04.08 / 01/16/97 - 02354

DRAFT

FEASIBILITY STUDY

OPERABLE UNIT NO. 10
SITE 35 - CAMP GEIGER AREA FUEL FARM

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0232

JANUARY 16, 1997

Prepared For:

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

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/kg	Microgram per Kilogram
µg/L	Microgram per Liter
ACFM	actual cubic feet per minute
ARARs	Applicable or Relevant and Appropriate Requirements
AST	Aboveground Storage Tank
ATEC	ATEC Associates, Inc.
ATM	atmospheres
Baker	Baker Environmental, Inc.
bgs	Below Ground Surface
BRA	Baseline Risk Assessment
BTEX	Benzene, Toluene, Ethylbenzene, and Total Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	Contaminants of Concern
COPC	Contaminant of Potential Concern
CSA	Comprehensive Site Assessment
CSF	Carcinogenic Slope Factor
CWA	Clean Water Act
DCE	Dichloroethene
DOT	Department of Transportation
DRMO	Defense Reauthorization and Marketing Office
EMD	Environmental Management Division
EPA	Environmental Protection Agency (U.S.)
ESE	Environmental Science and Engineering, Inc.
ESD	Explanation of Significant Differences
FS	Feasibility Study
FFS	Focused Feasibilty Study
gpm	Gallons per Minute
GAL	Granular Activated Carbon
HHRA	Heiman Health Risk Assessment
HI	Hazard Index
IAS	In-situ Air Sparging
ICR	Incremental Cancer Risk
IDW	Investigative Derived Wastes
Kg	Kilogram

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LAW	Law Engineering
LUST	Leaking Underground Storage Tank
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
msl	Mean Sea Level
MTBE	Methyl-tertiary-butyl-ether
MW	Monitoring Well
NAOC	Northern Area of Concern
NCAC	North Carolina Administrative Code
NC DEHNR	North Carolina Department of Environment, Health and Natural Resources
NC DOT	North Carolina Department of Transportation
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NCWQS	North Carolina Water Quality Standards
NEHC	Navy Environmental Health Center
NPL	National Priorities List
NUS	NUS Corporation
O&G	Oil and Grease
O&M	Operations and Maintenance
OU	Operable Unit
OHM	OHM Corporation
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
PRAP	Proposed Remedial Action Plan
PVC	Polyvinyl Chloride
PW	Pumping Well
QI	Quotient Index
RA	Risk Assessment
RAA	Remedial Action Alternative
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RI	Remedial Investigation
RL	Remediation Levels
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SAOC	Southern Area of Concern
SAP	Sampling and Analysis Plan

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

SDWA	Safe Drinking Water Act
SCFM	Standard Cubic Feet Per Minute
SGI	Supplemental Groundwater Investigation
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TBC	To Be Considered
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TEX	Toluene, Ethylene and Xylene
TPH	Total Petroleum Hydrocarbons
TRC	Technical Review Committee
TW	Temporary Monitoring Well
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WAR	Water and Air Research, Inc.
WQSV	Water Quality Screening Values
Yr	Year

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the Draft Feasibility Study (FS) for groundwater at Operable Unit (OU) No. 10, Site 35 - Camp Geiger Fuel Farm, located at Marine Corp Base (MCB) Camp Lejeune, North Carolina. It has been prepared by Baker Environmental, Inc. (Baker) and submitted for review to the United States Environmental Protection Agency (USEPA) Region IV; the North Carolina Department of Environment, Health and Natural Resources (NC DEHNR); MCB, Camp Lejeune Environmental Management Department (EMD); the Navy Environmental Health Center (NEHC); and the Agency for Toxic Substances and Disease Registry; and the Naval Facilities Engineering Command, Atlantic Division (LANTDIV).

The focus of this FS is the groundwater contamination in the surficial aquifer south of the proposed U.S. Route 17 Bypass right-of way. This FS is based on data collected at Site 35 during the Supplemental Groundwater Investigation (SGI) conducted during the spring and summer of 1996, and the Remedial Investigation (RI) that was conducted in the spring of 1994. Surficial groundwater contamination north of the proposed U.S. Route 17 Bypass right-of-way is addressed in the Record of Decision (ROD) for Surficial Groundwater for a Portion of Operable Unit 10, Site 35 - Camp Geiger Area Fuel Farm.

Purpose of the FS

The purpose of the FS is to identify and evaluate various remedial actions for surficial groundwater contamination associated with previous activities at Site 35, that are protective of human health and the environment, and will attain federal and state requirements. In general, the FS process under CERCLA assures that the appropriate remedial alternatives are developed and evaluated, such that pertinent information concerning the remedial action options can be presented and an appropriate remedy selected. The FS involves two major phases: development and screening of remedial action alternatives, and detailed analysis of remedial action alternatives.

Site Description and Location

Camp Geiger is located at the extreme northwest corner of Camp Lejeune and contains a mixture of troop housing, personnel support and training facilities. The main entrance is located along U.S. Route 17 approximately 3.5 miles southeast of the City of Jacksonville, North Carolina. Site 35 - the Camp Geiger Area Fuel Farm - refers to a former fuel storage and dispensing facility that was located just north of the intersection of Fourth and "G" Streets. The Fuel Farm consisted primarily of five, 15,000-gallon aboveground storage tanks (ASTs), a pump house, a fuel loading/unloading pad, an oil/water separator, and a distribution island. The facility actively served Camp Geiger and the New River Air Station from 1945 to 1995, when it was demolished to make way for the proposed U.S. Route 17 Bypass. This Bypass will be a six-lane divided highway that will be constructed by the North Carolina Department of Transportation (NCDOT).

Site History

Construction of Camp Geiger was completed in 1945, four years after construction of MCB, Camp Lejeune was initiated. Originally, the Fuel Farm ASTs were used for the storage of No. 6 fuel oil. An underground distribution line (now abandoned) extended from the ASTs to the former Mess Hall Heating

Plant, located adjacent to "D" Street, between Third and Fourth Streets. The underground line dispensed No. 6 fuel oil to a UST which fueled the Mess Hall boiler. The Mess Hall, located across "D" Street to the west, is believed to have been demolished along with its Heating Plant in the 1960s. At some unrecorded date, the facility was converted for storage of other petroleum products, including unleaded gasoline, diesel fuel, and kerosene.

From the date of this conversion until the facility was decommissioned in the spring of 1995, the ASTs at Site 35 were used to dispense gasoline, diesel and kerosene to government vehicles. The ASTs were also used to supply underground storage tanks (USTs) in use at Camp Geiger and the nearby New River Marine Corps Air Station.

During the lifetime of the facility, several releases of product occurred. Reports of a release from an underground distribution line near one of the ASTs date back to 1957-58. Routinely, the ASTs at Site 35 supplied fuel to an adjacent dispensing pump that was supplied by an underground line. A leak in an underground line at the station was reportedly responsible for the loss of roughly 30 gallons per day of gasoline over an unspecified period. The leaking line was subsequently sealed and replaced.

In April 1990, an undetermined amount of fuel was discovered by Camp Geiger personnel along two unnamed drainage channels north of the Fuel Farm. Apparently, the source of the fuel, believed to be diesel or jet fuel, was an unauthorized discharge from a tanker truck that was never identified.

The Fuel Farm was decommissioned and demolished during the spring of 1995. The ASTs were emptied, cleaned, dismantled, and removed along with all concrete foundations, slabs on grade, berms and associated underground piping. The Fuel Farm was demolished to make way for the U.S. Highway 17 Bypass, a six lane divided highway, proposed by the NCDOT.

In addition to the Fuel Farm dismantling, soil remediation activities were executed between the spring of 1995 and the spring of 1996 along the highway right-of-way as per an Interim Record of Decision executed on September 15, 1994.

Previous Investigations

Previous investigations/studies that have been conducted at the site include: Initial Assessment Study of Marine Corps Base, Camp Lejeune, North Carolina; Final Site Summary Report, MCB Camp Lejeune; Draft Field Investigation/Focused Feasibility Study, Camp Geiger Fuel Spill Site; Underground Fuel Investigation and Comprehensive Site Assessment; the Addendum Report of Underground Fuel Investigation and Comprehensive Site Assessment; the Interim Remedial Action Remedial Investigation/Feasibility Study for Soil; Remedial Investigation Report, Operable Unit No. 10, Site -35 Camp Geiger Area Fuel Farm; Interim Feasibility Study Operable Unit No. 10, Site -35 - Camp Geiger Area Fuel Farm; Supplemental Groundwater Investigation Report; and IAS Treatability Study Report.

Two of these investigations/studies have lead to the signing of interim RODs. The Interim Remedial Action Remedial Investigation/Feasibility Study for Soil The Interim Remedial Action RI/FS culminated with an Interim ROD, signed on September 15, 1994, for the remediation of contaminated soil along and adjacent to the proposed highway right-of-way at Site 35. The Interim Feasibility Study Operable Unit No. 10, Site -35 Camp Geiger Area Fuel Farm culminated with an Interim ROD on September 5, 1995, for the remediation of surficial groundwater in the vicinity of the Fuel Farm.

The Remedial Action Alternatives (RAAs) that were developed and analyzed for this FS were based on data that was collected during RI and SGI field investigation efforts. Research on treatment technologies performed as a part of the Interim FS was also used in this effort. In addition, the impacts of the remedy selected in the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 were also considered.

Remediation Levels

Remedial action objectives for Site 35 were developed to address fuel and solvent-related contamination in the surficial aquifer. These remedial action objectives are as follows:

- Mitigate the potential for direct exposure to the contaminated groundwater in the surficial aquifer.
- Minimize or prevent the horizontal and vertical migration of contaminated groundwater in the surficial aquifer.
- Restore the surficial aquifer to the remediation levels established for the groundwater contaminants of concern (COCs).

Fuel and solvent-related COCs and the associated remediation levels are as follows:

• Benzene	1 µg/L
• cis-1,2-Dichloroethene	70 µg/L
• Ethylbenzene	29 µg/L
• Methyl Tertiary Butyl Ether	200 µg/L
• trans-1,2-Dichloroethene	70 µg/L
• 1,2-Dichloroethene	70 µg/L
• Trichloroethene	2.8 µg/L
• Tetrachloroethene	0.7 µg/L
• 1,1,2,2-Tetrachloroethane	0.41 µg/L
• Xylenes	530 µg/L
• Vinyl chloride	0.015 µg/L

SUMMARY OF ALTERNATIVES

Six RAAs were developed and evaluated for the contaminated groundwater:

- RAA 1: No Action
- RAA 2: Site Controls and Long-Term Monitoring
- RAA 3: Natural Attenuation
- RAA 4: Extraction Wells and Ex Situ Treatment
- RAA 5: In Situ Passive Treatment/Slurry Cut-Off Wall
- RAA 6: In -Well Aeration and Off-Gas Carbon Adsorption

The following paragraphs describe these alternatives.

RAA 1: No Action

Capital Cost:	$0
Annual Operation and Maintenance (O&M) Cost:	$0
Net Present Worth (NPW):	$0
Years to Implement:	None

Under the no action RAA, no remedial actions will be performed to reduce the toxicity mobility, or volume of contaminants identified in groundwater or to monitor subsurface conditions at Site 35. The no action alternative is required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) to provide a baseline for comparison with other RAAs that provide a greater level of response.

Since contaminants will remain at the site under this RAA, the lead agency is required to review the effects of this alternative at least once every five years.

RAA 2: Site Controls and Long-Term Monitoring

Capital Cost:	$36,000
Annual O&M Cost (Years 1-5):	$112,700
Annual O&M Cost (Years 6-30):	$62,800
NPW:	$1,220,000
Years to Implement:	30 years of groundwater monitoring (quarterly for 5 years and semiannually for 25 years)

Under RAA 2, no engineered remedial actions will be applied at Site 35. Instead, site controls and a long-term groundwater monitoring program will be implemented.

Site Controls

Site controls, or aquifer-use restrictions, will mitigate the potential for exposure to contaminated groundwater. The aquifer-use restrictions will include the regulation of supply well construction and the identification of restricted use areas in the Base Master Plan. The regulation of new supply wells will be the responsibility of the Activity department that provides potable water or that is tasked with protecting public health. Such restrictions will prohibit the construction of new potable water supply wells in the vicinity (approximately a one-mile radius) of the contaminant plume at Site 35. Construction of supply wells for fire protection will be considered on a case by case basis. To identify restricted use areas at the Base, the Base Master Plan will include a long-term strategy for the development of groundwater resources. The Plan will clearly identify areas, such as Site 35, where the development of groundwater resources is prohibited.

Groundwater Monitoring

The purpose of the groundwater monitoring program is to track the contaminant plume's migration over time, identify any fluctuations in contaminant levels, and monitor the effectiveness of any other remedial actions that may be implemented at Site 35. The monitoring program will include 2 wells in the Castle Hayne aquifer, 16 wells in the lower portion of the surficial aquifer, and 14 wells in the upper portion of the surficial aquifer. The groundwater samples will be collected and analyzed for VOCs on a quarterly basis. If groundwater quality appears to be improving, the monitoring frequency may be reduced from quarterly to semiannual. For cost estimating purposes, 5 years of quarterly sampling was assumed, followed by 25 years of semiannual sampling.

RAA 3: Natural Attenuation

Capital Cost:	$290,000
Annual O&M Cost (Years 1-5):	$251,000
Annual O&M Cost (Years 6-30):	$142,000
NPW:	$2,470,000
Years to Implement:	30 years of groundwater monitoring (quarterly for 5 years and semiannually for 25 years)

RAA 3 involves natural attenuation, otherwise known as intrinsic bioremediation, of the contaminated groundwater. At Site 35, the daughter products of trichloroethene degradation reactions (e.g., dichloroethene and vinyl chloride) have been detected in the shallow aquifer. The existence of these daughter products provides strong evidence that the solvent contamination may be naturally biodegrading (i.e., naturally attenuating) at the site. Based on technical literature that strongly supports the natural attenuation of fuel contaminants in a variety of subsurface conditions, degradation of the fuel contamination is most likely occurring. As a result, natural attenuation appears to be a viable alternative for the contaminated groundwater at Site 35.

RAA 3 includes a treatability study, a long-term monitoring program, and fate and transport modeling updates, which are described below. Since contaminants will remain at the site under this RAA, the lead agency is required to review the effects of this alternative at least once every five years.

Treatability Study

The treatability study will be used to assess the ability of the naturally occurring subsurface processes at Site 35 to reduce the fuel and solvent contamination in toxicity, mobility, volume, and concentration. The treatability study will include the following:

- A laboratory microcosm study to determine if indigenous microbes are capable of degrading site contaminants, and the estimated rate of degradation.

- An initial round of soil and groundwater sampling to assess the impacts of natural attenuation at Site 35.

- Development of a baseline contaminant fate and transport model that takes into account the natural attenuation mechanism. This model will be used to predict contaminant plume reduction and changes in the chemical character of the plume.

Long-Term Groundwater Monitoring

Assuming the treatability study confirms that natural attenuation processes are occurring at Site 35, a long-term groundwater monitoring program will be implemented. This program will monitor contaminant levels and provide additional data to support contaminant fate and transport model updates. The samples will be collected on a quarterly basis. If groundwater quality appears to be improving, the monitoring frequency may be reduced from quarterly to semiannual. For cost estimating purposes, 5 years of quarterly sampling was assumed, followed by 25 years of semiannual sampling.

Fate and Transport Modeling Updates

Under RAA 3, annual updates of the contaminant fate and transport model will be performed. These updates will be used to verify the assumptions of the initial modeling effort and to provide a means for regularly re-evaluating the effectiveness of natural attenuation over time.

RAA 4: Extraction and Ex Situ Treatment

Capital Cost:	$1,268,000
Annual Monitoring O&M Cost (Years 1-5):	$113,000
Annual Monitoring O&M Cost (Years 6-30):	$63,000
Annual Treatment System O&M Cost (Years 1-30):	$47,000
NPW:	$3,760,000
Years to Implement:	30 years of groundwater monitoring (quarterly for 5 years and semiannually for 25 years), and 30 years of system O&M

RAA 4 is a conventional pump and treat alternative which includes the installation of seven extraction wells in the shallow aquifer and the construction of a 40 gallon per minute (gpm) treatment facility.

Four extraction wells will be located in a line (with overlapping radii of influence) along the eastern edge of the contaminant plume to serve as a downgradient barrier. The radii of influence of these wells are expected to be approximately 120 feet each, and the pumping rates are expected to be 5 to 10 gpm each. Three extraction wells will be installed in the "hot spot" area of the plume to actively treat the highest contaminant concentrations. The radii of influence of these wells are expected to be approximately 80 feet each, and the pumping rates are expected to be 2 gpm each. (RAA 4 requires a pump test so that a better estimate of the expected radii of influence and pumping rates can be made.) All extraction wells will be screened from the semiconfining unit which is located approximately 40 feet below ground surface, to the water table which is located approximately 6 to 10 feet below ground surface.

The 40 gpm treatment facility will consist of air stripping and carbon adsorption for VOC removal, and coagulation/flocculation, clarification/sedimentation, and filtration for metals removal. Once treated, the groundwater will be discharged to Brinson Creek via an adjacent storm drain system which will be upgraded to accommodate the 40 gpm flow.

In addition to groundwater extraction and treatment, RAA 4 incorporates the site controls (i.e., aquifer-use restrictions) and long-term groundwater monitoring program identified in RAA 2. Until remediation levels are met, the lead agency is required to review the effects of this alternative at least once every five years.

RAA 5: In Situ Passive Treatment/Slurry Cut-Off Wall

Capital Cost:	$5,976,000
Annual O&M Cost (Years 1-5) :	$130,430
Annual O&M Cost (Years 6-30):	$71,600
NPW:	$7,330,000
Years to Implement:	30 years of groundwater monitoring (quarterly for 5 years and semiannually for 25 years)

RAA 5 includes the construction of in situ passive treatment and slurry cut-off walls. This type of technology is referred to as a "funnel and gate" system. The slurry wall directs or funnels groundwater flow to the passive treatment wall gates that treat the groundwater as it passes through. The treatment gates consist of a vertical section of iron filings sandwiched between two vertical gravel sections. The iron filings facilitate the dechlorination of solvent-contaminated groundwater into non-toxic byproducts as groundwater flows through the gates.

Alternating sections of passive treatment wall and slurry wall will be installed as a vertical barrier beneath the ground surface. To effectively block contaminant migration, the walls are installed through the aquifer down to the confining unit. A 10:1 ratio is usually employed for the lengths for the treatment and slurry walls (i.e., 10 feet of slurry wall is constructed for every 1 foot of treatment wall).

Under RAA 5, two treatment/slurry cut-off walls will be constructed at the downgradient edges of the plume. One wall will be approximately 1,300 feet in length, with a total of 1,170 feet of funnel and 150 feet of gate. The other wall will be approximately 1,000 feet in length, with a total of 900 feet of funnel and 100 feet of gate. The treatment gates will be approximately 9 feet wide and the slurry funnels will be approximately 3 feet wide. Prior to construction, a bench-scale test is required to determine the exact formulation of the iron material and composition of the slurry wall.

In addition to groundwater extraction and treatment, RAA 5 incorporates the site controls (i.e., aquifer-use restrictions) and long-term groundwater monitoring program identified in RAA 2. Until remediation levels are met, the lead agency is required to review the effects of this alternative at least once every five years.

RAA 6: In-Well Aeration and Carbon Off-Gas Treatment

Capital Cost:	$1,060,000
Annual Monitoring O&M Cost (Years 1-5):	$113,000
Annual Monitoring O&M Cost (Years 6-30):	$63,000
Annual Treatment System O&M Cost:	$72,000
NPW:	$3,350,000
Years to Implement:	30 years of monitoring (quarterly for 5 years and semiannually for 25 years), and 30 years of system O&M

RAA 6 involves the in-well aeration technology, otherwise known as in-well air stripping. This technology involves air injection into a groundwater well which results in an in-well air-lift pump effect. The pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out of the top of the well. As the groundwater circulates through the well, the injected air stream strips away VOCs. The VOCs are captured at the top of the well and treated via carbon adsorption.

Under RAA 6, ten aeration wells will be installed, with overlapping radii of influence, at Site 35. Seven wells will be located in a line along the eastern limit of the contaminant plume. These wells will intercept the contaminant plume and mitigate horizontal migration. Three wells will be installed in the "hot spot" area of the plume. These wells will actively treat the most contaminated portion of the plume. VOCs that are stripped within the aeration wells will be treated by a trailer mounted unit that will include a blower, knockout tank, vacuum pump, and vapor-phase carbon adsorption unit. Under RAA 6, two to three aeration wells will be connected to a single trailer mounted treatment unit, so three units will be required.

In addition to groundwater extraction and treatment, RAA 6 incorporates the site controls (i.e., aquifer-use restrictions) and long-term groundwater monitoring program identified in RAA 2. Until remediation levels are met, the lead agency is required to review the effects of this alternative at least once every five years.

1.0 INTRODUCTION

This report presents the Draft Feasibility Study (FS) for groundwater at Operable Unit (OU) No. 10, Site 35 - Camp Geiger Fuel Farm, located at Marine Corp Base (MCB) Camp Lejeune, North Carolina. It has been prepared by Baker Environmental, Inc. (Baker) and submitted to the United States Environmental Protection Agency (USEPA), Region IV; the North Carolina Department of Environment, Health and Natural Resources (NC DEHNR); MCB, Camp Lejeune Environmental Management Department (EMD); the Navy Environmental Health Center (NEHC); the Agency for Toxic Substances and Disease Registry (ASTDR); and the Naval Facilities Engineering Command, Atlantic Division (LANTDIV) for their review.

This FS has been conducted in accordance with the guidelines and procedures delineated in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) for remedial actions (40 CFR 300.430). The guidance document used for the preparation of this FS was the USEPA's Guidance For Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988).

The focus of this FS is the groundwater contamination in the surficial aquifer south of the southern boundary of the proposed U.S. Route 17 Bypass right-of way. Surficial groundwater contamination north of the proposed U.S. Route 17 Bypass right-of-way is addressed in the Record of Decision (ROD) for Surficial Groundwater For A Portion Of Operable Unit 10, Site 35 - Camp Geiger Area Fuel Farm (Baker, 1995b). This FS is based on data collected at Site 35 during the Supplemental Groundwater Investigation (SGI) (Baker, 1996) conducted during the spring and summer of 1996, and the Remedial Investigation (RI) (Baker, 1995a) that was conducted in the spring of 1994.

1.1 Purpose of the FS

The purpose of the FS is to identify and evaluate various remedial actions for surficial groundwater contamination associated with previous activities at Site 35 that are protective of human health and the environment and will attain federal and state requirements. In general, the FS process under CERCLA assures that the remedial alternatives are developed and evaluated, such that pertinent information concerning the remedial action options can be presented and an appropriate remedy selected. The FS involves two major phases:

1. Development and screening of remedial action alternatives, and
2. Detailed analysis of remedial action alternatives.

The first phase includes the following activities:

- Developing remedial action objectives and remediation levels
- Developing general response actions
- Identifying volumes or areas of affected media
- Identifying and screening potential technologies and process options
- Evaluating process options
- Assembling alternatives
- Defining alternatives
- Screening and evaluating alternatives.

Section 121(b)(1) of CERCLA requires the assessment of possible solutions and alternative treatment technologies or resource recovery technologies that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant. In addition, according to CERCLA, treatment alternatives should be developed ranging from an alternative that, to the degree possible, would eliminate the need for long-term management, to alternatives which involve treatment that would reduce toxicity, mobility, or volume as their principal element. A containment option involving little or no treatment and a no-action alternative should also be developed.

The second phase includes the following activities:

- Evaluating the potential alternatives in detail with respect to nine evaluation criteria that address statutory requirements and preferences of CERCLA.
- Performing a comparison analysis of the evaluated alternatives.

1.2 Report Organization

This FS Report is organized in five sections. The Introduction (Section 1.0) presents the purpose of the report, a brief discussion of the FS process, pertinent site background information and summaries of all investigations conducted at Site 35. Section 2.0 contains the remedial action objectives and remediation levels that have been established for the site. Section 3.0 presents the general response actions, and the identification and preliminary screening of the remedial action technologies and process options. Section 4.0 presents the development and screening of Remedial Action Alternatives (RAAs). Section 5.0 presents a detailed analysis, and comparison of remedial action alternatives for Site 35. References are provided at the end of each of the five sections.

1.3 Background of Site 35

This subsection presents a summary of pertinent information concerning the site setting, geology, hydrogeology, and site history.

1.3.1 Site Location and Setting

Camp Lejeune is located in Onslow County, North Carolina near the city of Jacksonville (Figure 1-1). It currently covers approximately 234 square miles and is bisected by the New River. Camp Geiger is located at the extreme northwest corner of Camp Lejeune and contains a mixture of troop housing, personnel support and training facilities. Camp Geiger is roughly bounded by Brinson Creek to the north and northeast, the abandoned Seaboard Railroad right-of-way to the east, Curtis Road to the south, and U. S. Route 17 to the west.

Site 35, Camp Geiger Area Fuel Farm refers a former fuel storage and dispensing facility that was located just north of the intersection of Fourth and "G" Streets. The Fuel Farm consisted primarily of five, 15,000-gallon aboveground storage tanks (ASTs), a pump house, a fuel loading/unloading pad, an oil/water separator, and a distribution island. The facility actively served Camp Geiger and the New River Air Station from 1945 to 1995, when it was demolished to make way for the proposed U.S. Route 17 Bypass, a six-lane divided highway, to be constructed by the North Carolina Department of Transportation (NCDOT) (see Figure 1-2). Groundwater contamination north of the proposed U.S. Route 17 Bypass is addressed under the Record of Decision (ROD) for Surficial Groundwater for a Portion of Operable Unit No. 10 - Camp Geiger Area Fuel Farm (Baker, 1995b).

Results of various past environmental investigations have expanded the study area beyond the confines of the former Fuel Farm. The RI study area encompassed approximately 50 adjacent acres and the SGI expanded the study area to 150 acres (Figure 1-3).

The groundwater contamination, that is the focus of this FS, is roughly bounded to the north by the proposed U.S. Route 17 Bypass right-of-way, to the east by the Camp Geiger tree line, to the south by Ninth Street and to the west by "C" Street. Solvent-related groundwater contamination was detected during the SGI south of Ninth Street. However, the data indicates this contamination appears to have a source in the vicinity of the Defense Reauthorization and Marketing Office (DRMO) and is not associated with past activities in the vicinity of Site 35. A description of the nature and extent of this contamination is provided in the Phase I Site Investigation Report, Operable Unit No. 16, Sites 89 and 93 (Baker, 1996b).

1.3.2 Site Geology

In general, the upper-most soils at Site 35 are comprised of sand with lesser amounts of silt and clay. Lenses of silts and clays are present throughout the sand. Immediately below this sand are calcareous sands with varying amounts of shell and fossiliferous limestone fragments, interbedded with shell and fossiliferous limestone fragment layers. Collectively, these soils comprise what is called the undifferentiated formation, as well as the surficial aquifer. The amount of shell and fossil material observed in the calcareous layer during the SGI differs from that observed during the RI. The RI reported that this layer contained 0 to 35 percent shell fragments. Observations from the SGI indicate that the shell content is often greater than 50 percent, and in some instances approaches 90 percent. This difference may be attributable to facies changes.

A generally fine sand with lesser amounts of silt and clay is present immediately below the calcareous sands and shell/limestone fragment layer. This unit has been interpreted as the Belgrade Formation, or Castle Hayne Confining Unit. This unit was observed throughout the study area, typically at an elevation of approximately 20 to 30 feet below mean sea level (msl). The soils of this unit have a distinct green, or greenish-gray color, and contain less water than the overlying soils. This unit was observed to be seven to 12 feet thick.

A fine to medium sand with lesser amounts of shell fragments, silt, and clay is present immediately below the Castle Hayne Confining Unit. This unit has been interpreted as the River Bend Formation, or the upper portion of the Castle Hayne Aquifer. The top of this unit is approximately 35 to 40 feet below msl.

Geologic cross-sections were constructed from existing cross-sections in the RI Report using additional geologic data gathered during the SGI to illustrate the subsurface stratigraphy beneath the SGI study area. As shown on Figure 1-4, several areas were traversed to provide a cross-sectional view of the study area. Three cross-sections were constructed: A-A' crosses west to east along the northern portion of the study area; B-B' crosses north to south; C-C' crosses west to east along the central portion of the study area; and D-D' crosses west to east in the south central portion of the study area.

Cross-section A-A' depicts subsurface soils to an elevation of -51.3 feet msl from the western boundary of the study area to the eastern boundary. As illustrated on Figure 1-5, the soil underlying this portion of the area consist of fine to medium sands, clayey silts, and silty sands.

In general, in the western portion of the study area, a fine sand with trace to some silt is underlain by another fine sand that is partially cemented with calcium carbonate and contains 10 to 20 percent shell fragments to a depth of approximately -25 msl. Underlying the partially cemented sand is a very dense to dense, greenish gray, fine sand containing some silt, trace to some shell fragments. This semi-confining unit separates the Quaternary sediments from the Castle Hayne Aquifer and appears to be approximately eight to 12 feet thick, generally thickening toward the east. The Castle Hayne Formation is present beneath this unit. Borings were advanced only 10 to 15 feet into this formation during the RI, therefore providing limited knowledge of specific details regarding the condition of the Castle Hayne beneath the study area. The upper portion of the Castle Hayne was described as a partially cemented, gray, fine sand with some shell fragment and limestone fragments encountered periodically.

In the eastern portion of the study area this entire sequence of subsurface soil types appears to be overlain by silty clay or a clayey silt. The unit is not uniform and varies from approximately four to 20 feet thick.

Cross-section B-B' (Figures 1-6 and 1-6A) begins within the northern area of concern (NAOC) on Onslow County property (northeast side of Brinson Creek), and extends through the middle of the study area to the southern limits of the study area. This section shows the same sequence of units as section A-A'. The sand and calcareous sand/shells and limestone of the undifferentiated formation (surficial aquifer) overlay the green sand and silt of the Castle Hayne Confining Unit. A substantial silty clay layer is present within the surficial aquifer in the vicinity of 35-TW04B and 35-MW43B. Groundwater typically occurs within 10 feet of the surface.

Cross-section C-C' illustrates the soils beneath the southern portion of the site to an elevation of -51.3 (Figure 1-7). In general, the soils consist of the same types observed in the other cross-sections previously discussed. The only difference in this cross-section, when compared with the others, is the increase in interbedded soils in the eastern portion of the area.

Cross-section D-D' (Figure 1-8) depicts the area located south of cross-section C-C', and was created to reflect the larger dimension of the study area. Again, this cross-section shows the same sequence of units as in the other sections, demonstrating the consistent sequence of soil types.

The upper sand unit of the undifferentiated formation (surficial aquifer) is present throughout the study area. Lenses of silts and clays are generally limited in extent and found throughout the study area. These fine-grained soils are predominant along the western portion of cross-section A-A' (near Brinson Creek), and in the middle of cross-section B-B' (between Sixth and Seventh Streets). The lower calcareous sand/shell and limestone unit of the undifferentiated formation is also present throughout the study area. The top of this unit is typically 10 feet below msl, with one exception; cross-sections A-A' and B-B' show that the top of this unit dips to nearly 20 feet below msl in the vicinity of Brinson Creek. This may be a result of historic stream erosion of the calcareous sand/ shell and limestone unit, following a depositional period. The sands and silts of the Castle Hayne Confining Unit are also present throughout the study area.

Overall, the soils encountered during investigations within the study area are fairly consistent throughout. Within the study area, a laterally continuous confining unit was present between -26.0 and -28.1 feet msl. The location of the confining unit separating the surficial aquifer from the Castle Hayne Aquifer was encountered approximately 40 feet bgs. This is consistent with the range reported by the USGS, but exceeds the reported average of 25 feet (Cardinell, et al, 1993). It should be noted that results of the RI and SGI indicate that a semi-confining unit separates the surficial aquifer from the Castle Hayne Aquifer (consistent with the Harned, et al, report of 1989).

1.3.3 Site Hydrogeology

The following section describes the site hydrogeologic conditions for the surficial (water table aquifer) and the deep (Castle Hayne Aquifer) water-bearing zones at Site 35. Hydrogeologic characteristics in the vicinity of the site were evaluated by reviewing groundwater data gathered during the RI and SGI. The findings of the SGI are generally consistent with those presented in the RI Report (Baker, 1995). Some seasonal and temporal variations are evident when comparing SGI to RI data. Such variations include differences in static water levels and hydraulic conductivity.

Groundwater was encountered at varying depths during the RI and SGI drilling programs. This variation is primarily attributable to topographic changes. In general, the groundwater was encountered between 5.5 and 8.5 feet bgs. The water table nears the ground surface in the area of Brinson Creek, where the topographic elevation decreases.

The direction of surficial aquifer groundwater flow in the vicinity of Site 35 is to the northeast, toward Brinson Creek as determined by the RI and SGI (Figure 1-9). The groundwater flow gradient in July 1996 was approximately 0.007 feet/foot and 0.017 feet /foot in September 1994. Groundwater in the surficial aquifer appears to discharge to Brinson Creek based on the groundwater flow direction, the relative elevations of the creek, the ground surface elevations, and the groundwater potentiometric surface.

Groundwater flow direction in the upper portion of the Castle Hayne Aquifer in the vicinity of Site 35 is to the northeast, at a gradient of 0.008 feet/foot. According to the USGS Hydrogeologic Study for Camp Lejeune (Cardinell, et al., 1993), deep groundwater flows and discharges to the New River, located approximately 3/4 of a mile east and northeast of Site 35.

The average surficial aquifer (lower portion) hydraulic conductivity values calculated for the SGI study are on the same order of magnitude as the value in Cardinell, et al., 1993. The average hydraulic conductivity of the falling head slug tests conducted on wells constructed during the SGI is 89.5 feet/day. This is slightly higher, but comparable to the Cardinell value of 50 feet/day (Cardinell, et., al., 1993). The average hydraulic conductivity of falling head tests conducted on wells constructed during the RI was 5.16 feet/day, approximately an order of magnitude less. These results indicate that the surficial aquifer in the southern area of Site 35 has a higher hydraulic conductivity than the northern area.

The measured hydraulic conductivity and transmissivity in the Castle Hayne Aquifer at Site 35 are 7.3 ft/day and 1,460 ft^2/day, respectively, and are similar to the RI data, as well as the Cardinell data. The RI presented a hydraulic conductivity value of 6.03 ft/day. Cardinell reported hydraulic conductivity and transmissivity values from several studies that ranged from 14 to 91 ft/day, and 820 ft^2/day to 26,000 ft^2/day, respectively.

1.3.4 Site History

Construction of Camp Lejeune began in 1941 with the objective of developing the "Worlds Most Complete Amphibious Training Base." Construction started at Hadnot Point, where the major functions of the Activity are centered. Development at the Activity is primarily in five geographical locations under the jurisdiction of the Base Command. These areas include Camp Geiger, Montford Point, Courthouse Bay, Mainside, and the Rifle Range Area.

Construction of Camp Geiger was completed in 1945, four years after construction of Camp Lejeune was initiated. Originally, the Fuel Farm ASTs were used for the storage of No. 6 fuel oil. An underground distribution line (now abandoned) extended from the ASTs to the former Mess Hall Heating Plant, located adjacent to "D" Street, between Third and Fourth Streets. The underground line dispensed No. 6 fuel oil to a UST which fueled the Mess Hall boiler. The Mess Hall, located across "D" Street to the west, is believed to have been demolished along with its Heating Plant in the 1960s. At some unrecorded date the facility was converted for storage of other petroleum products, including unleaded gasoline, diesel fuel, and kerosene.

From the date of this conversion until the facility was decommissioned in the spring of 1995 the ASTs at Site 35 were used to dispense gasoline, diesel and kerosene to government vehicles and to supply underground storage tanks (USTs) in use at Camp Geiger and the nearby New River Marine Corps Air Station. The ASTs were supplied by commercial carrier trucks which delivered product to fill ports located on the fuel loading/unloading pad located south of the ASTs. Six, short-run (120 feet maximum), underground fuel lines were utilized to distribute the product from the unloading pad to the ASTs.

During the lifetime of the facility several releases of product occurred. Reports of a release from an underground distribution line near one of the ASTs date back to 1957-58 (ESE, 1990). Apparently, the leak occurred as the result of damage to a dispensing pump. At that time the Camp Lejeune Fire Department estimated that thousands of gallons of fuel were released although records of the incident have since been destroyed. The fuel reportedly migrated to the east and northeast toward Brinson Creek. Interceptor trenches were excavated and the captured fuel was ignited and burned.

Routinely, the ASTs at Site 35 supplied fuel to an adjacent dispensing pump that was supplied by an underground line. A leak in an underground line at the station was reportedly responsible for the loss of roughly 30 gallons per day of gasoline over an unspecified period (Law, 1992). The leaking line was subsequently sealed and replaced.

In April 1990, an undetermined amount of fuel was discovered by Camp Geiger personnel along two unnamed drainage channels north of the Fuel Farm. Apparently, the source of the fuel, believed to be diesel or jet fuel, was an unauthorized discharge from a tanker truck that was never identified. The Activity reportedly initiated an emergency clean-up which included the removal of approximately 20 cubic yards of soil.

The Fuel Farm was decommissioned and demolished during the spring of 1995. The ASTs were emptied, cleaned, dismantled, and removed along with all concrete foundations, slabs on grade, berms and associated underground piping. The Fuel Farm was demolished to make way for the proposed U.S. Route 17 Bypass, a six lane divided highway, proposed by the North Carolina Department of Transportation (NCDOT).

In addition to the Fuel Farm dismantling, soil remediation activities were executed between the spring of 1995 and the spring of 1996 along the proposed highway right-of-way as per an Interim Record of Decision executed on September 15, 1994.

1.4 Summary of Site Investigations

The purpose of this section is to summarize existing information pertaining to previous environmental studies involving Site 35. Section 1.4.1, Previous and Other Investigations, describes site activities that did not directly support this FS. Sections 1.4.2 through 1.4.4 describe the Remedial Investigation Report (Baker, 1995a), Interim Feasibility Study for Shallow Groundwater in the Vicinity of the Former Fuel Farm (Baker, 1995c), and the Draft SGI Report (Baker, 1996a), respectively. Data and information contained in these reports was used to directly support the development and analysis of alternatives included in this FS.

1.4.1 Previous and Other Investigations

Information presented in subsection 1.4.1 can be found in the Initial Assessment Study of Marine Corps Base, Camp Lejeune, North Carolina (WAR, 1983), Final Site Summary Report, MCB Camp Lejeune (ESE, 1990); Draft Field Investigation/Focused Feasibility Study, Camp Geiger Fuel Spill Site (NUS, 1990), Underground Fuel Investigation and Comprehensive Site Assessment (Law, 1992); the Addendum Report of Underground Fuel Investigation and Comprehensive Site Assessment (Law, 1993); the Interim Remedial Action Remedial Investigation/Feasibility Study for Soil (Baker, 1994a); and In-Situ Air Sparging (IAS) Treatability Study (Baker, 1996c). Sample locations associated with each of the studies conducted prior to the SGI are shown in a figure included in Appendix A of the Draft SGI Report (Baker, 1996a).

1.4.1.1 Initial Assessment Study

Camp Lejeune was placed on the National Priority List (NPL) in 1983 after the Initial Assessment Study identified 76 potentially contaminated sites at the Activity (WAR, 1983). Site 35 was identified as one of 23 sites warranting further investigation. Sampling and analysis of environmental media was not conducted during the Initial Assessment Study.

1.4.1.2 Confirmation Study

Confirmation Studies of the 23 sites requiring further investigation after the Initial Assessment Study included a study of the Fuel Farm between 1984 and 1987 (ESE, 1990). In 1984, Environmental Science and Engineering (ESE) advanced three hand-auger borings downgradient of the site and collected groundwater and soil samples from each location. Soils were analyzed for lead and oil and grease (O&G). Lead was detected at concentrations ranging from 6 to 8 mg/kg, and O&G was detected at concentrations ranging from 40 to 2,200 mg/kg.

Shallow groundwater samples obtained from the open boreholes were analyzed for lead, O&G, and volatile organic compounds (VOCs) including benzene, trans-1,2,-dichloroethene (trans-1,2,-DCE), trichloroethene (TCE), and methylene chloride. Lead was detected in each sample ranging from 1,063 µg/L to 3,659 µg/L. O&G was detected in a single sample at 46,000 µg/L. Methylene chloride was also detected in a single sample at 4 µg/L.

In 1986, ESE collected two sediment and surface water samples from Brinson Creek and installed three permanent monitoring wells (35GW-4, -5, and -6 which were later renamed EMW-5, -6, and -7), two east and one west of the Fuel Farm. These wells were screened in the upper portion of the surficial aquifer. Surface water and sediment samples were analyzed for lead, O&G and ethylene dibromide. Three groundwater samples were obtained in December 1986 and again in March 1987. These samples were analyzed for lead, O&G, and VOCs.

No target analytes were detected in either surface water sample. Both sediment samples were reported to contain lead and O&G, although no data indicating actual levels of detection were provided in ESE's report. Levels were reported to be higher in the upstream sample, prompting ESE to suggest that the discharge of contaminated groundwater to the creek is occurring at the far northern section of the Fuel Farm above ground storage tanks (ASTs) or that the source of O&G and lead may be upstream.

Lead was detected in only one of six groundwater samples collected from the three permanent monitoring wells at a concentration of 33 µg/L. O&G was detected in all six samples ranging from 200 µg/L to 12,000 µg/L. Detected VOCs included benzene (ranging from 1.3 µg/L to 30 µg/L), trans-1,2,-DCE (ranging from 3.2 µg/L to 29 µg/L), and TCE (detected at 11 µg/L on both sample dates).

