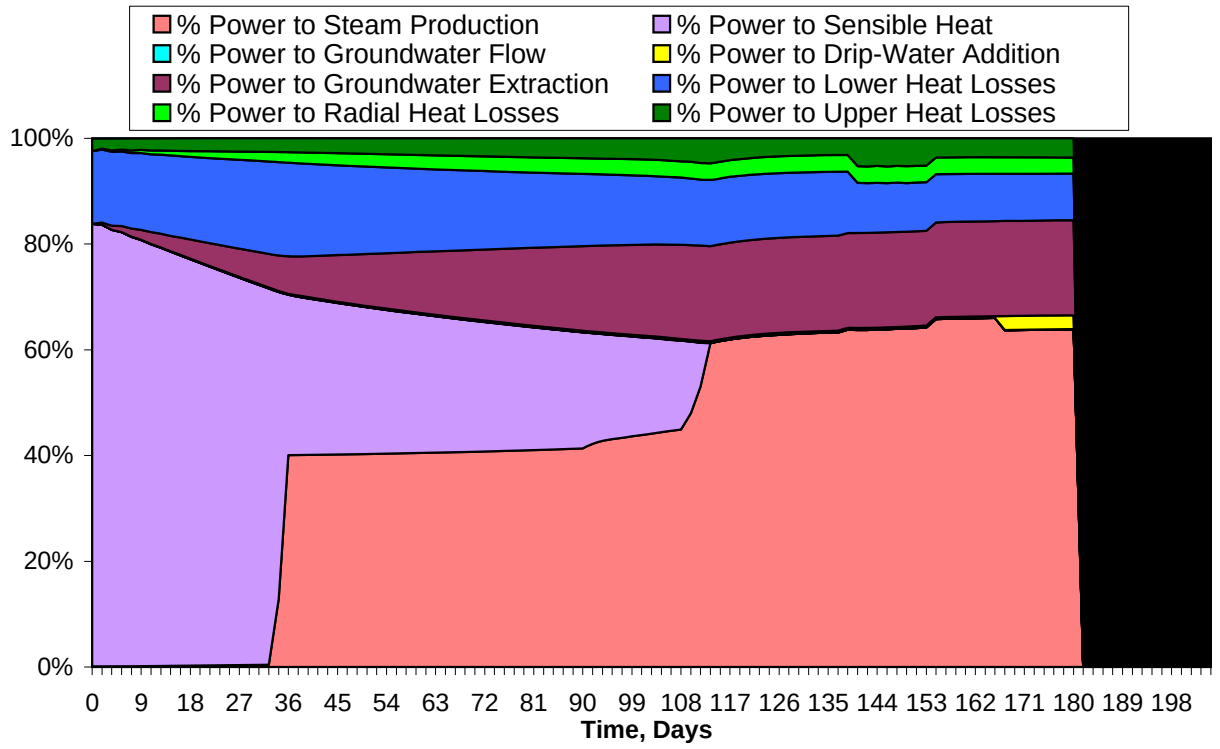
Predicted Subsurface Temperature Trends



Estimated Subsurface Energy Distribution



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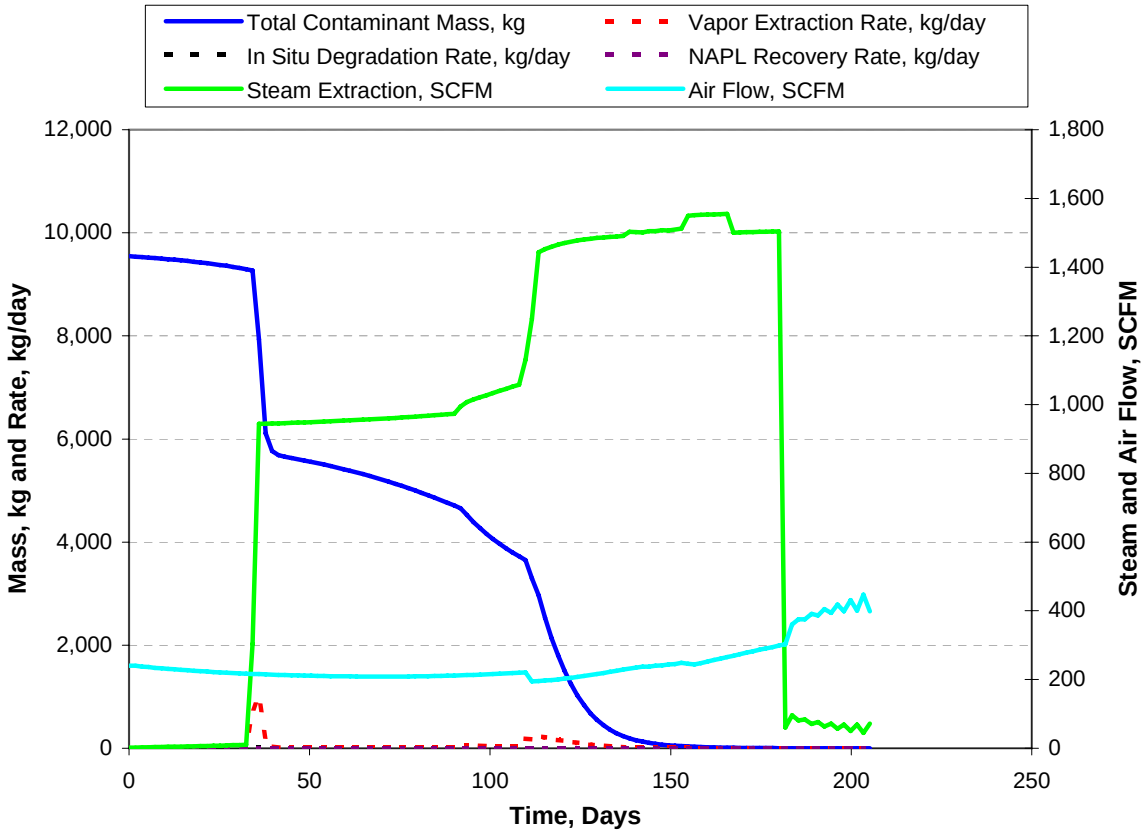
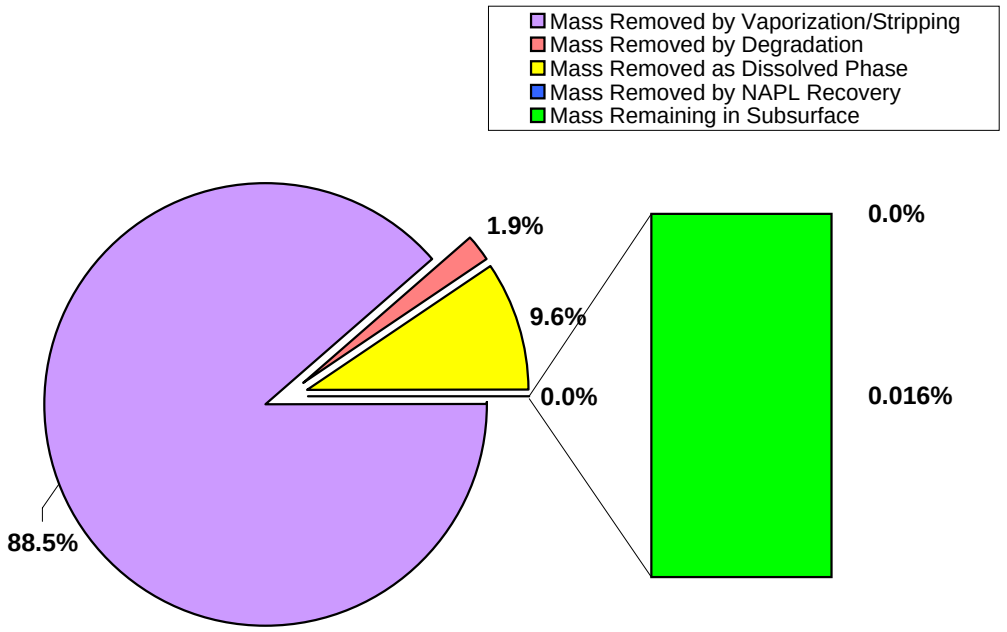
Projected Treatment Performance and Removal rates