ESE recommended further investigations designed to determine the horizontal and vertical extent of contamination residing within the soils and groundwater beneath the site and sediments in Brinson Creek. In addition, ESE recommended investigation of the adjacent automotive maintenance/hobby shop to determine if it is a source of VOC contamination. In conjunction with the investigations, ESE recommended a risk assessment for portions of the ESE report that pertain to Site 35.

1.4.1.3 Focused Feasibility Study

A Focused Feasibility Study (FFS) was conducted by NUS Corporation (NUS) in 1990 in the area north of the Fuel Farm. Although the FFS was conducted, a Record of Decision (ROD) was not signed as a result. The FFS included the installation of four groundwater monitoring wells numbered EMW-1, -2,-3, and -4. Baker was not able to obtain a copy of the NUS report. It was, however, discussed in the Comprehensive Site Assessment Report (Law, 1992). Law Environmental (Law) indicated that the results of laboratory analysis revealed groundwater in one well and soil cuttings from two borings were contaminated with petroleum hydrocarbons although non-aqueous product was not observed. No quantifiable data was provided in the Law report.

A geophysical investigation was also conducted by NUS as part of the FFS in an attempt to identify USTs at the site of the former gas station. The results indicated the presence of a geophysical anomaly in the vicinity of the former gas station.

1.4.1.4 Comprehensive Site Assessment

Law conducted a Comprehensive Site Assessment (CSA) during the fall of 1991 (Law, 1992). The CSA involved the drilling of 18 soil borings to depths ranging from 15 to 44.5 feet. These soil borings were ultimately converted to nested wells (MW-8 through 25) that monitor the water table aquifer along two zones. The shallow wells were constructed to monitor the water table and generally are screened from 2.5 to 17.5 feet below ground surface (bgs). The deeper wells monitored the lower portion of the surficial aquifer and are generally screened from 17.5 to 35 feet bgs. Five additional soil borings were drilled and nine soil borings were hand-augered to provide data regarding vadose zone soil contamination. Three soil borings were drilled specifically to provide subsurface stratigraphic data. Additional groundwater data was provided via 21 drive-point groundwater or "Hydropunch" samples. A "Tracer" study was also performed to investigate the integrity of the ASTs and underground distribution piping.

Soil and groundwater samples obtained under the CSA were analyzed for both organic and inorganic compounds. Groundwater analyses included purgeable hydrocarbons, purgeable aromatics and methyl-tertiary-butyl-ether (MTBE), polynuclear aromatic hydrocarbons (PAHs), and unfiltered lead. Soil analyses were limited to total petroleum hydrocarbons (TPH) (gasoline/diesel fractions) and lead. In addition, ten soil samples were analyzed for ignitability.

The results of the CSA identified areas of impacted soil and groundwater. The nature of the contamination included both halogenated organic compounds (e.g. TCE, trans-1,2-DCE, and vinyl chloride) and nonhalogenated, fuel-related constituents (e.g., TPH, MTBE, benzene, toluene, ethylbenzene, and xylene). The contamination encountered was typically identified in both shallow (2.5 to 17.5 feet bgs) and deep (17.5 to 35 feet bgs) wells.

Law also identified several plumes of shallow groundwater contamination that included two plumes that were comprised primarily of petroleum-based constituents (e.g., benzene, toluene, ethylbenzene, and xylenes) and two plumes comprised of halogenated organic compounds (e.g., TCE). The plumes were all located north of Fourth Street and east of E Street, except for a portion of a TCE plume that extended southwest beyond the corner of Fourth and E Streets.

In general, contaminant concentrations in soil were greatest in those samples taken at or below the water table. Law concluded that soil contamination at Site 35 was likely due to the presence of a dissolved phase groundwater plume and seasonal fluctuations of the water table.

A follow-up to the CSA was conducted by Law in 1992. Reported as an Addendum to the CSA (Law, 1993), it was designed to provide further characterization of the southern extent of the previously identified petroleum contamination. Three monitoring wells were installed including MW-26, -27, and PW-28. Soil samples were obtained from each of these locations and analyzed for TPH (gasoline and diesel fractions). As part of the follow-up, a pump test was performed to estimate the hydraulic characteristics of the surficial aquifer. This test was designed to determine performance characteristics of the pumping well (PW-28) and to estimate hydraulic parameters of the aquifer. An approximate hydraulic conductivity of 100 feet/day was determined for the surficial aquifer.

1.4.1.5 Interim Remedial Action RI/FS for Soil

An Interim Remedial Action field investigation was initiated by Baker in December 1993 to: 1) provide additional soil data to augment the existing Site 35 database; 2) determine the presence of non-fuel related chemical contaminants; 3) provide additional information regarding the extent of soil contamination; and 4) support an Interim Remedial Action FS.

Seven soil borings were advanced to depths of 6 to 12 feet bgs for the purpose of collecting samples for chemical analysis. Samples submitted to the laboratory were analyzed for Target Compound List (TCL) volatiles and semivolatiles, Target Analyte List (TAL) inorganics, TPH (gasoline/diesel fractions) and oil and grease. A composite sample was analyzed for the TCLP and RCRA Hazardous Waste Characteristics.

In addition, 13 shallow surface soil samples were collected at a depth of zero to 12 inches from topographically low areas of Brinson Creek and the drainage channel located north of the Fuel Farm. Soil samples were analyzed for TCL volatiles and semivolatiles, TAL inorganics, TPH and oil and grease. Three soil samples were analyzed for TPH (gasoline/diesel fractions) and oil and grease only. A composite sample was analyzed for full TCLP and RCRA characteristics.

In general, analytical data gathered during the Interim RI suggested that the petroleum hydrocarbon contamination was primarily located near the surface of the shallow groundwater. The results indicate that the highest TPH-related contamination occurs at or below the water table and groundwater fluctuations likely account for the subsurface soil contamination detected immediately above the top of the groundwater.

The Interim Remedial Action RI/FS culminated with an executed Interim ROD, signed on September 15, 1994, for the remediation of contaminated soil along and adjacent to the proposed highway right-of-way at Site 35. Three areas of contaminated soil were identified. The first area was located in the vicinity of the Fuel Farm ASTs, and the two other areas were located north of the Fuel Farm. The larger of these two areas was located along "F" Street in the vicinity of monitoring well MW-25. Baker estimated that approximately 3,600 cubic yards (4,900 tons) of contaminated soil was present in these areas. Contaminated soil located in these areas was excavated and disposed at an off-site soil recycling facility beginning in 1995 as part of an Interim Remedial Action executed by OHM Corporation (OHM). As a part of this activity monitoring wells MW-15, MW-20, MW-21, MW-24, MW-25 and GWD-4 were abandoned.

A fourth area of soil contamination, located immediately north of Building G480, was also identified in the Interim ROD. Additional data pertaining to this fourth area became available subsequent to the execution of the Interim ROD. This data indicated that contaminated soil was encountered in this area during the removal of UST in January 1994. The contaminated soil was excavated and reportedly disposed off site; however, no documentation was available regarding how or where the soil was disposed. An additional soil investigation was conducted in this area by OHM as part of the Interim Remedial Action. OHM confirmed that the contaminated soil was not returned to the excavation and that a follow-up soil remediation in this area was not necessary.

1.4.1.6 IAS Treatability Study

An in-situ air sparging (IAS) pilot evaluation was conducted by Baker during July and August of 1996 to assess the viability of IAS as a possible remedial alternative. A technology for shallow groundwater contamination in the vicinity of Brinson Creek at Site 35. As part of this study, 14 permanent monitoring wells, two air sparging wells, and six soil gas probes were installed in the wetland area along Brinson Creek approximately 500 feet to the northeast of the former Fuel Farm.

During the pilot test, air was injected into shallow and intermediate wells under two different flow rates. Helium was injected with the air as a tracer gas. Prior to the start of the test, a round of groundwater and air samples were collected from monitoring wells and soil gas probes to establish a baseline of control data. During the first two days of the test, air was injected into the sparge wells at a rate of five standard cubic feet per minute (scfm). During the second two days of the test, air was injected at a rate 20 scfm. At regular intervals during the test static water levels and dissolved oxygen levels were measured in the monitoring wells and groundwater samples were collected. Oxygen, pressure, and helium were measured in soil gas probes and soil gas samples were collected at regular intervals during the pilot test.

The report generally concluded the following:

- IAS via vertical injection would have limited effectiveness on solvent-related contaminants at the base of the surficial aquifer. The semiconfining layer is too impermeable to allow air injection below the base of the surficial aquifer.

- IAS would be ineffective in the northeast area of the site where a large clay lens exist. The clay layer would inhibit the release of contaminants to the atmosphere.

- Fuel-related groundwater contamination is not present in the Brinson Creek wetland area adjacent to Site 35.

- Vertical air injection into wells screened above the semiconfining layer did have a favorable impact. A radius of influence on ther order of 20 and 30 feet was observed when air was injected at 7.5 actual cubic feet per minute (acfm) and 20 acfm, respectively.

Based on these conclusion the following was recommended:

- An IAS where air is injected horizontally along the top of the semiconfining unit is preferable to conventional vertical IAS.

- Due to site conditions and lack of BTEX contamination in groundwater north of the proposed U.S. Highway 17 Bypass right-of-way the IAS system would be more effective if installed along the southern edge of the proposed right-of-way.

- A pilot test or phased construction should precede implementation of a full-scale horizontal IAS system.

1.4.1.7 Other Investigations

Two USTs located near the Fuel Farm have been the subject of previous investigations conducted under the Activity's UST program. The two USTs include a No. 6 fuel oil UST situated adjacent to the former Mess Hall Heating Plant and a No. 2 fuel oil UST situated adjacent to Building G480. The former was abandoned in place years ago (date unknown) and has been the subject of previous environmental investigations performed by ATEC Associates, Inc. (ATEC) and Law; the latter was removed in January 1994. Contaminated soils adjacent to the UST were reportedly removed with the tank; however, samples were not collected to confirm the limits of contamination.

As part of the Interim Remedial Action for Soil that was executed between July 1995 and April 1996 by OHM, four soil borings were advanced in the immediate vicinity of the former No. 2 fuel oil UST. Soil samples were collected from each location immediately above the water table and analyzed for TPH. Sample results verified the remaining soils do not contain hydrocarbon contamination associated with the former UST.

ATEC conducted a site assessment in the vicinity of Building TC341 to investigate contamination associated with the UST previously used to supply fuel to the Mess Hall Heating Plant. During the investigation, ATEC installed three shallow monitoring wells and analyzed the soils and groundwater for TPH and BTEX (ATEC, 1992).

TPH in soils ranged from 110 mg/kg to 2,000 mg/kg. Total BTEX in soils ranged from non-detected concentrations to 5,530 μg/kg TPH in groundwater was detected in MW-1 at a concentration of 5 mg/L and in MW-2 at 3 mg/L. Total BTEX was detected in the groundwater sample collected from MW-2 at a concentration of 34 μg/L. Based on these results, ATEC had recommended removal of the UST and associated piping.

Law submitted a report to LANTDIV for a leaking underground storage tank (LUST) site assessment for Building TC341 on April 13, 1994, summarizing the activities conducted in March 1994. The assessment was conducted in order to delineate the extent of contamination identified by ATEC and involved the installation of 12 Type II and two Type III groundwater monitoring wells and analysis of soils and groundwater. The soils were analyzed for TPH and O&G, TCLP metals, ignitability, and pH. Groundwater samples were analyzed for purgeable aromatic hydrocarbons, polynuclear aromatic hydrocarbons and the eight RCRA metals.

Results of TPH in soils ranged from nondetectable concentrations to 4,100 mg/kg. TPH was detected in soil samples from 11 mg/kg to 800 mg/kg. In addition, TCLP metals (barium, chromium, and cadmium) were detected in samples at concentrations below TCLP limits. Results for pH in soils ranged between 5.53 to 7.48 and ignitability was not detected.

RCRA metals, volatile organic compounds, and semivolatile organic compounds were detected in groundwater samples from monitoring wells MW-1 through MW-17. RCRA metals were detected in both of the samples submitted for metals analyses. VOCs were detected in four of the five samples submitted for analyses. Seventeen (17) samples were submitted for analyses of semivolatile organic compounds of which five possessed detectable concentrations. Law concluded that the majority of the soil and groundwater contamination originating from the tank system at Building TC341 had been adequately defined.

1.4.2 Remedial Investigation

This section summarizes the results of the RI performed by Baker in 1994.

1.4.2.1 Purpose of RI

The purpose of this RI was to evaluate the nature and extent of the threat to public health and the environment caused by the release of hazardous substances, pollutants or contaminants. This was accomplished by sampling several media (soil, groundwater, sediment, surface water, fish, crabs, and benthic macroinvertebrates) at OU No. 10, evaluating the analytical data and performing a human health risk assessment (RA) and ecological RA. The RI Report contains the results of all field investigations, a technical memorandum summarizing groundwater data and aquifer characteristics at Camp Lejeune, the human health RA, and the ecological RA.

1.4.2.2 RI Study Area

The RI Study Area consisted of approximately 50 acres adjacent to the former Fuel Farm. It was roughly bounded by Second Street to the north, "C" Street to the west, Fifth Street and Building TC 560 to the south, the Camp Geiger tree line to the east, and Brinson Creek to the northeast. This area is shown in Figure 1-3.

1.4.2.3 Field Activities

The RI field program was initiated in April 1994 and completed in October 1994. Data gathering activities were derived from: a soil gas survey and groundwater screening investigation; a soil investigation; a groundwater investigation; a surface water and sediment investigation; and an ecological investigation.

Soil Gas Survey and Groundwater Screening Investigation

Baker monitored the collection of 67 soil gas samples and 72 groundwater screening samples from sample locations established across the Site 35 study area. This investigation focused on obtaining additional information to assess the source(s) of halogenated compounds in shallow groundwater. The majority of the sample locations were located south of the Fuel Farm and south of Fourth Street, and were based on the results of previous investigations, which revealed TCE in groundwater. The purpose of this activity was to assist in the placement of soil borings/monitoring wells.

Soil Investigation

The soil investigation involved the drilling of 26 soil borings at locations primarily determined by the results of the soil gas survey and groundwater screening investigation. Borings were advanced to three depths and included 10 shallow borings (14 to 17 feet bgs), 11 intermediate borings (41 to 47 feet bgs), and five deep borings drilled to a depth equivalent to 5 to 10 feet below the semi-confining layer separating the surficial aquifer from the Castle Hayne Aquifer (51.0 to 66.0 feet bgs).

Soil samples (surface and subsurface) obtained from the borings were analyzed for the following parameters: TCL volatiles; semivolatiles; pesticides/PCBs; TAL metals; and a variety of engineering parameters.

Groundwater Investigation

The groundwater investigation included the installation of shallow, intermediate, and deep groundwater monitoring wells. The shallow monitoring wells were installed to intercept the upper portion of the surficial aquifer. The intermediate wells were constructed to monitor the lower portion of the surficial aquifer with screens set just above what appeared to be a semiconfining layer separating the surficial aquifer from the underlying Castle Hayne Aquifer. A total of 21 shallow and intermediate wells were installed under the RI. In addition, five deep groundwater wells were installed to monitor the upper portion of the Castle Hayne Aquifer immediately below the suspected semiconfining layer.

Groundwater samples were obtained from each of the 26 newly installed wells and 29 existing wells. The samples were analyzed for TCL volatiles, semivolatiles, pesticides/PCBs, and TAL metals and a variety of engineering parameters.

Surface Water/Sediment Investigation

Surface water and sediment samples were obtained along Brinson Creek which borders the Fuel Farm to the northeast. Samples were obtained from ten stations including three upstream and seven adjacent/downstream locations. Surface water and sediment samples were also collected from an off-base reference station. The reference station included the White Oak River watershed.

The surface water and sediment samples were analyzed for TCL volatiles, semivolatiles, pesticides/PCBs, TAL metals, and particle-size distribution.

Ecological Investigation

The ecological investigation included biological sampling (i.e., fish, shellfish, and benthic macroinvertebrates) along Brinson Creek and along three streams in the nearby White Oak River watershed that included Webb Creek, Hadnot Creek, and Holland Mill Creek. The work performed in the White Oak River watershed was part of an overall ecological background investigation conducted under the RI.

1.4.2.4 Nature and Extent of Contamination

The nature and extent of contamination at Site 35 determined during the RI was based on the analytical results of the various media including soil, groundwater, sediment, surface water, and fish tissue. The RI results were also compared to the results from previous environmental investigations performed at Site 35, when applicable.

Surface and Subsurface Soil

Relatively few detections of VOCs and SVOCs were observed in surface and subsurface soil samples obtained under the RI. The most significant contamination detected involved tetrachloroethane in subsurface soil at boring 35MW-30B located near the barracks southwest of the Fuel Farm. Pesticides were detected in surface soil samples only, but, are not deemed to be site related. No PCBs were detected in surface soil samples. Detected inorganics were generally similar to background surface and subsurface soil concentrations at Camp Lejeune.

Groundwater

The nature and extent of groundwater contamination was considered based on the interval of groundwater monitored and included: the upper portion of the surficial aquifer; the lower portion of the surficial aquifer; and the upper portion of the Castle Hayne Aquifer.

No substantial contamination was detected in the upper portion of the Castle Hayne Aquifer. This indicated that at the time the RI was conducted the suspected semiconfining layer that separates the surficial aquifer from the Castle Hayne Aquifer was serving as an aquitard.

Fuel and solvent-related groundwater contamination was observed in the upper and lower portion of the surficial aquifer. The limits of fuel and solvent-related groundwater contamination in the upper portion of the surficial aquifer determined during the RI are shown in Figures 1-10 and 1-11. The limits of fuel and solvent-related groundwater contamination in the lower portion of the surficial aquifer determined during the RI are shown in Figures 1-12 and 1-13, respectively. Fuel-related organic contaminants, when encountered, appear more prevalent in the upper portion of the surficial aquifer. Conversely, solvent-related organic contaminants, when encountered, appear more prevalent in the lower portion of the surficial aquifer. This is likely due to the fact that the latter are the more dense compounds having a specific gravity greater than groundwater.

The extent of fuel-related contamination was adequately defined based on the data obtained during the RI. At the time the RI was conducted, this contamination was limited to the area north of Fourth Street in the vicinity of suspected sources such as the Fuel Farm and nearby former UST sites.

The extent of solvent-related contamination was not completely defined or sources identified by the RI. Based on RI data, solvent-related contamination appears to extend from north of Fourth Street and south to Fifth Street beyond which the RI did not extend in the southerly direction. The source of this plume was not determine during the RI. A second smaller plume was identified in the vicinity of the Former Vehicle Maintenance Garage (Building TC474). The smaller plume appears to be adequately defined and the source of contamination is likely Building TC474 and the immediate vicinity.

Elevated levels of inorganic contaminants (total and dissolved) were detected in groundwater samples obtained from within the surficial aquifer. However, these results were similar to those obtained by Baker at other Camp Lejeune sites. The elevated total metals were believed to be caused by suspended particulates in the samples.

Surface Water and Sediment

Significant levels of organic and inorganic contaminants were detected in sediment samples obtained from locations adjacent to and downstream of Site 35. The results of VOC analyses were "masked" by the presence of high levels of Tentatively Identified Compounds (TICs), and consequently, few VOC detections were reported. Nevertheless, the Baker field team commented during sampling that the sediment samples appeared to contain elevated levels of fuel-related contaminants which could also explain the presence of TICs. Lead at elevated levels was also detected in these sediment samples and, like the organic contaminants, could be related to Site 35.

Surface water contamination was limited to a single detection of lead and zinc downstream of Site 35 at levels in excess of the Water Quality Screening Values (WQSV) and the North Carolina Water Quality Standards (NCWQS). No organic contaminants were detected in surface water samples.

Fish

A variety of organic and inorganic contaminants were detected in fillet and whole body fish samples analyzed under this RI. The most significant contaminants detected were the pesticides dieldrin and 4,4'-DDD, as well as, a single detection of inorganic mercury. These contaminants were primarily responsible for the calculated risk to human health in excess of EPA guidelines.

1.4.2.5 Baseline Human Health Risk Assessment

The BRA highlighted the media of interest from the human health standpoint at OU No. 10 by identifying areas with elevated incremental cancer risk (ICR) and Hazard Index (HI) values. Current and future potential receptors at the site included current military personnel, current recreational adults and children, future residents (i.e., children and adults), and future construction workers. Contaminants of Potential Concern (COPCs) were identified by media and the total site risk for each of these receptors was estimated by logically summing the multiple pathways likely to affect the receptor during a given activity (see Table 1-1). The following algorithms defined the total site risk for the current and future potential receptor groups assessed in a quantitative manner. The risk associated with each site was derived using the estimated risk from multiple areas of interest.

1. Current Military Personnel

    a. Incidental ingestion of COPCs in surface soil + dermal contact with COPCs in surface soil + inhalation of airborne COPCs

2. Future Residents (Children and Adults)

    a. Incidental ingestion of COPCs in surface soil + dermal contact with COPCs in surface soil + inhalation airborne of COPCs

    b. Ingestion of COPCs in groundwater + dermal contact with COPCs in groundwater + inhalation of volatile COPCs

3. Future Construction Worker

    a. Incidental ingestion of COPCs in on-site subsurface soil + dermal contact with COPCs in subsurface soil + inhalation of airborne COPCs

4. Current Recreational Children and Adults

    a. Ingestion of COPCs in surface water and sediment + dermal contact with COPCs in surface water and sediment

    b. Ingestion of fish tissue (adults only)

The total site ICR and HI values associated with current and future receptors at this site are presented in Table 1-2. The total site ICR for the current recreational child (4.4×10^{-7}) current recreational adult (1.9×10^{-5}), and current military personnel (3.1×10^{-6}) were below the USEPA's upper bound risk range (1×10^{-4} to 1×10^{-6}), therefore adverse effects were considered unlikely. The total site HI for the current recreational child (0.01) and current military personnel (0.09) did not exceed unity. Therefore, adverse effects were considered unlikely. The total site HI for the current recreational adult (1.8) was slightly above unity. The total site risk was due to potential exposure from fish fillet ingestion which is driven by the presence of mercury. However, the exposure parameters used to calculate risk from fish ingestion are very conservative; mercury was not found to be causing a risk in any other media at Site 35; and the fish collected at Site 35 are considered migratory and move along Brinson Creek, therefore this risk may not be due to contamination at the site. Therefore, the risk from ingestion of fish may not be site related.

The total site ICR and HI for the future construction worker (1.2×10^{-7} and 0.02, respectively) was below the USEPA's risk range, therefore, risk to this receptor was considered unlikely. The total site ICR for future adult residents (4.3×10^{-3}) and future child residents (2.1×10^{-3}) exceeded the USEPA's upper bound risk range (1×10^{-4} to 1×10^{-6}). The total site risk was driven by future potential exposure to groundwater. The ICR values were driven by the presence of arsenic and beryllium. The total site HI for the future adult resident (44) and the future child resident (104) exceed unity. The total site risk was driven by future potential exposure to groundwater. The HI values are driven by the presence of cis-1,2-dichlorothene, trichloroethene, benzene, antimony, arsenic, barium, chromium, cadmium, manganese, and vanadium.

1.4.2.6 Ecological Risk Assessment

Overall, metals and pesticides appeared to be the most significant site related COPCs that have the potential to affect the integrity of the aquatic and terrestrial receptors at Site 35. Although the American alligator has been observed at Site 35, potential adverse impacts to this species could not be quantitatively evaluated.

Aquatic Ecosystem

Surface water quality showed exceedances of aquatic reference values for lead, mercury, and zinc. In addition, iron, cobalt and manganese were above the concentration that caused adverse impacts to aquatic species in a few studies. However, most of the studies did not meet the criteria for reliability, and other studies indicated that potential impacts to aquatic organisms did not occur at the concentrations detected in the surface water at Brinson Creek. For sediments, concentrations of lead and the organics dieldrin, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endrin, alpha-chlordane, and gamma-chlordane exceeded the aquatic reference values. In the surface water, mercury exceeded aquatic reference values in the upstream stations. Although these levels were indicative of a high potential for risk (QI > 100), mercury is not believed to be site related. Zinc only exceeded unity slightly and was only found at a single station. Lead had a single exceedance of the aquatic reference value by slightly greater than 10 indicating a moderate potential for risk to aquatic receptors. Lead also was found in the groundwater samples at similar levels and was believed to be site related.

In the sediments, lead exceeded the lower sediment aquatic reference value throughout Brinson Creek. The only exceedances of the higher sediment aquatic reference value occurred downstream of Site 35 with the highest QI of 137 representing a high potential for risk to aquatic receptors. The lead detected in the sediments is likely site related, the result of past reported surface spills/runoff and past and ongoing groundwater discharges to surface water.

Pesticides exceeded the sediment aquatic reference values throughout Brinson Creek. The highest QI, 2,600 for dieldrin, represents a high potential for risk to aquatic receptors. There is no documented pesticide disposal or storage/preparation activities at Site 35. The pesticide levels detected in the sediments probably are a result of routine application in the general vicinity of Site 35.

Although, the pesticides in the sediments were found at levels indicating contamination throughout the watershed, the highest levels were observed in the lower reaches of Brinson Creek. This deposition trend may be related to the higher organics in the sediments in the lower reach, which would accumulate more of these types of contaminants.

The fish community sampled in Brinson Creek was representative of an estuarine ecosystem with both freshwater and marine species present. In addition, the presence of blue crabs, grass shrimp, and crayfish support the active use of Brinson Creek by aquatic species.

The absence of pathologies observed in the fish collected from Brinson Creek indicates that the surface water and sediment quality may not adversely impact the fish community.

The benthic macroinvertebrate community demonstrated the typical tidal/freshwater species trend of primarily chironmids and oligochaetes in the upper reaches and polychaetes and amphipods in the lower reaches. Species representative of both tolerant and intolerant taxa were present. Species richness and densities were representative of an estuarine ecosystem.

In summary, the aquatic community in Brinson Creek was representative of an estuarine community and did not appear to be significantly impacted by surface water and sediment quality.

Terrestrial Ecosystem

Surface soil quality indicated a potential for adversely impacting the terrestrial receptors that have direct contact with the surface soils. This adverse impact is primarily due to cadmium in the surface soils. Cadmium was detected at a relatively high concentration in only one out of ten surface soil samples, therefore any estimation of adverse effects on terrestrial receptors using this cadmium concentration is conservative.

There also appears to be impacts to the terrestrial receptors due to copper in the fish tissue. Copper was not detected in the surface water but was detected in sediment samples collected downstream of Site 35 at concentrations lower than the sediment samples taken upstream of Site 35. As such, the copper in the fish tissue does not appear to be site related.

1.4.2.7 Recommendations

Based on the data obtained, it was recommended that:

- The remedial investigation at Site 35 be extended south of Fifth Street as needed to define the extent and locate the source(s) of solvent-related groundwater contamination in the surficial aquifer.

- The monitoring wells screened within the surficial aquifer that were sampled under the RI for inorganic contaminants (total phase only) be resampled using a low-flow sampling technique.

- Surface soils and sediments be resampled for mercury and zinc in order to replace that data which was rejected during validation..

- Sediment samples along Brinson Creek be obtained at locations adjacent to and downstream of Site 35 and analyze for TPH (EPA Methods 5030 and 3550) so as to provide data regarding the extent of organic contamination that was "masked" by TICs in results obtained under the RI.

- An Interim Remedial Action Feasibility Study be prepared that focuses on groundwater in the vicinity of the Fuel Farm and north of Fourth Street. The purpose of this Interim FS will be to address groundwater contamination in this area which may be a continuing source of contamination to Brinson Creek.

- The northeastern edge of the halogenated organic plume was not been delineated. Therefore, soil and groundwater samples should be collected on the northern side of Brinson Creek in order to determine if the creek is acting as a barrier to groundwater contamination that may be migrating off-site.

- Special precautions be taken when soil excavation is performed during the construction of the new highway. Specifically, it is recommended that the written construction work plans reference the need for monitoring of volatile organic contaminant concentrations in the breathing zone of the workers, and that institutional and engineering controls be established to minimize human exposure to both VOCs and fugitive dust particulates. Although the calculated risk to human health for future construction workers on Site 35 was well below the EPA acceptable range, adverse exposure to a volatilized fraction of contaminants in the subsurface soil or inhalation of airborne contaminants is possible.

1.4.3 Interim Remedial Action Feasibility Study for Shallow Groundwater in the Vicinity of the Fuel Farm

This section summarizes the purpose, remediation levels, alternatives, and comparison of alternatives that were presented in the Interim Feasibility Study for Shallow Groundwater in the Vicinity of the Fuel Farm at located at Marine Corps Base (MCB), Camp Lejeune, North Carolina (Baker, 1995b). The Interim FS is based on data collected during the Remedial Investigation (RI) conducted at Site 35 between April and October of 1994 (Baker, 1995a).

1.4.3.1 Purpose of the Interim FS

The purpose of the Interim FS was to identify and evaluate various remedial actions for contaminated shallow groundwater in the vicinity of the Fuel Farm at Site 35. The Interim FS was intended to develop potential remedial actions that will provide for the protection of human health and the environment from contaminated groundwater in this area prior to the completion of a comprehensive FS that was to consider remedial actions for the entire area of contaminated groundwater as well as other media.

1.4.3.2 Remediation Levels

The remediation levels (RLs) associated with OU 10 were based on a comparison of contaminant-specific applicable or relevant and appropriate requirements (ARARs), ARAR-based remediation goal options(RGOs) and the site-specific risk-based RGOs. If a COC had an ARAR, the most limiting (or conservative) ARAR was selected as the RL for that contaminant. If a COC did not have an ARAR, the most conservative risk-based RGO was selected for the RL.

In order to determine the final COCs for OU No. 10, the contaminant concentrations detected at each site were compared to the RLs. The contaminants which exceeded at least one of the RLs were retained as final COCs. The contaminants that did not exceed any of the RLs were no longer considered as COCs with respect to the Interim FS. The final COCs associated with the Interim FS and their corresponding RLs are presented on Table 1-3.

Several inorganic COCs including arsenic, beryllium, antimony, barium, cadmium, manganese, nickel, and vanadium were detected in concentrations that exceeded remediation levels. However, these inorganics were not addressed in the Interim FS. It was believed that these constituents were not a result of past site activities, but rather due to sampling methods. As in the RI, the Interim FS recommended that inorganics at OU No. 10 not be addressed until after wells were re-sampled using a low-flow sampling protocol.

1.4.3.3 Summary of Alternatives

Various technologies and process options were screened and evaluated under the Interim FS. Ultimately, five Remedial Action Alternatives (RAAs) were developed as follows:

- RAA 1 - No Action
- RAA 2 - No Action with Institutional Controls
- RAA 3 - Groundwater Collection and On-Site Treatment
- RAA 4 - In Situ Air Sparging and Off-Gas Carbon Adsorption
- RAA 5 - In Well Aeration and Off-Gas Carbon Adsorption

A brief description of each alternative as well as the estimated cost and time frame to implement the alternative are as follows:

- RAA 1: No Action

  Total Net Present Worth (30 years): $0
  Months to Implement: 0

Under the No action RAA, no remedial actions were to be performed to reduce the toxicity, mobility, or volume of the contaminated surficial groundwater at Site 35. This method assumed that passive remediation would occur via natural attenuation processes and that the contaminant levels would be reduced over an indefinite period of time.

The National Oil and Hazardous Substance Contingency Plan (NCP) required the No Action RAA to provide a baseline for comparison with other alternatives. Since contaminants were remain at the site under this alternative, a review of this alternative by the USEPA would have been required on a five year basis according to the NCP [40 CFR 300.515(e) (ii)].

- RAA 2: No Action with Institutional Controls

  Total Net Present Worth (30 years): $299,800
  Months to Implement: 2

Under RAA No. 2, no remedial actions were to be performed to reduce the toxicity, mobility, or volume of the contaminated surficial groundwater at Site 35. This RAA required the revision of the Base Master Plan to include restrictions on the use of the surficial aquifer in the vicinity of the Fuel Farm. This would reduce the risk to human health and the environment posed by this media by eliminating one exposure pathway; however, the impacted surficial groundwater would remain a potential source of contamination to Brinson Creek.

In addition to the aquifer-use restrictions, long-term groundwater monitoring was included under this RAA to provide data regarding the impact of natural attenuation and the progress of contaminant migration. Long-term groundwater monitoring included the semi-annual collection and analysis (TCL VOCs) of groundwater samples from 11 monitoring wells, the development of a semi-annual monitoring report, and the replacement of one monitoring well every five years.

Since contaminants were to remain at the site under this alternative, a review of this alternative by the USEPA would have been required on a five year basis according to the NCP [40 CFR 300.515(e) (ii)].

- RAA 3: Groundwater Collection and On-Site Treatment

  Total Net Present Worth (30 years): $3,000,500
  Months to Implement: 3

RAA 3 was a source collection and treatment alternative, the source was the contaminated surficial groundwater in the vicinity of the Fuel Farm at Site 35. Under this alternative a vertical interceptor trench, approximately two feet wide, by 30 feet deep, by 1,080 feet long, was to be installed at the downgradient edge of the contaminated plume in the area between the proposed highway and Brinson Creek. The interceptor trench was to be constructed from the ground surface to the semi-confining layer at the base of the surficial aquifer. The purpose of the interceptor trench was to collect contaminated surficial groundwater for transfer to an on-site treatment facility prior to it being discharged to Brinson Creek.

The interceptor trench was to be designed to collect groundwater at a rate roughly equal to the groundwater flow (5 to 10 gpm) across the upgradient face of the trench (31,900 square feet). Flow across the downgradient face of the trench was to be restricted by an impermeable geomembrane barrier. Drawdown of the groundwater surface was to be minimized so as to mitigate the potential of excessive ground settlement beneath the highway. The collected groundwater was to be conveyed to an on-site treatment plant located just east of the proposed highway right-of-way, creek-side, where it appears that adequate space and firm foundation material were available. In this Interim FS, Baker proposed an access road running along the east side of the highway from the south.

The collected groundwater was to be treated sufficiently to allow for its discharge to Brinson Creek at a point downstream of Site 35.

RAA 3 required the Base Master Plan to be modified to include restrictions on the use of the surficial aquifer in the vicinity of the Fuel Farm. This would reduce the risk to human health and the environment posed by this media by eliminating one exposure pathway.

In addition to aquifer-use restrictions, long-term groundwater monitoring was to be included under this RAA to provide date regarding the impact of natural attenuation and the progress of contaminant migration.

Since contaminants were to remain at the site under this alternative, a review of this alternative by the USEPA would have been required on a five year basis according to the NCP [40 CFR 300.515(e) (ii)].

- RAA 4: In Situ Air Sparging and Off-Gas Carbon Adsorption

  Total Net Present Worth (30 years): $2,459,600
  Months to Implement: 3

Under this RRA in- situ air sparging (IAS) was to be employed for the purpose of removing organic contaminants primarily via volatilization and secondarily via aerobic biodegradation. Air injection wells would have introduced contaminant-free air into the surficial aquifer near the base of the zone of contamination, forcing VOC contaminants to transfer from the groundwater into sparged air bubbles. Contamination would have been transported via air bubbles into soil pore spaces in the unsaturated zone where vapor phase contamination would have been collected via soil vapor extraction (SVE) and conveyed to an on-site, off-gas treatment system.

An IAS system typically is comprised of the following components: 1) air injection wells; 2) an air compressor; 3) air extraction wells; 4) a vacuum pump; 5) associated piping and valving for air conveyance; and 6) an off-gas treatment system (e.g., activated carbon, combustion, or oxidation). Under RAA 4 a line of air sparging wells was to be installed between the proposed highway and Brinson Creek in order to treat and contain the contaminated plume near its downgradient extreme. For the purpose of the FS, Baker estimated that 43 sparging wells, 30 feet deep, and 43 SVE wells, 4 feet deep, would be required. The proposed off-gas treatment system (activated carbon) was to be located just east of the proposed highway right-of-way, creek-side, where it appears that there is adequate space and firm foundation material available. The air emissions from the off-gas treatment system were to be sampled monthly to insure that all applicable air emissions standards were being met.

RAA 4 required the Base Master Plan to be modified to include restrictions on the use of the surficial aquifer in the vicinity of the Fuel Farm. This would reduce the risk to human health and the environment posed by this media by eliminating one exposure pathway.

In addition to aquifer-use restrictions, long-term groundwater monitoring was to be included under this RAA to provide data regarding the impact of natural attenuation and the progress of contaminant migration.

Since contaminants were to remain at the site under this alternative, a review of this alternative by the USEPA would have been required on a five year basis according to the NCP [40 CFR 300.515(e) (ii)].

- RAA 5: In Well Aeration and Off-Gas Carbon Adsorption

  Total Net Present Worth (30 years): $2,519,700
  Months to Implement: 3

In well aeration is a new technology that utilizes circulating air flow within a groundwater well that, in effect, turns the well into an air stripper. In well aeration differs from air sparging in that volatilization occurs outside the well via air sparging and within the well via in well aeration. Similar to air sparging, this technique removes organic contaminants from groundwater primarily via volatilization and secondarily via aerobic biodegradation.

Under RAA 5 a line of in well aeration wells was to be installed between the proposed highway and Brinson Creek in order to treat and contain the contaminated plume near its downgradient extreme. The radius of influence, or capture zone, of an in well aeration well is reportedly much greater than that of a typical air sparging well system. Using modeling equations and graphical solutions, the developers of this technology have calculated a radius of influence of over 100 feet at Site 35.

For the purpose of the FS, Baker estimated that six in well aeration wells would be required. Volatilized organics collected by this technology, unlike air sparging, will be treated at each in well aeration well by independent air treatment/carbon adsorption systems which will rest adjacent to the wells. The air emissions from the off-gas treatment system were to be sampled monthly to insure that all applicable air emissions standards were being met. Each well and aboveground off-gas treatment system was to be housed in a small prefabricated building.

In well aeration systems, like IAS systems, are most effective in sandy soils. A field pilot test was recommended to determine the loss of efficiency over time as a result of inorganics precipitation and oxidation, the radius of influence of the wells under various heads of injection air pressure, and the rate of off-gas organic contaminant removal via carbon adsorption and carbon breakthrough.

In this Interim FS, Baker proposed an access road running along the east side of the highway from the south.

RAA 5 required the Base Master Plan to be modified to include restrictions on the use of the surficial aquifer in the vicinity of the Fuel Farm. This would reduce the risk to human health and the environment posed by this media by eliminating one exposure pathway.

In addition to aquifer-use restrictions, long-term groundwater monitoring was to be included under this RAA to provide data regarding the impact of natural attenuation and the progress of contaminant migration.

Since contaminants were to remain at the site under this alternative, a review of this alternative by the USEPA would have been required on a five year basis according to the NCP [40 CFR 300.515(e) (ii)].

A detailed analysis of each RAA was performed including an assessment and summary profile of each RAA against an evaluation criteria and a comparative analysis among the RAAs to assess relative performance of each with respect to the criteria. The purpose of this analysis is to identify the relative advantages and disadvantages of each RAA.

1.4.3.4 Post Interim FS Activities

The Interim Remedial Action FS culminated with the execution of the Interim ROD For Surficial Groundwater for a Portion of Operable Unit No. 10 - Camp Geiger Fuel Farm," signed on September 5, 1995. The Interim ROD detailed the five RAAs described in the Interim FS for the remediation of organic contamination of the surficial aquifer. RAA 5, In Well Aeration with Off-Gas Carbon Adsorption, was selected as the preferred remedy in the Interim ROD, contingent upon the successful execution of preliminary field pilot-scale tests.

The Interim ROD indicated the viability of in-well aeration was to be determined by means of a field pilot that was to have been initiated in September 1995. Results were to have been available in February 1996. The viability of inwell aeration technology at Camp Lejeune is currently being evaluated via field pilot test at Site 69. However, the pilot test at Site 69 has experienced substantial delays to date and is anticipated to be completed in 1997. The results of this test were to determine the viability of in well aeration at Camp Lejeune. The Interim ROD prescribed RAA 3, Groundwater Collection and On-Site Treatment, be substituted as the preferred remedy in the event in well aeration could not be implemented.

In August 1995, the EPA, NC DEHNR, LANTDIV, Camp Lejeune, and Baker agreed that a treatability study employing in-situ air sparging (IAS) would be appropriate at this site to evaluate this technology as a possible alternative to those presented in the Interim ROD. This test was performed in August 1996. The results indicated that IAS with via vertical air injection wells located on the north side of the proposed U.S. Route 17 Bypass right-of-way would not impact groundwater contamination as expected. In addition, the IAS Treatability Report recommended the implementation of IAS via horizontal injection trenches to be located on the south side of the proposed U.S. Route 17 Bypass right-of-way (ROW).

The EPA, NC DEHNR, LANTDIV, Camp Lejeune, and Baker concurred in November 1996, that it is appropriate to consider IAS via horizontal injection trenches along the south side of the ROW as an alternative to IAS via vertical air injection wells on the north side of the ROW and as a possible alternative to RAA 3. Prior to the full-scale implementation of IAS via horizontal injection trenches a field pilot-scale test or phased construction will be implemented along the south side of the ROW. However, additional location-specific data will be needed to determine if local site conditions are amenable IAS. This data will include a detailed profile of subsurface lithology and contamination at the location of the proposed pilot-scale test or phased construction. It is anticipated that this work will occur during the summer of 1997.

If the results of the pilot-scale test of IAS via horizontal injection trenches are sufficiently positive, the EPA may request Baker to prepare an explanation of significant differences (ESD) document to modify the selected remedy in the Interim ROD.

1.4.4 Supplemental Groundwater Investigation

This section summarizes the results of the SGI conducted by Baker in 1995.