Contaminant Fate Projection



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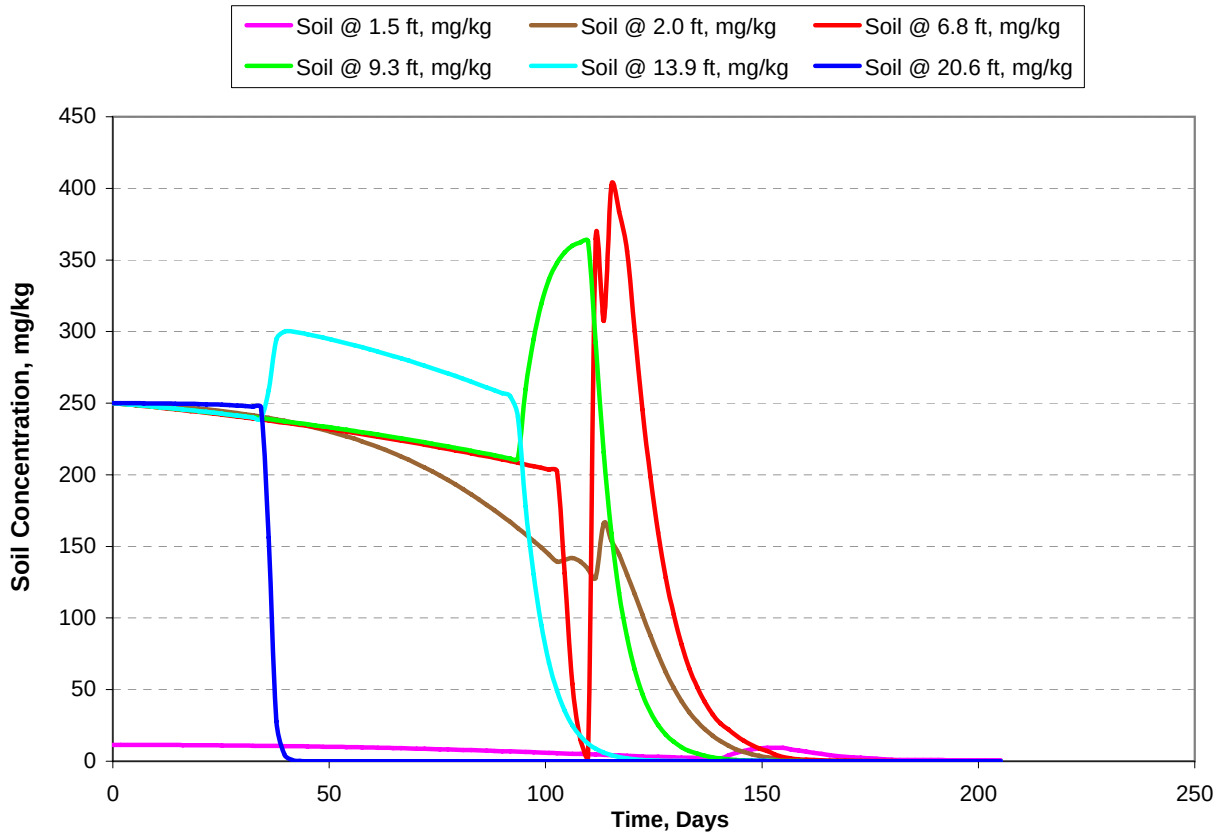
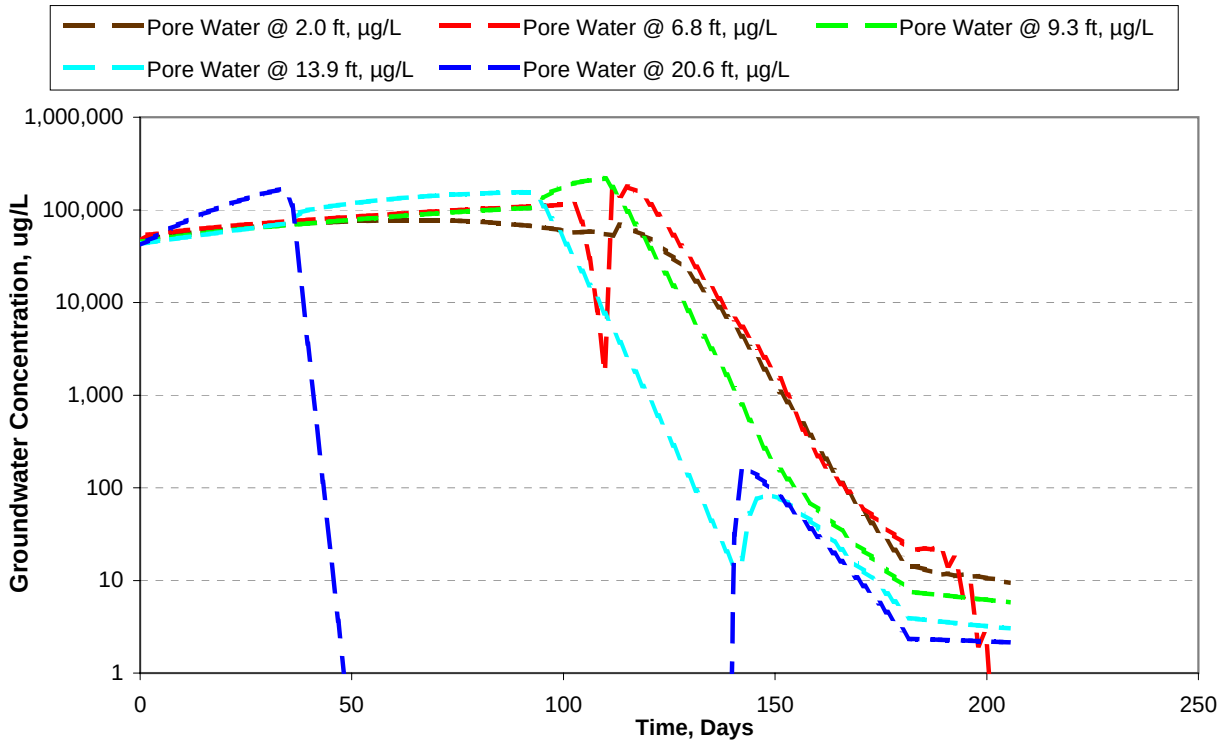
Predicted Soil and Groundwater Concentrations





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Preliminary Project Schedule

Assumed Project Start Date: 9/28/2007

Task	Task Description	Duration (Wks)	Total (Wks)	Completion
0	Testing, Modeling, Site Evaluation:	5	5	11/2/2007
1	Design, Work Plans, Permits:	13	18	2/1/2008
2	Subsurface Installation:	5	23	3/7/2008
3	Equipment Mobilization:	2	25	3/21/2008
4	SPH Construction and Setup:	7	32	5/9/2008
5	SVE Construction and Setup:	9	41	7/11/2008
6	Start-Up Operations:	3	44	8/1/2008
7	SPH, DVE and SVE Operation:	26	70	1/30/2009
8	Demobilization and Final Report:	3	73	2/20/2009

Cost Assumptions

Electricity	@ $0.07 per kW-hr	
Granular Activated Carbon	@ $6.90 per pound	
Condensate Water Disposal	@ $0.05 per gallon	
Drilling Waste Disposal	@ $500 per ton	(via spread and heat)
Electrode Drilling Installation	@ $45 per foot	
Vent Drilling Installation	@ $38 per foot	
Monitoring Well Installation	@ $23 per foot	

There is a source of potable water on site
Operations proceed with no delay outside of CESs control
Well abandonment by filling with grout is acceptable
Proposed schedule assumes regulatory permit approval time of 3 weeks.
Pre-existing plastic (PVC) monitoring wells have been removed or grouted in place.
Telephone service can be installed at site

Budgetary Project Cost Estimate

Estimated Total Project Cost	**$3,648,441**
Estimated CES Costs	$1,989,131
Estimated Costs by Others	$1,659,310

Breakdown of Estimated CES Budget

Lab Testing, Modeling, and Site Evaluation:	$13,129	0%
Design, Work Plans, Permits:	$99,339	3%
Subsurface Installation:	$379,762	10%
Equipment Construction & Mobilization:	$121,937	3%
SPH Field Construction and Setup:	$271,475	7%
SVE Construction and Setup:	$182,955	5%
Start-Up Operations:	$84,114	2%
SPH Equipment Lease & Operational Support:	$748,556	21%
Demobilization and Final Report:	$87,863	2%
Total Budgetary Estimate for CES Service:	**$1,989,131**	55%
Service Cost per Additional Week of Operation:	**$28,020**	

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Service Options Included in CES Budget

Number of Confirmatory Soil Borings:	0	
Number of Confirmatory Soil Samples:	0	
Site Evaluation Test?	yes	
Lab Electrical Test?	yes	
Lab Corrosion Tests?	no	Not required
Laboratory Bench Tests?	no	Not required
Contaminant Degradation Tests?	no	Not required
Numerical Modeling?	no	Not required
Air Permit?	no	Client to provide
Sewer Discharge Permit?	no	Client to provide
Building Permit?	no	Client to provide
Well Logs and Report?	no	Client to provide
Soil Analyses?	no	Client to provide
Vapor Analyses?	no	Client to provide
Water Analyses?	no	Client to provide
Locator Survey?	no	Client to provide
Forklift Rental?	no	Client to provide
Security/Exclusion Zone Fence?	no	Client to provide
Sound Wall for Blower?	yes	
Electrode Abandonment?	no	Client to provide
Post-Remediation Site Restoration?	no	Client to provide

Budgetary Estimate for Services not Included in CES Price

Electrical Utility Connection:	$30,000	1%
Electrical Use:	$672,431	18%
Water, Telephone, DSL Connections:	$0	0%
Drill Cuttings, Water, and NAPL Disposal:	$401,240	11%
Catox Rental, Testing and Propane Use:	$122,360	3%
Diesel Fuel and Generator:	$0	0%
Vapor Extraction Unit (Blower):	$0	0%
Utility Step-Down Transformer Rental:	$20,445	1%
Miscellaneous Rental:	$16,250	0%
Soil, Water, Vapor Sampling & Analyses:	$34,360	1%
Well Logs, Geologist Supervision:	$0	0%
Subcontract Drilling Service:	$180,430	5%
Trenching & Concrete Cutting Service:	$15,170	0%
Construction Clearing, Grading, Restoration Services:	$5,150	0%
Locator Survey:	$880	0%
Crane Service :	$1,875	0%
Electrode & Well Abandonment:	$39,688	1%
Below Grade Materials & Well Vaults:	$0	0%
Extraction System Manifold:	$0	0%
Exclusion Zone & Security Fence & Ground Mat:	$20,125	1%
Site Cap Materials:	$98,920	3%
Electrode Power Cables and Drip Tubes:	$0	0%
Thermocouples (placed in Thermowells):	$0	0%
Other Work Performed by Client:	-$10	0%
Services Typically Required but Not Included:	**$1,659,310**	45%

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Appendix B

TABLE B-1
Chemical-Specific ARARs for Groundwater
Site 89 MCB Camp Lejeune

Contaminant of Concern	Federal MCL	NCWQS
cis-1,2-Dichloroethene	70 μg/L	70 μg/L
trans-1,2-Dichloroethene	100 μg/L	70 μg/L
1,1,2,2 Tetrachloroethane	N/A	0.17 mg/L (interim)
Trichloroethene	5 μg/L	2.8 μg/L
Vinyl Chloride	2 μg/L	0.015 μg/L

Notes: NCWQS – North Carolina Water Quality Standards for Groundwater (2L standard)
MCL – Safe Drinking Water Act Maximum Contaminant Level
μg/L – micrograms per liter