1.4.4.1 <u>Purpose of the SGI</u>

The SGI had two primary purposes as follows: fill data gaps identified in the RI Report; and gather additional soil and groundwater data that would support the implementation of an in-situ air sparging pilot test. The specific objectives of the SGI included the following:

- Extend the Remedial Investigation (RI) south of Fifth Street as needed to define the extent and locate sources of solvent related groundwater contamination in the surficial aquifer.

- Gather additional inorganic groundwater samples from existing wells, screened in the surficial aquifer and sampled during the RI, through the use of a low-flow pumping technique in order to more accurately quantify total metals contamination.

- Resample surface soils and sediments to replace data that was rejected during the validation of the RI sample results.

- Collect sediment samples along Brinson Creek and analyze for TPH (EPA Methods 5030 and 3550) to determine the extent of organic contamination that was "masked by tentatively identified compounds" (tics) under the RI.

- Collect soil and groundwater samples from the northeast side of Brinson Creek to determine if Brinson Creek is acting as a barrier to groundwater contamination that may be migrating off site.

- Collect groundwater, soil and lithologic data from an area downgradient of the former Fuel Farm and adjacent to Brinson Creek to support the implementation of an in-situ air sparging pilot test.

1.4.4.2 SGI Study Area

Results of previous investigations have expanded the study area beyond the confines of the former Fuel Farm. The RI study area encompassed approximately 50 adjacent acres and the SGI expanded the study area to 150 acres. For clarity, the study area was broken down into the following areas of concern:

- Northern Area of Concern (NAOC) - This area encompasses approximately 10 acres and is located in the northeast corner of the SGI study area, immediately adjacent to the former Fuel Farm. Approximately six acres of this area are on the northeast side of Brinson Creek and are owned by Onslow County. The remaining four acres are on the southwest side of Brinson Creek on Activity property.

- RI Study Area - This area encompasses approximately 50 acres immediately surrounding the former Fuel Farm facility

- Southern Area of Concern (SAOC) - This area encompasses approximately 90 acres located between, Fifth and Ninth Streets south of the former Fuel Farm.

1.4.4.3 SGI Field Investigation

The SGI field program consisted of the following activities: a soil screening investigation; a groundwater screening investigation; a groundwater investigation that occurred in two rounds (Round 3 and 4); a sediment investigation; a site survey; and investigative derived waste (IDW) handling. SGI field activities occurred periodically between July 25, 1995 and October 9, 1996.

Soil Screening Investigation

During the soil screening investigation borings were advanced in the NAOC and SAOC for the purpose of lithologic description, monitoring well installation and sample collection. Soils samples were collected from the shallow temporary monitoring well borings and were analyzed by an on-site mobile laboratory for cis-1,2- dichloroethene, trans-1,2-dichloroethene; and trichloroethene.

Groundwater Screening Investigation

Groundwater screening activities included temporary well installation and sampling. Groundwater samples that were collected were analyzed by an on-site mobile laboratory for cis-1,2-dichloroethene; trans-1,2-dichloroethene and trichloroethene. This investigation was conducted for the purpose of meeting the following location-specific objectives.

- NAOC - Activity property (northeast side of Brinson Creek)
  Determine if Brinson Creek is acting as a hydraulic barrier to fuel and solvent-related groundwater contamination migrating off-site onto Onslow County property. To achieve this objective four temporary monitoring wells were installed and sampled on Onslow County property

- NAOC - Activity property (southwest side of Brinson Creek)
  Provide a detailed vertical profile and determine the horizontal extent of solvent and fuel-related groundwater contamination downgradient of the Fuel Farm at the boundary of the Brinson Creek wetland. To achieve this objective a total of 32 temporary monitoring wells were installed and sampled in this area.

- SAOC - Activity property (area between Fifth Street and Ninth Street)
  Sufficiently define the horizontal extent of solvent-related groundwater contamination in the upper and lower portions of the surficial aquifer south of Fifth Street to effectively locate permanent monitoring wells. To achieve this objective a total of 27 temporary monitoring wells were installed in this area.

Groundwater Investigation

The groundwater investigation at the site consisted of several activities including: installation of permanent shallow, intermediate and deep monitoring wells; well development, groundwater sampling, and aquifer testing. The objectives of the groundwater investigation were as follows:

- To gather inorganic groundwater data from existing wells located in the RI Study Area and screened in the surficial aquifer through the use of low-flow pumping techniques to more accurately quantify total metals contamination. This data was gathered during Round 3 conducted in August, 1995.

- Confirm the presence or absence of fuel and solvent-related contamination in the surficial aquifer and the upper portion of the Castle Hayne Aquifer in the RI Study Area, NAOC and SAOC. To achieve these objectives seven type-two wells and two type-three wells were installed and sampled. Samples were analyzed for TCL VOCs. Sampling of these wells was conducted during Round 4 conducted during August, 1996.

- Evaluate the shallow and deep groundwater flow patterns site-wide.

Sediment Investigation

Sediment samples were collected from 10 stations along Brinson Creek to assess gross fuel- related contamination from Site 35 operation and to replace metals data rejected during RI validation. These samples were analyzed for TPH (EPA Methods 5030 and 3550), zinc and mercury.

1.4.4.4 Site Geology

In general the findings of the SGI are consistent with the findings of the RI. The upper most soils consist of sand with lesser amounts of silt and clay. Immediately below this sand are calcareous sands with varying amounts of shell and fossiliferous limestone fragments. A generally fine sand with lesser amounts of clay is present below the calcareous sands and shell/limestone fragments. This layer is generally known as the Castle Hayne confining unit and is colored a distinctive greenish-gray and has a noticeable change in moisture content, becoming dryer.

1.4.4.5 Nature and Extent of Contamination

In general, widespread organic contamination was detected in the sediments of Brinson Creek and the lower portion of the surficial aquifer. Inorganic constituents were detected in the surficial aquifer and the upper portion of the Castle Hayne. To fully assess the nature and extent of groundwater contamination, data from the SGI groundwater screening and groundwater investigations were evaluated together.

Groundwater

The results of these investigations are presented by area to best address the project specific objectives. In the NAOC on the Onslow County property (northeast side of Brinson Creek) a total of seven groundwater samples were collected and analyzed for TCL VOCs.

On the NAOC Activity property southwest side of Brinson Creek, samples were collected from 32 temporary wells and eight permanent wells during groundwater screening activities. Results identified two contaminant plumes. A solvent-related plume appears to be centered around temporary well cluster 365-TW17 and is approximately 780-feet wide. Solvent-related contamination is predominant in the lower portion of the surficial aquifer. A fuel-related plume appears to be centered around temporary well cluster 35-TW23 and is approximately 265-feet wide. Fuel-related contamination is predominant in the upper portion of the surficial aquifer.

In the RI Study Area during Round 3, samples were collected from 20 existing monitoring wells and analyzed for TAL metals. In general, four metals (iron, manganese ,aluminum and antimony) were detected at levels that exceed regulatory limits.

During Round 4, samples were collected from 12 existing wells (8 intermediate and 4 shallow) located within the RI Study Area and analyzed for TCL VOCs. In general, the limits of solvent-related contamination in the lower portion of the surficial aquifer remained the same. The levels and limits of fuel-related contamination in the lower portion of the surficial aquifer appear to have changed. Due to the limited number of samples collected during the SGI from the upper portion of the surficial aquifer in the RI Study Area the limits of fuel and solvent related contamination in the upper portion cannot be drawn with an acceptable level of precision

To assess the limits of solvent-related groundwater contamination in the SAOC, groundwater samples were collected from 27 temporary wells and six permanent wells. The limits of solvent-related groundwater contamination in the lower portion of the surficial aquifer determined by the SGI are shown in Figure 1-14.

A single sample was collected from a well located in the SAOC that was installed into the upper portion of the Castle Hayne Aquifer and analyzed for VOCs. No contamination was detected in this sample.

Soil Screening Investigation

No fuel or solvent-related contamination was detected in any soil sample that was collected under the SGI.

Sediment Investigation

Two samples were collected from each of the ten sampling locations along Brinson Creek and analyzed for TPH, mercury and zinc. TPH contamination was detected at nine of the ten sampling locations. The highest levels of TPH contamination were located adjacent to and downstream of Site 35.

1.4.4.6 Baseline Human Health Risk Assessment

A human health risk assessment was conducted on SGI groundwater data collected in August ,1994 (metals) and August 1996 (VOCs). This BRA process evaluates the data generated during the sampling and analytical phase of the SGI to supplement the results of the original risk assessment conducted as part of the RI. COPC were chosen qualitatively (if detected it was included) for VOCs and quantitatively for inorganic data. The COPCs selected are shown in Tables 1-4 and 1-5. These values were then added to organic values from the RI replacing the original inorganic data. The exposure scenario was future adult and child via ingestion and dermal contact with groundwater.

As shown in the conclusions of the previous risk assessment, the elevated risk levels were associated with the future receptors and more specifically, future potential exposure to groundwater at Site 35. The carcinogenic risk drivers include arsenic and beryllium. The noncarcinogenic risk drivers include cis-1,2-dichloroethene, trichloroethene, benzene, antimony, arsenic, barium, chromium, cadmium, manganese, and vanadium. The initial RI recommended further groundwater sampling to assess the extent of the VOC plume. Also, it was recommended to resample groundwater using low-flow purge technique to remove high concentrations of metals due to sedimentation. The purpose of this risk assessment is to evaluate the potential risks from exposure to groundwater based on the most recent data.

The Round 4 VOC data were examined qualitatively in this supplemental BRA. All detected VOCs were chosen as qualitative COPCs. The detected concentrations of these compounds were generally lower than those detected in the first round. In addition, fewer VOCs were detected in this second round of data. The additional data suggests that the potential for adverse health effects to occur would not increase.

Carcinogenic and noncarcinogenic risks were calculated for the low-flow purge inorganic data. These values were added to the organic risk calculations from the initial BRA, replacing the inorganic data from the initial RI. The total groundwater ICR for future child residents ($1.4x10^{-4}$) and adult residents ($3.1x10^{-4}$) slightly exceeded the USEPA's upper bound risk range ($1x10^{-6}$ to $1x10^{-4}$). These elevated total ICR values were driven by the ingestion of trichloroethene and benzene (approximately 60 percent combined) in the groundwater. Arsenic contributed approximately 35 percent to the total ICR. It should be noted that arsenic is a naturally occurring element. In addition, there is no historical record of any use or disposal of arsenic at Site 35. When compared to the results of the previous risk assessment, the carcinogenic risk from groundwater was one order of magnitude less. Beryllium, the main driver of the previous carcinogenic risk calculations, was not detected in the supplemental investigation. As a result, the VOCs became the main contributors to the ICR value. These results are shown in Table 1-6.

The total groundwater HI values for the future child resident (48) and the future adult resident (21) exceeded unity. The ingestion pathway contributed over 90 percent to these elevated HI values. The total HI values for future adults and children are driven by benzene (approximately 37 percent) and trichloroethene (approximately 20 percent) from the RI organic data. The detected concentrations of VOCs from the initial investigation also drive the noncarcinogenic risk. These results are shown in Table 1-6.

1.4.4.7 Conclusions

Based on the data obtained under the SGI the following conclusions, presented by media, were as follows:

Groundwater

- Levels of iron and arsenic detected in samples collected from wells located in the RI Study Area and screened in the surficial aquifer create an unacceptable human health risk if consumed (groundwater in this area is not used as a potable supply).

- Based on the results of the qualitative risk assessment, Baker determined that solvent-related VOCs in the groundwater would result in a human health risk if the groundwater was consumed.

- Samples collected using a low-flow sampling technique yielded results with lower concentrations of metals than those obtained in the RI, indicating that suspended solids may have influenced the inorganic levels observed in the RI data.

- Elevated levels of metal constituents in groundwater are not atypical in the Camp Lejeune groundwater. Previous studies have determined that groundwater in the Camp Lejeune area is rich in iron and manganese; samples often exceed NCWQS of 300 and 50 ug/L, respectively. The preliminary conclusion of the draft report "Evaluation of Metals in Groundwater at MCB Lejeune, North, Carolina" (Baker, 1994b) generally supports the theory that concentrations of metals in groundwater are due to geologic conditions rather than site-related contamination.

- Specifically at Site 35, detections of aluminum, and manganese do not appear to emerge in a pattern that would suggest that an identifiable source exists. Elevated levels of iron were present in wells adjacent to areas where petroleum contaminated soil was identified. An available study indicates that elevated iron levels in groundwater can be associated with BTEX contamination (Becker, 1995).

- The limits of the solvent-related groundwater contamination in the lower portion of the surficial aquifer were identified to a location South of Fifth Street. In general this plume extends southward along "C" Street from Building G534 to the intersection of "C" and Sixth Street. The edge of the plume extends from this intersection across Camp Geiger to Building TC773 . At this point, the edge of the plume swings northward along the eastern tree line of Camp Geiger and continues north to Fifth Street.

- No fuel or solvent-related groundwater contamination was detected in samples collected in the NAOC on the northeast side of Brinson Creek. Therefore, fuel and solvent-related contamination apparently has not migrated off-site onto Onslow County property.

Soils

- No fuel or solvent-related contamination was detected during soil screening activities at Site 35. These results indicate that the spilled solvents and fuels have probably migrated into the saturated zone and are no longer acting as a continued source in the soil.

Sediment

- Fuel-related contamination is widespread in Brinson Creek sediments. Low levels of both gasoline and diesel fractions of the fuel-related contamination were detected in the sediments upstream of Site 35. This contamination may have been transported in part via storm runoff from U. S. Highway 17 and/or adjacent commercial property. Fuel-related contamination was detected in samples collected from all sediment sampling locations situated adjacent to and downstream of the former Fuel Farm. The highest diesel fraction was observed at sediment sampling station 35/SD06 located approximately 850 feet downstream of Site 35; the highest gasoline fraction was observed at sediment sampling station 35/SD04 located adjacent to Site 35. Therefore, previous operations most likely have contributed to fuel-related sediment contamination in Brinson Creek in areas adjacent to and downstream of the former Fuel Farm.

- Based on the analytical results and the lack of historical evidence that zinc or mercury was used at Site 35, it can be concluded that previous operations at Site 35 likely have not contributed to observed concentrations of mercury and zinc in Brinson Creek sediments.

1.4.4.8 Recommendations

No additional follow-up investigative actions were recommended following the SGI.

1.5 References

ATEC. 1992. Underground Storage Tank (UST) Site Check Investigation Report, Former Mess hall Heating Plant UST. Marine Corps Base, Camp Geiger, North Carolina.

Baker. 1994a. Baker Environmental Inc. Interim Remedial Action, Remedial Investigation/ Feasibility Study, Operable Unit No. 10, Site 35 - Camp Geiger Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1994b. Evaluation of Metals in Groundwater at MCB, Camp Lejeune, North Carolina.

Baker. 1995a. Remedial Investigation Report, Operable Unit No. 10, Site 35, Camp Geiger Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1995b. Record of Decision (ROD) for Surficial Groundwater for a Portion of Operable Unit No. 10. Camp Geiger Area Fuel Farm. Marine Corps Base Camp Lejeune, North Carolina.

Baker. 1995c. Interim Feasibility Study for Shallow Groundwater in the Vicinity of the Former Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1996a. Supplemental Groundwater Investigation (SGI) Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1996b. Phase I Site Investigation Report, Operable Unit No. 16, Sites 89 and 93.

Baker. 1996c. Treatability Study Work Plan, Pilot-Scale Evaluation of In-Situ Air Sparging. Marine Corps Base, Camp Lejeune, North Carolina.

Cardinell, Alex P., et al, 1993. Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina. U.S. Geological Survey, Water-Resources Investigation Report 93-4049.

ESE, 1990. Final Site Summary Report, MCB Camp Lejeune. ESE Project No. 49-02036, September 1990.

Harned, Douglas A., et al, 1989. Assessment of Hydrologic and Hydrogeologic Data at Camp Lejeune Marine Corps Base, North Carolina. U.S. Geological Survey, Water-Resources Investigations Report 89-4096.

Law. 1992. Final Report, Underground Fuel Investigation and Comprehensive site Assessment. Camp Geiger Fuel Farm. Marine Corps Base, Camp Lejeune North Carolina.

Law. 1993. Addendum to Report of Underground Fuel Investigation and Comprehensive site Assessment. Camp Geiger Fuel Farm, Marine Corps Base, Camp Lejeune, North Carolina.

Law. 1994. Leaking underground Storage Tan Site Assessment Report, Building TC-341. Marine Corps Base Camp Lejeune, North Carolina.

NUS. 1990. Draft Field Investigation/Focused Feasibility Study Camp Geiger Fuel Spill Site, Marine Corps Base, Camp Lejeune, North Carolina.

USEPA. 1993. Region III Contaminants of Concern (COC) Screening Criteria Table.

USEPA. 1996. United States Environmental Protection Agency. Region III Risk-Based Concentration Table. Philadelphia, Pennsylvania. January - June, 1996.

Water and Air Research, Inc. 1983. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity.

SECTION 1.0 TABLES

TABLE 1-1

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN FROM RI
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Ground-water		Surface Water		Sediment		Fish	
VOCs												
Acetone				X						X	•	X
1,1,2,2-Tetrachloroethane						X						
Chloroform						X						
Methylene Chloride				X								X
1,1,2-Trichloroethane						X						
1,1-Dichloroethane						X						
1,1-Dichloroethene					•	X						
2-butanone												X
Benzene					•	X						
Carbon disulfide		X										X
cis-1,2-Dichloroethene					•	X						
Ethylbenzene					•	X						
Methyl Tertiary Butyl Ether					•	X						
Tetrachloroethene				X		X						
Toluene		X			•	X				X		X
trans-1,2-Dichloroethene					•	X						
Trichloroethene					•	X						
Xylenes (Total)		X			•	X						
SVOCs												
Benzo(a) pyrene		X										
Indeno(1,2,3-cd) pyrene		X										
Dibenz(a,h) anthracene		X										
Benzo(g.h,i) perylene	•	X										
4-Methylphenol						X						
2,4-Dimethylphenol						X						
Naphthalene					•	X						
Dibenzofuran					•	X						
Fluorene						X						
Anthracene						X						
Carbazole						X						
Diethylphthalate									•	X		
Di-n-butylphthalate										X		

TABLE 1-1 (Continued)

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN FROM RI
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Ground-water		Surface Water		Sediment		Fish	
Bis(2-ethylhexyl)phthalate		X								X		
Phenol		X				X						
2-Methylnaphthalene					•	X						
2-Methylphenol						X						
Acenaphthene		X										
Phenanthene	•	X			•	X						
Carbazole		X										
Fluoranthene		X										
Pyrene		X		X								
Butylbenzlphthalate		X										
Benzo(a)anthracene		X										
Chrysene		X										
Benzo(b) fluoranthene	•	X	•	X								
Pesticides												
Aldrin						X						X
gamma-BHC												X
alpha-Chlordane		X							•	X	•	X
beta-BHC		X				X				X	•	X
Dieldrin	•	X							•	X	•	X
Endosulfan II	•	X							•	X	•	X
Endrin Ketone	•	X							•	X	•	X
Endrin Aldehyde	•	X							•	X	•	X
Endrin		X							•	X	•	X
delta-BHC					•	X				X		X
gamma-Chlordane		X							•	X		
Heptachlor					•	X				X	•	X
Heptachlor Epoxide									•	X		X
Methoxychlor									•	X		
4,4'-DDE		X							•	X	•	X
4,4'-DDT		X				X			•	X	•	X
4,4'-DDD	•	X				X			•	X	•	X
Inorganics												
Aluminum		X		X		X		X		X	•	X
Antimony		X			•	X	•	X				
Arsenic	•	X	•	X	•	X	•	X	•	X		
Barium		X		X	•	X		X	•	X	•	X
Beryllium		X			•	X			•	X		
Cadmium		X		X	•	X						X

TABLE 1-1 (Continued)

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN FROM RI
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Ground-water		Surface Water		Sediment		Fish	
Calcium		X		X		X		X		X		
Chromium		X		X	●	X	●	X	●	X		
Cobalt		X		X	●	X	●	X	●	X		
Copper		X		X		X			●	X	●	X
Lead	●	X	●	X	●	X	●	X	●	X	●	X
Magnesium		X		X		X		X		X		
Manganese	●	X		X	●	X	●	X	●	X	●	X
Mercury						X	●	X		X	●	X
Nickel		X		X	●	X			●	X		
Potassium				X		X		X		X		
Selenium		X		X		X		X	●	X	●	X
Silver				X	●	X						
Sodium						X		X		X		
Thallium		X	●	X	●	X	●	X	●	X		
Vanadium		X		X	●	X	●	X	●	X		
Zinc		X		X	●	X	●	X	●	X	●	X
Iron		X		X		X		X		X		

● Selected as COPC.
X Positively detected in media.

TABLE 1-2

TOTAL SITE RISK DETERMINED BY RI
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptors	Soil		Groundwater		Surface Water		Sediment		Fish		TOTALS	
	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Future Child Resident	4.5E-05 (<1)	0.93 (1)	2.1E-03 (99)	103 (99)	NA	NA	NA	NA	NA	NA	2.1E-03	104
Future Adult Resident	2.7E-05 (<1)	0.10 (<1)	4.3E-03 (99)	44 (99)	NA	NA	NA	NA	NA	NA	4.3E-03	44
Future Construction Worker	1.2E-07 (100)	0.02 (100)	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-07	0.02
Current Military Personnel	3.1E-06 (100)	0.09 (100)	NA	NA	NA	NA	NA	NA	NA	NA	3.1E-06	0.09
Current Recreational Child	NA	NA	NA	NA	1.1E-07 (27)	<0.01 (<1)	3.3E-07 (73)	0.01 (99)	NA	NA	4.4E-07	0.01
Current Recreational Adult	NA	NA	NA	NA	1.2E-07 (<1)	<0.01 (<1)	4.5E-07 (<1)	<0.01 (<1)	1.8E-05 (99)	1.8 (99)	1.9E-05	1.8

Notes:

ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
ND = Not Determined
NA = Not Applicable
( ) = Percent Contribution to Total Risk

TABLE 1-3

**ORGANIC COCs THAT EXCEED REMEDIATION LEVELS
DETERMINED DURING THE STE 35 INTERIM FEASIBILITY STUDY
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB CAMP LEJEUNE, NORTH CAROLINA**

Contaminant of Concern	RL[(1,2)]
Benzene	1
Trichloroethene	2.8
cis-1,2-Dichloroethene	70
trans-1,2-Dichloroethene	70
Ethyl Benzene	29
Methyl Tertiary Butyl Ether	200
Xylenes	530

Notes:

(1) RL = Remediation Level
(2) Groundwater RLs expressed as ug/L (ppb)

TABLE 1-4

VOC GROUNDWATER DATA AND COPC SELECTION SUMMARY FROM THE SUPPLEMENTAL GROUNDWATER INVESTIGATION OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM FEASIBILITY STUDY, CTO-0232 MCB, CAMP LEJEUNE, NORTH CAROLINA

Compound	Groundwater Criteria					Frequency/Range		Comparison to Criteria				
	NCWQS[1] (µg/L)	MCL[2] (µg/L)	Region III Tapwater COC Value[3] (µg/L)	Federal Health Advisories[4] (µg/L)		No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above COC	No. of Detects Above Health Advisories	
				10 kg Child	70 kg Adult						10 kg Child	70 kg Adult
Volatiles:												
Vinyl Chloride*	0.015	2	0.019	10	50	1/30	13	1	1	1	1	0
Acetone	700	NE	370	NE	NE	1/30	66J	0	NA	0	NA	NA
1,1-Dichloroethene*	7	7	0.044	1,000	4,000	3/30	4J - 6J	0	0	3	0	0
1,1-Dichloroethane*	700	NE	81	NE	NE	2/30	3J - 4J	0	NA	0	NA	NA
1,2-Dichloroethene (Total)	NE	70	5.5	3,000	11,000	18/30	2J - 1,200	NA	6	15	0	0
Trichloroethene*	2.8	5	1.6	NE	NE	12/30	4J - 740	12	11	12	NA	NA
Benzene*	1	5	0.36	NE	NE	4/30	2J - 4J	4	0	4	NA	NA
Tetrachloroethene*	0.7	5	1.1	1,000	5,000	1/30	2J	1	0	1	0	0
1,1,2,2-Tetrachloroethane*	NE	NE	0.052	NE	NE	2/30	17J - 23	NA	NA	2	NA	NA
Toluene*	1,000	1,000	75	2,000	7,000	2/30	2J - 4J	0	0	0	0	0

Notes:

(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) USEPA Region III Contaminants of Concern (COC) Screening Criteria Table (1993, 1996)
(4) Longer Term Health Advisories for a 10 kg Child and 70 kg Adult
NE - No Criteria Established
NA - Not Applicable
J - Estimated Value
* Retained as COPC

TABLE 1-5

INORGANIC GROUNDWATER DATA AND COPC SELECTION SUMMARY
FROM THE SUPPLEMENTAL GROUNDWATER INVESTIGATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	Groundwater Criteria					Frequency/Range		Comparison to Criteria				
	NCWQS[1] (µg/L)	MCL[2] (µg/L)	Region III Tapwater COC Value[3] (µg/L)	Federal Health Advisories[4] (µg/L) 10 kg Child	Federal Health Advisories[4] (µg/L) 70 kg Adult	No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above COC	No. of Detects Above Health Advisories 10 kg Child	No. of Detects Above Health Advisories 70 kg Adult
Aluminum	NE	50/200[5]	3,700	NE	NE	12/20	22.6J-520	NA	7/4	0	NA	NA
Antimony	NE	6	1.5	10	15	1/20	20J	NA	1	1	1	1
Arsenic*	50	50	0.045	NE	NE	7/20	3.2J-13.3	0	0	7	NA	NA
Barium	2,000	2,000	260	NE	NE	9/20	20.9J-98.4J	0	0	0	NA	NA
Calcium+	NE	NE	NE	NE	NE	20/20	6,380-142,000	NA	NA	NA	NA	NA
Cobalt	NE	NE	220	NE	NE	10/20	2.2J-16J	NA	NA	0	NA	NA
Iron*	300	300[5]	1,100	NE	NE	20/20	58.4J-40,400	14	14	10	NA	NA
Lead	15	15[6]	NE	NE	NE	8/20	1-15.4	1	1	NA	NA	NA
Magnesium+	NE	NE	NE	NE	NE	20/20	1,550J-4,990J	NA	NA	NA	NA	NA
Manganese*	50	50[5]	180	NE	NE	20/20	7.5J-275	5	5	1	NA	NA
Potassium+	NE	NE	NE	NE	NE	20/20	728J-4,400	NA	NA	NA	NA	NA
Selenium	50	50	18	NE	NE	2/20	2.6J-3.4J	0	0	0	NA	NA
Silver	18	NE	18	200	200	1/20	10.9	0	NA	0	0	0
Sodium+	NE	NE	NE	NE	NE	20/20	4,350J-31,900	NA	NA	NA	NA	NA

TABLE 1-5 (Continued)

INORGANIC GROUNDWATER DATA AND COPC SELECTION SUMMARY
FROM THE SUPPLEMENTAL GROUNDWATER INVESTIGATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	Groundwater Criteria					Frequency/Range		Comparison to Criteria				
	NCWQS[1] (µg/L)	MCL[2] (µg/L)	Region III Tapwater COC Value[3] (µg/L)	Federal Health Advisories[4] (µg/L) 10 kg Child	Federal Health Advisories[4] (µg/L) 70 kg Adult	No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above COC	No. of Detects Above Health Advisories 10 kg Child	No. of Detects Above Health Advisories 70 kg Adult
Thallium*	NE	2	0.29	7	20	3/20	0.7J-1	NA	0	3	0	0
Vanadium	NE	NE	26	NE	NE	2/20	5.5J-9.1J	NA	NA	0	NA	NA
Zinc	2,100	5,000[5]	1,100	3,000	10,000	11/20	6.5J-29.5	0	0	0	0	0

Notes:

Shaded areas indicate parameter selected as COPC.
(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) USEPA Region III Contaminants of Concern (COC) Screening Criteria Table (1993, 1996)
(4) Longer Term Health Advisories for a 10 kg Child and 70 kg Adult
(5) SMCL = Secondary Maximum Contaminant Level
(6) Action Level for drinking water.
+ - Essential Nutrient
NE - No Criteria Established
NA - Not Applicable
J - Estimated Value
* Retained as COPC

TABLE 1-6

TOTAL SITE GROUNDWATER RISK DETERMINED IN THE SUPPLEMENTAL GROUNDWATER INVESTIGATION OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM FEASIBILITY STUDY, CTO-0232 MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptors	Rounds 2 and 3 Organics Groundwater		Low-Flow Purge Sampling Inorganics Groundwater		Total Groundwater Risk	
	ICR	HI	ICR	HI	ICR	HI
Future Child Resident	$9.1x10^{-5}$ (65)	37 (77)	$5.2x10^{-5}$ (35)	11 (23)	$1.4x10^{-4}$	48
Future Adult Resident	$2.0x10^{-4}$ (65)	16 (77)	$1.1x10^{-4}$ (35)	4.7 (23)	$3.1x10^{-4}$	21

Notes:

ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
( ) = Percent contribution to total risk

SECTION 1.0 FIGURES

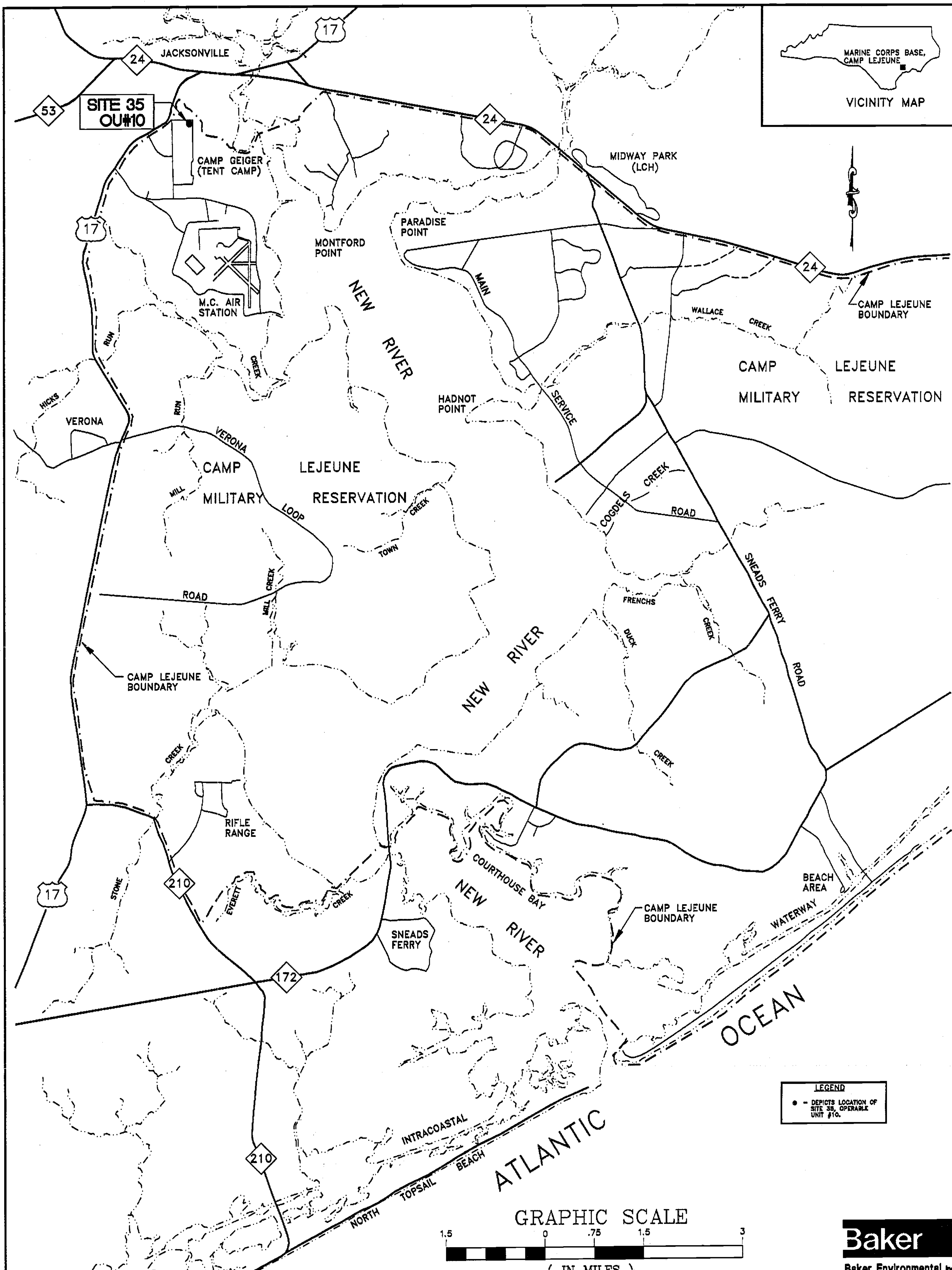
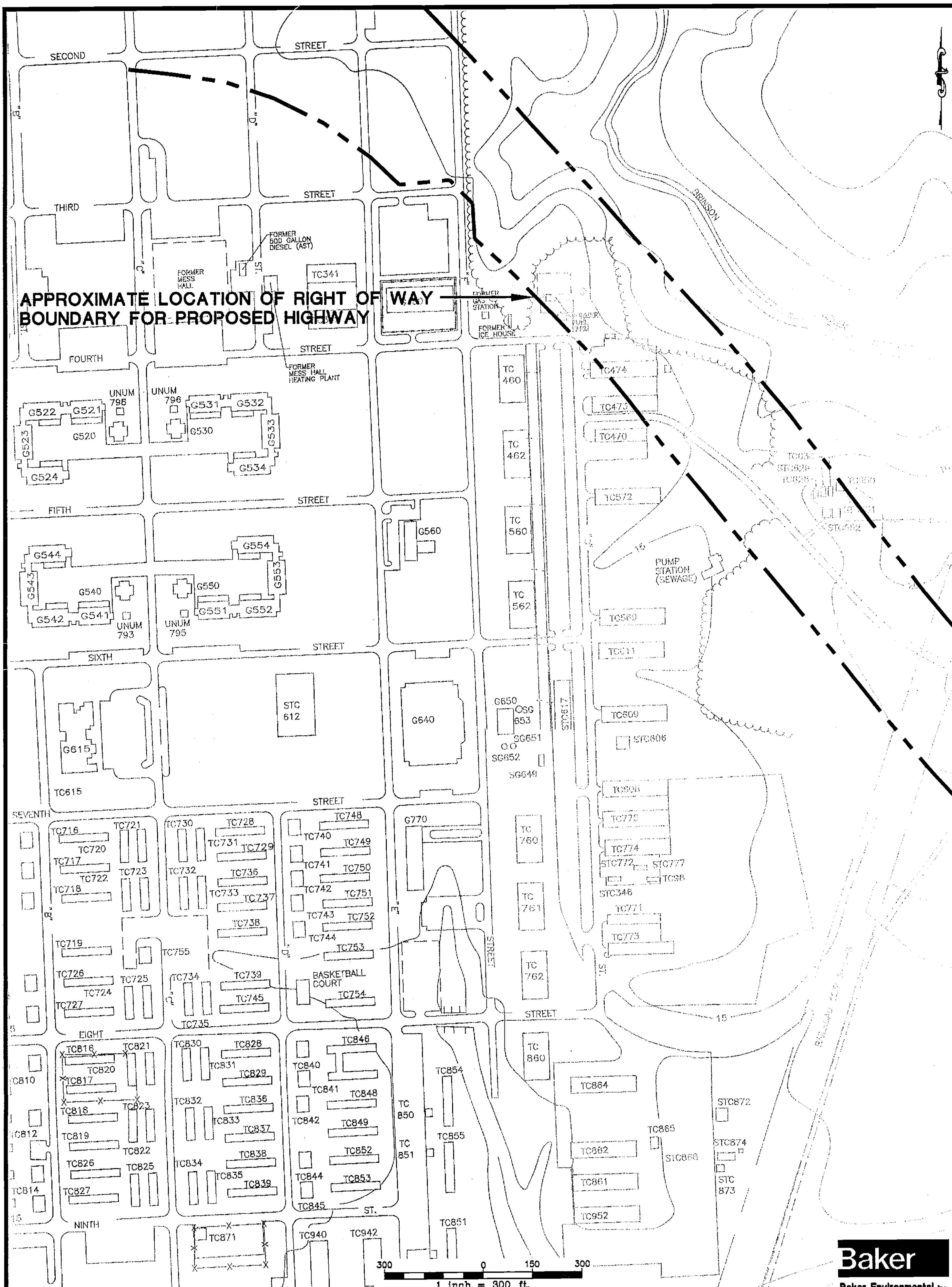


FIGURE 1-1
CAMP LEJEUNE AND SITE 35
LOCATION MAP
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02354GGB12

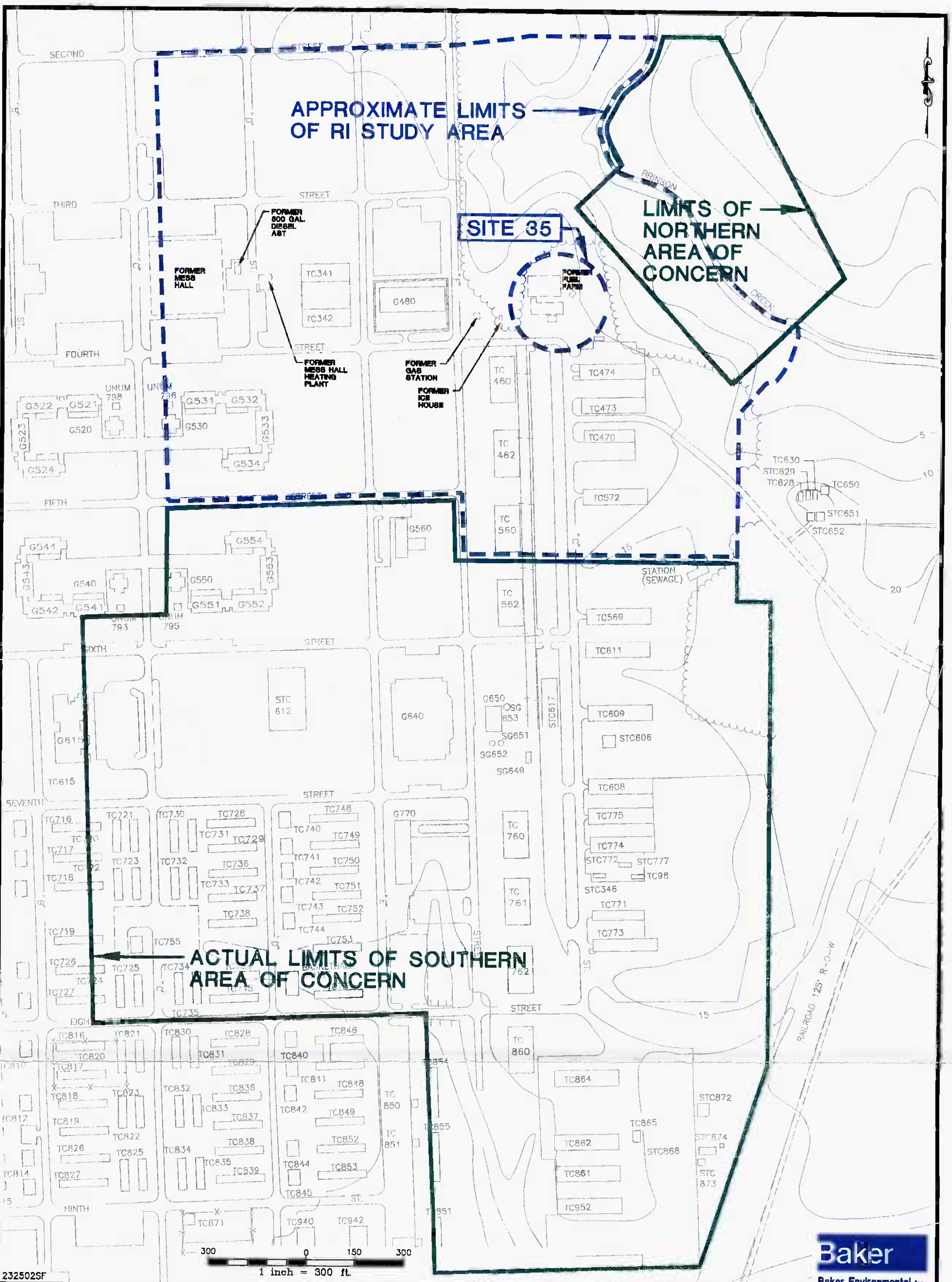


LEGEND

- — 10 — – SURFACE ELEVATION CONTOUR
- —x— – FENCE
- ▭ – STRUCTURE
- ︶︶︶ – TREE LINE
- ▬ ▬ ▬ – APPROXIMATE LIMITS OF U.S. HIGHWAY 17 BYPASS

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-2
LOCATION OF PROPOSED HIGHWAY RIGHT-OF-WAY
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



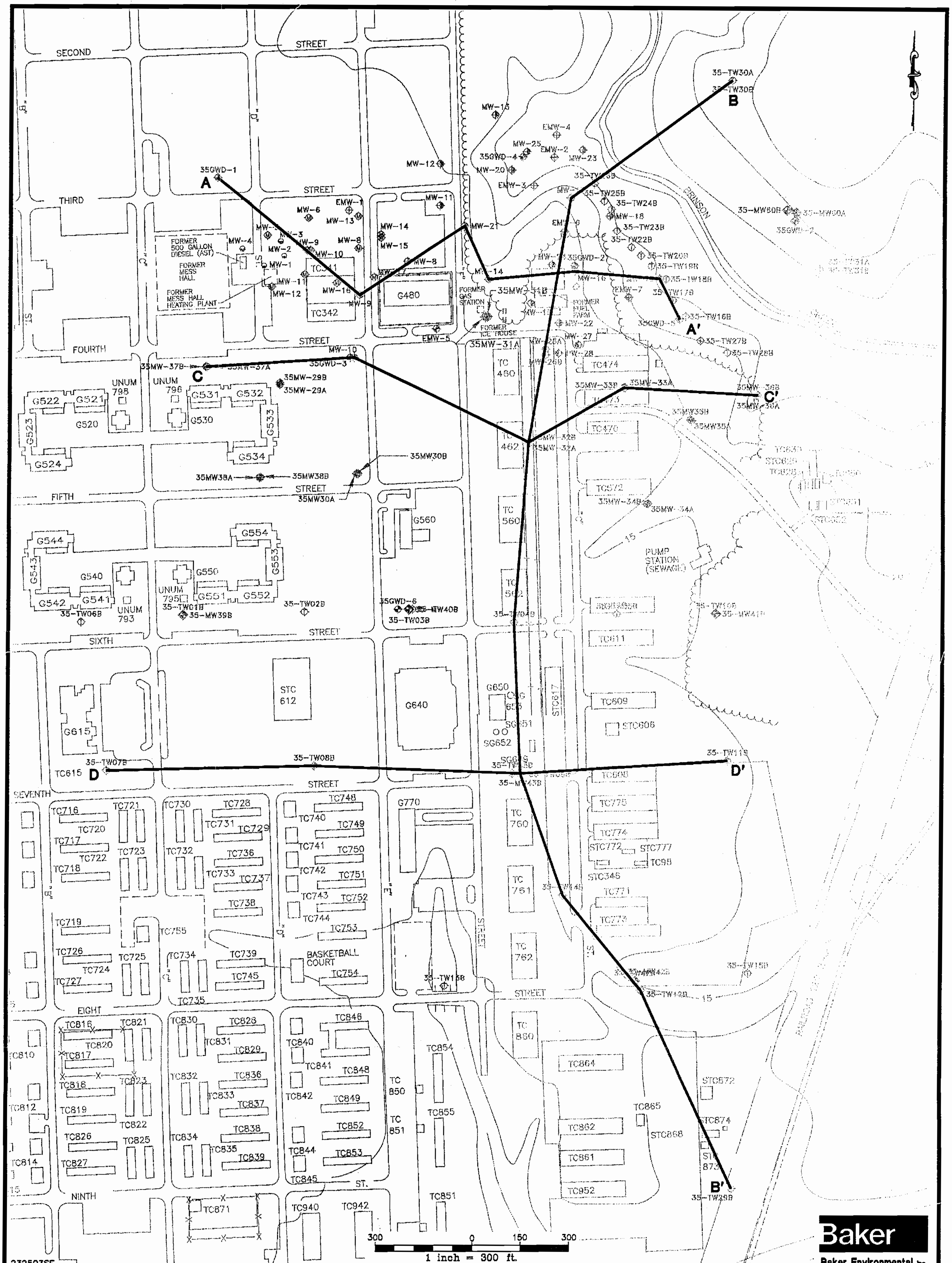
LEGEND

- SURFACE ELEVATION CONTOUR
- FENCE
- STRUCTURE
- TREE LINE
- ABANDONED RAILROAD
- UNIMPROVED ROAD/ PARKING LOT
- EDGE OF PAVEMENT

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-3
SITE PLAN
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

A ——— A' - CROSS SECTION

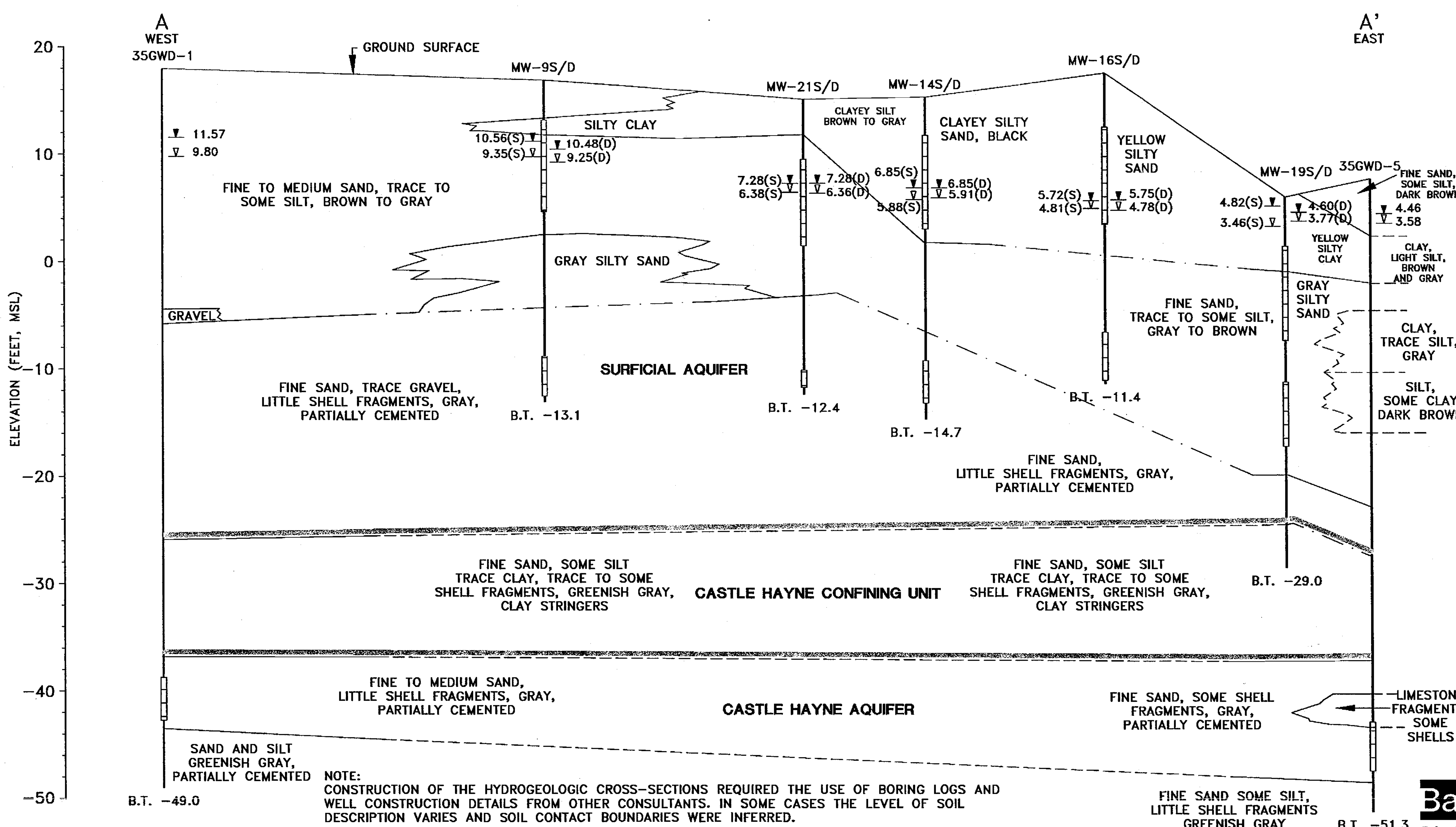
SOURCE: LANTDIV, OCT. 1991

FIGURE 1-4
CROSS SECTION LOCATION MAP
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02354GGB22

232504SF



NOTE:
CONSTRUCTION OF THE HYDROGEOLOGIC CROSS-SECTIONS REQUIRED THE USE OF BORING LOGS AND WELL CONSTRUCTION DETAILS FROM OTHER CONSULTANTS. IN SOME CASES THE LEVEL OF SOIL DESCRIPTION VARIES AND SOIL CONTACT BOUNDARIES WERE INFERRED.

Baker
Baker Environmental, Inc.

LEGEND

10.48	GROUNDWATER ELEVATION COLLECTED ON 9-9-94 (MSL)
9.25	GROUNDWATER ELEVATION COLLECTED ON 7-20-94 (MSL)
B.T. -49.0'	BORING TERMINATED, ELEVATION MSL
	WELL SCREEN INTERVAL
— · —	INFERRED SOIL CONTACT
———	ESTIMATED SOIL CONTACT
— — —	PROJECTED SOIL CONTACT
	HYDROGEOLOGIC UNIT BOUNDARY

160 0 80 160 320

Horizontal Scale: 1 inch = 160 ft.

10 0 5 10 20

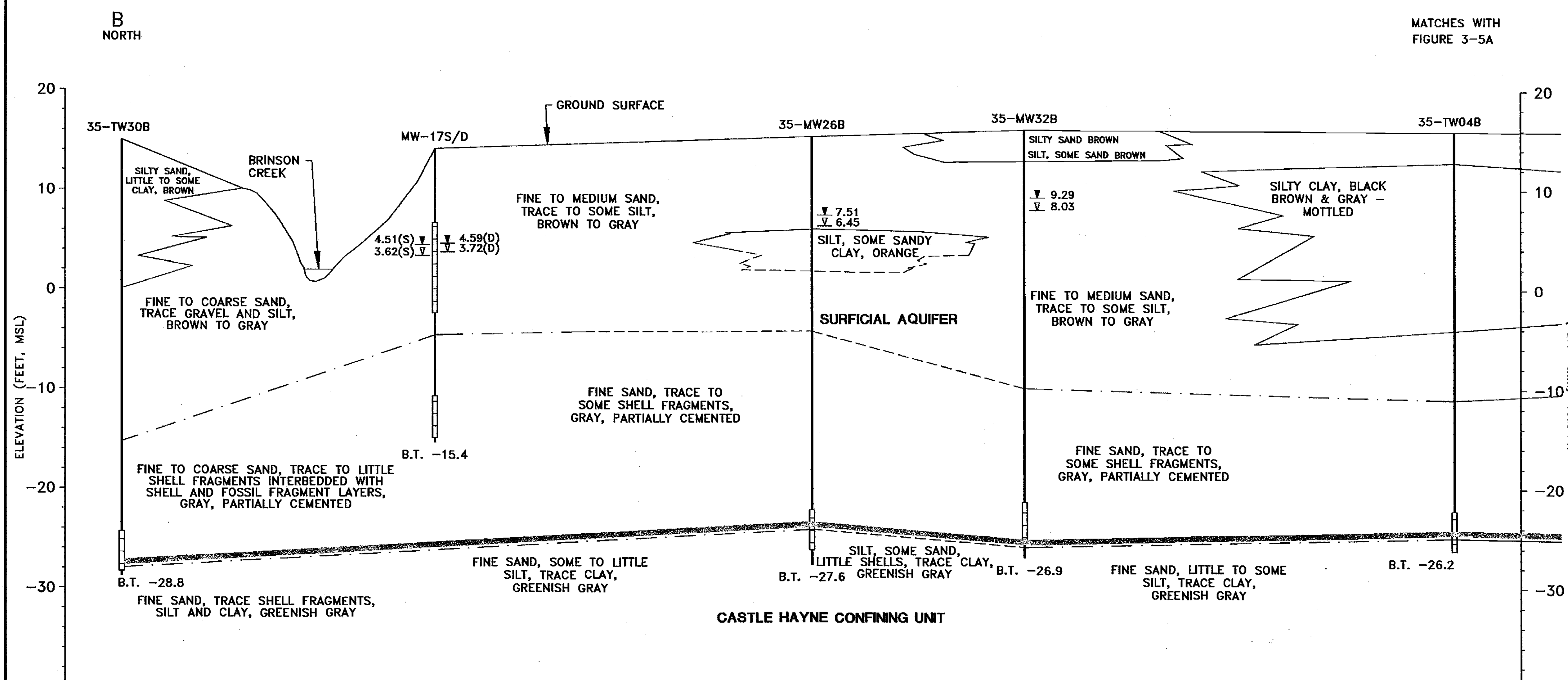
Vertical Scale: 1 inch = 10 ft.

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

FIGURE 1-5
HYDROGEOLOGIC CROSS-SECTION A-A'
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

232505SF



NOTE:
CONSTRUCTION OF THE HYDROGEOLOGIC CROSS-SECTIONS REQUIRED THE USE OF BORING LOGS AND WELL CONSTRUCTION DETAILS FROM OTHER CONSULTANTS. IN SOME CASES THE LEVEL OF SOIL DESCRIPTION VARIES AND SOIL CONTACT BOUNDARIES WERE INFERRED.

Baker
Baker Environmental, Inc.

LEGEND

- 5.22 GROUNDWATER ELEVATION COLLECTED ON 9-9-94 (MSL)
- 4.30 GROUNDWATER ELEVATION COLLECTED ON 7-20-94 (MSL)
- B.T. -42.1' BORING TERMINATED, ELEVATION MSL
- WELL SCREEN INTERVAL
- INFERRED SOIL CONTACT
- ESTIMATED SOIL CONTACT
- PROJECTED SOIL CONTACT
- HYDROGEOLOGIC UNIT BOUNDARY

130 0 65 130 260
Horizontal Scale: 1 inch = 130 ft.

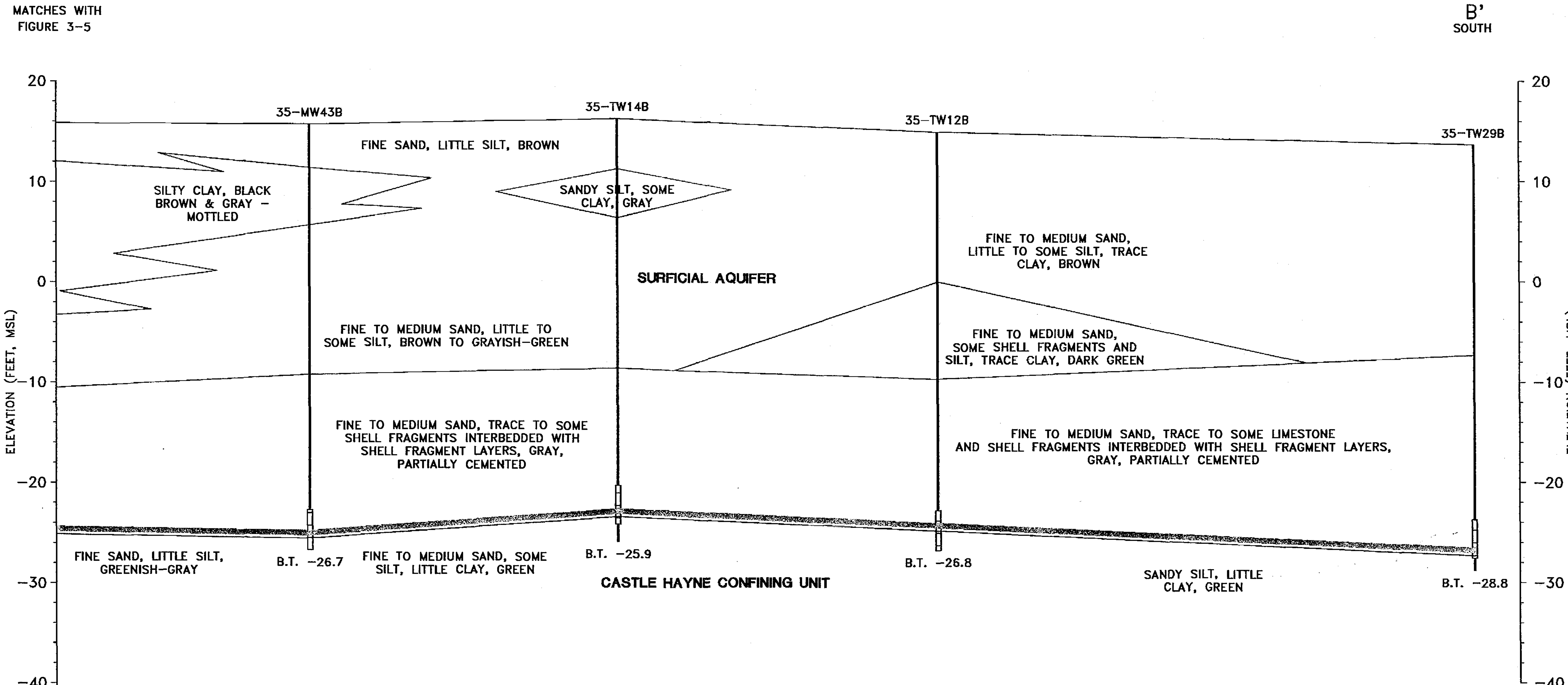
10 0 5 10 20
Vertical Scale: 1 inch = 10 ft.

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

FIGURE 1-6
HYDROGEOLOGIC CROSS-SECTION B-B'
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

232506SF



NOTE:
CONSTRUCTION OF THE HYDROGEOLOGIC CROSS-SECTIONS REQUIRED THE USE OF BORING LOGS AND WELL CONSTRUCTION DETAILS FROM OTHER CONSULTANTS. IN SOME CASES THE LEVEL OF SOIL DESCRIPTION VARIES AND SOIL CONTACT BOUNDARIES WERE INFERRED.

Baker
Baker Environmental, Inc.

LEGEND

- 5.22 GROUNDWATER ELEVATION COLLECTED ON 9-9-94 (MSL)
- 4.30 GROUNDWATER ELEVATION COLLECTED ON 7-20-94 (MSL)
- B.T. -42.1' BORING TERMINATED, ELEVATION MSL
- WELL SCREEN INTERVAL
- INFERRED SOIL CONTACT
- ESTIMATED SOIL CONTACT
- PROJECTED SOIL CONTACT
- HYDROGEOLOGIC UNIT BOUNDARY

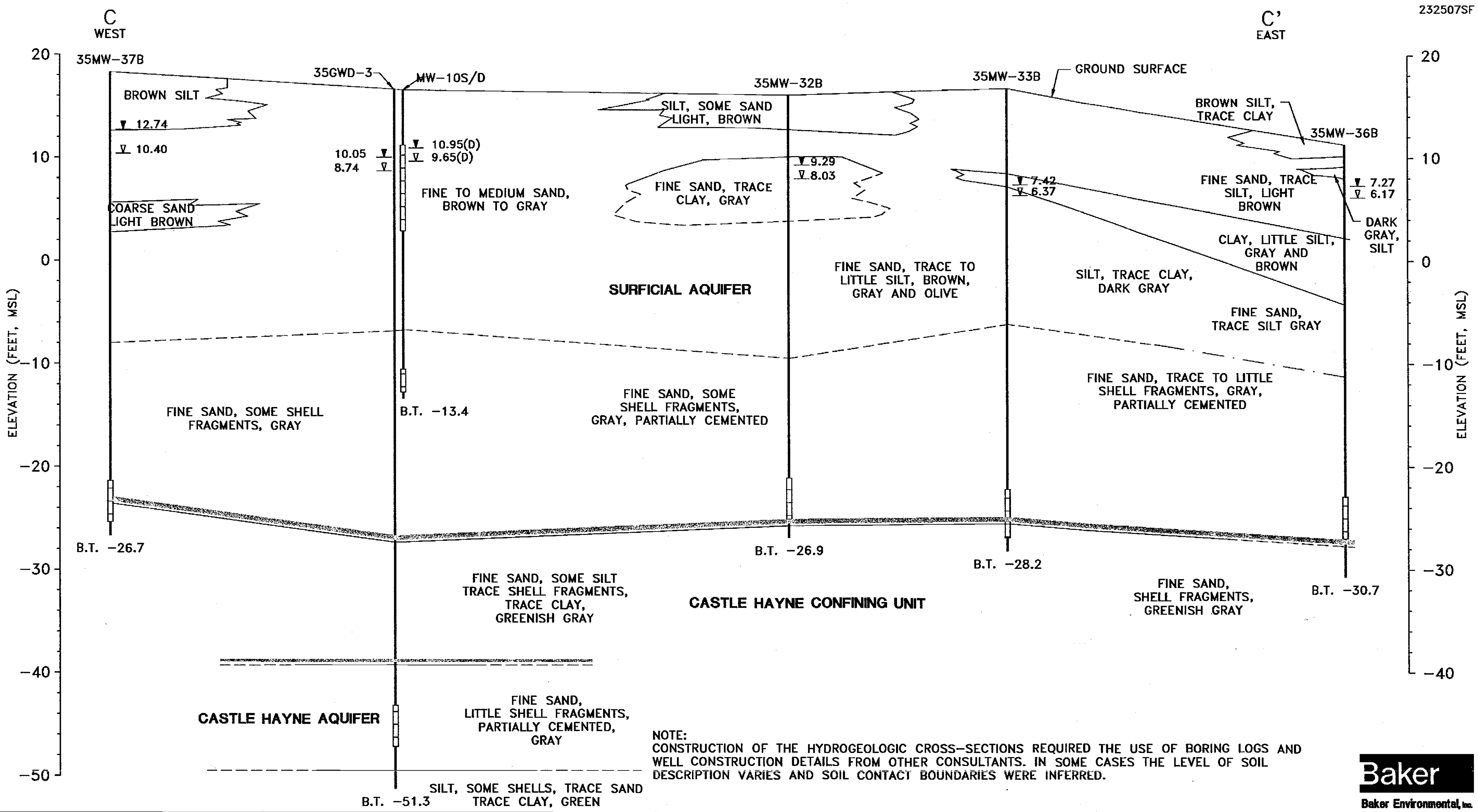
130 0 65 130 260
Horizontal Scale: 1 inch = 130 ft.

10 0 5 10 20
Vertical Scale: 1 inch = 10 ft.

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

FIGURE 1-6A
HYDROGEOLOGIC CROSS-SECTION B-B'
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

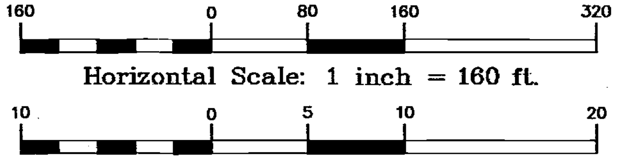


NOTE:
CONSTRUCTION OF THE HYDROGEOLOGIC CROSS-SECTIONS REQUIRED THE USE OF BORING LOGS AND WELL CONSTRUCTION DETAILS FROM OTHER CONSULTANTS. IN SOME CASES THE LEVEL OF SOIL DESCRIPTION VARIES AND SOIL CONTACT BOUNDARIES WERE INFERRED.

Baker
Baker Environmental, Inc.

LEGEND

12.74	GROUNDWATER ELEVATION COLLECTED ON 9-9-94 (MSL)
10.40	GROUNDWATER ELEVATION COLLECTED ON 7-20-94 (MSL)
B.T. -26.7'	BORING TERMINATED, ELEVATION MSL
	WELL SCREEN INTERVAL
— · —	INFERRED SOIL CONTACT
———	ESTIMATED SOIL CONTACT
— — —	PROJECTED SOIL CONTACT
	HYDROGEOLOGIC UNIT BOUNDARY



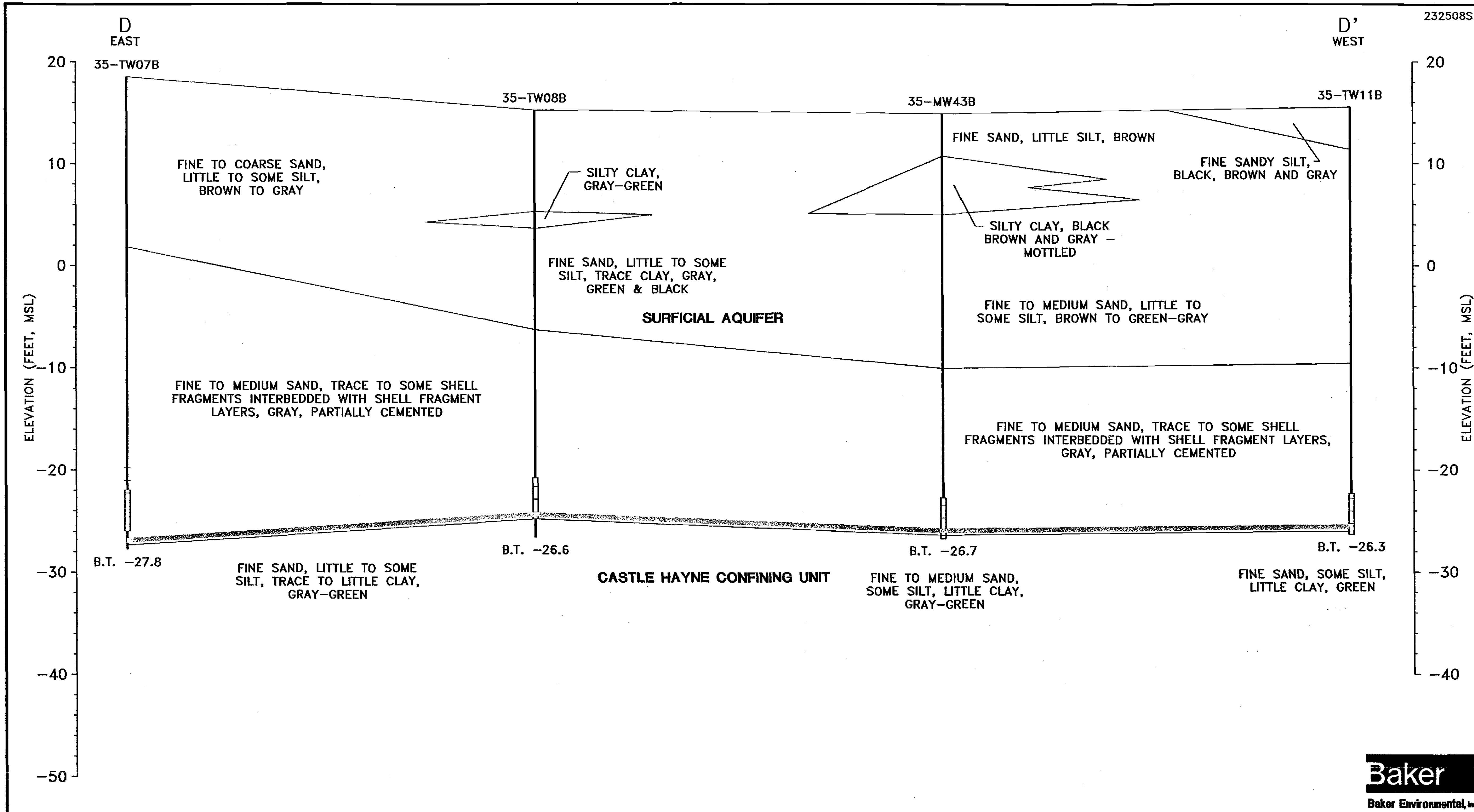
Horizontal Scale: 1 inch = 160 ft.

Vertical Scale: 1 inch = 10 ft.

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

FIGURE 1-7
HYDROGEOLOGIC CROSS-SECTION C-C'
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

LEGEND

B.T. -26.7'	BORING TERMINATED, ELEVATION MSL
	WELL SCREEN INTERVAL
— · —	INFERRED SOIL CONTACT
——	ESTIMATED SOIL CONTACT
— — —	PROJECTED SOIL CONTACT
▬	HYDROGEOLOGIC UNIT BOUNDARY

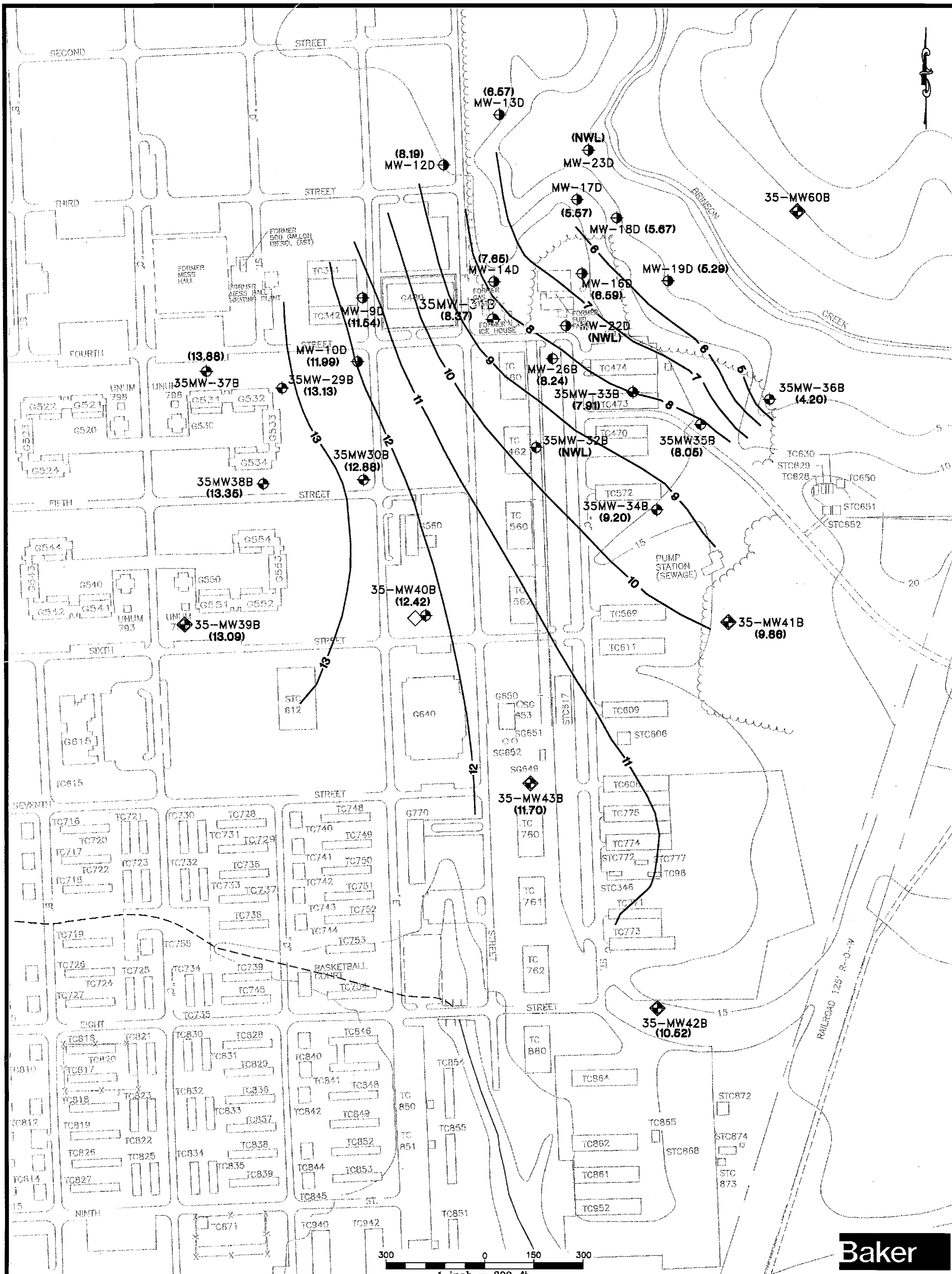
160 0 80 160 320
Horizontal Scale: 1 inch = 160 ft.

10 0 5 10 20
Vertical Scale: 1 inch = 10 ft.

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

FIGURE 1-8
HYDROGEOLOGIC CROSS-SECTION D-D'
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
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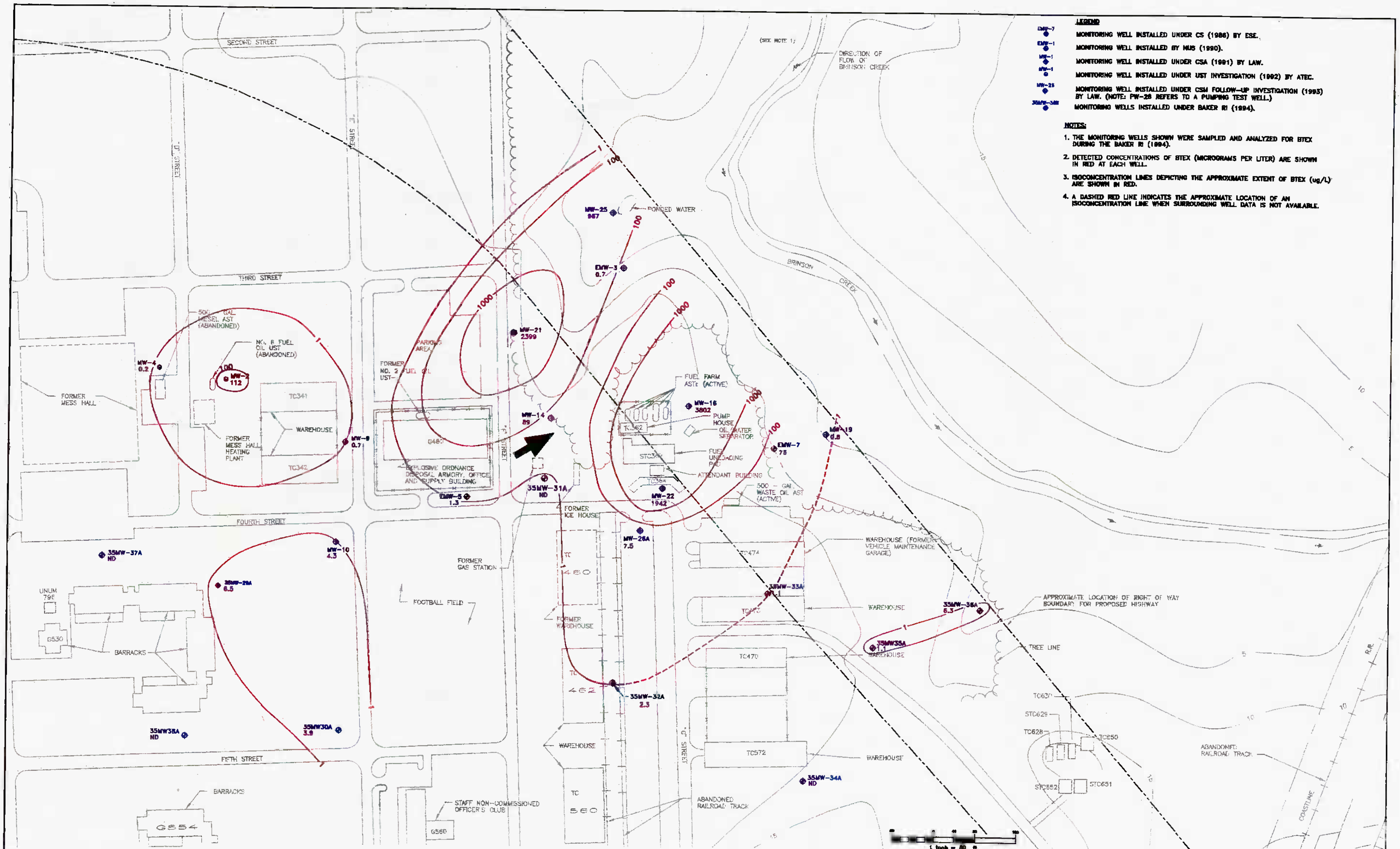
35MW-38B (13.35)	MONITORING WELL WITH STATIC WATER ELEVATION (FT ABOVE MSL).
(NWL)	NO WATER LEVEL MEASUREMENT OBTAINED.
—— 10 ——	GROUNDWATER EQUAL POTENTIAL CONTOUR.
————	EDWARDS CREEK
– – – – – –	(UNDERGROUND) EDWARDS CREEK

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-9
GROUNDWATER ELEVATION CONTOURS FOR THE SURFICIAL AQUIFER
(JULY 29, 1996)
SITE 35, CAMP GEIGER FUEL FARM FS
CONTRACT TASK ORDER – 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- FENCE LINE
- CONTOUR LINES DEPICTING SURFICIAL RELIEF
- ISOCONCENTRATION LIMITS OF COMBINED BTEX
- APPROXIMATE LOCATION OF RIGHT OF WAY BOUNDARY FOR PROPOSED HIGHWAY
- APPROXIMATE GROUNDWATER FLOW DIRECTION

DATE	JANUARY 1997
SCALE	1" = 80'
DRAWN	WJH
REVIEWED	JSC
S.O.#	62470-232-0000-07000
CADD#	2325105F

NORTH

SITE 35, CAMP GEIGER AREA FUEL FARM FS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

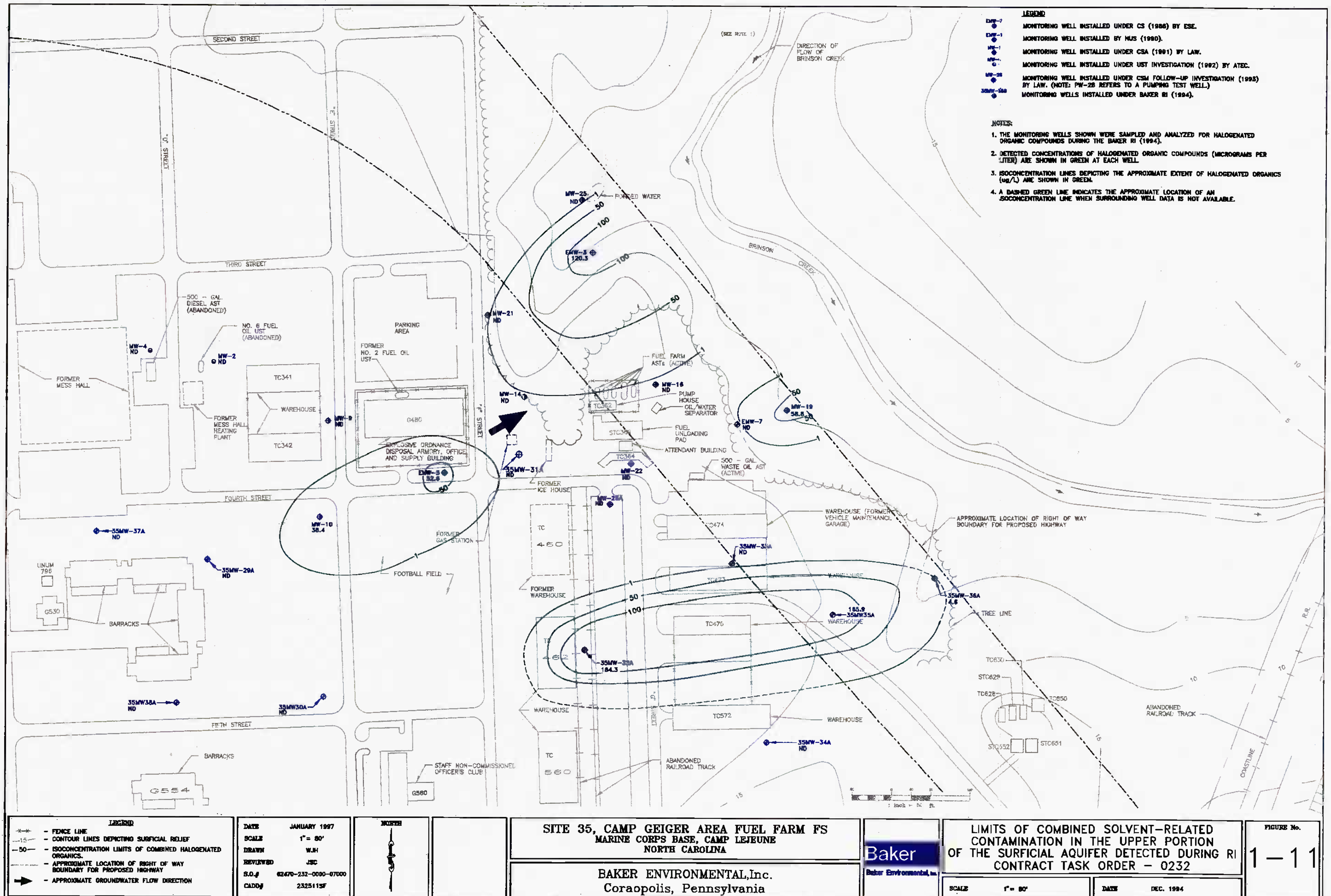
Baker
Baker Environmental, Inc.