TABLE B-2
Potential Action-Specific ARARs
Site 89 MCB Camp Lejeune

Standard	Action	General Citation
RCRA	Capping	40 CFR 264
	Closure	40 CFR 264, 244
	Container Storage	40 CFR 264, 268
	New Landfill	40 CFR 264
	New Surface Impoundment	40 CFR 264
	Dike Stabilization	40 CFR 264
	Excavation, Groundwater Diversion	40 CFR 264, 268
RCRA	Incineration	40 CFR 264, 761
	Land Treatment	40 CFR 264
	Land Disposal	40 CFR 264, 268
	Slurry Wall	40 CFR 264, 268
	Tank Storage	40 CFR 264, 268
	Treatment	40 CFR 264, 265, 268; 42 USC 6924; 51 FR 40641; 52 FR 25760
	Waste Pile	40 CFR 264, 268
CWA	Discharge to Water of United States	40 CFR 122, 125, 136
	Direct Discharge to Ocean	40 CFR 125
	Discharge to POTW	40 CFR 403, 270
	Dredge / Fill	40 CFR 264; 33 CFR 320-330; 33 USC 403
CAA (NAAQS)	Discharge to Air	40 CFR 50
SDWA	Underground Injection Control	40 CFR 144, 146, 147, 268
TSCA	PCB Regulations	40 CFR 761
DOT	DOT Rules for Transportation	49 CFR 107
NC Groundwater Corrective Action	Regulations for cleanup of contaminated groundwater.	15A NCAC 2L .0106
NC Well Construction Standards	Construction and abandonment requirements for water wells.	15A NCAC 2C .0100
NC Injection Well Construction Standards	Construction requirements for injection wells.	15A NCAC 2C .0200
NC Water Quality Discharge Requirements	Waste water requirements for discharges and infiltration galleries.	15A NCAC 2H .0100 & .0200
NC Sedimentation Control Rules	Requirements for storm water management and erosion control	15A NCAC 4B
NC Hazardous Waste	Design and treatment requirements	15A NCAC 13A

TABLE B-2
Potential Action-Specific ARARs
Site 89 MCB Camp Lejeune

Standard	Action	General Citation
Management Rules	for hazardous waste	
NC Solid Waste Management Rules	Design and monitoring requirements for solid waste disposal sites	15A NCAC 13B
NC Air Pollution Control Requirements	Regulates air quality and establishes emissions standards.	15A NCAC 2D, 2H .0600, 2Q

Notes:

RCRA - Resource Conservation Recovery Act
CWA - Clean Water Act
CAA - Clean Air Act
NAAQS - National Ambient Air Quality Standards
SDWA - Safe Drinking Water Act
DOT - Department of Transportation
CFR - Code of Federal Regulations
USC - United States Code
FR - Federal Register
NCAC - North Carolina Administrative Code

TABLE B-3
Potential Location-Specific ARARs
Site 89 MCB Camp Lejeune

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
National Historic Preservation Act of 1966 – requires action to take into account effects on properties included in or eligible for the National Register of Historic Places and to minimize harm to National Historic Landmarks.	16 USC 470; 40 CFR 6.301(b); and 36 CFR 800	No known historic properties are within or near Site 89, therefore, this act will not be considered an ARAR.
Archeological and Historic Preservation Act – establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain.	16 USC 469; 40 CFR 6.301 (c)	No known historical or archeological data is known to be present at the sites, therefore, this act will not be considered an ARAR.
Historic Sites, Buildings and Antiquities Act – requires action to avoid undesirable impacts on landmarks on the National Registry of Natural Landmarks.	16 USC 461467; 40 CFR 6.301 (a)	No known historic sites, buildings or antiquities are within or near Site 89, therefore, this act will not be considered as an ARAR.
Fish and Wildlife Coordination Act – requires action to protect fish and wildlife from actions modifying streams or areas affecting streams.	16 USC 661-666	Edwards Creek is located near and within the operable unit boundaries. If remedial actions are implemented that modify this creek, this will be an applicable ARAR.
Federal Endangered Species Act – requires action to avoid jeopardizing the continued existence of listed endangered species or modification of their habitat.	16 USC 1531; 50 CFR 200; and 50 CFR 402	Many protected species have been sited near and on MCB Camp Lejeune such as the American alligator, the Bachmans sparrow, the Black skimmer, the Green turtle, the Loggerhead turtle, the piping plover, the Red-cockaded woodpecker, and the rough-leaf loosestrife (LeBlond, 1991), (Fussell, 1991). Therefore, this will be considered an ARAR.
North Carolina Endangered Species Act – per the North Carolina Wildlife Resources Commission. Similar to the Federal Endangered Species Act, but also includes State special concern species, State significantly rare species, and the State watch list.	GS 113-331 to 113-337	Since the American alligator has been sighted within MCB Camp Lejeune, this will be considered an ARAR.
Rivers and Harbors Act of 1899 (Section 10 Permit) – requires permit for structures or work in or affecting navigable waters.	33 USC 403	No remedial actions will affect the navigable waters of the New River. Therefore, this act will not be considered an ARAR.
Executive Order 11990 on Protection of Wetlands – establishes special requirements for federal agencies to avoid the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.	Executive Order Number 11990; and 40 CFR 6	Based on a review of Wetland Inventory Maps, Edwards Creek has areas of wetlands. Therefore, this will be an applicable ARAR.