LIMITS OF COMBINED FUEL-RELATED CONTAMINATION IN THE UPPER PORTION OF THE SURFICIAL AQUIFER DETECTED DURING RI
CONTRACT TASK ORDER - 0232

SCALE 1" = 80' DATE JANUARY 1997

FIGURE No.
1-10

02354GGB3Y



DATE	JANUARY 1997
SCALE	1" = 80'
DRAWN	W.H
REVIEWED	JSC
S.O.#	62470-232-0000-07000
CADD#	2325115F

SITE 35, CAMP GEIGER AREA FUEL FARM FS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

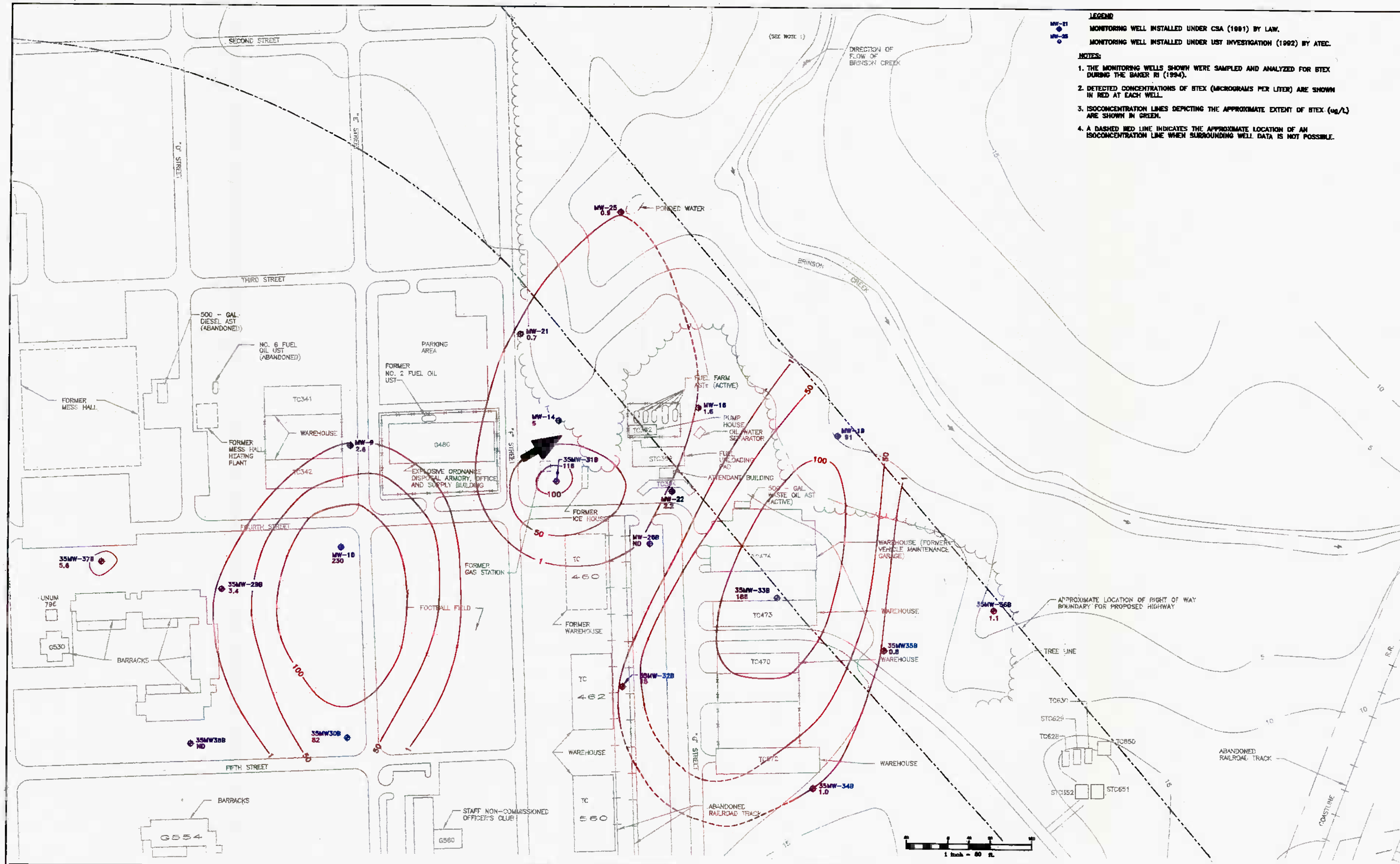
BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

LIMITS OF COMBINED SOLVENT-RELATED CONTAMINATION IN THE UPPER PORTION OF THE SURFICIAL AQUIFER DETECTED DURING RI CONTRACT TASK ORDER - 0232

SCALE 1" = 80' DATE DEC. 1994

FIGURE No. 1-11



LEGEND

- FENCE LINE
- CONTOUR LINES DEPICTING SURFICIAL RELIEF
- ISOCONCENTRATION LIMITS OF COMBINED BTEX
- APPROXIMATE LOCATION OF RIGHT OF WAY BOUNDARY FOR PROPOSED HIGHWAY
- APPROXIMATE GROUNDWATER FLOW DIRECTION

DATE	JANUARY 1997
SCALE	1" = 80'
DRAWN	WJH
REVIEWED	JSC
S.O.#	62470-232-0000-07000
CADD#	2325125F

NORTH

SITE 35, CAMP GEIGER AREA FUEL FARM FS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

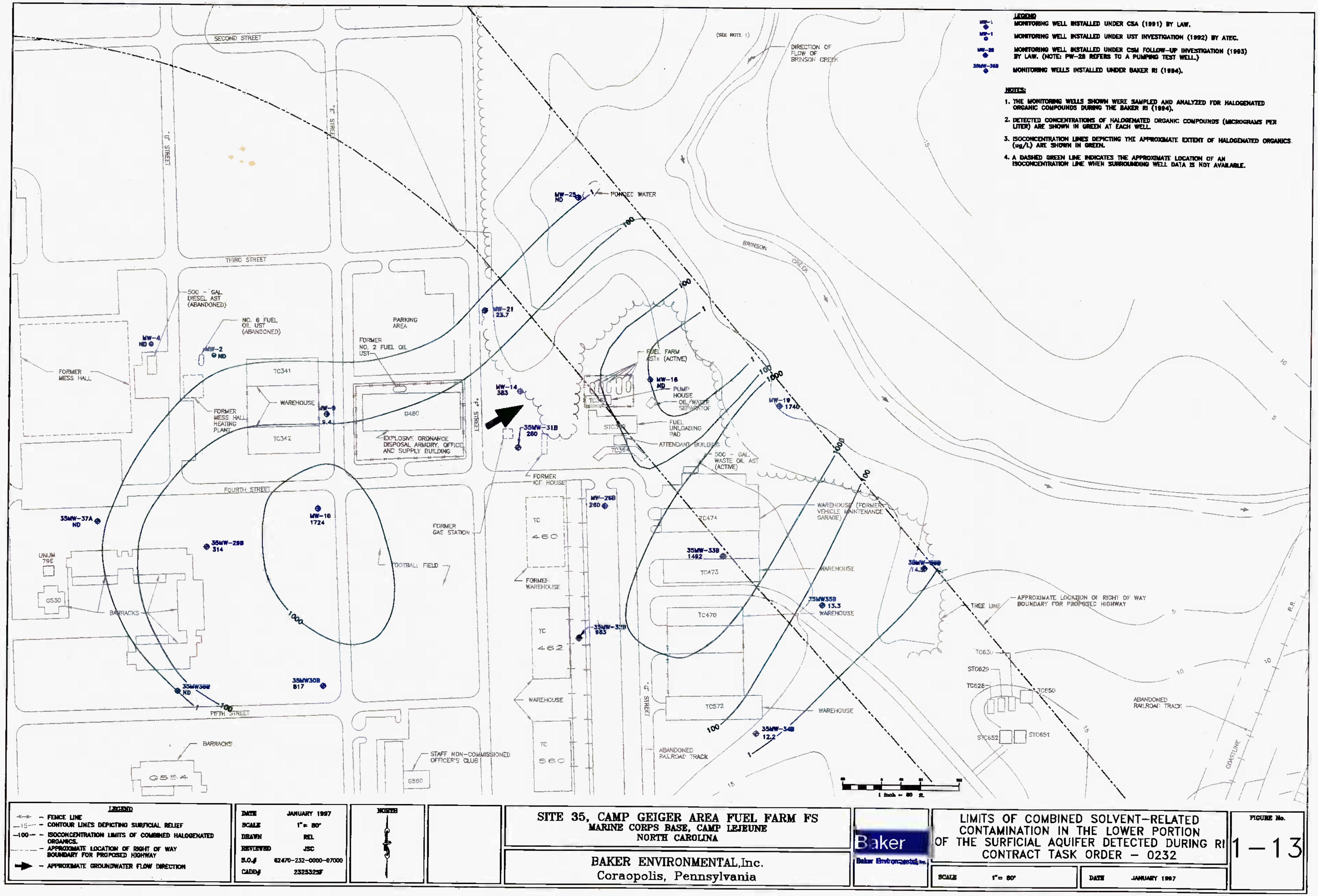
BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

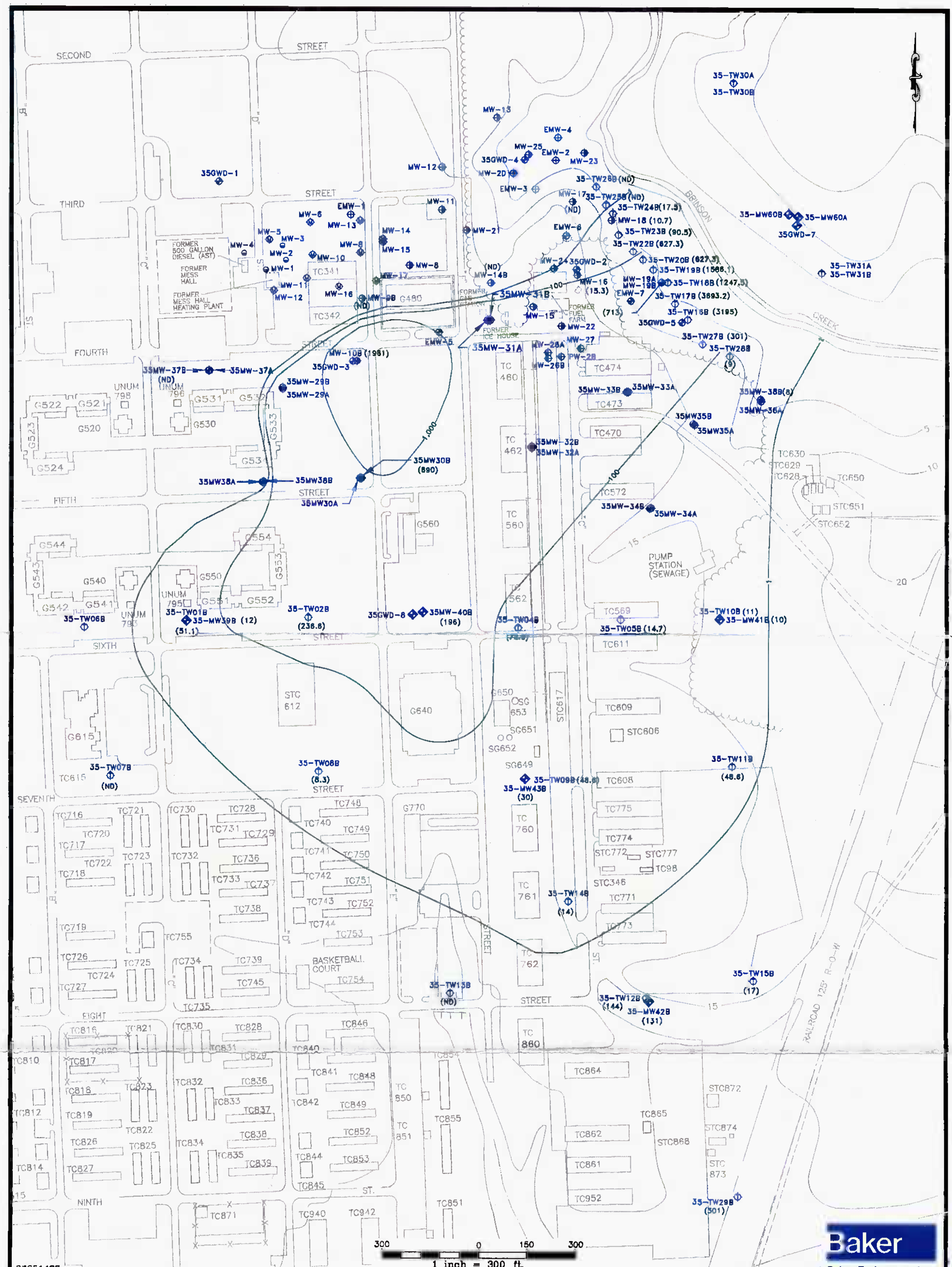
Baker
Baker Environmental, Inc.

LIMITS OF COMBINED FUEL-RELATED CONTAMINATION IN THE LOWER PORTION OF THE SURFICIAL AQUIFER – SPRING – DETECTED DURING RI
CONTRACT TASK ORDER – 0232

SCALE 1" = 80'   DATE JANUARY 1997

FIGURE No. 1-12


LEGEND
MONITORING WELL INSTALLED UNDER CSA (1991) BY LAW.
MONITORING WELL INSTALLED UNDER UST INVESTIGATION (1992) BY ATEC.
MONITORING WELL INSTALLED UNDER CSM FOLLOW-UP INVESTIGATION (1993) BY LAW. (NOTE: PW-28 REFERS TO A PUMPING TEST WELL.)
MONITORING WELLS INSTALLED UNDER BAKER RI (1994).
NOTES:
1. THE MONITORING WELLS SHOWN WERE SAMPLED AND ANALYZED FOR HALOGENATED ORGANIC COMPOUNDS DURING THE BAKER RI (1994).
2. DETECTED CONCENTRATIONS OF HALOGENATED ORGANIC COMPOUNDS (MICROGRAMS PER LITER) ARE SHOWN IN GREEN AT EACH WELL.
3. ISOCONCENTRATION LINES DEPICTING THE APPROXIMATE EXTENT OF HALOGENATED ORGANICS (ug/L) ARE SHOWN IN GREEN.
4. A DASHED GREEN LINE INDICATES THE APPROXIMATE LOCATION OF AN ISOCONCENTRATION LINE WHEN SURROUNDING WELL DATA IS NOT AVAILABLE.
SECOND STREET
THIRD STREET
FOURTH STREET
FIFTH STREET
"D" STREET
"E" STREET
"F" STREET
"G" STREET
DIRECTION OF FLOW OF BRINSON CREEK
BRINSON CREEK
PONDED WATER
500 - GAL DIESEL AST (ABANDONED)
NO. 6 FUEL OIL UST (ABANDONED)
PARKING AREA
FORMER NO. 2 FUEL OIL UST
FORMER MESS HALL
FORMER MESS HALL HEATING PLANT
WAREHOUSE
TC341
TC342
G480
EXPLOSIVE ORDNANCE DISPOSAL ARMORY, OFFICE AND SUPPLY BUILDING
FUEL FARM ASTs (ACTIVE)
PUMP HOUSE
OIL/WATER SEPARATOR
FUEL UNLOADING PAD
ATTENDANT BUILDING
500 - GAL WASTE OIL AST (ACTIVE)
FORMER ICE HOUSE
FORMER GAS STATION
FOOTBALL FIELD
FORMER WAREHOUSE
WAREHOUSE (FORMER VEHICLE MAINTENANCE GARAGE)
TC474
TC473
TC470
TC572
TREE LINE
APPROXIMATE LOCATION OF RIGHT OF WAY BOUNDARY FOR PROPOSED HIGHWAY
ABANDONED RAILROAD TRACK
STAFF NON-COMMISSIONED OFFICER'S CLUB
BARRACKS
G554
G530
G560
MW-25 ND
MW-21 23.7
MW-4 ND
MW-2 ND
MW-14 383
35MW-31B 280
MW-16 ND
MW-19 1740
MW-9 9.4
MW-10 1724
35MW-37A ND
35MW-29B 314
MW-26B 260
35MW-33B 1492
35MW-35B 13.3
35MW-32B 983
35MW36B ND
35MW30B 817
35MW-34B 12.2
1 inch = 80 ft.
LEGEND
FENCE LINE
CONTOUR LINES DEPICTING SURFICIAL RELIEF
ISOCONCENTRATION LIMITS OF COMBINED HALOGENATED ORGANICS.
APPROXIMATE LOCATION OF RIGHT OF WAY BOUNDARY FOR PROPOSED HIGHWAY
APPROXIMATE GROUNDWATER FLOW DIRECTION
DATE JANUARY 1997
SCALE 1" = 80'
DRAWN REL
REVIEWED JSC
S.O.# 62470-232-0000-07000
CADD# 2325325F
NORTH
SITE 35, CAMP GEIGER AREA FUEL FARM FS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA
BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania
Baker
LIMITS OF COMBINED SOLVENT-RELATED CONTAMINATION IN THE LOWER PORTION OF THE SURFICIAL AQUIFER DETECTED DURING RI
CONTRACT TASK ORDER - 0232
SCALE 1" = 80'
DATE JANUARY 1997
FIGURE No.
1-13



LEGEND

EMW-7	MONITORING WELL INSTALLED UNDER CS (1986) BY ESE.
EMW-1	MONITORING WELL INSTALLED BY NUS (1990).
MW-1	MONITORING WELL INSTALLED UNDER CSA (1991) BY LAW.
MW-5	MONITORING WELLS INSTALLED UNDER WST SITE ASSESSMENT (1994).
35MW-36B	MONITORING WELLS INSTALLED UNDER BAKER RI (1994).
35GWD-1	MONITORING WELL INSTALLED UNDER BAKER RI INVESTIGATION (1994).
35-TW12B	TEMPORARY MONITORING WELLS INSTALLED UNDER BAKER SGI (1996).
35-MW42B	MONITORING WELLS INSTALLED UNDER BAKER SGI (1996).

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-14
LIMITS OF COMBINED SOLVENT-RELATED CONTAMINATION IN THE LOWER PORTION OF THE SURFICIAL AQUIFER DETECTED DURING THE SGI
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

2.0 REMEDIATION GOAL OPTIONS, REMEDIATION LEVELS, AND REMEDIAL ACTION OBJECTIVES

This section presents remediation goal options (RGOs), remediation levels (RLs), and remedial action objectives for Operable Unit (OU) No. 10 (Site 35). Section 2.1 describes the media and contaminants of concern (COCs) based on findings presented in the Remedial Investigation (RI) Report (Baker, 1995) and Supplemental Groundwater Investigation (SGI) Report (Baker, 1996). Section 2.2 presents the exposure routes and receptors evaluated in the human health risk assessment (RA) conducted for Site 35. In Section 2.3, RGOs and final RLs are developed. Section 2.3 also includes a final set of COCs for the Feasibility Study (FS). Based on the RLs, remedial action objectives and areas of concern are identified in Section 2.4.

2.1 Media of Concern/Contaminants of Concern

The results of the baseline human health RA presented in the RI Report combined with the results of the human health RA from the SGI Report indicate that the total carcinogenic and noncarcinogenic risk exceed the USEPA acceptable risk range. This exceedence is driven by future potential exposure to the surficial groundwater. The results of the SGI supported conclusions and recommendations of the Interim FS (Baker, 1995).

Contaminants of Potential Concern (COPCs) initially selected and evaluated in the RAs prepared for the RI and the SGI were selected on the basis of frequency of detection, toxicity, and comparison to established criteria or standards. Groundwater COPCs from the RA presented in the RI were revised based on the qualitative and quantitative risk results from the SGI. Under the SGI, groundwater samples were collected using a low-flow purge technique and analyzed for inorganics. Due to the reduction in suspended particulates using this technique, the analytical findings better represent the nature of the groundwater and therefore, are more reliable in assessing risk. Hence, the inorganic COPCs from the RI were replaced with the inorganic COPCs from the SGI.

The COPCs that contributed to unacceptable risks were considered COCs for this FS and are presented in Table 2-1. However, the COPCs iron, lead, manganese, and thallium were not considered in the list of COCs for the following reasons:

- There is no historical record of any use or disposal of iron or manganese at Site 35.
- Groundwater in the Camp Lejeune area is naturally rich in iron and manganese.
- Existing evidence suggests that in areas of BTEX plumes, where biodegradation is occurring, dissolved iron concentrations in groundwater increase (Becker, 1995). It is believed that ferric compounds present in soil can act as an electron receptor and are reduced (Borden, et al., 1995).
- Lead was detected at a maximum concentration of 15.4 µg/L in the samples collected for the SGI, which exceeded the action level of 15 µg/L for groundwater. However, the average lead concentration was 6.1 µg/L, which is considered below the level of health concern. For this reason it was not retained as a COPC in the SGI.
- Thallium contributed only 7% to the total groundwater noncarcinogenic risk.

Detected concentrations of the COCs will be compared to the remediation levels developed in Section 2.3.4 to generate a final list of COCs for this FS. Any COC that does not exceed its applicable regulatory or health-based remediation level will be eliminated from the final list of COCs, thus eliminating it from consideration in this FS. The final list of COCs will become the basis for a set of remedial action objectives applicable to the site.

2.2 Exposure Routes and Receptors

Potential exposure pathways and receptors used to determine RGOs were site-specific and consider the future land use of this site. For this FS, the sum of most conservative exposure pathways, ingestion and dermal contact, was used in the development of RGOs. Although exposure to groundwater can occur via inhalation of volatile contaminants, this exposure pathway was not included. Groundwater does not appear to pose an appreciable risk with respect to inhalation. The RGOs were calculated for future (adult and child) residential receptors in order to provide site-specific RGOs from which remedial alternatives could be generated.

2.3 Remediation Goal Options and Remediation Levels

RGOs are established based on federal and state criteria and risk-based RGOs. Section 2.3.1 presents the definition of applicable or relevant and appropriate federal and state requirements (ARARs) and "to be considered" (TBCs) requirements. Section 2.3.2 provides an evaluation of federal and state criteria applicable to the COCs at Site 35. Development of site-specific risk-based RGOs for the COCs at Site 35 are provided in Section 2.3.3. The federal and state criteria for each COC and risk-based RGOs developed for each COC are all considered RGOs. From these, one RGO is chosen for each COC to develop a final set of RLs for the FS.

2.3.1 Definition of Applicable or Relevant and Appropriate Federal and State Requirements and "To Be Considered" Requirements

Under Section 121(d)(1) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), remedial actions must attain a degree of cleanup which assures protection of human health and the environment. Additionally, CERCLA remedial actions that leave any hazardous substances, pollutants, or contaminants on site must meet, upon completion of the remedial action, a level or standard of control that at least attains standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. These requirements are known as "ARARs" or applicable or relevant and appropriate requirements. ARARs are derived from both federal and state laws. USEPA Interim Guidance (52 Fed. Reg. 32496, 1987) provides the following definition of "Applicable Requirements":

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Drinking water criteria may be an applicable requirement for a site with contaminated groundwater that is used as a drinking water source. The definition of "Relevant and Appropriate Requirements" is:

Note that the water quality standards for Class GA and Class GSA ground waters are the same except for chloride and total dissolved solids concentrations (15A NCAC 2L.0202).

The Class GA groundwater NCWQS for the groundwater COCs for OU No. 10, Site 35, are listed on Table 2-2. The NCWQS will be considered an ARAR for Site 35.

2.3.2.2 Location-Specific ARARs

Potential location-specific ARARs identified for Site 35 are listed on Table 2-3. An evaluation determining the applicability of these location-specific ARARs with respect to Site 35 is also presented and summarized on Table 2-3. Based on this evaluation, specific sections of the following location-specific ARARs may be applicable to Site 35:

- Fish and Wildlife Coordination Act
- Federal Endangered Species Act
- North Carolina Endangered Species Act
- Executive Order 11990 on Protection of Wetlands
- Executive Order 11988 on Floodplain Management
- RCRA Location Requirements

Please note that the citations listed on Table 2-3 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

2.3.2.3 Action-Specific ARARs

Action-specific ARARs are typically evaluated following the development of alternatives, since they are dependent on the type of action being considered. Therefore, at this step in the FS process, potential action-specific ARARs have only been identified, not evaluated, for Site 35. A set of potential action-specific ARARs are listed on Table 2-4. These ARARs are based on RCRA, CWA, SDWA, and Department of Transportation (DOT) requirements. Note that the citations listed on Table 2-4 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

These ARARs will be evaluated after the remedial action alternatives have been identified for Site 35. Additional action-specific ARARs may also be identified and evaluated at that time.

2.3.3 Site-Specific Risk-Based RGOs

In this section of the FS, site-specific risk-based RGOs are developed for the COCs. The determination of derived RGOs for Site 35 involves establishing acceptable human health risk criteria, determining allowable risk associated with the COCs, and back calculating media-specific concentrations for the established risk levels.

The methodology used for the derived RGOs is in accordance with USEPA risk assessment guidance (USEPA, 1989a; USEPA, 1991). For noncarcinogenic effects, concentrations were calculated to correspond to an Hazard Index (HI) of 1.0, 0.1 and 0.01. At these levels of contaminant exposure, via all significant exposure pathways for a given medium, even the most sensitive populations are unlikely to experience health effects. A 1.0 risk level was used as an end point for determining noncarcinogenic RGOs for remediation. For carcinogenic effects, concentrations were calculated to correspond to $1x10^{-4}$ (one in ten thousand), $1x10^{-5}$ (one in one hundred thousand), and $1x10^{-6}$ (one in one million) estimated incremental lifetime cancer risk (ICR) over a lifetime of exposure to the carcinogen. Exposure was evaluated for all significant exposure pathways for a given medium. A $1x10^{-6}$ risk level was used as an end point for determining carcinogenic RGOs for remediation. Based on the NCP (40 CFR 300.430) for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an ICR between $1x10^{-4}$ and $1x10^{-6}$. RGOs are representative of acceptable incremental risks at the evaluated site based on current and probable future use of the area.

Three steps were involved in estimating the risk-based RGOs for the COCs. These steps involved identifying the most significant (1) exposure pathways and routes, (2) exposure parameters, and (3) equations. The equations included calculations of total intake from a given medium and were based on identified exposure pathways and associated parameters.

2.3.3.1 Risk Evaluation Assessment

Medium-specific risk-based RGOs were determined in accordance with USEPA guidance (USEPA, 1989a). Reference doses (RfDs) were used to evaluate noncarcinogenic RGOs, while cancer slope factors (CSFs) were used to evaluate carcinogenic RGOs. These toxicity values were dermally-adjusted when evaluating the dermal contact exposure scenario. In order to maintain a conservative approach, the ingestion and dermal pathways were summed when calculating the risk-based RGOs.

Consistent with USEPA guidance, noncarcinogenic health effects were estimated using an average annual exposure. The RGO incorporates the exposure time and/or frequency that represents the number of hours per day and the number of days per year exposure occurs. This is used with a term known as the averaging time, which converts the daily exposure to an annual exposure. Carcinogenic health effects were calculated as an incremental lifetime cancer risk, and, therefore, represent exposure duration over the course of a potentially exposed individual's lifetime (i.e., 70 years).

Estimation methods and models used in this section were consistent with current USEPA risk assessment guidance (USEPA, 1989a; USEPA, 1991). Exposure estimates associated with the exposure route are presented below. Carcinogenic RGOs for the future residential land use (i.e., ingestion of groundwater) were based on six years for a child (weighing 15 kg on average) and 24 years for an adult (weighing 70 kg on average). The following presents the equations and inputs used to estimate RGOs.

Ingestion of Groundwater

Currently, there are no receptors exposed to groundwater. Groundwater is obtained from noncontaminated Camp Lejeune supply wells and pumped to water treatment plants. The treated water is distributed via the Base water system. However, for the purposes of calculating RGOs, it is assumed that the site wells are potable and supply groundwater for public consumption. Groundwater ingestion RGOs can be characterized using the following equation:

$$Cw = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * EF * ED * IR}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (yr)
IR	=	ingestion rate (L/day)

Under the residential use scenario, the following input parameters were used to estimate RGOs: adult residents were assumed to ingest two liters of water per day, 350 days per year over a 30 year exposure duration; and child residents are assumed to ingest one liter of water per day, 350 days per year for an exposure period of six years (USEPA, 1989a). Table 2-5 summarizes the input parameters used to estimate the groundwater ingestion RGOs.

<u>Dermal Contact with Groundwater</u>

Groundwater dermal contact RGOs can be characterized using the following equation:

$$Cw = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * SA * PC * ET * EF * ED * CF}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
SA	=	skin surface area (cm^2)
PC	=	chemical-specific dermal permeability constant (cm/hr)
ET	=	exposure time (0.25 hours)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)

CF = conversion factor (0.001L/ml)

Under the residential use scenario, the following input parameters were used to estimate RGOs: adult residents were assumed have surface areas of 23,000 cm^2 available for dermal contact for 350 days per year over a 30 year exposure duration; and child residents are assumed to have 10,000 cm^2 available for dermal contact 350 days per year for an exposure period of six years (USEPA, 1989a). Table 2-5 summarizes the input parameters used to estimate the groundwater exposure RGOs.

2.3.3.2 Summary of Site-Specific Risk-Based RGOs

Site-specific and media-specific risk-based RGOs were calculated from the risk evaluation assessment. These levels are used in determining end points for remediation.

Risk-based RGOs were only generated for contaminants with available toxicity data. A summary of the RGOs calculated for the potential exposure scenarios is presented below. Separate RGOs for future adult and child residents were calculated. When applicable, both carcinogenic and noncarcinogenic RGOs were determined. Calculations are provided in Appendix A of this report.

All possible routes of exposure were included when calculating the RGOs. As a result, ingestion and dermal contact were assessed for groundwater exposure RGOs. As explained previously, inhalation was not included in the calculations. Tables 2-6 through 2-10 present the risk-based RGOs calculated for the carcinogenic and noncarcinogenic COCs in the groundwater.

2.3.3.3 Comparison of RGOs to Maximum Contaminant Concentrations in Groundwater

Generally, risk-based RGOs are not required for any contaminants in a medium with a cumulative cancer risk of less than $1x10^{-6}$, where an HI is less than or equal to 1.0, or where the RGOs are clearly defined by ARARs. However, there may be cases where a medium or contaminant appears to meet the protectiveness criterion but contributes to the risk of another medium. In some cases, contamination may be unevenly distributed across the site resulting in hot spots (areas of high contamination relative to other areas of the site). Therefore, if the hot spot is located in an area which is visited or used more frequently, exposure to the spot should be assessed separately.

In order to decrease uncertainties in estimating the reasonable maximum exposure (RME) (i.e., the maximum exposure that is reasonably expected to occur at the site), the maximum concentration of a contaminant in a medium can be compared to the estimated RGO, instead of using the concentration term (i.e., the 95th percent upper confidence limit), which is used to estimate the RME. To assess hot spot contaminants, a more conservative approach is followed. This maximum value is usually compared to the estimated risk-based RGO because, in most situations, assuming long-term contact with the maximum contaminant concentration is not reasonable.

Conclusions of the RA, including revisions after the SGI, indicate that the cumulative future baseline cancer risks associated with groundwater were not within the USEPA's acceptable risk range of $1x10^{-4}$ to $1x10^{-6}$, primarily because of the presence of VOCs. A comparison between the maximum detected concentrations of these COCs and the risk-based RGOs and chemical-specific ARARs is shown in Table 2-8.

Identifying remedial alternatives should not rely solely on estimating risk-based RGOs, especially in the event of hot spot contamination. Comparing maximum contaminant concentrations to risk-based RGOs provides an upper-bound (i.e., worst case) conservative estimate, and aids in screening and identifying remedial alternatives. Risk-based RGOs are not to be used solely in making final remedial decisions.

2.3.3.4 Uncertainty Analysis

Uncertainties associated with calculating risk-based RGOs are summarized below. The RGO estimates presented in the previous section are quantitative in nature and are highly dependent upon input accuracy. The accuracy with which input values can be quantified is critical to the degree of confidence that the decision maker has in the RGOs.

Most scientific computation involves a limited number of input variables tied together by a scenario to provide a desired output. Some RGO inputs are based on literature values rather than measured values. In such cases, the degree of certainty may be expressed in terms of whether the estimate was based on literature values or measured values, and not how well defined the distribution of the input was. Some RGOs are based on estimated parameters; the qualitative statement that the RGO was based on estimated inputs defines certainty in a qualitative manner.

Toxicity factors (i.e., CSFs and RfDs), have uncertainties built into the assumptions used to calculate these values. Because the toxicity factors are determined from high doses administered to experimental animals and extrapolated to low doses to which humans may be exposed, uncertainties exist. Thus, toxicity factors could either overestimate or underestimate potential effects on humans. However, because human data exists for very few chemicals, risks are based on these conservative values obtained primarily from animal studies.

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

2.3.4 Summary of RLs and Final COCs

RLs associated with the COCs at Site 35 are presented on Table 2-9. This list was based on a comparison of chemical-specific standards and the site-specific risk-based RGOs identified throughout Section 2.3.2 and 2.3.3. If a COC had an standard, the most limiting (or conservative) standard was selected as the RL for that contaminant. If a COC did not have a standard, the most conservative risk-based RGO was selected as the RL. The basis for each of the RLs is also presented on Table 2-9.

In order to determine the final set of COCs, the maximum contaminant concentrations detected in the medium of concern were compared to the remediation levels presented in Tables 2-9. The contaminants that exceeded at least one of the remediation levels were retained as COCs. The contaminants that did not exceed any of the remediation levels were no longer considered to be COCs with respect to this FS. Based on this comparison, the following COCs exceeded a remediation level and were retained as COCs for Site 35: benzene, cis-1,2-dichloroethene, ethylbenzene, methyl tertiary butyl ether, trans-1,2-dichloroethene, 1,2-dichloroethene, trichloroethene, tetrachloroethene, 1,1,2,2-tetrachloroethane, xylenes, and vinyl chloride. The final set of COCs and the associated RLs are presented on Table 2-10.

2.4 Remedial Action Objectives

Remedial action objectives are medium-specific or operable unit-specific goals established for protecting human health and the environment. At Site 35, the specific media to be addressed by the Remedial Action is contaminated groundwater south of the proposed U.S. Route 17 bypass right-of-way. This area of concern is shown in Figure 2-1.

Objectives developed for groundwater at Site 35 include:

- Mitigate the potential for direct exposure to the contaminated groundwater in the surficial aquifer.
- Minimize or prevent the horizontal and vertical migration of contaminated groundwater in the surficial aquifer.
- Restore the surficial aquifer to the remediation levels established for the groundwater COCs.

2.5 References

Baker. 1995. Interim Feasibility Study for Shallow Groundwater in the Vicinity of the Former Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1995. Remedial Investigation Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Baker. 1996. Supplement Groundwater Investigation (SGI) Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Marine Corps Base, Camp Lejeune, North Carolina.

Becker, 1995.

Borden, et al., 1995.

North Carolina Administrative Code, Title 15A, Department of Environment, Health, and Natural Resources, Division of Environmental Management, Subchapter 2L, Sections .0200 through .0300, Classifications and Water Quality Standards Applicable to the Groundwater of North Carolina.

USEPA, 1987. United States Environmental Protection Agency. Interim Guidance. 52 Fed. Reg. 32496. 1987.

USEPA, 1989a. United States Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A) Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/1-89-002. December 1989.

SECTION 2.0 TABLES

TABLE 2-1

CONTAMINANTS OF CONCERN FOR THE FS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminants of Concern (based on RI and SGI results) [1]
Groundwater	1,1-Dichloroethene Benzene cis-1,2-Dichloroethene Ethylbenzene Methyl Tertiary Butyl Ether Toluene trans-1,2-Dichloroethene 1,2-Dichloroethene (total) Trichloroethene Tetrachloroethene 1,1,2,2-Tetrachloroethane Xylenes (total) Vinyl Chloride Arsenic

Notes:

(1) This list includes contaminants of potential concern evaluated in the the RI (Baker, 1995) after revisions based on the results of the SGI (Baker, 1996).

TABLE 2-2

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs FOR GROUNDWATER COCs OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM FEASIBILITY STUDY, CTO-232 MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Federal MCL (µg/L)	NCWQS (µg/L)
1,1-Dichloroethene	7	7
Benzene	5	1
cis-1,2-Dichloroethene	70	70
Ethylbenzene	700	29
Methyl Tertiary Butyl Ether	NE	200
Toluene	1,000	1,000
trans-1,2-Dichloroethene	100	70
1,2-Dichloroethene	70	NE
Trichloroethene	5	2.8
Tetrachloroethene	6	0.7
1,1,2,2-Tetrachloroethane	NE	NE
Xylenes (total)	10,000	530
Vinyl Chloride	2	0.015
Arsenic	50	50

Notes:

NCWQS = North Carolina Water Quality Standards for Groundwater
MCL = Safe Drinking Water Act Maximum Contaminant Level
NE = No Criteria Established

TABLE 2-3

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

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 OU No. 10, 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, and 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, and 40 CFR 6.301(a)	No known historic sites, buildings or antiquities are within or near OU No. 10, 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	Brinson 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),(Walters, 1991). In addition, the alligator has been sighted on Base (in Wallace Creek). Therefore, this will be considered an ARAR.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
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 rate species, and the State watch list.	GS 113-331 to 113-337	Since the American alligator has been sighted within MCB Camp Lejeune (in Wallace Creek), 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, Brinson Creek has areas of wetlands. Therefore, this will be an applicable ARAR.
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, OU No. 10 is primarily within a minimal flooding zone (outside the 500-year floodplain). However, the immediate areas around Brinson 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 area 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.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
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 wetland 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.

Notes:

LeBlond, Richard. 1991. "Critical Species List. Camp Lejeune. Endangered Species and Special-Interest Communities Survey." Principal Investigator.

TABLE 2-4

POTENTIAL ACTION-SPECIFIC ARARs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Standard [1]	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
	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

Notes:

[1] 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

TABLE 2-5

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor	
		Future Residential Child	Future Residential Adult
Groundwater			
Ingestion Rate, IR	L/d	1	2
Surface Area, SA	cm^2	10,000	23,000
Exposure Frequency, EF	d/y	350	350
Exposure Duration, ED	y	6	30
Exposure Time, ET	h/d	0.25	0.25
Averaging Time, Noncarc., ATnc	d	2,190	10,950
Averaging Time, Carc., ATcarc	d	25,550	25,550
Conversion Factor, CF	L/cm^3	0.001	0.001
Body Weight, BW	kg	15	70
Permeability Constant, PC	cm/hr	chemical-specific	chemical-specific
Cancer Slope Factor, CSF	$(mg/kg\text{-}day)^{-1}$	chemical-specific	chemical-specific
Reference Dose, RfD	mg/kg-day	chemical-specific	chemical-specific

References:

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

USEPA Exposure Factors Handbook, July, 1989

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

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

USEPA Region IV Guidance for Soil Absorbance

TABLE 2-6
GROUNDWATER CARCINOGENIC RGOs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Carcinogenic Risk-Based RGOs (μg/L) Future Residents					
	Target Risk Level $1.0x10^{-4}$		Target Risk Level $1.0x10^{-5}$		Target Risk Level $1.0x10^{-6}$	
Contaminant of Concern	Adult	Child	Adult	Child	Adult	Child
1,1-Dichloroethene	13	29	1.3	2.9	0.13	0.29
Benzene	210	468	21	46.8	2.1	4.68
Trichloroethene	424	965	42.4	96.5	4.24	9.65
Tetrachloroethene	70	163	7	16.3	0.7	1.63
1,1,2,2-Tetrachloroethene	41	89	4.1	8.9	0.41	0.89
Vinyl Chloride	4	9	0.4	0.9	0.04	0.09
Arsenic	6	12	0.6	1.2	0.06	0.12

TABLE 2-7
GROUNDWATER NONCARCINOGENIC RGOs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Noncarcinogenic Risk-Based RGOs (µg/L) Future Residents					
	Target Hazard Quotient 1.0		Target Hazard Quotient 0.1		Target Hazard Quotient 0.01	
Contaminant of Concern	Adult	Child	Adult	Child	Adult	Child
1,1-Dichloroethene	311	134	31.1	13.4	3.11	1.34
cis-1,2-Dichloroethene	352	152	35.2	15.2	3.52	1.52
Ethylbenzene	795	379	79.5	37.9	7.95	3.79
Methyl Tertiary Butyl Ether	182	78	18.2	7.8	1.82	0.78
Toluene	1,589	758	158.9	75.8	15.89	7.58
trans-1,2-Dichloroethene	705	303	70.5	30.3	7.05	3.03
1,2-Dichloroethene	317	137	31.7	13.7	3.17	1.37
Trichloroethene	120	55	12	5.5	1.2	0.55
Tetrachloroethene	157	73	15.7	7.3	1.57	0.73
Xylenes (total)	56,699	25,029	5669.9	2502.9	566.99	250.29
Arsenic	11	5	1.1	0.5	0.11	0.05

TABLE 2-8

COMPARISON OF SITE MAXIMUM LEVEL TO CRITERIA
FUTURE RESIDENTS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Maximum Groundwater Concentration	NCWQS[1]	Federal MCL[2]	RGO[3]	
				Adult	Child
1,1-Dichloroethene	6.9[4]	7	7	0.13[6] 3.11[7]	0.29[6] 1.34[7]
Benzene	1,660[4]	1	5	2.1	4.68
cis-1,2-Dichloroethene	973[4]	70	70	3.52	1.52
Ethylbenzene	824[4]	29	700	7.95	3.79
Methyl Tertiary Butyl Ether	319[4]	200	NE	1.82	0.78
Toluene	984[4]	1,000	1,000	15.89	7.58
trans-1,2-Dichloroethene	176[4]	70	100	7.05	3.03
1,2-Dichloroethene	1,200[5]	NE	70	3.17	1.37
Trichloroethene	900[4]	2.8	5	4.24[6] 1.2[7]	9.65[6] 0.55[7]
Tetrachloroethene	2[5]	0.7	6	0.7[6] 1.57[7]	1.63[6] 0.73[7]
1,1,2,2-Tetrachloroethane	23[5]	NE	NE	0.41	0.89
Xylenes (total)	1,700[4]	530	10,000	566.99	250.29
Vinyl Chloride	13[5]	0.015	2	0.04	0.09
Arsenic	13.3[5]	50	50	0.06[6] 0.11[7]	0.12[6] 0.05[7]

Notes:

Concentrations expressed in microgram per liter (µg/L)

[1] NCWQS = North Carolina Water Quality Standards for Groundwater
[2] MCL = Safe Drinking Water Act Maximum Contaminant Level
[3] RGO = Risk-based Remediation Goal Option
Carcinogenic Target Risk Level - 1×10^{-6}
Noncarcinogenic Target Hazard Quotient - 1.0
[4] Maximum detected concentration from RI.
[5] Maximum detected concentration from SGI.
[6] Carcinogenic RGO
[7] Noncarcinogenic RGO
NE = No Criteria Established

TABLE 2-9

REMEDIATION LEVELS FOR COCs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE

Contaminant of Concern	RL[1]	Basis of Goal	Corresponding Risk
1,1-Dichloroethene	7	NCWQS[2]	
Benzene	1	NCWQS	
cis-1,2-Dichloroethene	70	NCWQS	
Ethylbenzene	29	NCWQS	
Methyl Tertiary Butyl Ether	200	NCWQS	
Toluene	1,000	NCWQS	
trans-1,2-Dichloroethene	70	NCWQS	
1,2-Dichloroethene	70	MCL[3]	
Trichloroethene	2.8	NCWQS	
Tetrachloroethene	0.7	NCWQS	
1,1,2,2-Tetrachloroethane	0.41	Risk-Ingestion and dermal contact	TR[4] = 1.0×10^{-6}
Xylenes (total)	530	NCWQS	
Vinyl Chloride	0.015	NCWQS	
Arsenic	50	NCWQS	

Notes:

Concentrations expressed in micrograms per liter (µg/L).

[1] RL = Remediation Level
[2] NCWQS = North Carolina Water Quality Standards for Groundwater
[3] MCL = Maximum Contminant Level
[4] TR = Total Lifetime Risk

TABLE 2-10

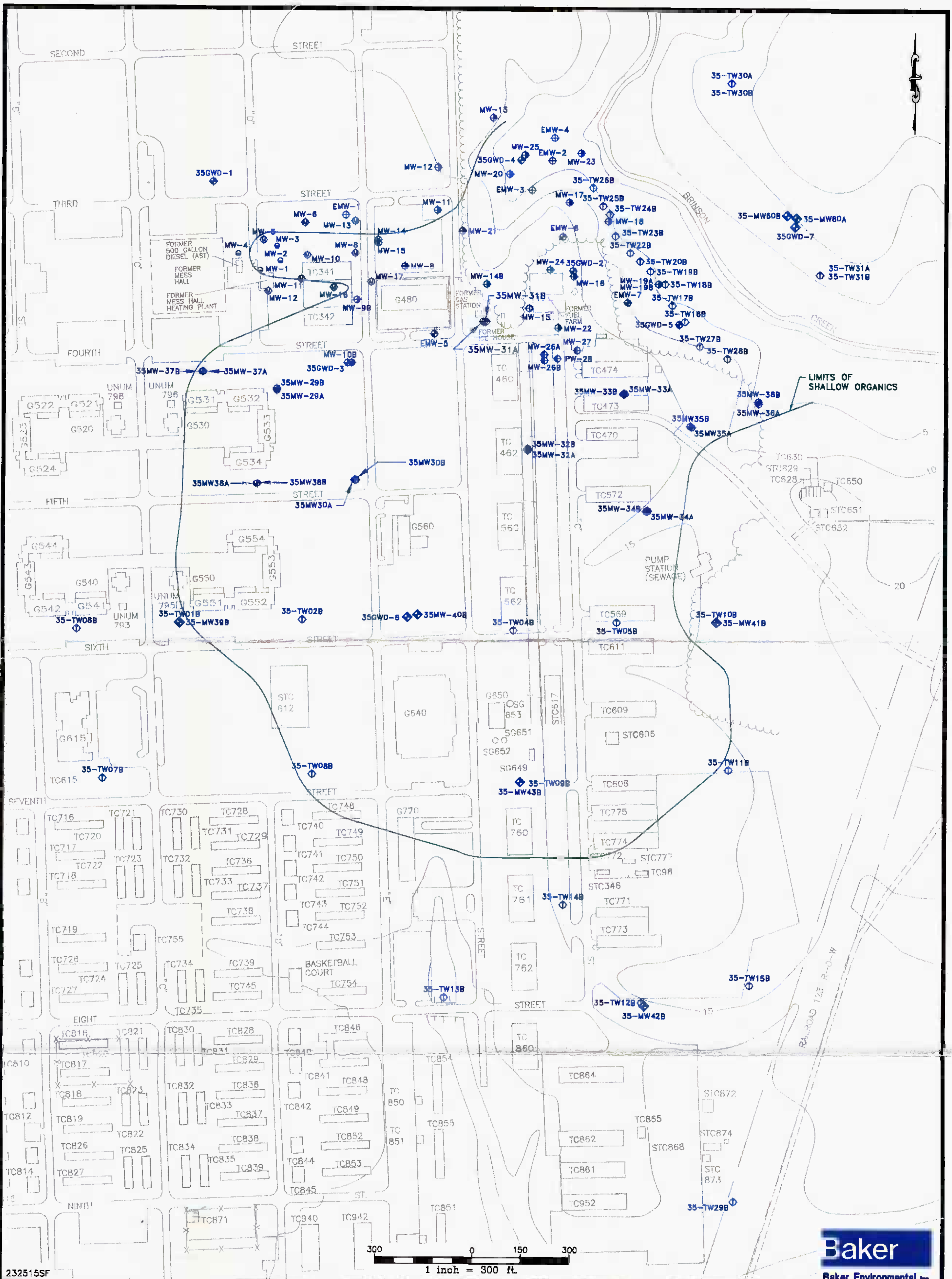
FINAL SET OF COCs
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Remediation Level (μg/L)	Basis
Benzene	1	NCWQS
cis-1,2-Dichloroethene	70	NCWQS
Ethylbenzene	29	NCWQS
Methyl Tertiary Butyl Ether	200	NCWQS
trans-1,2-Dichloroethene	70	NCWQS
1,2-Dichloroethene	70	MCL
Trichloroethene	2.8	NCWQS
Tetrachoroethene	0.7	NCWQS
1,1,2,2-Tetrachloroethane	0.41	Risk-based RGO(1)
Xylenes (total)	530	NCWQS
Vinyl Chloride	0.015	NCWQS

Note:

(1) Based on a carcinogenic target risk level of 1×10^{-6}

SECTION 2.0 FIGURES



LEGEND

EMW-7	MONITORING WELL INSTALLED UNDER CS (1988) BY ESE.
EMW-1	MONITORING WELL INSTALLED BY NUS (1990).
MW-1	MONITORING WELL INSTALLED UNDER CSA (1991) BY LAW.
MW-5	MONITORING WELLS INSTALLED UNDER WST SITE ASSESSMENT (1994).
35MW-36B	MONITORING WELLS INSTALLED UNDER BAKER RI (1994).
35GWD-1	MONITORING WELL INSTALLED UNDER BAKER RI INVESTIGATION (1994).
35-TW12B	TEMPORARY MONITORING WELLS INSTALLED UNDER BAKER SGI (1996).
35-MW42B	MONITORING WELLS INSTALLED UNDER BAKER SGI (1996).

SOURCE: LANTDIV, OCT. 1991

FIGURE 2-1
ESTIMATED AREA OF CONCERN
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER – 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

0235466024

3.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Section 3.0 includes the identification and preliminary screening of remedial action technology types and process options that may be applicable to the remediation of groundwater at Site 35. More specifically, Section 3.1 identifies a set of general response actions, Section 3.2 identifies remedial action technology types and process options for each general response action, and Section 3.3 presents the preliminary screening of the remedial action technology types and process options. After the preliminary screening, the remaining technology types and process options undergo an evaluation in Section 3.4. Based on the evaluation, a final set of remedial action and technology process options presented in Section 3.5.

3.1 General Response Actions

General response actions are broad-based, medium-specific categories of actions that can be identified to satisfy the remedial action objectives of an FS. Seven general response actions have been identified that satisfy remedial action objectives developed in Section 2.4. These general response actions include: no action, site controls, collection/containment actions, ex situ treatment actions, long-term monitoring, in situ treatment actions, and discharge actions. A brief description of these general response actions follows.

3.1.1 No Action

The NCP requires the evaluation of the no action response as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that offer a greater level of response. A no action alternative may be considered appropriate when there are no adverse or unacceptable risks to human health or the environment, or when a response action may cause a greater environmental or health danger than the no action alternative.

3.1.2 Long-Term Monitoring Actions

A long-term monitoring action can be implemented as a part of a complete remedial action. Long-term monitoring includes quarterly (years one through five) and semiannual (years six through 30) monitoring of selected existing monitoring wells for the COCs associated with the site. Long-term monitoring is designed to assess the effectiveness of treatment and monitor the movement of a contaminant plume toward receptors.

3.1.3 Site Control Actions

Site controls are various actions that can be implemented as part of a complete remedial action alternative. The purpose of site controls is to minimize exposure to potentially contaminated groundwater through site-specific aquifer-use restrictions. Aquifer-use restrictions generally prohibit the construction of new supply wells or operation of existing supply wells within the impacted area.

3.1.4 Collection/Containment Actions

This general response action combines both containment and collection actions. Containment actions include technologies which contain and/or isolate contaminants by covering, sealing, chemically stabilizing, or providing an effective barrier that prevents contaminant migration.

Collection actions include technologies that collect contaminated groundwater for treatment via withdrawal techniques such as extraction wells or interceptor trenches. Collection actions are often applied at areas with high levels of contamination (i.e., hot spots) or to mitigate the potential migration of contaminated groundwater.

3.1.5 Ex Situ Treatment Actions

Ex situ treatment actions are conducted after contaminated groundwater has been extracted. Ex situ treatment actions for contaminated groundwater include; physical/chemical, biological, thermal, engineered wetlands, and off-site treatment systems. Ex situ treatment actions are usually followed by discharge actions.

3.1.6 In Situ Treatment Actions

In situ treatment actions may require a groundwater collection/containment action but are conducted in the aquifer within the limits of the contaminant plume. These actions include in situ physical/chemical and biological treatment systems (natural and engineered).

3.1.7 Discharge Actions

Discharge actions involve the on-site and/or off-site destinations where groundwater may be discharged. Discharge actions are employed after the groundwater has been treated ex situ.

3.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable remedial action technologies and process options were identified for each general response action. The results of this initial identification step are included in Table 3-1. The term "remedial action technology" refers to general categories of technologies or activities such as, long-term monitoring, aquifer-use restrictions, capping, vertical barriers, horizontal barriers, groundwater collection, biological treatment, physical/chemical treatment, thermal treatment, engineered wetlands, off-site treatment , on-site discharge and off-site discharge.

The term "process option" refers to specific processes associated with a remedial action technology category. For example, air stripping, carbon adsorption, and reverse osmosis are process options that fall under the remedial action technology category of physical/chemical treatment actions. Several remedial action technology categories may be identified for each general response action, and numerous process options may exist within each remedial action technology category.

3.3 Preliminary Screening of Remedial Action Technologies and Process Options

During the preliminary screening, the set of remedial action technology types and process options identified in Table 3-1 were screened by evaluating the technology types with respect to contaminant-specific and general site-specific factors. This screening step was accomplished by using readily available information from the RI and SGI (with respect to contaminant types, contaminant concentrations, and on-site characteristics) to screen out remedial action technology categories and process options that could not be effectively implemented at the site (USEPA, 1988). The results of the preliminary screening along with an explanation for retaining or eliminating a remedial action technology category or specific process option are included in Table 3-2. Remedial action technology categories and process options selected as potentially applicable are included in Table 3-3.

3.4 Process Option Evaluation

The objective of the process option evaluation was to select only one process option for each applicable remedial action technology category to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. In some cases more than one process option was selected for a remedial action technology category if the individual processes were sufficiently different and applicable. The representative process option provides a basis for developing performance specifications during preliminary design. However, the specific process option used to implement the remedial action may not be selected until the remedial design phase.

During the process option evaluation, the process options listed on Table 3-3 were evaluated based on three criteria: effectiveness, implementability, and relative cost. The effectiveness evaluation focused on: the potential effectiveness of process options in meeting the remedial action objectives; the potential impacts to human health and the environment during the construction and implementation phase; and how reliable the process is with respect to the contaminants of concern. The implementability evaluation focused on the administrative feasibility of implementing a technology (e.g., obtaining permits), since the technical implementability was previously considered in the preliminary screening. The relative cost evaluation played a limited role in this screening. As directed by USEPA guidance the relative capital and operating and maintenance (O&M) costs of each process option were based on engineering judgement instead of detailed estimates (USEPA,1988).

A summary of the process option evaluation is presented on Table 3-4. It is important to note that the elimination of a process option does not mean that the process option can never be reconsidered for the site. As previously stated, the purpose of this part of the FS process is to simplify the development and evaluation of potential alternatives.

3.5 Final Set of Remedial Action Technologies and Process Options

Table 3-5 identifies the final set of feasible technology types and process options that will be used to develop the remedial action alternatives (RAAs) for Site 35. A brief description of each technology type/process option is presented below.

3.5.1 No Action

The no action response provides a baseline for comparison with other response actions. Under the no action response no active or passive process options will be conducted. The NCP requires the evaluation of the no action response as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that offer a greater level of response. A no action alternative may be considered appropriate when there are no adverse or unacceptable risks to human health or the environment, or when a response action may cause a greater environmental or health danger than the no action alternative.

3.5.2 Groundwater Monitoring

This process option includes the development and implementation of a long-term groundwater monitoring program at Site 35. Groundwater samples would be collected and analyzed for site specific COCs on a quarterly basis during years one through five, and semiannually for years six through 30. This program would continue to provide information regarding the effectiveness of any groundwater remediation activity conducted at the site and monitor contaminant migration over time.

3.5.3 Regulation of Supply Well Construction

Under this process option the Activity department that is responsible for providing potable water or protecting public health would prohibit the construction of new potable water supply wells in the vicinity of the contamninant plume at Site 35. This would reduce the risk of exposure to Activity personnel from ingestion and direct contact of contaminated groundwater.

3.5.4 Restrictions in Base Master Plan

To insure an adequate supply of potable groundwater the Base Master Plan should include a long-term strategy for the development of groundwater resources. Such a management plan would clearly identify areas, such as Site 35, where the development of groundwater resources for potable use is prohibited. This action would help reduce the risk to both human and ecological populations from ingestion and direct contact with the contaminants within the aquifer.

3.5.5 Slurry Cut-Off Wall

The extent and migration of a contaminated groundwater plume may be contained or directed to a treatment zone by a relatively impermeable barrier. Under this process option a low permeability bentonite slurry cut-off wall would be constructed along the eastern edge of the groundwater contaminant plume at a location where groundwater contamination exceeds regulatory limits. This barrier would direct the flow of contaminated groundwater to an in situ passive treatment wall system (iron filings). The passive treatment wall system is discussed in a subsequent paragraph.

The cut-off wall would be approximately three feet in width and would extend into the semiconfining layer. A trench would be excavated and a slurry consisting of bentonite (or grout) and native material would be mixed and pumped into the excavation. Excavation is stopped when the specified depth is reached and the wall is allowed to cure. Slurry cut-off walls have been effectively used a barriers in passive walls systems.

3.5.6 Extraction Wells

The extent and migration of a contaminated groundwater plume may be contained or collected via pumping techniques. Under this process option extraction wells would be strategically located on the down-gradient edge of the contaminant plume. The extraction wells would be pumped along specific rates such that the cone of influence from the well system would intercept the contaminant plume. In addition, extraction wells would be placed in "hot spots" in order to collect highly contaminated groundwater in the existing plume. Groundwater extraction wells may be combined with ex situ treatment actions and discharge actions.

Pumping techniques utilizing extraction wells represent a commercially available technology for the management of groundwater contamination. Extraction well installation is relatively easy and quick.

3.5.7 Air Stripping

Air stripping is a physical/chemical treatment process in which water and air are brought into contact with each other for the purpose of transferring dissolved phase volatile contaminants in the groundwater to vapor phase contamination in a stream of air. Air stripping is an effective treatment technology for VOCs with Henry's Law constants above 10 atmospheres (atm). The off-gas stream generated during the treatment process may require collection and subsequent treatment. Air stripping has been widely used in the remediation of aquifer contaminated with solvents.

Air stripping is most effectively accomplished in a packed tower or low-profile perforated tray system with a counter current flow of air and water. Contaminated groundwater is pumped to the top of the tower or tray and distributed across the packing or tray. As the water flows downward through the perforated trays or packing, air is blown upward through the system. This turbulent flow creates an optimal environment for the transfer of contamination to the vapor phase. Contaminant laden air travel to the top of the tower or tray system where it is captured and treated (Freeman, 1989).

3.5.8 Carbon Adsorption

Carbon adsorption is a physical/chemical treatment process that binds organic molecules to the surface of the activated carbon particles. The adsorption process involves contacting a waste stream with carbon, usually by flow through a series of packed-bed reactors. Once the micropore surfaces of the carbon are saturated with organics, the carbon is "spent" and must be replaced or regenerated. The time to reach breakthrough is the most critical operating parameter of this type of treatment system (Rich, 1987).

3.5.9 Coagulation/Flocculation

Coagulation and flocculation are terms that are used to describe physical processes that are typically used together in a treatment train. These processes are used to remove suspended solids and heavy metals. Coagulation refers to the chemical dispersion and mixing of a precipitating agent or flocculent. Flocculation refers to the physical agitation of the water at a low velocity to support the agglomeration of the suspended particles into a well defined floc.

The difference between solids removal and dissolved metals removal is basically the chemicals that are added to the waste stream. Generally, to remove metals, lime or sodium sulfide is added to the wastewater in a rapid mixing tank in order to precipitate out dissolved metals. Flocculating agents such as alum, ferric chloride, and ferric sulfate may be added to enhance the agglomeration of precipitate particles. To remove only suspended solids only a flocculent is added to the waste stream. The insoluble flocculent is then removed for recovery or disposal in the clarification/ sedimentation process.

3.5.10 Clarification/Sedimentation

Clarification/sedimentation is a physical process in which colloidal particles (floc containing metals precipitant or other suspended solids) are allowed to settle out of an aqueous waste stream via gravity separation. The solid products of this process must then be disposed of.

3.5.11 Filtration

Filtration is a physical process used to remove suspended solids and biological floc from wastewater. The separation is accomplished by passing water through a physically restrictive medium, resulting in the entrapment of suspended particulate matter. The media typically used for filtration include sand, coal, garnet, and diatomaceous earth. Filtration is generally preceded by coagulation/flocculation clarification/sedimentation.

3.5.12 Air Sparging Trench

Air sparging can be thought of as in situ air stripping. The process incorporates the injection of air into the water saturated zone for the purpose of removing organic contaminants via volatilization. Dissolved phase contamination is transferred to the vapor phase and is transported by air to surface Once volatilized, the contaminant laden air may collected to prevent migration into a structure. Soil vapor extraction may be used to collect the volatilized contaminants and convey them to an off-gas treatment system.

Typically air sparging is performed via vertical air injection wells. However, since the contamination at Site 35 is concentrated on the top of the confining layer, vertical air injection will not develop a sufficient capture zone at the top of the semiconfining layer. To overcome this a trench will be constructed to the top of the semiconfining unit and a horizontal pipe with air difussers will be placed at the bottom. The trench will be filled with a material that is more permeable than the surrounding soils. Air will then be injected into the trench via the horizontal pipe. Contaminant mass will be transferred to the air that will migrate to the surface and be released to the atmosphere.

3.5.13 In-Well Aeration

The process of in-well aeration involves injecting air into a specially-designed well (although the air may enter the aquifer in a dissolved form). The resulting in-well airlift pump effect causes water to flow into the well from the deeper screened portion of the well and out of the well from the shallower screened portion (Hinchee, 1994). Volatiles are stripped from the groundwater within the well, rise to the top of the well with the injected air, and are collected and treated at an above ground treatment facility.

3.5.14 Natural Attenuation

The term natural attenuation refers to naturally occurring processes that occur in groundwater without the assistance of engineered systems to reduce contaminant mass, toxicity, mobility, volume, or concentration of contamination. The natural attenuation of contaminated groundwater occurs as the result of destructive and nondestructive subsurface mechanisms. Biodegradation, reduction of contamination to innocuous byproducts by microbes, is the most important destruction mechanism. Although abiotic destruction, chemical reduction (or oxidation) of contamination to innocuous byproducts does occur. Nondestructive attenuation mechanisms include sorption, dispersion, dilution from recharge, and volatilization (Wiedemeier, et al, 1996).

The natural attenuation option advanced by this FS includes the collection of data and analysis that indicate the process is leading to aquifer restoration. The data collection and analysis effort associated with this process option is much greater than that associated with traditional long-term monitoring. Monitoring for natural attenuation encompasses a range of analytic parameters that include the contaminants of concern. Analysis associated with traditional long-term monitoring has been limited to site COCs. In addition, a quantitative contaminant fate and transport model that accounts for the biological activity must be developed and maintained as a part of this option.

3.5.15 Passive Treatment Wall

This process option consists of an in situ treatment wall that is installed perpendicular to the flow path of the contaminant plume. The plume is allowed to move passively through the wall that consist of a permeable iron formulation, and dissolved phase chlorinated solvents are degraded to ethene, ethane, methane and chloride ions. Generally the process includes the oxidation of the iron and the reductive dechlorination of the chlorinated solvents. The result is the substitution of chlorine atoms with hydrogen atoms (USEPA,1995).

3.5.16 Discharge to Surface Water

It appears that treated groundwater from Site 35 can be discharged on-site directly into an existing storm drain system that discharges to Brinson Creek. The capacity of the storm drain system, as well as any required discharge permits, must be considered if it is to be used as a discharge location.

3.6 References

Freeman, 1989. Standard Handbook of Hazardous Waste Treatment and Disposal. McGraw-Hill Inc., New York, New York.

Gillham, Robert W. and Stephanie F. O'Hannesin. 1994. Enhanced degradation of Halogenated Aliphatics by Zero-Valent Iron, Groundwater v. 32 ,no. 6, pp. 958-967.

Hinchee, 1994. Air Sparging for Site Remediation. Lewis Publishers, Columbus, Ohio.

Rich, Gerald and Kenneth Cherry. 1987. Hazardous Waste Treatment Technologies. Third Printing. Pudvan Publishing Company, Northbrook, Illinois.

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

USEPA, 1990. United States Environmental Protection Agency. National Oil and Hazardous Substances Pollution Contingency Plan. 55FR8665. Office of Emergency and Remedial Response. Washington, D.C. March 1990.

SECTION 3.0 TABLES

TABLE 3-1

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Long-Term Monitoring	Periodic Groundwater Monitoring	Collection and Analysis of Groundwater (COCs only)
	Institutional Controls	Aquifer-Use Restrictions	Regulate Supply Well Construction
			Abandon Existing Supply Wells
			Point-Of-Use Treatment
			Restrictions in Base Master Plan
			Deed Restrictions
	Plume Collection/Containment	Capping	Clay/Soil Cap Asphalt/Concrete Cap, Multilayer Cap
		Vertical Barrier	Grout Curtain
			Slurry Wall
			Sheet Piling
			Rock Grouting
		Horizontal Barrier	Grout Injection
			Block Displacement
		Groundwater Collection	Extraction Wells
			Extraction/Injection Wells
			Interceptor Trenches
			Hydraulic Fracturing

TABLE 3-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater (Continued)	Ex Situ Treatment Actions	Physical/Chemical Treatment	Air/Steam Stripping
			Carbon Absorption
			Chemical Dechlorination
			Chemical Reduction
			Chemical Oxidation
			Reverse Osmosis
			Ion Exchange
			Electrodialysis
			Electrochemical Ion Generation
			Ultraviolet Oxidation
			Distillation
			Neutralization
			Coagulation/Flocculation
			Clarification/Sedimentation
			Filtration
			Oil/Water Separation
		Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powdered Activated Carbon Treatment • Tricking Filter • Biological Contractor
			Anaerobic

TABLE 3-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater (Continued)	Ex Situ Treatment Actions (Continued)	Thermal Treatment	Molten Glass
			Liquid Injection
			Plasma Arc Torch
			Pyrolysis
			Wet Air Oxidation
			Super Critical Oxidation
		Engineered Wetland Treatment	Constructed Wetlands
		Off-Site Treatment	POTW
			RCRA Facility
			Site 82 or HPIA Treatment Plant
			Base Sewage Treatment Plant
	In Situ Treatment Actions	Biological	Oxygen and Nutrient Enhanced Biodegradation
		Physical/Chemical	Air Sparging - Vertical Wells
			Air Sparging - Trench
			In-Well Aeration
			Dual-Phase Vacuum Extraction
			Natural Attenuation
			Passive Treatment Wall
	Discharge Actions	On-Site Discharge	Discharge to Surface Water
			Discharge to On-Site Sanitary Sewer System
			Reinjection • Injection Wells • Infiltration Galleries
		Off-Site Discharge	Discharge to POTW

TABLE 3-2

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No Action	Potentially applicable; required by the NCP	Retained
Long-Term Monitoring	Periodic Groundwater Monitoring	Collection and Analysis of Groundwater Samples	Groundwater samples are periodically collected from existing to confirm progress of remediation.	Potentially applicable. Samples would be analyzed for contaminants of concern	Retained
Site Controls	Aquifer-Use Restrictions	Regulate Supply Well Construction	Activity would prohibit the construction of additional down-gradient supply wells in the vicinity of Site 35.	Potentially applicable	Retained
		Abandon Existing Supply Wells	Activity would abandon any supply well operating within the present or predicted path of the contaminant plume	Not applicable. No existing or proposed supply wells are located within the existing plume.	Eliminated
		Point -Of -Use Treatment	No groundwater is extracted from the plume for any use.	Not applicable. No operational supply wells are located within the existing plume.	Eliminated
		Restrictions in Base Master Plan	Base Master Plan should include a long term strategy for the development of groundwater. Restricted areas such as Site 35 would be identified.	Potentially applicable	Retained
		Deed Restrictions	Limit the future use of land including placement of supply wells.	Not applicable. Deed restrictions are applicable only to military installations that are to be closed.	Eliminated
Collection/ Containment Actions	Capping	Clay/Soil Cap Asphalt/Concrete Cap Multilayered Cap	Capping material placed over areas of contamination.	Plume covers a large area that is a highly developed. A cap over of the plume are would be impractical.	Eliminated
	Vertical Barriers	Grout Curtain	Pressure injection of grout into boreholes that limits contamination migration.	Method could potentially result in gaps which would allow operational flow	Eliminated
		Slurry Wall	A trench around the contamination is filled with a soil bentonite slurry to limit migration of contaminants.	Potentially applicable if used as part of an in situ passive wall system.	Retained
		Sheet Piling	Interlocking sheet pilings are installed with a drop hammer	Potentially applicable if used as apart of an in situ passive wall system.	Retained
		Rock Grouting	Specialty operation for sealing fractures, fissures, solution cavities, or other voids in rock to control flow of groundwater.	Depth to bedrock limits practicality.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Collection/ Containment Actions (Continued)	Horizontal Barriers	Grout Injection	Pressure injection of grout to form a bottom seal across a site at a specific depth.	Not Applicable. The existing semiconfining unit is currently preventing vertical migration of the contamination.	Eliminated
		Block Displacement	Continued pumping of grout into specially notched holes causing displacement of a block of contaminated groundwater.	Not Applicable. This technique is experimental. Large area over which this would be required limits this technique.	Eliminated
	Groundwater Collection	Extraction Wells	Extraction wells pull water from the aquifer. A line of wells can be placed to halt the advancing contaminant plume and collect groundwater from "hot spots."	Potentially applicable. The process may induce intolerable settlement in nearby roadway and building foundations.	Retained
		Extraction/Injection Wells	Extraction wells pull water from the aquifer. Injection wells inject uncontaminated groundwater to enhance collection of contaminated groundwater via the extraction wells. Or the injection wells can also inject material into an aquifer to remediate groundwater.	The uncontaminated area up-gradient of the plume is the site of several multistory buildings. The process may induce intolerable settlement under adjacent foundations.	Eliminated
		Interceptor Trenches	Perforated pipe installed in trenches backfilled with porous media to collect contaminated groundwater.	Potentially applicable. Contamination is limited to the surficial aquifer. Some utility relocation will be required.	Retained
		Hydraulic Fracturing	Pressurized water is injected into the formation to create fractures in the formation, thus improving permeability.	Fracture may create pathways for contaminant migration through semiconfining layer	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment Actions	Physical/Chemical Treatment	Air/Stream Stripping	Mixing large volumes of air/steam with water in a packed column to promote transfer of VOCs to air. Applicable to volatile organics.	Potentially applicable to COCs.	Retained
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column. Applicable to wide range of organics.	Potentially applicable to COCs.	Retained
		Chemical Dechlorination	Process which uses specifically synthesized chemical reagents that destroy hazardous chlorinated molecules or detoxify them into less harmful forms. Effective for PCBs, chlorinated phenols and creosols, and dioxins.	Not applicable for site specific organic COCs	Eliminated
		Chemical Reduction	Addition of a reducing agent to lower the oxidation state of a substance to reduce toxicity/solubility. Mainly applicable for chromium, mercury, and lead.	Not applicable for site specific organic COCs. Inorganic compounds are not a primary treatment concern at this site	Eliminated
		Chemical Oxidation	Addition of an oxidizing agent to raise the oxidation state of a substance. Applicable to phenols, pesticides, sulfur containing wastes, and some metals (primarily iron and manganese).	Not applicable for site specific organic COCs. Inorganic compounds are not a primary treatment concern at this site	Eliminate
		Reverse Osmosis	Using high pressure to force water through a membrane leaving contaminants behind. Process is used to separate water from a feed stream containing inorganic ions .	Not applicable. Inorganic compounds are not a primary treatment concern at this site.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Applicable for inorganics, not organics.	Not applicable for organic COCs. Inorganic compounds are not a primary treatment concern at this site.	Eliminated
		Electrodialysis	Metal ions are removed when an electric current drives contaminated water through an ion exchange membrane.	Not applicable for organic COCs. Inorganic compounds are not a primary treatment concern at this site.	Eliminated
		Electrochemical Ion Generation	Electrical currents are used to put ferrous and hydroxyl ions into solution for subsequent removal via precipitation. Applicable to metals removal.	Not applicable for organic COCs. Inorganic compounds are not a primary treatment concern at this site.	Eliminated
		UV Oxidation	Ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank; an ozone destruction unit treats off-gases from the treatment tank.	Potentially applicable.	Retained
		Distillation	Contaminated groundwater is heated so it evaporates leaving contaminants behind. Water vapor is then cooled resulting in the condensation of purified water. This process is energy intensive	Because this process is highly energy intensive it is not practical to treat groundwater with relatively low levels of contamination	Eliminated
		Neutralization	Addition of an acid or base to a waste in order to adjust its pH. Applicable to acidic or basic waste streams.	Adjustment of pH at this site is not necessary	Eliminated
		Coagulation/Flocculation	Coagulant/Flocculent is added for solid phase for removal of metals and TSSs.	Inorganic compounds are not a primary treatment concern at this site. However, TSSs are a concern	Retained
		Clarification/Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation.	Applicable for the removal of suspended solids.	Retained

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex-Situ Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Filtration	Removal of suspended solids from solution by forcing the liquid through a porous medium. Applicable to suspended solids and inorganics.	Potentially applicable for suspended solids removal.	Retained
		Oil/Water Separation	Materials in solution are transferred into a separate phase for removal. Applicable to petroleum hydrocarbons	Not applicable. No free product has been detected at proposed treatment locations.	Eliminated
	Biological Treatment	Aerobic ● Aerated Lagoon ● Activated Sludge ● Powdered Activated Carbon Treatment ● Trickling Filter ● Rotating Biological Contractor	Degradation of organics using microorganisms in an aerobic environment.	Not highly effective for halogenated VOCs such as TCE.	Eliminated
		Anaerobic	Degradation of organics using microorganisms in an anaerobic environment.	Potentially applicable to halogenated VOCs Technology is not widely demonstrated	Eliminated
	Thermal Treatment	Liquid Injection	Combustion of waste at high temperatures. Effective for pumpable organic wastes.	Incineration is impractical when there are relatively low contaminant concentrations in groundwater; such as the VOCs at Site 35.	Eliminated
		Molten Glass	Advanced incineration; waste contacts hot molten salt to undergo catalytic destruction. Effective for hazardous liquids, low ash, high chlorine wastes.	Incineration is impractical when there are relatively low contaminant concentrations.	Eliminated
		Plasma Arc Torch	Advanced incineration; pyrolyzing wastes into combustible gases in contact with a gas which has been energized to its plasma state by an electrical discharge. Effective for liquid organic waste.	Incineration is impractical when there are relatively low contaminant concentrations in groundwater.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment Actions (Continued)	Thermal Treatment (Continued	Pyrolysis	Advanced incineration; thermal conversion of organic material into solid, liquid, and gaseous components; takes place in an oxygen-deficient atmosphere. Effective for organics and inorganics.	Pyrolysis is impractical when there are relatively low contaminant concentrations in groundwater.	Eliminated
		Wet Air Oxidation	Advanced incineration; aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures. Effective for organics with high COD, high strength wastes, and for oxidizable inorganics.	Incineration is impractical when there are relatively low contaminant concentrations in groundwater.	Eliminated
		Supercritical Oxidation	An enhanced wet-air oxidation process with reaction conditions in supercritical range of water.	Incineration is impractical when there are relatively low contaminant concentrations in groundwater.	Eliminated
	Engineered Wetlands	Constructed Wetlands	An engineered complex of plants, substrates, water, and microbial populations. Contaminants are removed via plant uptake, biodegradation (organics only), precipitation, and sorption processes.	Large contaminant plume would require a large wetlands area which would be impractical to maintain.	Eliminated
	Off-site Treatment	POTW	Extracted groundwater discharged to Jacksonville POTW for treatment.	City of Jacksonville would not accept wastes.	Eliminated
		RCRA Facility	Extracted groundwater discharged to licensed RCRA facility for treatment and/or disposal.	Volume generated would make this impractical. Provider may not have capacity as it is needed.	Eliminated
		Site 82 or HPIA Plants	Groundwater would be trucked to Site 82 or HPIA.	Constant deliveries would disrupt operations at other plants. Mixed stream could create process difficulties.	Eliminated
		Base Sewage Treatment Plant	Extracted groundwater discharged to Base STP for treatment. STPs could be modified to accommodate solvent contaminated groundwater.	Camp Geiger STP is closing. Conveyance system to mainside plant was not designed to accommodate this additional flow.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
In Situ Treatment Actions	Biological Treatment	Oxygen and nutrient enhanced Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Applicable to nonhalogenated organic compounds.	Potentially applicable. Process has been implemented at sites with BTEX contamination. Field effectiveness of the process on TCE and DCE contamination has not been demonstrated.	Retained
	Physical/Chemical Treatment	Air Sparging - Vertical Wells	Air is injected under pressure into vertical injection wells into the aquifer. VOCs are volatilized and transported by the air into the vadose zone where it is either extracted and treated or discharged to the surface. Introduction of air also may promote microbial degradation of contaminants .	Not applicable. Chlorinated solvent contamination is located in the lower portion of the surficial aquifer immediately above the semiconfining unit. Air movement through this unit is limited as was demonstrated in a previous pilot study at Site 35.	Eliminated
		Air Sparging - Trench	Air is injected under pressure into a horizontal perforated pipe that is located in a trench. The trench is constructed below the water table and is filled with material more permeable than the surrounding material . Air carries the vapor phase VOC to the surface where it is discharged.	Not applicable. The trench would have to be located in a developed area. Contaminant-laden vapors could migrate into adjacent structures and utility conduits.	Eliminated
		In Well Aeration	Air is circulated with-in a well and an airlift effect is created. As the contaminated water is "lifted" the VOCs are stripped out. Off-gas is treated and discharged, and clean water is injected into the aquifer in the upper portion of the well.	Potentially applicable.	Retained
		Dual-Phase Vacuum Extraction	Extraction of a two-phase air-water stream under high vacuum using wells screened above and below the water table.	Maximum suction lifts approximately 30 feet below ground surface (bgs). The depth of the confining unit averages 35-40 feet bgs.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
In Situ Treatment Actions (Continued)	Physical Chemical Treatment (Continued)	Natural Attenuation	This process consists of monitoring natural subsurface mechanisms that reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the environment. These mechanisms include biodegradation, dispersion, dilution, sorption, volatilization, and chemical/biochemical stabilization.	Potentially applicable. The presence of daughter products of TCE, reduced levels of dissolved BTEX, elevated dissolved iron concentrations indicate that natural attenuation mechanisms are possibly occurring.	Retained
		Passive Treatment Wall (funnel and gate)	A permeable subsurface reaction wall consisting of iron filings is installed across the flow path of a contaminant plume, allowing the plume to passively more through the wall.. Portions of an impermeable wall direct groundwater flow to the. This process is applicable to solvent and fuel-related contamination.	Potentially applicable. Solvent and fuel-related groundwater contamination can be treated by this method.	Retained
Discharge Actions	On-Site Discharge	Discharge to Surface Water	Treated water discharged to Brinson Creek.	Potentially applicable.	Retained
			Treated water discharged to Edwards Creek.	The contaminant plume is closer to Brinson Creek.	Eliminated
		Discharge to On-site Sanitary Sewer	Treated water discharged to Camp Geiger sanitary sewer system.	Camp Geiger STP will be closing. The pumping facility located at Site 35, that will pump Camp Geiger wastewater to the Camp Lejeune main plant was not designed to accommodate flows from remediation sites	Eliminated
		Reinjection ● Injection Wells ● Infiltration Galleries	Treated water is reinjected into the site aquifer via use of shallow infiltration galleries (trenches) or injection wells.	Injected liquid may mound in the subsurface formation and cause damage to existing adjacent structures	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Discharge Actions (continued)	Off-Site Discharge	Discharge to POTW	Treated water is discharged to City of Jacksonville sanitary sewer system	The City of Jacksonville does not typically provide sanitary sewer service to Camp Geiger.	Eliminated

TABLE 3-3

REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM FEASIBILITY STUDY, CTO-0232 MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Long-Term Monitoring	Periodic Groundwater Monitoring	Collection and Analysis of Groundwater (COCs only)
	Institutional Controls	Aquifer Use Restrictions	Regulate Supply Well Construction
			Restrictions in Base Master Plan
	Plume Collection/Containment	Vertical Barrier	Slurry Wall
			Sheet Piling
		Groundwater Collection	Extraction Wells
			Interceptor Trenches
	Ex Situ Treatment Actions	Physical/Chemical Treatment	Air/Steam Stripping
			Carbon Absorption
			Ultraviolet Oxidation
			Coagulation/Flocculation
			Clarification/Sedimentation
			Filtration
	In Situ Treatment Actions	Biological	Oxygen and Nutrient Enhanced Biodegradation
		Physical/Chemical	In-Well Aeration
			Natural Attenuation
			Passive Treatment Wall
	Discharge Actions	On-Site Discharge	Discharge to Surface Water

TABLE 3-4

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
No Action	No Action	Not Applicable	• Not applicable.	• Easily implemented.	• No cost	Retained, requirement of the NCP.
Long-term Monitoring Actions	Periodic Ground-water Monitoring	Collection of Groundwater Samples and Analysis for COCs	• Will effectively detect changes in contaminant levels and plume movement so that exposure can be avoided. • Will monitor the effectiveness of remedial action plans that may be implemented at the site.	• Easily implemented.	• Low capital • Low O&M	Retained because of its effectiveness, implementability, and low cost.
Site Control Actions	Aquifer Use Restrictions	Regulate Supply Well Construction	• Will effectively prevent future exposure to groundwater. • Effectiveness dependent on continued future implementation.	• Easily implemented.	• Negligible cost	Retained because of its effectiveness, implementability, and negligible cost.
		Restrictions to Base Master Plan	• Will support future efforts to effectively prevent future exposure to groundwater contamination. • Effectiveness dependent on continued implementation.	• Easily implemented. • Master Plans are not an enforceable ordinance. Master plans generally provide guidance to planning and publics works offices.	• Low cost	Retained because of its effectiveness, implementability, and negligible cost.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Collection/ Containment Actions	Vertical Barriers	Slurry Cut-off Wall	• Slurry walls are not completely impermeable, but are considered to be a proven containment technology. • Slurry walls are typically used with funnel and gate technology. • Uniform construction is possible. • Groundwater flow and fate and transport models would be needed to determine if contamination would be transported through the semi-confining layer and cut-off wall.	• A contractor with slurry wall experience would be needed. • May require off-site disposal of a small volume of soils and decontamination fluids. • Would require predesign comparability test. • Construction could potentially be performed in level C. • Excavation can be done with standard equipment up to 70' below ground surface. • A large volume or bentonite could be lost to voids or preferential pathways. Slug test indicate voids may exist in the area.	• High Capital Cost • No Maintenance Costs	Retained because installation can be controlled.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation: Effectiveness	Evaluation: Implementability	Evaluation: Relative Cost	Evaluation Results
Collection/ Containment Actions (Continued)	Vertical Barriers (Continued)	Sheet Piling	• Sheet piling is not completely impermeable. Water can leak at the joints. However, joints can be grouted to reduce flow. comparable to a slurry wall • Corrosion is a potential problem with metal sheet piling. • A corrosion study would be needed to approximate performance life. • Groundwater flow and fate and transport models would needed to determine if contamination would be transported through the semi-confining layer .	• Uses standard equipment that is readily available. • Subsurface conditions of the pilings during installations cannot be observed (i.e. a piling could be damaged by a boulder or buried debris, the grout may not seal the void at the joint).	• High Capital Cost • High O&M Cost • (assuming replacement)	Eliminated because it is not typically used with funnel and gate construction, and cost is substantially greater than slurry walls.
	Ground-water Collection	Extraction Wells	• Effective for containing a contaminated groundwater plume. • Inorganics may precipitate and clog well screens; this necessitates frequent maintenance and equipment replacement. • Conventional, widely applied.	• Easily implemented. • Uses standard equipment that is readily available. • Can be located and operated in a manner that will minimize settling under adjacent foundations. • Extraction wells can be easily added/replaced. • Pump test will be required.	• Moderate capital • Low to Moderate O&M	Retained because it is a conventional technology and more easily implemented than an interceptor trench.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Collection/ Containment Actions (Continued)	Ground-water Collection (Continued)	Interceptor Trenches	• Effective for containing a contaminated groundwater plume. • More effective for shallow groundwater plumes. • Slower recovery than extraction wells.	• Requires extensive excavation • Extensive excavation could disrupt operations. • May require off-site disposal of soils. • Well screens can become clogged. • Requires an experienced specialty contractor (slurry wall or bioslurry wall construction). • Equipment readily available. • Level "C" may be required by construction personnel.	• High capital • Low to moderate O&M	Eliminated because trenches are less cost effective than extraction wells when installed at the depths anticipated at Site 35.
Ex Situ Treatment Actions	Physical/ Chemical Treatment	Air/Steam Stripping	• Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling. • Commercially proven technology for treatment of COCs. • Contaminant transfer rather than destruction technology.	• Off-gas and/or tower scale treatment may be required. • Equipment and vendors readily available. • Requires periodic carbon replacement. • May require air emissions permit. • Requires groundwater extraction.	• Low to moderate capital • Low to moderate O & M	Air stripping will be retained because of its effectiveness on Site 35 COCs and relatively low cost.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment Actions (continued)	Physical/ Chemical Treatment (continued)	Carbon Adsorption	• Effective for Site 35 COCs. • Loses efficiency for compounds with low molecular weight. • Loses efficiency for compounds with high polarity or are water-soluble. • Contaminant transfer technology. • Suspended solids, inorganics, and oil and grease can foul the system. • Commercially proven and widely used technology. • Less cost effective if used on a waste stream with high contaminant concentrations (greater than 1 mg/L).	• Readily available, conventional technology. • Spent carbon must be properly regenerated or disposed. • Pretreatment may be required to reduce or remove suspended solids. • Bench tests should be conducted to estimate carbon usage. • Requires groundwater extraction. • Will be used as a polishing step in the treatment train.	• Low to moderate capital • Moderate O&M (O&M is dependent on loading rates and carbon life)	Retained because of its commercial availability and performance record, and its relatively moderate cost.
		UV Oxidation	• Commercially proven technology. • Inorganics such as chromium, iron, and manganese may limit effectiveness. • High turbidity limits the transmission of UV light. • Contaminant destruction rather than transfer technology. • VOCs may be volatilized rather than destroyed and off-gas treatment will be required.	• Energy-intensive. • Handling and storage of oxidizers requires special safety precautions. • System is easily automated. • System is easy to transport and set up.	• Moderate to high capital • High O & M	Eliminated because of costs associated with energy consumption, and chemical reagents require special safety precautions, and have a relatively high cost.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation: Effectiveness	Evaluation: Implementability	Evaluation: Relative Cost	Evaluation Results
Ex Situ Treatment Actions (Continued)	Physical/ Chemical Treatment (Continued)	Coagulation/ Flocculation	• Technology has a long standing record in water and wastewater treatment industry for reducing suspended solids and metals removal. • Metals removal can generate a high volume of sludge. However, solids removal at this sight are not anticipated to generate a high volume of sludge. • Flocculation is applicable to any aqueous waste stream where particles must be agglomerated into larger more settleable particles prior to other types of treatment.	• Equipment is readily available • Compact, single units are available for delivery to the site. • Flocculents/coagulants would have to stored on-site. • Bench-scale test would be required to determine dosages and design parameters. • Used in conjunction with a clarification/ sedimentation step. • Requires groundwater extraction.	• Moderate capital • Moderate O & M	Retained because of longstanding track record in industry and moderate cost.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment Actions (Continued)	Physical/ Chemical Treatment (Continued)	Clarification/ Sedimentation	• Conventional, proven technology. • Effective for removing flocculents and precipitants. • Performance depends on density and particle size of the solids, effective charge on the suspended particles, types of chemicals used in pretreatment, surface loading, upflow rate, and rejection time. • Filtration may be required to remove residual floc. • Bench-scale test would be required to determine design parameters.	• Equipment is relatively simple to install and no chemicals are required. • Package units available. • Bench-scale test would be needed to support equipment selection. • Requires groundwater extraction. • Used with coagulation/flocculation.	• Low to moderate capital cost • Moderate O&M	Retained because it may be necessary as pretreatment.
		Filtration	• Conventional proven technology for removing suspended solids.	• Equipment is readily available and easily integrated.	Low capital cost Moderate O &M	Retained to remove residual floc.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment Actions	Biological Treatment	Oxygen and Nutrient Enhanced Biodegration (i.e. Oxygen Release Compound)	• Has been proven effective on BTEX contamination. • Is a contaminant destruction technology. • The treatment of TCE and DCE is in the experimental. • The impacts of this technology to natural process in a plume with both solvent and fuel related is uncertain.	• Existing 2" diameter monitoring well scan be used. • Carriers are environmentally safe • Limited number of providers. • A limited number of additional monitoring wells may be required. • A field pilot test would be required to estimate dosage an cleanup time. • This a proprietary technology. • Applications may be frequent depending on the site. • Applications can be performed by base personnel or firm performing long-term monitoring.	• Low capital • Low to moderate O &M	Eliminated due to uncertainties with respect to degradation of chlorinated solvents.
	Physical /Chemical Treatment	In -Well Aeration	• Can potentially remove COCs • Limited commercial track record. • Contaminant transfer technology rather than destruction technology.	• Technology provided by a single vendor. • Treatment of off-gas may be required • May require air emissions permit. • Pilot study in progress at another Camp Lejeune site.	• Moderate to high capital costs • Low to moderate O &M	Retained because of its potential effectiveness, and cost is comparble to an air sparging trench.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment Actions (Continued)	Physical /Chemical Treatment (Continued)	Natural Attenuation	• Is widely accepted as a treatment for fuel-related contamination. • Has been shown to be effective in the destruction of solvent-related groundwater contamination. • There are currently no human receptors of the solvent contaminated groundwater south of Fifth Street in the vicinity of the plume (no supply wells). • The leading edge of the solvent plume has not reached environmental receptors in Edwards Creek (south of Fifth Street). • Groundwater contamination north of Fifth Street will be remediated by an in situ air sparging system.	• A treatability study would have to be conducted that would include the following: - Microcosm study; - Determination of levels of geochemical constiuients needed to support continued natural attenuation; - Development of a contaminant fate and transport model of that considered natural attenuation. • Contaminant mass desruction can be documented. • Additional treatment remedies can be implemented if natural processess appear to have reched asymototic levels. • Monitoring plan woud include samping and anlysis for a variety of geochemical parameters as well as for COCs.	• Very low capital costs • Low to moderate O&M	Retained because of potential effectiveness and low capital cost.