TABLE B-3
Potential Location-Specific ARARs
Site 89 MCB Camp Lejeune

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
Executive Order 11988 on Floodplain Management – establishes special requirements for federal agencies to evaluate the adverse impacts associated with direct and indirect development of a floodplain.	Executive Order Number 11988; and 40 CFR 6	Based on the Federal Emergency Management Agency's Flood Insurance Rate Map for Onslow County, Site 89 is primarily within a minimal flooding zone (outside the 500-year floodplain). However, the immediate areas around Edwards Creek are within the 100-year floodplain (FEMA, 1987). Therefore, this may be an ARAR for the operable unit.
Wilderness Act – requires that federally owned wilderness areas are not impacted. Establishes nondegradation, maximum restoration, and protection of wilderness areas as primary management principles.	16 USC 1131; and 50 CFR 35	No known Federally-owned wilderness areas are located near the operable unit, therefore, this act will not be considered an ARAR.
National Wildlife Refuge System – restricts activities within a National Wildlife Refuge.	16 USC 668, and 50 CFR 27	No known National Wildlife Refuge areas are located near the operable unit, therefore, this will not be considered an ARAR.
Scenic Rivers Act – requires action to avoid adverse effects on designated wild or scenic rivers.	16 USC 1271; and 40 CFR 6.302(e)	No known wild or scenic rivers are located near the operable unit, therefore, this act will not be considered an ARAR.
Coastal Zone Management Act – requires activities affecting land or water uses in a coastal zone to certify noninterference with coastal zone management.	16 USC 1451	No activities at the site will affect land or water uses in a coastal zone, therefore, this act will not be considered an ARAR.
Clean Water Act (Section 404) – prohibits discharge of dredged or fill material into wetlands without a permit.	33 USC 404	No actions to discharge dredged or fill material into wetlands will be considered for the operable unit, therefore, this act will not be considered an ARAR.
RCRA Location Requirements – limitations on where on-site storage, treatment, or disposal of RCRA hazardous waste may occur.	40 CFR 264.18	These requirements may be applicable if the remedial actions for the operable unit include the on-site storage, treatment, or disposal of RCRA hazardous waste. Therefore, these requirements may be an applicable ARAR for the operable unit.
NC Hazardous Waste Management Rules	15A NCAC 13A	Location requirements and land disposal restrictions for hazardous waste excavated, stored, and/or treated onsite.
NC Solid Waste Management Rules	15A NCAC 13B .1600	Siting requirements for solid waste landfill facilities
NC Recordation of Inactive Hazardous Substance or Waste Disposal Sites	NCGS 130A-310.8	State requirement for recordation of inactive hazardous waste sites
NC Coastal Management	15A NCAC 7H	Guidelines for areas of environmental concern.

Notes:
USC - United States Code
CFR - Code of Federal Regulations
GS - General Statute

Appendix C

COST ESTIMATE FOR SOURCE AREA TREATMENT: EXCAVATION

SITE 89, Camp Lejeune

Assumptions:

Vertical Extent of Excavation = 25' bgs

Total Volume to be Excavated = 35,000 CY

CAPITAL AND OPERATIONAL COSTS					
Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Subcontractor					
Mobilization	1	EA	$20,000	$20,000	Engineer's Estimate
Site Preparation/Site Setup	1	EA	$10,000	$10,000	Engineer's Estimate
Survey	1	LS	$16,000	$16,000	Engineer's Estimate
Utility Location and Abandonment	1	LS	$8,000	$8,000	Engineer's Estimate
Design, Work Plans, HASP, Permits	1	LS	$5,000	$5,000	Engineer's Estimate
Sheetpile: rental, drive, extract and salvage	94000	SF	$24	$2,256,000	Engineer's Estimate
Dewatering of excavation	1	LS	$59,000	$59,000	Engineer's Estimate
Water Treatment On-site	180000	GAL	$0.10	$18,000	Engineer's Estimate
Excavate and load soil	35000	CY	$8	$280,000	Engineer's Estimate
Transportation and disposal of hazardous material (1.5 tons/CY)*	52500	Tons	$340	$17,850,000	Engineer's Estimate
Backfill with No. 57 stone (35,000 yd3 @ 2350 lb/yd3)	41125	Tons	$20	$822,500	Engineer's Estimate
Seed and landscape	35,000	SF	$1	$35,000	Engineer's Estimate
Air monitoring	1	LS	$15,000	$15,000	Engineer's Estimate
Confirmation sampling & analysis	1	EA	$40,000	$40,000	Engineer's Estimate
Level B PPE premium	60	days	$1,000	$60,000	Engineer's Estimate
Subtotal *Subcontractor*				$21,474,500	
Groundwater Monitoring					
Sample Labor, Travel, Perdiem	7	event	$10,000	$70,000	9 existing MWs + 7 rounds at 10 new MWs
Fixed lab analysis	133	sample	$128	$17,024	Lab BOA rates
Sampling Supplies	7	event	$300	$2,100	
GW Sampling Equipment Rental	7	event	$600	$4,200	
Subtotal *Groundwater Sampling*				$93,324	
Professional Services					
Project Management			10%	$2,156,782	
Construction Management and Procurement			15%	$3,235,174	
Engineering Support			5%	$1,078,391	
Overhead			10%	$2,156,782	
Profit			5%	$1,078,391	
G&A and Fee			11%	$2,372,461	
Contingency			20%	$4,313,565	
Subtotal *Professional Services*				$16,391,546	
TOTAL COST				**$37,959,370**	

Costs presented herein are for comparison purposes only and not intended to function as a guarantee of fixed costs

* Assumes off-site hazardous soil disposal at Emelle

COST ESTIMATE FOR SOURCE AREA TREATMENT: ELECTRICAL RESISTANCE HEATING (ERH)

SITE 89, Camp Lejeune

Assumptions:

Treatment Volume = 35,000 CY
Controlling Contaminant = TCE
Vertical Interval of Heating = 1 to 25' bgs
Number of Vertical Heating Intervals = 2
Number of Electrodes = 119
Distance Between Electrodes = 20'
Number of Monitoring Wells = 26
Number of SVE Wells = 119 (Co-Located with Electrodes)
Total Steam/Condensate Produced, to be treated on-site = 6,500,000 gallons
Total Heating Time = 6 months (previous pilot test was 4 months)

CAPITAL AND OPERATIONAL COSTS

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Subcontractor					
Site Preparation (clearing and grubbing, placement of geotextile and gravel in low areas, erosion controls)	1	LS	$20,000	$20,000	Engineer's Estimate
Electrical Power Drop (460 V/3ph/2900A)	1	LS	$45,000	$45,000	Engineer's Estimate
Survey	1	LS	$16,000	$16,000	Engineer's Estimate
Utility Location and Abandonment	1	LS	$8,000	$8,000	Engineer's Estimate
Lab Testing, Modeling, Site Evaluation	1	LS	$13,129	$13,129	Written Estimate from CES
Design, Work Plans, Permits	1	LS	$99,339	$99,339	Written Estimate from CES
Mobilization	1	LS	$121,937	$121,937	Written Estimate from CES
Subsurface Installation, Including Well and Electrode Drilling/Installatior	1	LS	$379,762	$379,762	Written Estimate from CES
SPH Construction and Set-Up	1	LS	$271,475	$271,475	Written Estimate from CES
SVE Construction and Set-Up	1	LS	$182,955	$182,955	Written Estimate from CES
Start-Up Operations	1	LS	$84,114	$84,114	Written Estimate from CES
SPH and SVE Operations for Six Months	1	LS	$748,556	$748,556	Written Estimate from CES
Therm-ox Rental/Operation for Six Months	1	LS	$122,360	$122,360	Written Estimate from CES
Electrical Usage for Six Months	1	LS	$672,431	$672,431	Written Estimate from CES, based on $0.072/kW-hr
Water Treatment On-Site	6500000	GAL	$0.10	$650,000	Written Estimate from CES, based on previous pilot test
Soil, Water, and Vapor Analysis	1	LS	$45,450	$45,450	Engineer's Estimate
Drill Cuttings Disposal	1	LS	$401,240	$401,240	Written Estimate from CES
Rental Equipment and Misc Fees	1	LS	$37,000	$37,000	Written Estimate from CES
Demobilization and Final Report	1	LS	$87,863	$87,863	Written Estimate from CES
Level B PPE Premium	60	days	$1,000	$60,000	Engineer's Estimate
Electrode Abandonment and Site Restoration	1	LS	$46,000	$46,000	Engineer's Estimate
Subtotal *Subcontractor*				$4,112,611	
Groundwater Monitoring					
Sample Labor, Travel, Perdiem	7	event	$10,000	$70,000	9 existing MWs + 7 rounds at 10 new MWs
Fixed lab analysis	133	sample	$128	$17,024	Lab BOA rates
Sampling Supplies	7	event	$300	$2,100	
GW Sampling Equipment Rental	7	event	$600	$4,200	
Subtotal *Groundwater Sampling*				$93,324	

COST ESTIMATE FOR SOURCE AREA TREATMENT: ELECTRICAL RESISTANCE HEATING (ERH)

SITE 89, Camp Lejeune

Professional Services		
Project Management	10%	$420,594
Construction Management and Procurement	15%	$630,890
Engineering Support	5%	$210,297
Overhead	10%	$420,594
Profit	5%	$210,297
G&A and Fee	11%	$462,653
Contingency	20%	$841,187
Subtotal *Professional Services*		$3,196,511
TOTAL COST		**$7,402,446**

Costs presented herein are for comparison purposes only and not intended to function as a guarantee of fixed costs

COST ESTIMATE FOR SOURCE AREA TREATMENT: SOIL MIXING

SITE 89, Camp Lejeune

Assumptions:

Treatment Volume = 35,000 CY
Controlling Contaminant = PCA
Vertical Interval of Mixing = 5 to 25' bgs
Number of Mix Columns = 725
Auger Diameter = 8.5'
Mix design = 2% ZVI, 1% Bentonite (by weight)
Soil Density = 1.5 tons/yd3
Estimated Time to Complete = 80 days (incl mob/demob)

CAPITAL AND OPERATIONAL COSTS

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Subcontractor					
Subcontractor					
Laboratory Bench Scale Study	1	LS	$45,000	$45,000	Engineer's Estimate
Site Preparation (clearing and grubbing, placement of geotextile and gravel in low areas, erosion controls)	1	LS	$20,000	$20,000	Engineer's Estimate
Survey	1	LS	$16,000	$16,000	Engineer's Estimate
Utility Location and Abandonment	1	LS	$8,000	$8,000	Engineer's Estimate
Design, Work Plans, Permits, Final Report	1	LS	$8,000	$8,000	Written Estimate
Mobilization	1	LS	$50,000	$50,000	Written Estimate
Set-Up, and Decon	1	LS	$20,000	$20,000	Written Estimate
Excavation & Staging of Top 4-5 Feet of Soil for Mixing "Freeboard"	7037	CY	$7	$49,259	Engineer's Estimate
ZVI Purchase and Delivery	787	TON	$700	$550,900	Written Estimate
Soil Mixing	35000	CY	$36	$1,260,000	Written Estimate
Soil, Water, and Vapor Analysis	1	LS	$45,000	$45,000	Engineer's Estimate
Water Management System (dikes, drains, site grading)	1	LS	$45,000	$45,000	Engineer's Estimate
Water Treatment On Site	100000	gal	$0.10	$10,000	Written Estimate from CES, based on previous pilot test
Licensing Fees	35000	CY	$5	$175,000	CSU terms
Level B PPE Premium	60	days	$1,000	$60,000	Engineer's Estimate
Site Restoration	1	LS	$1,000	$10,000	Engineer's Estimate
Subtotal *Subcontractor*				$2,372,159	
Groundwater Monitoring					
Sample Labor, Travel, Perdiem	7	event	$20,000	$140,000	9 existing MWs + 7 rounds at 10 new MWs
Fixed lab analysis (VOCs, chlorides, and iron in gw)	133	sample	$128	$17,024	Lab BOA rates
Fixed lab analysis (VOCs in soil)	221	sample	$122	$26,962	Lab BOA rates
DPT (soil sampling)	7	event	$1,000	$7,000	
Sampling Supplies	7	event	$500	$3,500	
Soil / GW Sampling Equipment Rental	7	event	$1,000	$7,000	
Subtotal *Groundwater Sampling*				$201,486	

COST ESTIMATE FOR SOURCE AREA TREATMENT: SOIL MIXING

SITE 89, Camp Lejeune

Professional Services		
Project Management	10%	$257,365
Construction Management and Procurement	15%	$386,047
Engineering Support	5%	$128,682
Overhead	10%	$257,365
Profit	5%	$128,682
G&A and Fee	11%	$283,100.95
Contingency	20%	$514,729
Subtotal Professional Services		$1,955,970
TOTAL COST		**$4,529,615**

Costs presented herein are for comparison purposes only and not intended to function as a guarantee of fixed costs

* Assumes non-hazardous soil disposal at Base landfill

COST ESTIMATE FOR SOURCE AREA TREATMENT: IN SITU THERMAL DESORPTION (ISTD)

SITE 89, Camp Lejeune

Assumptions:

Treatment Volume = 35,000 CY
Controlling Contaminant = TCE
Vertical Interval of Heating = 1 to 25' bgs
Number of Heater Wells = 193
Distance Between Heaters = 15'
Number of Monitoring Borings = 35
Number of Horizontal SVE Wells = 11
Total Steam/Condensate Produced, to be treated on-site = 6,500,000 gallons
Total Heating Time = 6 months