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment Action (Continued)	Physical/ Chemical Treatment (Continued)	Natural Attenuation (Continued)	• The following items suggests the nature and extent of contamination may be impacted by natural destructive forces: - Fuel-related contamination in monitoring wells resampled under the SGI was lower than RI levels; - The levels of daughter products of TCE degradation continue to increase; - A substantial distance and difference in contaminant levels exists between the potential source area and the leading edge of the plume (suggests dilution is occuring) Levels of dissolved iron are higher than base background levels in areas with fuel- related contamination			
		Passive Treatment Wall	• Demonstrated to be effective in the remediation of chlorinated solvent contamination. • Chlorinated solvents are fully reduced.	• Would be used with slurry cut-off wall • Retro fit may be required between 10 to 15 years. • Field pilot study would be required		

TABLE 3-4 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment Actions (Continued)	Physical/ Chemical Treatment (Continued)	Passive Wall (Continued)	• Additional treatment remedies could be applied if necessary.	• Bench-scale test required. • Proprietary technology. • Subsurface area where gate is constructed is considered confined space. This will require level A protection for workers. • Will require additional moitoring wells downgradient of the gate areas. • A minimum of two gates areas will be required. • Will require some utility. dislocation/relocation .	• High capital costs • Moderate to high O & M costs	Retained because of its potential effectiveness.
Discharge Action	On-Site Discharge	Dischagre to Surface Water	• Treated water can be effectively discharged to Brinson Creek.	• Storm sewers under proposed highway willl require upgrade. • Existing open bar ditch/storm sewer near proposed groundwater treatment plant would have to upgraded to accommodate flow.	• Moderate capital costs • Low O & M	Retained because of its potential effectiveness, implementability, and moderate costs.

TABLE 3-5

FINAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Long-Term Monitoring	Periodic Groundwater Monitoring	Collection and Analysis of Groundwater (COCs only)
	Site Controls	Aquifer Use Restrictions	Regulate Supply Well Construction
			Restrictions in Base Master Plan
	Collection/Containment Actions	Vertical Barrier	Slurry Wall
		Extraction	Extraction Wells
	Ex Situ Treatment Actions	Physical/Chemical Treatment	Air/Steam Stripping
			Carbon Absorption
			Coagulation/Flocculation
			Clarification/Sedimentation
			Filtration
	In Situ Treatment Actions	Physical/Chemical	In-Well Aeration
			Natural Attenuation
			Passive Treatment Wall
	Discharge Actions	On-Site Discharge	Discharge to Surface Water

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

In this section, general response actions, remedial action technologies and process options selected in Section 3.0 and listed in Table 3-5 for Site 35 were combined to form remedial action alternatives (RAAs). Following development of the RAAs (Section 4.1), an initial screening of the potential RAAs can be conducted if too many RAAs emerge during the development process. Because the RAAs that were developed were all potentially applicable, the decision was made to carry all of the RAAs forward through the detailed evaluation process (Section 5.0).

4.1 Development of Remedial Action Alternatives

Five RAAs were developed for Site 35 to provide for remediation of surficial groundwater. The RAAs that were developed include:

RAA 1:	No Action
RAA 2:	Site Controls and Long-Term Monitoring
RAA 3:	Natural Attenuation
RAA 4:	Extraction Wells and Ex Situ Treatment
RAA 5:	In Situ Passive Treatment/ Slurry Cut-Off Wall
RAA 6:	In Well Aeration and Off Gas Carbon Adsorption

The following sections provide descriptions of each RAA. Conceptual layouts, process flow diagrams, equipment and sampling methods associated with specific RAAs were based on available data and developed to support a comparative analysis of alternatives, and an FS cost estimate. Conceptual layouts, process flow diagrams, equipment, and sampling methods considered in this FS are subject to change during the design phase based on new and/or more accurate information that may become available and are not intended to serve as the final design or the basis of design.

These RAAs were developed with the understanding that a separate Interim Remedial Action is currently under design by Baker that focuses on the surficial groundwater in the vicinity of the Fuel Farm. The implementation of this Interim Remedial Action is scheduled for 1997.

4.1.1 RAA 1: No Action

Under the no action RAA, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater or to monitor subsurface conditions at Site 35. The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs that provide a greater level of response.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

4.1.2 RAA 2: Site Controls and Long-Term Monitoring

Under RAA 2, no engineered remedial actions will be applied at Site 35. Instead, site controls and long-term groundwater monitoring will be implemented.

4.1.2.1 Site Controls

Site controls will involve the implementation of aquifer-use restrictions to mitigate the potential for Activity personnel to be exposed to contaminated groundwater. These measures will include the regulation of supply well construction and identification of restricted use areas in the Base Master Plan

The regulation of new supply wells will be the responsibility of the Activity department that provides potable water or that is tasked with protecting the public health. Such restrictions will prohibit the construction of new potable water supply wells in the vicinity of the contaminant plume at Site 35. Construction of supply wells for fire protection will be considered on a case-by-case basis. Currently, no operational supply wells are located within the existing limits of the contamination plume or immediately downgradient.

To ensure an adequate supply of clean potable groundwater, the Base Master Plan should include a long-term strategy for the development of groundwater resources. Such a management plan should clearly identify areas, such as Site 35, where the development of groundwater resources for potable use is prohibited. The plan should routinely be revised as sites are remediated or additional sites are identified.

4.1.2.2 Groundwater Monitoring

The purpose of the groundwater monitoring program is to track the contaminant plume's migration over time, identify any fluctuations in COC levels, and monitor the effectiveness of any other remedial actions. Under the program, groundwater samples will be collected and analyzed for Target Compound List (TCL) VOCs quarterly for the first five years and semiannually thereafter.

RAA 2 will address site-wide groundwater contamination even though the area north of the U.S. Highway 17 Bypass right-of way was considered as part of the Interim FS for Surficial Groundwater for a Portion of Operable Unit No. 10. The monitoring plan to be developed for this RAA will provide for monitoring the upper portion of the Castle Hayne Aquifer, and the lower and upper portions of the surficial aquifer using existing and proposed wells. Figure 4-1 identifies the existing and proposed monitoring wells that will be monitored as a part of this RAA. To assess groundwater conditions at Site 35, a total of 36 wells will be monitored. These wells can be grouped as follows:

- Two existing wells, GWD-3 and GWD-6, will be monitored to assess the potential vertical movement of contamination through the semiconfining unit into the upper portion of the Castle Hayne aquifer.

- Thirteen existing wells and four proposed wells will be monitored to assess changes in contaminant levels and plume migration in the lower portion of the surficial aquifer. The existing wells include MW-14B, -17B, -18B, -19B, -22B, -34B, -36B, -41B, -42B, -39B, -38B, -37B, and -09D. Proposed permanent wells will be constructed in the vicinity of former temporary well locations TW11B, TW14B, TW7B and TW8B.

- Three existing wells MW10D, -30B and -40B will be monitored to assess the development and movement of a vinyl chloride plume in the lower portion of the surficial aquifer located in the vicinity of Fourth , Fifth and E Streets.

- Fourteen existing wells will be monitored to assess changes in contaminant levels and plume migration in the upper portion of the surficial aquifer. These wells include MW-34A, -30A, -29A, -37A, -9A, -5, -11, -14A, -17A, -18A, -19A, -22A, -33A and -36A.

In addition to the monitoring wells, three piezometers will be installed to further characterize groundwater flow in the vicinity of B and D Streets between Seventh and Ninth Streets.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

4.1.3 RAA 3: Natural Attenuation

RAA 3 involves natural attenuation, otherwise known as intrinsic bioremediation, of the contaminated groundwater. The Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater (Wiedemeier, 1995) provides the following definition of natural attenuation:

> "The term 'Natural Attenuation' refers to naturally-occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. These in-situ processes include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants."

The RI/FS Sampling and Analysis Plan (SAP) For Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm (Baker, 1993) that was used to support RI and SGI field efforts did not include parameters for monitoring natural attenuation processes. Parameters included in the SAP were intended to be supportive of another remedial alternatives such as air sparging, in-well aeration, or pump and treat. Natural attenuation has gained considerable acceptance since the SAP was prepared. A review of available data indicates some evidence that natural attenuation processes are ongoing at Site 35. Some of this evidence is as follows:

- Results from the RI that was conducted during the spring of 1994 indicate no vinyl chloride was present in MW10D, which is located in an area of high solvent-related contamination. During the SGI that was conducted in the spring of 1996, vinyl chloride was detected at 13 ppb. The presence of vinyl chloride is considered to be indicative of biodegradation. The primary chlorinated solvent of concern at Site 35, TCE, typically degrades to cis-1,2-DCE and then to vinyl chloride.

- A substantial drop in dissolved BTEX concentrations was observed between the RI conducted in 1994 and SGI conducted in 1996.

- During the RI free product was noted in several areas of the wetlands adjacent to Brinson Creek. During the SGI no such observations were made.

- In the southern area of concern during the SGI, the primary contaminant detected in the lower portion of the aquifer was cis-1,2- DCE, a daughter product of TCE.

- In the northern area of concern during the SGI, cis-1,2- DCE was the primary contaminant detected in samples collected from temporary wells. Concentrations in the lower portion of the surficial aquifer ranged from 17 µg/L to 1,417 µg/L.

- Substantial BTEX contamination was detected in the temporary wells installed in the vicinity of former Fuel Farm. However, no BTEX were detected in samples collected from wells installed approximately 200 feet downgradient of the temporary well locations.

- Elevated levels of Fe III are indicative that biodegradation of BTEX is occurring. Although Fe III was not was not one of the parameters included during the last round of sampling for inorganics, iron levels in several wells adjacent to the former Fuel Farm appeared to be elevated.

To support the evidence noted above, RAA 3 includes a natural attenuation treatability study, that will assess the effectiveness of natural attenuation processes in the surficial aquifer. Upon completion of the treatability study, a long-term monitoring program that will include and fate and transport modeling updates will be implemented. Activities associated with the treatability study, long-term monitoring in support of natural attenuation, and fate and transport modeling are described below.

4.1.3.1 Natural Attenuation Treatability Study

The natural attenuation treatability study will assess the ability of the naturally occurring subsurface processes to reduce fuel and solvent-related contaminant mass, toxicity, mobility, volume, or concentration. Included in the treatability study will be the following:

- A laboratory microcosm study to determine if indigenous microbes are capable of degrading site COCs as well as the estimated rate of degradation.

- An initial round of groundwater and soil sampling to provide additional data to assess the impact of natural attenuation and to determine if this process is contributing to reductions in contaminant concentrations or increases in metabolic end products/daughter products. For the purpose of developing a cost for this RAA it will be assumed that a single round of data will provide sufficient evidence to support the continued implementation of this RAA, although more than one round may be necessary. Table 4-1 lists the analytical parameters that will provide the appropriate physical and chemical data. A list of wells that will be sampled is presented in Section 4.1.3.2. The data will be collected and assessed based on protocols and methods outlined in:

  Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1996)

Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater (Wiedemeier, 1995)

- Development of a baseline contaminant fate and transport model that takes into account the natural attenuation mechanism. The model will be used to predict contaminant plume reduction and changes in the chemical character of the plume.

4.1.3.2 Long-term Groundwater Monitoring

Assuming the treatability study confirms that natural attenuation processes are effectively reducing contaminant levels, a long-term groundwater monitoring program will be implemented. This program will monitor levels of COCs and provide additional data to support contaminant fate and transport model updates.

Table 4-1 presents the analytical parameters that will be performed on groundwater samples as a part of the long-term monitoring program. For cost estimating purposes, it is assumed that monitoring will be conducted on a quarterly basis for the first five years and semiannually thereafter. The groundwater samples will be collected from the upper and lower portion of the surficial aquifer, and the upper portion of the Castle Hayne aquifer.

Figure 4-2 depicts the wells that have initially been considered for inclusion in the treatability study and monitoring program based on available data. As the groundwater contaminant plume shrinks, fewer wells will be required for monitoring. However, for the purpose of this FS, the following wells will be included in the treatability study and long-term monitoring effort:

- Existing wells to be monitored in the lower portion of the surficial aquifer include MW-18D, -19D, -16D, -22D, -26B, -33B, -36B, -35B, -32B, -34B, -41B, -43B, -42B, -40B, -38B, -29B, -37B, -10D, -9D, -31B, -30B and -14B. Monitoring wells MW-16D, -18D, -19D, -33B, -35B and -36B may need to be relocated upon construction of the U. S. Highway 17 Bypass.

- Samples will also be collected from three additional proposed intermediate wells that will be installed at locations TW8, TW11, and TW14.

- A proposed upgradient intermediate and shallow well pair to assess background conditions will be installed and sampled.

- Existing wells to be monitored in the upper portion of the surficial aquifer include MW-13S, MW-23S, EMW-3, MW-17S, MW-18S, EMW-6, MW-19S, MW-11, MW-14S, MW-31A, MW-1, MW-9S, MW-29A, MW-10A, MW-30A, MW-32A, MW-34A, MW-35A, and MW-36A. Monitoring wells MW-17S, -18S, -19S, -34A, -35A and -36A may have to be relocated upon construction of the U. S. Highway 17 Bypass.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

4.1.3.3 Fate and Transport Modeling Updates

Under RAA 3, annual updates of the contaminant fate and transport model will be performed. These updates will be used to verify the assumptions of the initial modeling effort and to provide a means for regularly re-evaluating the effectiveness of natural attenuation at this site.

4.1.4 RAA 4: Extraction and Ex Situ Treatment

Extraction and Ex Situ Treatment was selected as RAA 4. It is a conventional extraction and treatment alternative in which groundwater will be collected by extraction wells and conveyed to an on-site facility for treatment (i.e., primarily VOC removal). Once treated, the groundwater will then be discharged to Brinson Creek via an upgraded storm drain. In addition, sludge and spent activated carbon generated from the treatment process will be properly disposed.

RAA 4 includes the installation of seven, six-inch diameter extraction wells and the construction of a 40 gallon per minute (gpm) groundwater treatment facility. Figure 4-3 presents the conceptual site layout of this RAA. Four extraction wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. The combined capture zones of these extraction wells will intercept the contaminant plume and mitigate the horizontal migration of contaminants. In addition to the extraction wells along the eastern edge of the contaminant plume, three more extraction wells will be installed in a "hot spot" area near MW-10 where solvent-related contamination was on the order of 1,000 μg/L. These hot spot extraction wells are intended to reduce the overall contaminant mass in these areas.

In lieu of pump test data, the pumping rate and capture zone were estimated based on slug test data, the site geology, and the site hydrogeology. Because the hydraulic conductivity south of Fifth Street is generally an order of magnitude greater than the conductivity north of Fifth Street the estimated capture zone and pumping rates for the four interceptor wells are greater than the three hot spot wells. Capture of the interceptor wells is estimated to be approximately 120 feet per well and pumping rates are estimated to range from five to ten gpm per well. The capture radii of the hot spot wells is estimated to be approximately 80 feet per well and the pumping rate was estimated to be approximately two gpm per well. The total production rate of the entire system is estimated to be 40 gpm.

Based on the SGI data (Baker, 1996), the groundwater contamination in the southern and southeastern portion of the site is solvent-related and limited to the lower portion of the surficial aquifer. However, the potential for the migration of fuel-related contamination exists. In the hot spot areas, fuel- related groundwater contamination in the upper portion of the surficial aquifer coexists with solvent- related contamination in the lower portion of the surficial aquifer. Considering these facts, all extraction wells will be screened from the semiconfining unit located approximately 40 feet bgs to the water table located approximately six feet to ten feet bgs.

All of the above information was used to develop the conceptual system layout and cost estimate for the FS. If RAA 4 is selected as the preferred RAA, a pump test would be required to more accurately determine the pumping rates and capture radii that could be expected at the site. Data from the pump test will then be utilized to develop a groundwater flow and transport model (three-dimensional) to further evaluate the number and placement of extraction wells. Due to the low pumping rates of the extraction well system, potentially damaging settlement of nearby building foundations and infrastructure is not anticipated.

Extracted groundwater will be pumped from the wellhead to the on-site treatment facility. At the treatment facility, the groundwater will undergo suspended solids removal via coagulation/flocculation, clarification/sedimentation, and filtration units. Primary VOC removal will be accomplished by an air stripper with secondary treatment provided by a liquid-phase granular activated carbon (GAC) filter. VOC emissions from the air stripper will be treated with a vapor-phase GAC filter. A conceptual process flow diagram for the proposed treatment process is shown on Figure 4-4. Bench scale tests will be performed to estimate coagulant usage, sludge generation, and carbon usage.

Treated groundwater will be discharged to Brinson Creek via an adjacent storm drain system, which will be upgraded to accommodate the estimated 40 gpm flow rate. For the purpose of costing it is assumed that the implementation of the RAA will occur after the proposed U.S 17 Highway Bypass is completed.

If RAA 4 was selected and implementation would occur before the U.S. Highway 17 Bypass construction, a substantial cost will be incurred to extend the existing storm drain system approximately 200 feet across existing wetlands to Brinson Creek. This discharge action would also be subject to the U.S. Army Corp of Engineers approval.

In addition to groundwater extraction, treatment and discharge, RAA 4 incorporates the long-term groundwater monitoring program and site controls identified in RAA 2. Under the long-term monitoring program, a total of 36 groundwater samples will be collected and analyzed for TCL VOCs on a quarterly for the first five years and semiannually thereafter.

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

4.1.5 RAA 5: In Situ Passive Treatment/Slurry Cut-Off Wall

RAA 5 includes the construction of two separate sections of an in situ passive treatment/slurry cut-off wall as shown in Figure 4-5. Groundwater at the site generally flows in a northeasterly direction toward Brinson Creek. However, in the southern portion of the site, evidence suggests that a break potentially occurs where groundwater flows in a southeasterly direction. It is estimated that the northern treatment/cut-off wall will be approximately 1,300 feet in length, will consist of approximately 1,170 feet of slurry cut-off wall and 150 feet of gate, and will be positioned to intercept groundwater flowing toward Brinson Creek . It is estimated that the southern treatment/cut-off wall will be approximately 1,000 feet in length, will consist of approximately 900 feet of slurry cut-off wall and 100 feet of gate, and will be positioned to intercept groundwater flowing in a southeasterly direction.

This type of technology is referred to as a "funnel and gate" system. The slurry wall directs or funnels groundwater flow to gate sections that are packed with gravel and iron filings. The iron filings facilitate the dechlorination of solvent-contaminated groundwater into non-toxic byproducts. Gate and slurry wall cross-sections are shown in Figure 4-6. Gates consist of a vertical section of iron filings sandwiched between two vertical gravel sections. The gate would extend from the semiconfining unit, located about 40 feet bgs, to approximately 20 feet bgs. A slurry wall would be constructed on top of the gate from 20 foot bgs to the surface. It is assumed for this RAA that three gate sections will be constructed in the northern wall and two gate sections in the southern wall. The exact location and number of gate section would be determined by a groundwater flow model during the design phase. A bench-scale test would be required to determine the exact formulation of the iron material.

The slurry cut-off wall would be approximately three feet thick, and extend from the semiconfining unit to the surface. A bench scale test would be required to determine the appropriate slurry composition.

In addition, RAA 5 incorporates the site controls and the long-term groundwater monitoring program described in RAA 2. Five additional upgradient wells and five additional downgradient wells will be installed and sampled to determine the effectiveness of the treatment system. Under the long-term monitoring program associated with this alternative a total of 36 groundwater samples will be collected and analyzed for TCL VOCs quarterly for the first five years and semiannually thereafter.

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

RAA 6: In-Well Aeration and Off-Gas Carbon Treatment

RAA 6 consists of the installation and operation of ten in-situ aeration wells. Seven aeration wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. These wells will intercept the contaminant plume and mitigate horizontal migration. Assuming a conservative capture radius of approximately 100 feet, the combined capture zones of the "interceptor wells" will extend over a distance of approximately 1,400 feet. To reduce the contaminant mass in the hot spot area near MW-10, where solvent-related contamination is on the order of 1,000 µg/L, three additional aeration wells will be installed. The site layout for this RAA is shown in Figure 4-7.

During the operation of an in-well aeration system, air is injected into a groundwater well creating an in-well air-lift pump effect. This pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out the top of the well. As the groundwater circulates through the well, the injected air stream strips away VOCs. The VOCs are captured at the top of the well and treated via a carbon adsorption unit.

Each aeration well will be flush mounted and equipped with the appropriate down-hole seals, piping and valves, well screens, and filter packs. VOCs generated by this technology will be treated by trailer mounted unit that will include a blower, knockout tank, vacuum pump and vapor phase carbon adsorption units. Two or three aeration wells will be serviced by a single trailer-mounted blower/off-gas treatment unit. To assess the effectiveness of each in-well aeration unit, a pair of monitoring wells screened in the upper and lower portions of the surficial aquifer will be constructed. Air will be sampled monthly to ensure that all emission standards are being achieved. A well detail and general process flow diagram is provided in Figure 4-8.

Currently, an in-well aeration pilot test is being conducted at Camp Lejeune Site 69, Rifle Range Chemical Dump. The results are anticipated sometime during 1997. Once data becomes available regarding system operations and remedial success, RAA 6 may be modified.

RAA 6 also incorporates the site controls and the long-term groundwater monitoring program described in RAA 2. Two monitoring wells will have to be removed and reinstalled. Under the long-term monitoring program associated with this alternative a total of 36 groundwater samples will be collected and analyzed for TCL VOCs quarterly for the first five years and semiannually thereafter.

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

4.2 References

Baker. 1996. Baker Environmental Inc. Supplemental Groundwater Investigation Report, Operable Unit No. 10, Site 35-Camp Geiger Area Fuel Farm. Marine Corp Base, Camp Lejeune, North Carolina.

Baker, 1993. Baker Environmental, Inc. Remedial Investigation/Feasibility Study, Sampling and Analysis Plan for Operable Unit No. 10 (Site 35). Marine Corp Base, Camp Lejeune, North Carolina.

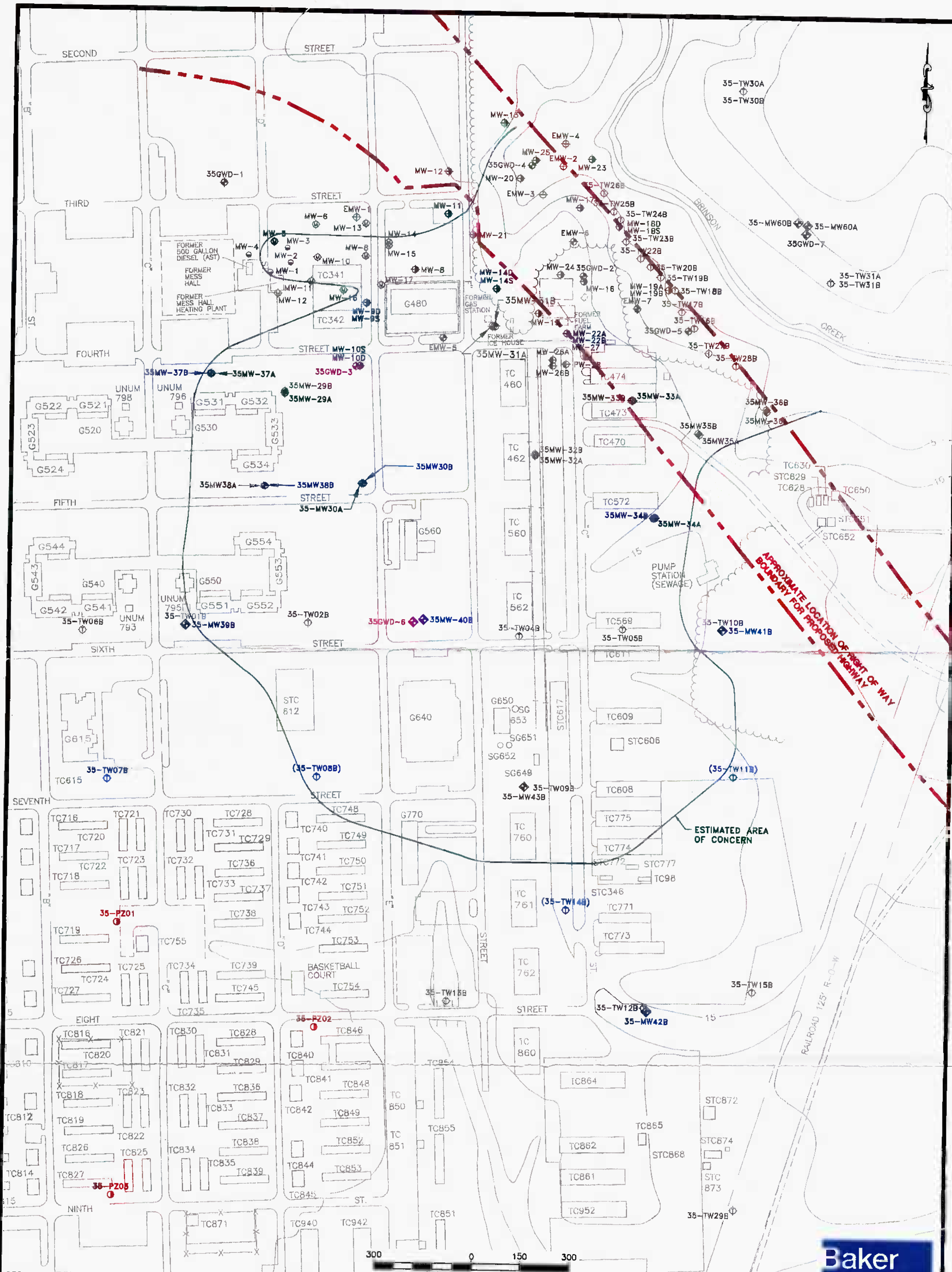
Baker, 1995. Baker Environmental, Inc. Remedial Investigation Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Marine Corp Base, Camp Lejeune, North Carolina.

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

Wiedemeier, Todd; et al. 1995. Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater Volumes I and II. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

Wiedemeier, Todd; et al. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

SECTION 4.0 FIGURES



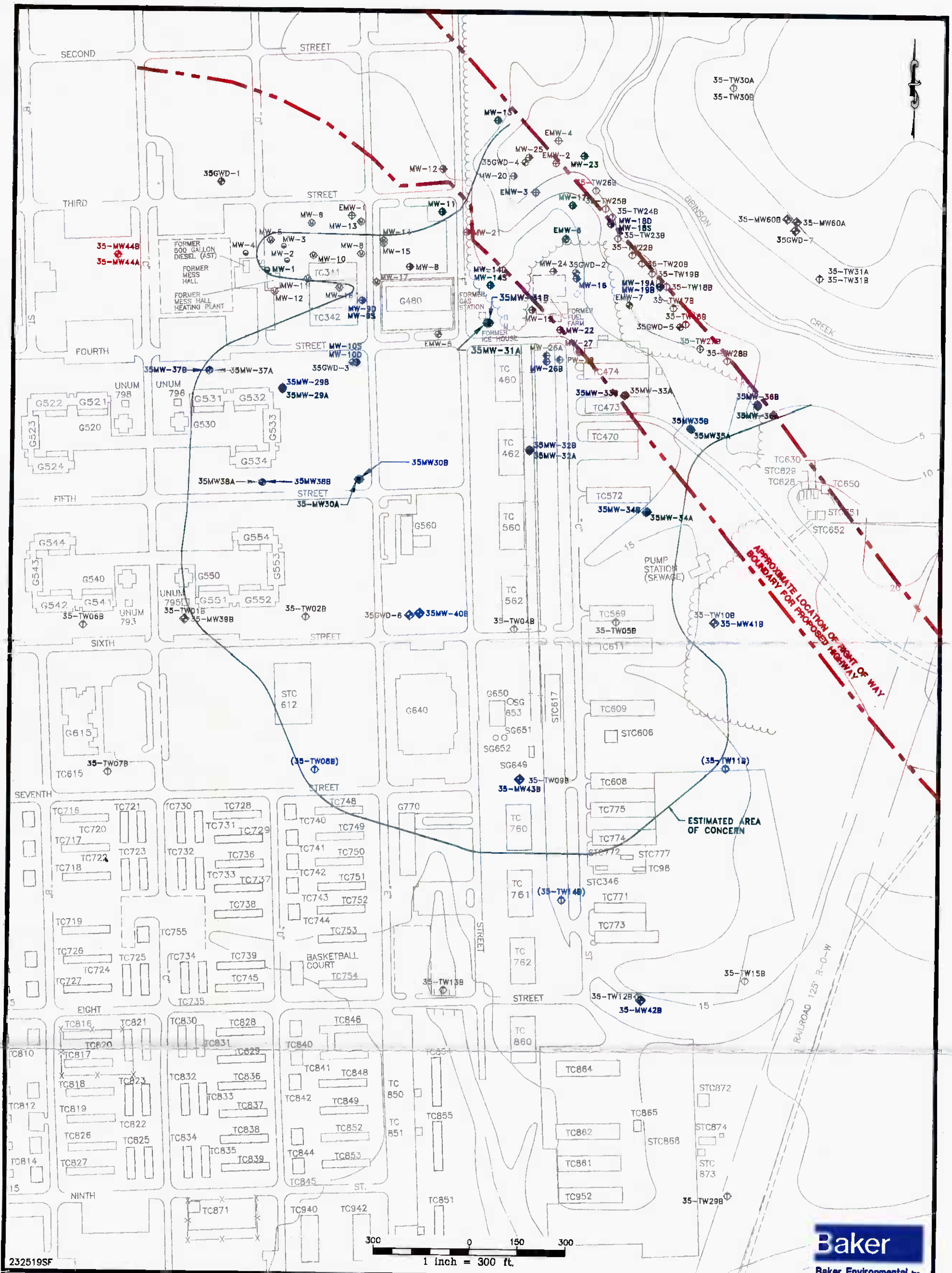
LEGEND

35-MW30A	WELL INSTALLED IN THE UPPER PORTION OF THE SURFICIAL AQUIFER
35-MW30B	WELL INSTALLED IN THE LOWER PORTION OF THE SURFICIAL AQUIFER
(35-TW08B)	PROPOSED ADDITIONAL INTERMEDIATE WELL
35-PZ01	PROPOSED PIEZOMETER
35GWD-6	WELL INSTALLED IN THE CASTLE HAYNE AQUIFER

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-1
RAA No. 2: SITE CONTROLS AND LONG-TERM MONITORING
MONITORING WELL LOCATION MAP
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01354GGB4Y



LEGEND

35-MW30A — WELL INSTALLED IN THE UPPER PORTION OF THE SURFICIAL AQUIFER

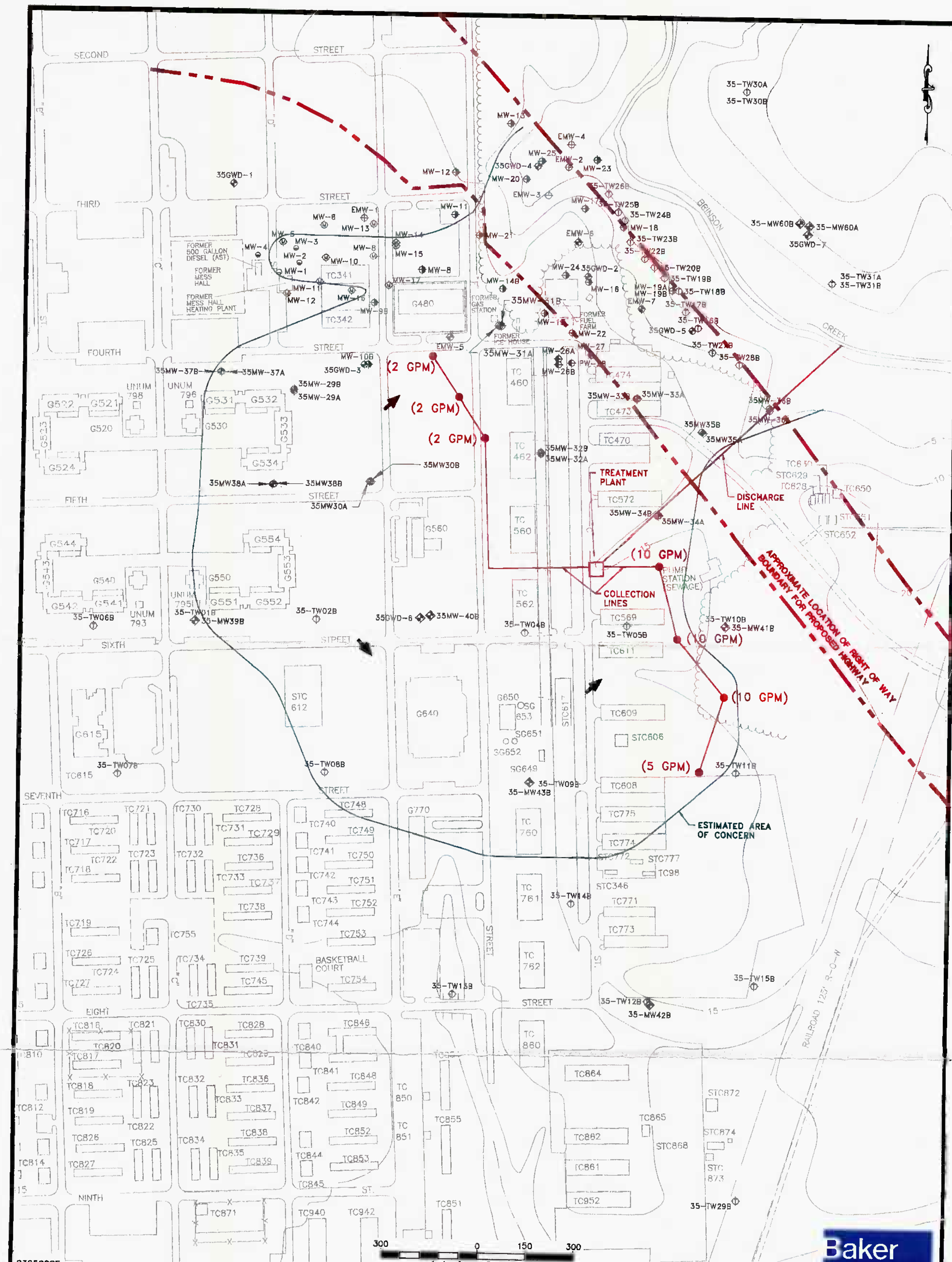
35-MW30B — WELL INSTALLED IN THE LOWER PORTION OF THE SURFICIAL AQUIFER

(35-TW08B) — PROPOSED ADDITIONAL INTERMEDIATE WELL

35-MW44B / 35-MW44A — PROPOSED UPGRADIENT WELL PAIR

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-2
RAA No. 3: NATURAL ATTENUATION
MONITORING WELL LOCATION MAP
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