CAPITAL AND OPERATIONAL COSTS

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Subcontractor					
Site Preparation (clearing and grubbing, placement of geotextile and gravel in low areas, erosion controls)	1	LS	$45,000	$45,000	Engineer's Estimate
Electrical Power Drop (460 V/3ph/2900A)	1	LS	$45,000	$45,000	Engineer's Estimate
Survey	1	LS	$16,000	$16,000	Engineer's Estimate
Utility Location and Abandonment	1	LS	$8,000	$8,000	Engineer's Estimate
Design, Work Plans, Permits	1	LS	$75,000	$75,000	Written Estimate from TerraTherm
Mobilization	1	LS	$81,000	$81,000	Written Estimate from TerraTherm
Subsurface Installation	1	LS	$616,000	$616,000	Written Estimate from TerraTherm
Surface Vapor Cover Installation	1	LS	$228,000	$228,000	Written Estimate from TerraTherm
Electrical Construction	1	LS	$118,000	$118,000	Written Estimate from TerraTherm
Mechanical Construction	1	LS	$140,000	$140,000	Written Estimate from TerraTherm
Vapor and Water Treatment System	1	LS	$266,000	$266,000	Written Estimate from TerraTherm
Comissioning	1	LS	$70,000	$70,000	Written Estimate from TerraTherm
Maintenance Hardware, etc.	1	LS	$137,000	$137,000	Written Estimate from TerraTherm
Operations Labor and Per Diem	1	LS	$157,000	$157,000	Written Estimate from TerraTherm
Electrical Usage	1	LS	$554,000	$554,000	Written Estimate from TerraTherm, based on $0.072/kW-hr
Sampling and Analysis (Process)	1	LS	$25,000	$25,000	Written Estimate from TerraTherm
Water Treatment On-Site	6500000	GAL	$0.10	$650,000	Written Estimate from CES, based on previous pilot test
Soil, Water, and Vapor Analysis	1	LS	$33,000	$33,000	Engineer's Estimate
Spent GAC Disposal and Misc Waste	1	LS	$25,000	$25,000	Written Estimate from TerraTherm
Drill Cuttings Disposal	1	LS	$115,000	$115,000	Written Estimate from TerraTherm
Rental Equipment and Misc Fees	1	LS	$25,000	$25,000	Written Estimate from TerraTherm
Demobilization and Final Report	1	LS	$72,000	$72,000	Written Estimate from TerraTherm
Travel, Office, and Engineering Support	1	LS	$390,000	$390,000	Written Estimate from TerraTherm
Licensing Fees	1	LS	$120,000	$120,000	Written Estimate from TerraTherm
Level B PPE Premium	60	days	$1,000	$60,000	Engineer's Estimate
Contingency and Indirect Cost	1	LS	$466,000	$466,000	Written Estimate from TerraTherm
Heater Well Abandonment and Site Restoration	1	LS	$46,000	$46,000	Engineer's Estimate
Subtotal *Subcontractor*				$4,583,000	

COST ESTIMATE FOR SOURCE AREA TREATMENT: IN SITU THERMAL DESORPTION (ISTD)

SITE 89, Camp Lejeune

Groundwater Monitoring				
Sample Labor, Travel, Perdiem	7 event	$10,000	$70,000	9 existing MWs + 7 rounds at 10 new MWs
Fixed lab analysis	133 sample	$128	$17,024	Lab BOA rates
Sampling Supplies	7 event	$300	$2,100	
GW Sampling Equipment Rental	7 event	$600	$4,200	
Subtotal *Groundwater Sampling*			$93,324	
Professional Services				
Project Management		10%	$467,632	
Construction Management and Procurement		15%	$701,449	
Engineering Support		5%	$233,816	
Overhead		10%	$467,632	
Profit		5%	$229,150	
G&A and Fee		11%	$514,396	
Contingency		20%	$935,265	
Subtotal *Professional Services*			$3,549,340	
TOTAL COST			**$8,225,664**	

Costs presented herein are for comparison purposes only and not intended to function as a guarantee of fixed costs

COST ESTIMATE FOR SOURCE AREA TREATMENT: AIR SPARGING

SITE 89, Camp Lejeune

Assumptions:

Installation of 73 Air Sparge Wells to 25 feet bgs
Installation of One Foot Thick Gravel Layer Over Graded Native Material and Horizontal SVE Wells With Gravel Zone
Sparge Manifold w/ Dual Claw Sparge Blowers, SVE Manifold w/ Single Centrifugal Blower; Catalytical Oxidizer rated for 600 cfm (first year only)
5 Years of O&M

CAPITAL COSTS

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Subcontractor Construction Services					
Mobilization	1	EA	$15,000	$15,000	Engineer's Estimate
Site Setup	1	LS	$15,000	$15,000	Engineer's Estimate
Survey	1	LS	$16,000	$16,000	Engineer's Estimate
Utility Location	1	LS	$8,000	$8,000	Engineer's Estimate
Complete Soil Borings and Pneumatic Fracturing	73	borings	$4,600	$335,800	Verbal Estimate - ARS Technologies/Pro-Sonic
Install Sparge Wells (Direct Bury, no manways)	73	wells	$1,350	$98,550	Engineer's Estimate
Subgrade Prep	38000	SF	$0.40	$15,200	Engineer's Estimate
HDPE Piping Materials, Trenching, and Installation	1,925	LF	$45.00	$86,625	Engineer's Estimate
Vapor Collection Layer (Materials - washed #57 rounded gravel -and Installation)	1400	CCY	$48.29	$67,606	Engineer's Estimate
Geotextile and LLDPE Layer Installation	38000	SF	$1.3	$49,400	Engineer's Estimate
Cover Soil (30-40% Sandy Loam)	700	CCY	$19.08	$13,356	Engineer's Estimate
Drainage Ditches	1200	LF	$12.31	$14,772	Engineer's Estimate
Treatment Compound Construction, Concrete Pier Supports, Oxidizer Pad	1	LS	$40,000	$40,000	Engineer's Estimate
Demobilization	1	LS	$6,000	$6,000	Engineer's Estimate
Electrical Power Drop, 460 V/3 ph/200 A Service, Transformers, Poles	1	LS	$34,000	$34,000	Engineer's Estimate
Natural Gas Service, Installation of New 1400 cf/hr service	1	LS	$28,000	$28,000	Engineer's Estimate
Final Electrical Connections, Installation of Service Panel and Disconnect	1	LS	$14,000	$14,000	Engineer's Estimate
Disposal of Development Water	650	gal	$1.25	$813	Engineer's Estimate
Transport & Disposal of Soil Cuttings	1	LS	$6,300	$6,300	(3) 20CY rolloffs with transport & disposal
Seed and landscape	38000	SF	$1	$38,000	Engineer's Estimate
Level B PPE premium	60	days	$1,000	$60,000	Engineer's Estimate
Subtotal *Subcontractor Construction Services*				*$962,422*	
Groundwater Monitoring					
Sample Labor, Travel, Perdiem	7	event	$10,000	$70,000	9 existing MWs + 7 rounds at 10 new MWs
Fixed lab analysis	133	sample	$128	$17,024	Lab BOA rates
Sampling Supplies	7	event	$300	$2,100	
GW Sampling Equipment Rental	7	event	$600	$4,200	
Subtotal *Groundwater Sampling*				*$93,324*	
Professional Services					
Project Management			10%	$105,575	
Construction Management and Procurement			15%	$158,362	
Overhead			10%	$105,575	
Profit			5%	$52,787	
Remedial Design			5%	$52,787	
G&A and Fee			11%	$116,132	
Contingency			20%	$211,149	
Subtotal *Professional Services*				*$802,367*	

COST ESTIMATE FOR SOURCE AREA TREATMENT: AIR SPARGING

SITE 89, Camp Lejeune

REMEDIATION EQUIPMENT - SUBCONTRACTOR				
SVE (Gravel Zone), Gardner Denver Turbotron, 400 gal Moisture Seperator,	1 skid	$24,500	$24,500	Verbal Estimate - Onion Equipment
Pressure Tranducer, Gauges, Mass Flow Meter, Transfer Pump, etc.				
Interior Piping/Manifolding for Above (4" flanged connections)	1 LS	$23,600	$23,600	Verbal Estimate - Onion Equipment
6, 4" Motorized Ball Valves, Gauges, 11 Manual Diaphragm Valves, etc				
Air Sparging Busch "Mink" Claw Blowers (2 per skid), Heat Exchanger,	1 skid	$35,500	$35,500	Verbal Estimate - Onion Equipment
Air Receiver, Pressure and Temperature Transmitters, Mass Flow Meter, etc				
Interior Piping/Manifolding for Above (3" flanged connections)	1 LS	$43,600	$43,600	Verbal Estimate - Onion Equipment
7, 3" Motorized Ball Valves, Gauges, 73 Manual Diaphragm Valves, etc				
Pre-Fab Steel Frame Building, R-12, HVAC, Lights, Office Space, 8 x 36'	1 Bldg	$25,600	$25,600	Verbal Estimate - Onion Equipment
CATOX Unit (Including Scrubber for Chlorinated Solvents and All Appurtenances)	1 EA	$175,000	$175,000	Verbal Estimate - Onion Equipment
Vapor Phase Carbon Beds (Epoxy Coated Steel, 2000#)	2 EA	$7,500	$15,000	Verbal Estimate - Onion Equipment
Exterior Canopy for Blowers	1 EA	$24,000	$24,000	Engineer's Estimate
System Control Panels	1 EA	$12,200	$12,200	Verbal Estimate - Onion Equipment
Drawings, O&M Manual	1 LS	$3,000	$3,000	Verbal Estimate - Onion Equipment
Shipping to Site	1 LS	$12,500	$12,500	Verbal Estimate - Onion Equipment
Start-Up Assistance and Expenses	1 LS	$6,250	$6,250	Verbal Estimate - Onion Equipment
Subtotal			$400,750	
Profit and G&A	11%		$38,792	
Fee	8%		$28,212	
Subtotal *Remediation Equipment*			*$467,754*	
TOTAL CAPITAL COST			**$2,325,866**	

COST ESTIMATE FOR SOURCE AREA TREATMENT: AIR SPARGING

SITE 89, Camp Lejeune

YEAR 1 OPERATIONS AND MAINTENANCE					
Description	Qty	Unit	Unit Cost	Cost	Comments
Vapor Sampling					
Treatment System, Weekly for One Month, Monthly Thereafter SUMMA cannisters	30	sample	$450	$13,500	2 Samples Per Round
Quarterly SVE "Group" Sampling (15 "Groups")	60	sample	$450	$27,000	
Subtotal *Vapor Sampling*				$40,500	
Reporting					
Reporting Labor (quarterly reports)	4	rpts	$6,200	$24,800	
Subtotal *Reporting*				$24,800	
System Startup					
Labor	2	weeks	$7,200	$14,400	
Startup Equipment Rental	2	weeks	$450	$900	
Travel and Perdiem	2	weeks	$5,000	$10,000	
Subtotal *System Startup*				$25,300	
Routine System O&M					
Monthly O&M Labor + Travel (Subcontractor)	12	events	$1,250	$15,000	
Vapor Sample Analysis	12	events	$625	$7,500	
Quarterly "Heavy" Maintenance	4	events	$1,800	$7,200	
Travel and PerDiem	4	events	$500	$2,000	
O&M Supplies	1	LS	$2,000	$2,000	
Subtotal *Routine System O&M*				$33,700	
Consumeables					
Electrical usage (120.hp total motor peak rating)	522096	kw-hr	$0.075	$39,157	
Natural Gas Usage (assuming 665 scfh per oxidizer)	75730	Ccf	$0.88	$66,642	
Water Usage (scrubber water for cat-ox units)	2745	100 ft3	$1.20	$3,294	
Sewerage Fees (Scrubber)	1680	1000 ga	$0.59	$991	
Sewerage Fees (purged groundwater)	275	1000 ga	$0.59	$162	Assume 0.2 gpm
NaOH required to Neutralize HCL (Scrubber)	27331	gal	$0.31	$8,473	Based on written estimate of NaOH usage by Global
Subtotal *Consumeables*				$118,720	
Subtotal				$243,020	
Project Management			10%	$24,302	
Engineering Support			5%	$12,151	
Contingency			20%	$48,604	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST				**$328,077**	

COST ESTIMATE FOR SOURCE AREA TREATMENT: AIR SPARGING

SITE 89, Camp Lejeune

SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE					
Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Vapor Sampling					
Treatment System, Quarterly, 2 SUMMA cannisters per event	8	sample	$450	$3,600	
Quarterly SVE "Group" Sampling (15 "Groups")	60	sample	$450	$27,000	
Subtotal *Vapor Sampling*				$30,600	
Reporting (Annual Report)					
Reporting Labor	1	rpt	$8,600	$8,600	
Subtotal *Reporting*				$8,600	
Routine System O&M					
Monthly O&M Labor + Travel (Subcontractor)	12	events	$1,250	$15,000	
Quarterly "Heavy" Maintenance	4	events	$1,800	$7,200	
Travel and PerDiem	4	events	$500	$2,000	
O&M Supplies	1	LS	$2,000	$2,000	
Subtotal *Routine System O&M*				$26,200	
Consumeables					
Electrical usage (120.hp total motor peak rating for both compounds)	522096	kw-hr	$0.075	$39,157	
Vapor Phase Carbon	18000	lb	$1.45	$26,100	Verbal quote from Carbonair (virgin), including
Subtotal *Consumeables*				$65,257	
Subtotal				$130,657	
Project Management			10%	$13,066	
Engineering Support			5%	$6,533	
Contingency			20%	$26,131	
SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE COST				**$176,387**	

PRESENT WORTH ANALYSIS		
Number of Years of Operation =	5 years	
Effective Interest Rate =	3.2%	
		Present Worth
Capital Cost =	$2,325,866	$2,325,866
Year1 O&M Cost =	$328,077	$317,904
Subsequent Years O&M Cost =	$176,387	$632,292
TOTAL PRESENT WORTH COST		**$3,276,061**

* This estimate is not intended to function as guarantee of fixed costs for field implementation.