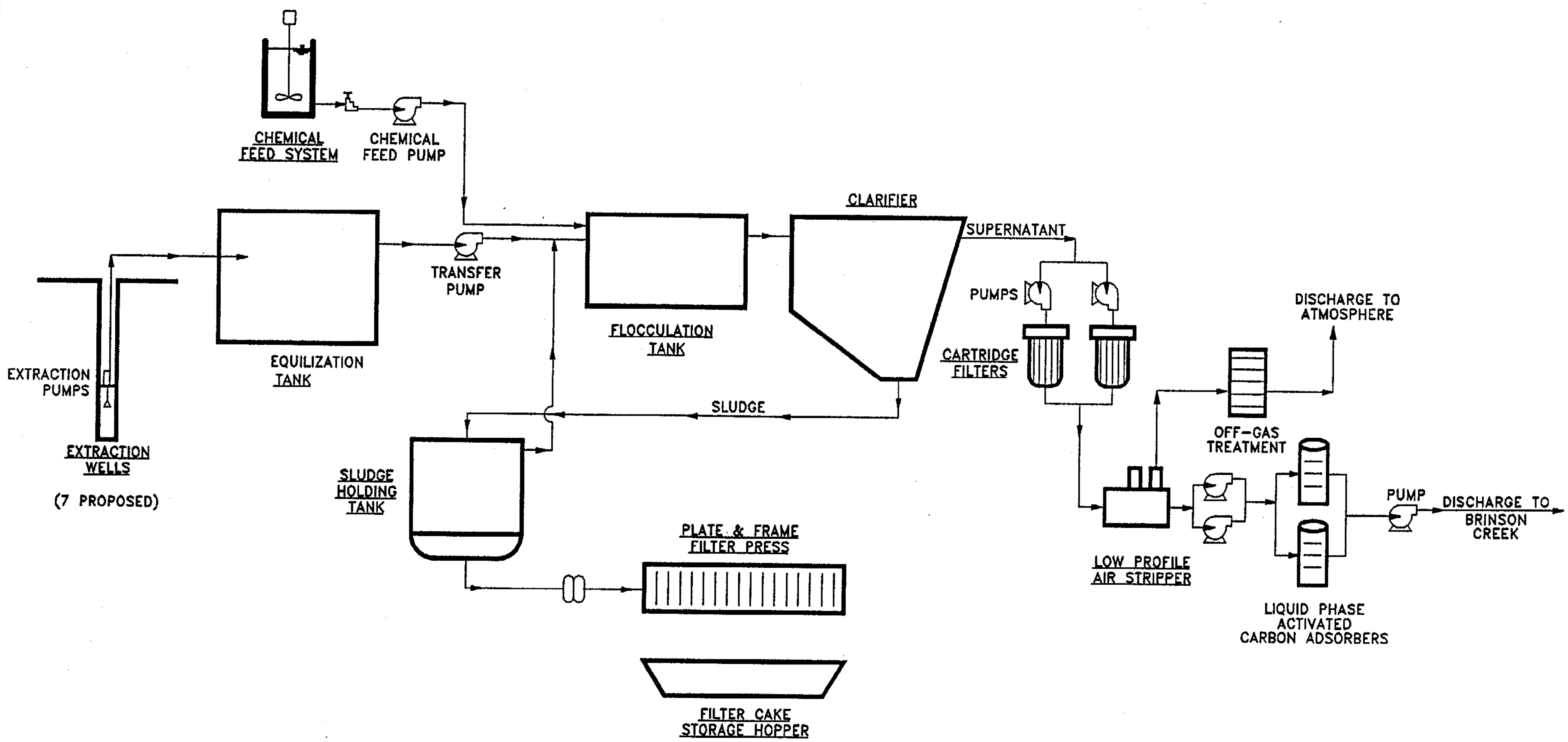


LEGEND

- GROUNDWATER EXTRACTION WELL
- GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-3
RAA No. 4: GROUNDWATER EXTRACTION AND EX SITU TREATMENT SITE PLAN
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER – 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
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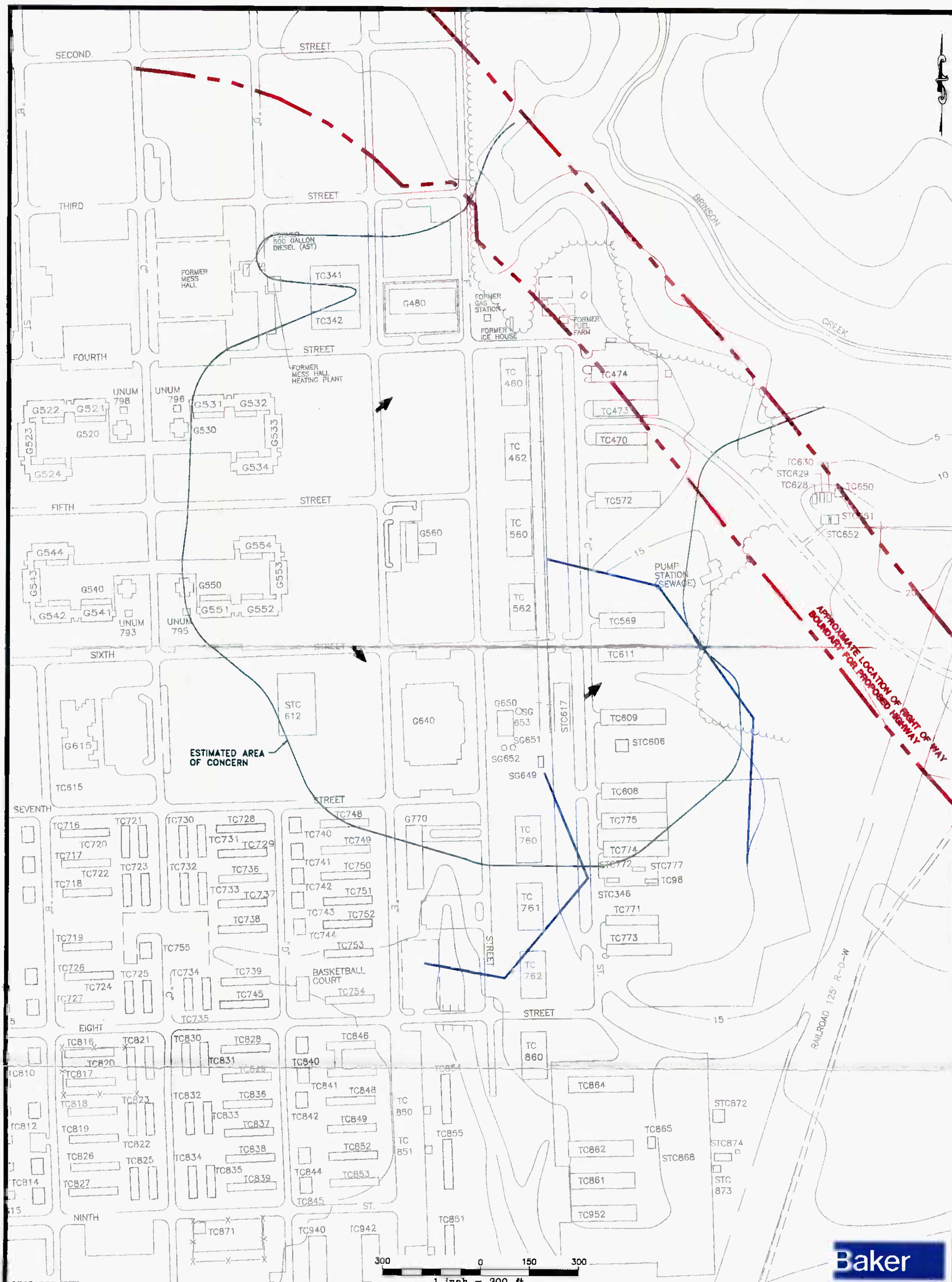
FIGURE 4-4
RAA No. 4: GROUNDWATER EXTRACTION AND EX SITU TREATMENT PROCESS FLOW DIAGRAM
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER – 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

232525SF



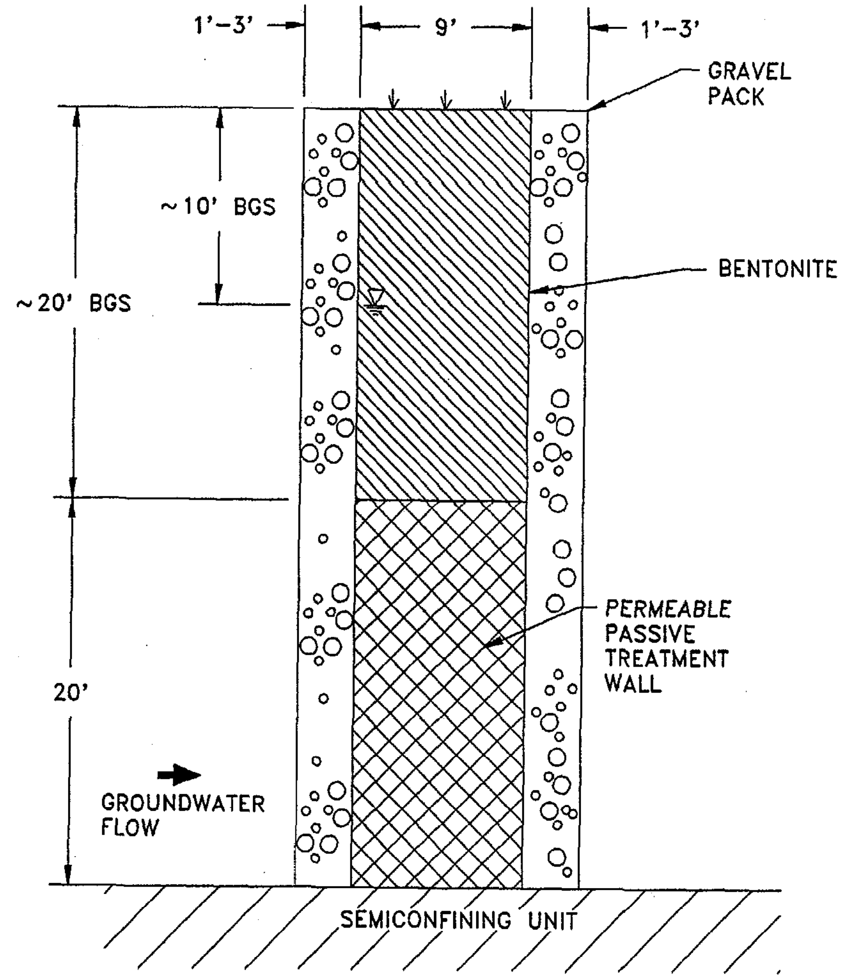
LEGEND

- PASSIVE TREATMENT/SLURRY CUT-OFF WALL
- 10 — SURFACE ELEVATION CONTOUR
- FENCE
- STRUCTURE
- TREE LINE
- GROUNDWATER FLOW DIRECTION
- APPROXIMATE LIMITS OF U.S. HIGHWAY 17 BYPASS

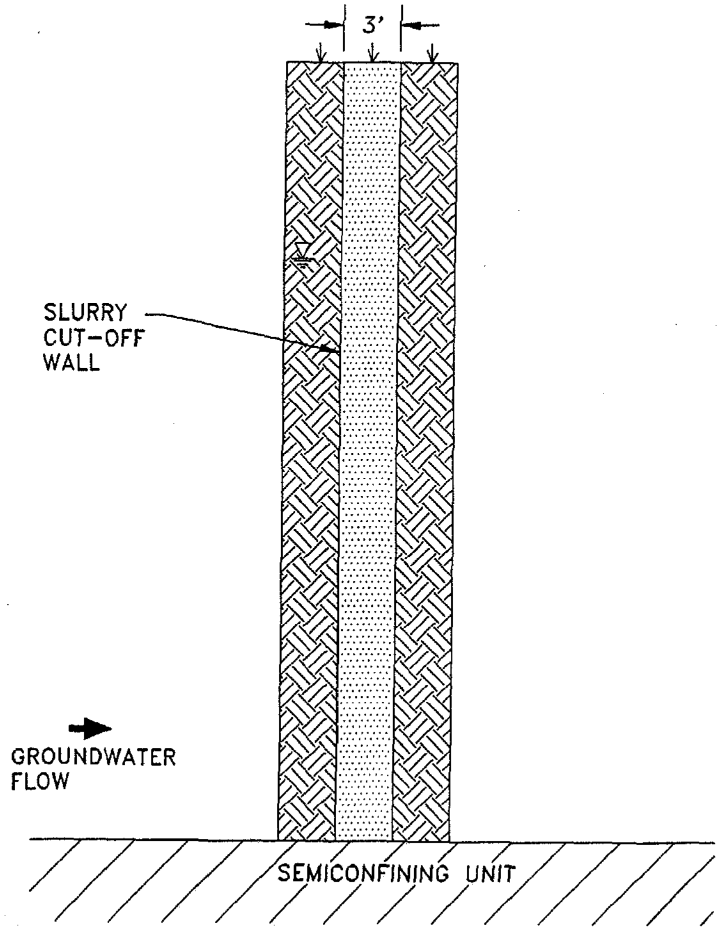
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-5
RAA No. 5: IN SITU PASSIVE TREATMENT/
SLURRY CUT-OFF WALL SITE PLAN
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER – 0232

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



TYPICAL SECTION OF GATE



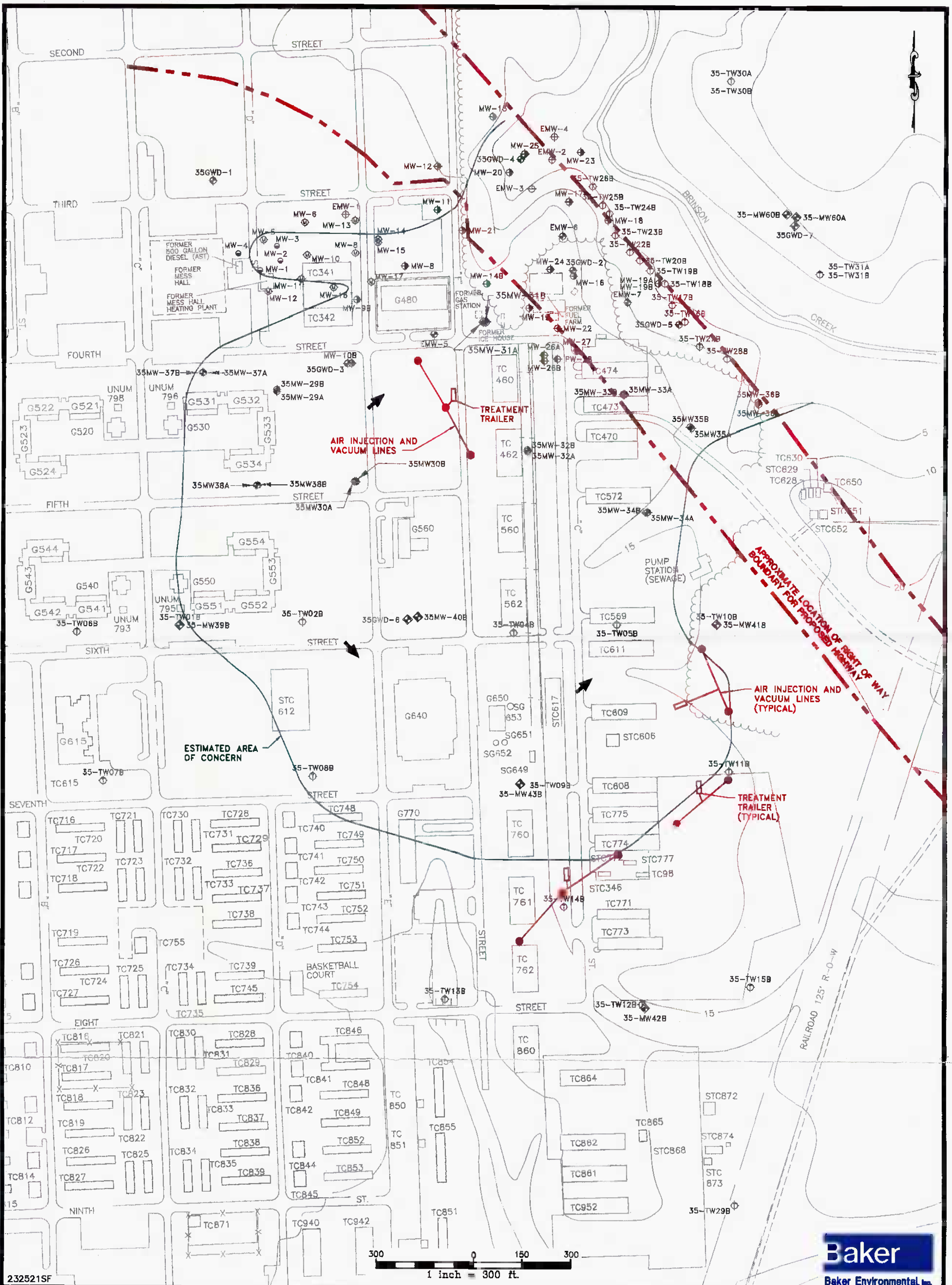
TYPICAL SECTION OF FUNNEL

NOT TO SCALE

Baker
Baker Environmental, Inc.

FIGURE 4-6
RAA No. 5: IN SITU PASSIVE TREATMENT/
SLURRY CUT-OFF WALL CROSS-SECTIONS
SITE 35, CAMP GIEGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

232D229F

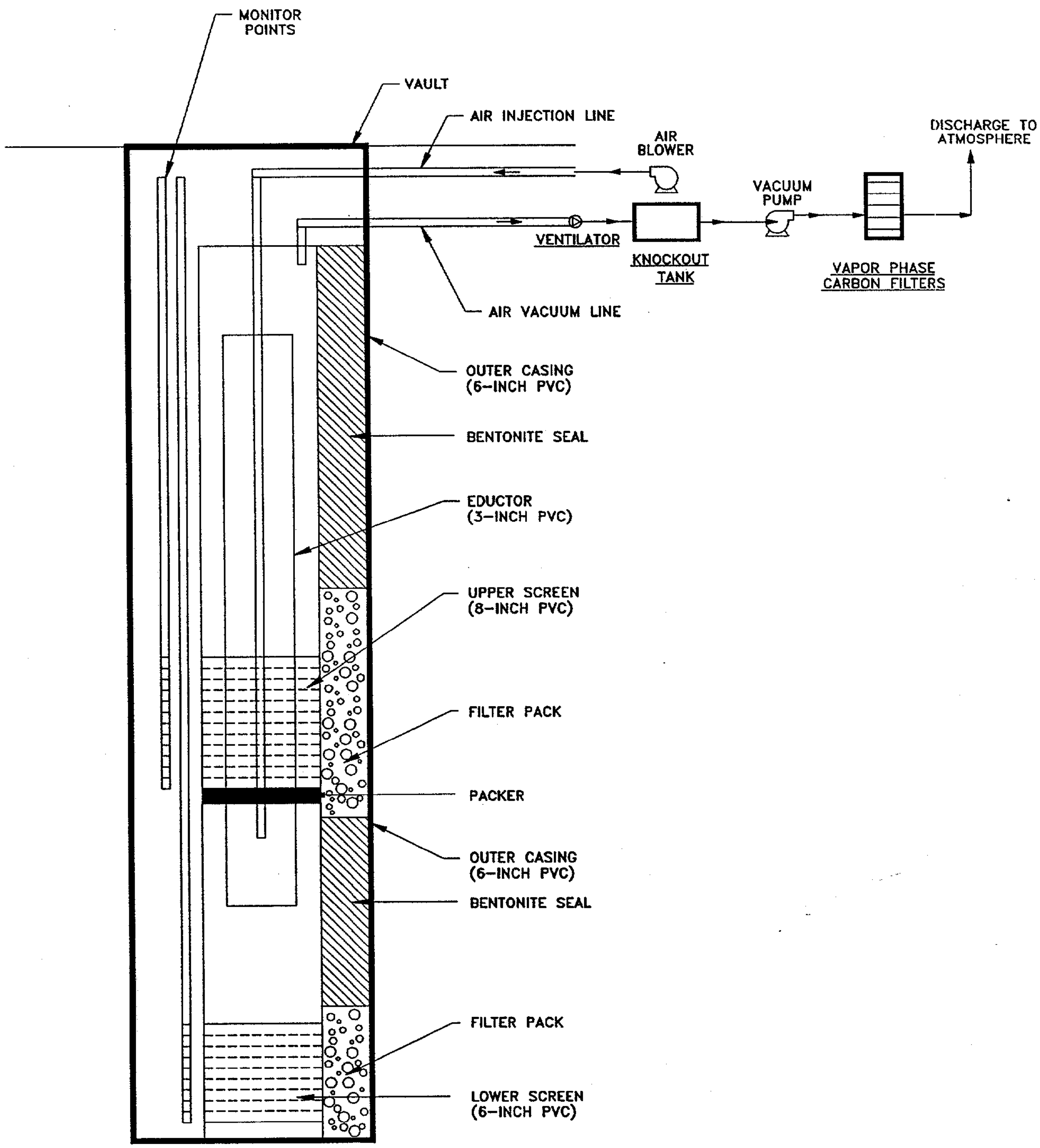


LEGEND

- IN-WELL AERATION WELL
- GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-7
RAA No. 6: IN-WELL AERATION WITH OFF-GAS CARBON ADSORBTION SITE PLAN
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

FIGURE 4-8
RAA No. 6: IN-WELL AREATION WITH OFF-GAS CARBON ADSORPTION TYPICAL WELL DETAIL AND PROCESS FLOW DIAGRAM
SITE 35, CAMP GEIGER AREA FUEL FARM FS
CONTRACT TASK ORDER - 0232
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

232526SF

5.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section presents the detailed analysis of the remedial action alternatives that were developed in Section 4.0. Section 5.1 presents an overview of evaluation criteria that will be used in the detailed analysis. Sections 5.2 and 5.3 present the two parts of the detailed analysis: the individual analyses and the comparative analysis of remedial action alternatives, respectively.

This detailed analysis has been conducted to provide sufficient information to adequately compare the alternatives, select an appropriate remedy for the site, and demonstrate satisfaction of the CERCLA remedy selection requirements in the Record of Decision (ROD). The extent to which alternatives are assessed during the detailed analysis is influenced by the available data, the number and types of alternatives being analyzed, and the degree to which alternatives were previously analyzed during their development and screening (USEPA, 1988).

The detailed analysis of alternatives was conducted in accordance with the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA, 1988) and the NCP, including the February 1990 revisions. In conformance with the NCP, seven of the following nine criteria were used for the detailed analysis:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance (not evaluated at this time)
- Community acceptance (not evaluated at this time)

State acceptance and community acceptance will be evaluated in the ROD by addressing comments received after the Technical Review Committee (TRC) has reviewed the FS and Proposed Remedial Action Plan (PRAP). The TRC includes participants from the NC DEHNR, USEPA Region IV, and the public.

5.1 Overview of Evaluation Criteria

The following paragraphs describe the evaluation criteria that are used in the detailed analysis.

Overall Protection of Human Health and the Environment: Overall protection of human health and the environment is the primary criteria that a remedial action must meet. A remedy is considered protective if it adequately eliminates, reduces, or controls all current and potential site risks posed through each exposure pathway at the site. A site where hazardous substances remain without engineering or institutional controls allows for unlimited exposure for human and environmental receptors. Adequate engineering controls, institutional controls, or some combination of the two, can be implemented to control exposure and thereby ensure reliable protection over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts on human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs): Compliance with ARARs is one of the statutory requirements for remedy selection. Alternatives are developed and refined throughout the FS process to ensure that they will meet all ARARs or that there is a sound rationale for waiving an ARAR. During the detailed analysis, the alternatives will be analyzed based on the federal and state contaminant-specific ARARs, the action-specific ARARs, and the location-specific ARARs that were presented in Section 2.0 of this FS.

Long-Term Effectiveness and Permanence: This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the environment in the distant future, as well as the near future. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford, the analysis will focus on the residual risks present at the site after the completion of the remedial action. The analysis will also include consideration of the following:

- Degree of threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering and institutional controls) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

Reduction of Toxicity, Mobility, or Volume Through Treatment: This criterion addresses the statutory preference for remedies that employ treatment as a principal element. The criterion ensures that the relative performance of the various treatment alternatives in reducing the toxicity, mobility, or volume will be assessed. Specifically, the analysis will examine the magnitude, significance, and irreversibility of reductions.

Short-Term Effectiveness: This criterion examines the short-term impacts associated with implementing the alternative. Implementation may impact the neighboring community, workers, or the surrounding environment. Short-term effectiveness also includes potential threats to human health and the environment associated with the excavation, treatment, and transportation of hazardous substances, the potential cross-media impacts of the remedy, and the time required to achieve protection of human health and the environment.

Implementability: Implementability considerations include the technical and administrative feasibility of the alternatives, as well as the availability of goods and services (including treatment, storage, or disposal capacity) associated with the alternative. Implementability considerations often affect the timing of remedial actions (e.g., limitations on the season in which the remedy can be implemented, the number and complexity of material handling steps, and the need to secure technical services). On-site activities must comply with the substantive portions of applicable permitting regulations.

Cost: Cost includes all capital costs and annual operation and maintenance costs incurred over the life of the project. The focus during the detailed analysis is on the present worth of these costs. Costs are used to select the most cost-effective alternative that will achieve the remedial action objectives.

In accordance with USEPA guidance (USEPA, 1988), the cost estimates will have an accuracy of -30 to +50 percent. The exact accuracy of each cost estimate depends upon the assumptions made and the availability of costing information. The present worth costs were calculated assuming a five percent discount factor and a zero percent inflation rate.

For this FS, it has been assumed that groundwater monitoring will be conducted semiannually for thirty years. This assumption has been made for costing purposes only.

State Acceptance: This criterion, which is an ongoing concern throughout the remedial process, reflects the statutory requirement to provide for substantial and meaningful state involvement. State comments will be addressed during the development of the FS, the PRAP, and the ROD, as appropriate.

Community Acceptance: This criterion addresses the community's comments on the remedial alternatives under consideration, where "community" is broadly defined to include all interested parties. These comments are taken into account throughout the FS process. However, formal public comment will not be received until after the public comment period for the PRAP is held, so only preliminary assessment of community acceptance can be conducted during the development of the FS.

5.2 Individual Analysis of Alternatives

The following subsections present the detailed analysis of RAAs on an individual basis. This individual analysis includes a brief description of each RAA and an assessment of how well the RAA performs against the evaluation criteria. Table 5-1 summarizes the individual, detailed analysis of alternatives.

5.2.1 RAA 1: No Action

Description

Under the no action RAA, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater or to monitor subsurface conditions at Site 35. The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs that provide a greater level of response.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 1, no remedial actions or monitoring activity will be implemented. As a result, no provision is made for protection of human health and the environment with respect to contaminated surficial groundwater at Site 35. Although no current receptors are at risk, this RAA does not provide for the reduction of risks to future residents by active means. Some passive reduction in risk to future resident may occur from the natural attenuation processes; however, this alternative does not provide for modeling or monitoring the effects of these processes.

Although this alternative does not provide for the protection of the environment, remedial actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10

(Baker, 1995) are currently being designed to mitigate the migration of site-related contamination into Brinson Creek. Implementation of this Interim Remedial Action is scheduled for 1997.

Compliance With ARARs: Under RAA 1, no active effort will be made to reduce contaminant levels to below federal and state chemical-specific ARARs. Over an indefinite period of time natural attenuation processes may reduce levels of COCs below ARARs. Compliance to the ARARs will be impossible to determine because no modeling or monitoring activity is performed as a part of the RAA.

No action-specific or location-specific ARARs apply to this RAA.

Long-Term Effectiveness and Permanence: Under RAA 1, any long-term permanent reductions in contaminant levels will be the result of natural attenuation processes. These processes may be reliable and adequate to meet remediation levels. However, without modeling and an appropriate monitoring program the extent and degree of remediation over time is impossible to predict.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years.

Reduction of Toxicity, Mobility, or Volume Through Treatment: Under RAA 1, natural attenuation processes such as biodegradation, dispersion, dilution, adsorption, volatilization, and chemical destruction may be occurring at Site 35. However, no predictive modeling or regular monitoring will be conducted under RAA 1 to evaluate the reduction of toxicity, mobility, or volume of contamination.

Short-Term Effectiveness: There are no remedial action activities associated with RAA 1. As a result, short-term potential risks to the community will not be increased, and there will be no additional environmental impacts resulting from remedial actions. Construction personnel working on the proposed U.S. Highway 17 Bypass in the vicinity of Site 35 may be required to wear personal protective equipment to avoid exposure to contaminated groundwater or airborne contaminants. Under RAA 1, it is impossible to estimate a time frame for achieving remediation levels through natural attenuation processes.

Implementability: The natural attenuation processes associated with this alternative are potentially ongoing. Because no engineered remedial action is included under RAA 1, issues associated with construction or operation activities are not applicable. The adoption of RAA 1, does not prevent the future implementation of active treatment. In terms of administrative feasibility, RAA 1 should not require additional coordination with other agencies, although a waiver of the state ARARs may be required since VOC levels in groundwater exceeding ARARs will remain on-site indefinitely.

Cost: There are no capital costs or O&M costs associated with this alternative. Therefore, the net present worth (NPW) is $0.

5.2.2 RAA 2: Site Controls and Long-Term Monitoring

Description

Under RAA 2, no engineered remedial actions will be applied at Site 35. Instead, site controls and long-term groundwater monitoring will be implemented. Site controls will involve the implementation of actions to mitigate human exposure to contaminated groundwater. These actions will include the restriction of supply well construction within the vicinity of Site 35, and identification of restricted aquifer-use areas in the Base Master Plan.

The purpose of the groundwater monitoring program is to track the contaminant plume's migration over time, identify any fluctuations in COC levels, and monitor the effectiveness of any other remedial actions. Under the program, groundwater samples will be collected from the surfical aquifer, as well as, the Castle Hayne aquifer, and analyzed for Target Compound List (TCL) VOCs quarterly for the first five years and semiannually thereafter.

Assessment

Overall Protection of Human Health and the Environment: RAA 2 provides for the overall protection of human health and the environment through the implementation of site controls and long-term groundwater monitoring for COCs. Site controls consist of restricting new supply well construction within the vicinity of Site 35 and identifying restricted aquifer-use areas in the Base Master Plan. Implementation of these actions will reduce the potential for human exposure to contaminated surficial groundwater at Site 35.

The long-term monitoring for COCs will identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure. The long-term monitoring program can also help identify contaminant reductions that may be occurring as a result of natural attenuation processes. However, without a predictive model and a monitoring program that includes parameters that quantify specific natural attenuation processes, the time frame for achieving remediation levels through the natural attenuation processes cannot be established. Analysis for COCs is insufficient for assessing natural attenuation processes.

Although this alternative does provide for the protection of the environment, actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 (Baker, 1995) are currently being implemented to mitigate the migration of site-related COCs into Brinson Creek. This RAA can provide some evidence of the natural attenuation processes occurring in the adjacent wetlands that are limiting contaminant migration towards Brinson Creek.

Compliance With ARARs: Under RAA 2, no active effort will be made to reduce contaminant levels to below federal and state chemical-specific ARARs. Over an indefinite period of time the natural attenuation processes may reduce levels of COCs below ARARs. Compliance to the ARARs can be determined with long-term groundwater monitoring for COCs.

No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence: Site controls and long-term groundwater monitoring of COCs can provide a permanent and reliable means for protecting human health. Restriction of supply well construction in the vicinity of Site 35, and identification of restricted aquifer-use areas in the Base Master Plan may prevent potential exposure to contaminated groundwater. Long-term monitoring of COCs can identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

The likelihood that natural attenuation processes will meet remediation levels developed in Section 2.3 cannot be determined under this RAA. Without a predictive model and a monitoring program that includes parameters that quantify specific natural attenuation processes, the time frame, for achieving remediation levels through the natural attenuation processes cannot be established However, long-term monitoring for COCs can provide some indication that natural attenuation processes are occurring by measuring decreasing levels of BTEX and TCE, and increasing levels of 1,2-DCE and vinyl chloride.

Site controls and long-term groundwater monitoring for COCs provide a permanent and reliable means for protecting human health. Restriction of supply well construction in the vicinity of Site 35 and identification of restricted aquifer-use areas in the Base Master Plan may prevent potential exposure to contaminated groundwater. Long-term monitoring for COCs will identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

Long-term management activities associated with this RAA will consist of the following:

- Monitoring for COCs, quarterly for the first five years and semiannually thereafter.
- Maintaining a data base of COC analytical results.
- Controlling laboratory and materials costs.
- Identifying and implementing the most up-to-date sampling equipment and techniques.
- Recording changes in site conditions or land use.
- Recording any accidental spills of fuel or chlorinated solvents.
- Routine assessment of the data to determine if migration is occurring and if natural attenuation processes are progressing toward remediation goals.
- Communicating the results of sampling efforts and data assessment with the appropriate regulatory agency.

Operation and maintenance activities associated with RAA 2 include: the replacement of PVC monitoring wells every five to ten year; the occasional painting of "stick-up" wells in visible areas; redevelopment of sediment-laden wells; changing rusted locks on wells; and trimming vegetation around well pads.

RAA 2 does not preclude the design and construction of an engineered remediation system. Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 2 does not provide an engineered treatment process for toxicity, mobility, or volume reduction of the contaminated groundwater. Over time contaminant reduction may be achieved by natural attenuation processes. These may include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical destruction of contaminants (Wiedemeier, 1996). Biodegradation is generally the most predominant natural attenuation process. Biodegradation processes associated with BTEX contamination, differ from biodegradation processes associated with chlorinated solvent contamination. BTEX biodegradation relies on an adequate supply of electron acceptors and in most hydrogeologic environments there appears to be an inexhaustible supply. During BTEX biodegradation, electron transfer occurs by aerobic respiration, denitrification, iron (III) reduction, sulfate reduction and methanogenesis. Reductive dechlorination requires both electron acceptors (chlorinated solvents) and electron donors (organic carbon source). If the system is depleted of electron donors before all chlorinated solvents are removed, reductive dechlorination will cease (Wiedemeier, 1996).

Short-Term Effectiveness: Because there are no engineered remedial actions associated with RAA 2, no increase of short-term potential risks to the community or site workers are anticipated. Additional environmental impacts resulting from long-term monitoring activities are also unlikely. Construction personnel working on the U.S. Highway 17 Bypass in the vicinity of Site 35 may be required to wear personal protective equipment to avoid exposure to contaminated groundwater or airborne contaminants.

Under RAA 2, it is impossible to estimate a time frame for achieving remediation levels through natural attenuation processes. However, for the purpose of developing a cost estimate comparable to other RAAs a 30-year project life was assumed.

Implementability: RAA 2 will be relatively easy to implement since no remediation activities are involved. Some effort will be required to modify the Base Master Plan and prepare a long-term monitoring plan. The latter document will be subjected to review and some agency interaction can be expected. The analytical results from long-term monitoring will be presented in a report prepared semiannually for agency review. This data will primarily be used to assess the migration of the contaminant plume and will provide some indication of the effects of natural attenuation processes.

Cost: Total direct and indirect capital costs for RAA 2 are primarily associated with drilling activities and are estimated to total $36,000. Annual O&M costs for RAA 2 are primarily associated with sampling and analysis activities and monitoring well replacement. Annual O&M costs for years one through five total $112,700 and annual costs for years six through 30 total $62,800 Considering these costs, a 30-year service life and a discount rate of 5%, the present worth value of RAA 2 is estimated to be $1,220,000. Backup for these costs are included in Table 5-2.

5.2.3 RAA 3: Natural Attenuation

Description

Under RAA 3, no engineered remedial actions will be implemented at Site 35. Instead, site controls and a long-term groundwater monitoring in support of natural attenuation will be implemented. Site controls will involve the implementation of actions to mitigate human exposure to contaminated groundwater. These actions will include the restriction of supply well construction within the vicinity of Site 35 and identification of restricted aquifer-use areas in the Base Master Plan.

Long-term monitoring will involve assessing, monitoring, and predicting the results of natural attenuation processes occurring in the subsurface environment that may be reducing the mass, toxicity, mobility, volume, or concentration of the COCs associated with Site 35. Activities associated with RAA 3 include the performance of a natural attenuation treatability study and the implementation of a long-term monitoring program that supports natural attenuation. A more detailed description of these activities is provided below.

Included in the treatability study will be the following:

- A laboratory microcosm study to determine if indigenous microbes are capable of degrading site COCs, as well as, the estimated rate of degradation.
- An initial round of groundwater and subsurface soil sampling to provide additional data to assess the impact of natural attenuation and to determine if this process is contributing to reductions in contaminant concentrations or increases in metabolic end products/daughter products.
- Development of a baseline contaminant fate and transport model that takes into account the natural attenuation mechanism. The model will be used to predict contaminant migration, plume reduction and changes in the chemical character of the plume.

Included in the long-term groundwater monitoring program in support of natural attenuation will be the following:

- Laboratory and field analysis of chemical and physical of parameters associated with specific natural attenuation processes . This data will be used to assess the status of natural attenuation at Site 35, and support contaminant fate and transport model updates.
- Submission of a semiannual report of sampling activities to the appropriate regulatory agencies.
- Annual updates of the contaminant fate and transport model. These updates will be used to verify the assumptions of the initial modeling effort, assist in regularly reevaluating the effectiveness of natural attenuation at this site and identify potential risks from migration or the development of daughter products.

Assessment

Overall Protection of Human Health and the Environment: RAA 3 provides for the overall protection of human health and the environment through the implementation of site controls and a long-term monitoring program that supports natural attenuation. Site controls consist of restricting new supply well construction in the vicinity of Site 35, and identifying restricted aquifer-use areas in the Base Master Plan. Implementation of these actions will reduce the potential for human exposure to contaminated surficial groundwater at Site 35.

Long-term monitoring in support of natural attenuation will involve monitoring, assessing, and predicting natural attenuation processes occurring in the subsurface environment that may be reducing the mass, toxicity, mobility, volume, or concentration of the COCs associated with Site 35. The predictive model can identify a time frame for achieving remediation levels through the natural attenuation processes and future risks resulting from potential contaminant migration or the development of daughter products. In addition, long-term monitoring in support of natural attenuation can identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

Although this alternative does provide for the protection of the environment, actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 (Baker, 1995) are currently being implemented that will mitigate the migration of site-related COCs into Brinson Creek. This RAA can provide evidence of the natural attenuation processes occurring in the adjacent wetlands that are limiting contaminant migration towards Brinson Creek.

Compliance With ARARs: Under RAA 3, no active effort will be made to reduce contaminant levels to below federal and state chemical-specific ARARs. Over a period of time the natural attenuation processes may reduce levels of COCs below ARARs. A time frame for achieving remediation levels and capacity of the natural system to remediate contaminated groundwater can be determined upon the completion of the treatability study.

No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence: Long-term groundwater monitoring in support of natural attenuation and site controls can provide a permanent and reliable means for protecting human health. Restriction of supply well construction in the vicinity of Site 35, and identification of restricted aquifer-use areas in the Base Master Plan may prevent potential exposure to contaminated groundwater.

The data gathered during long-term monitoring can be used to estimate a time frame for achieving remediation levels, capacity of the natural system to remediate contaminated groundwater, and future risks resulting from potential contaminant migration or the development of daughter products. Long-term monitoring in support of natural attenuation can identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. If potential risks are associated with detected or predicted contaminant migration, the appropriate action can be taken, if necessary, to limit human exposure.

The long-term effectiveness of the biodegration process, the primary natural attenuation process, is largely determined by the nature of the groundwater contamination. Generally BTEX biodegradation will continue until all of the contamination is destroyed. However, this is not always the case for chlorinated solvent contamination. If the source of organic carbon in the aquifer is adequate, chlorinated solvents may completely degraded. If the supply of organic carbon is removed or depleted reductive dechlorination may cease. An assessment of available organic carbon can be made during the proposed treatability study.

Residual contaminants that may remain on site until destroyed may include COCs and daughter products such as cis, 1-2 DCE and vinyl chloride. Daughter products of TCE such as vinyl chloride can be more toxic than the parent compound. Although unlikely, these residuals could migrate, into the Castle Hayne aquifer, or horizontally. However, long-term monitoring in support of natural attenuation can identify migration of these contaminants. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

The likelihood that natural attenuation processes will meet remediation levels determined in Section 2.3 can be initially assessed after the initial treatability study is performed and the predictive model developed. The capacity and time frame of the natural system to reach remediation levels will be refined as more natural attenuation data is gathered and assessed over time.

Long-term management activities associated with RAA 3 will consist of the following:

- Monitoring groundwater for natural attenuation parameters noted in Table 4-1 and COCs, on a quarterly basis for the first five years and semiannually thereafter.
- Maintaining a data base with the results of natural attenuation monitoring efforts and COC levels in monitoring wells and natural attenuation parameters.
- Controlling laboratory and materials costs.
- Identifying and implementing the most up-to-date sampling equipment and techniques.
- Recording changes in site conditions or land use.
- Identifying any changes to natural hydrogeologic conditions
- Recording any accidental spills of fuel or chlorinated solvents.
- Routine assessment of the data to determine if migration is occurring and if natural attenuation processes are progressing toward remediation levels.
- Communicating the results of sampling efforts and data assessment with the appropriate regulatory agency.

Operation and maintenance activities associated with RAA 3 include: the replacement of PVC monitoring wells every five to ten years; the occasional painting of "stick-up" wells in visible areas; redevelopment of sediment- laden wells; changing rusted locks on wells and trimming vegetation around well pads.

***Reduction of Toxicity, Mobility, or Volume Through Treatment*:** RAA 3 does not provide an engineered treatment process for toxicity, mobility, or volume reduction of the contaminated groundwater. Contaminant reduction may be achieved by natural attenuation processes. These may include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical destruction of contaminants (Wiedemeier, 1996). Biodegradation is generally the most predominant natural attenuation process that will toxicity, mobility or volume of the groundwater contamination.

Generally BTEX biodegradation will continue until all of the contamination is destroyed. BTEX remediation relies on an adequate supply of electron acceptors and in most hydrogeologic environments there appears to be an inexhaustible supply. Electron transfer during BTEX biodegradation occurs via aerobic respiration, denitrification, iron (III) reduction, sulfate reduction and methanogenesis. (Wiedemeier, 1996). However, this is not always the case for chlorinated solvent contamination. If the source of organic carbon in the aquifer is adequate, chlorinated solvents may be completely degraded. If the supply of organic carbon is removed or depleted reductive dechlorination may cease. An assessment of available organic carbon can be made during the proposed treatability study. Biodegradation of chlorinated solvents occurs via reductive dechlorination. This requires both electron acceptors (chlorinated solvents) and electron donors (organic carbon source). If the system is depleted of electron donors (organic carbon source) before all chlorinated solvents are reduced, reductive dechlorination will cease. However, if levels of organic carbon are adequate to maintain microbal activity chlorinated solvents will continue to be reduced (Wiedemeier, 1996). The status of electron acceptor/donor systems at a site can be assessed from data gathered through long-term monitoring in support of natural attenuation.

Residual contaminants that may remain on site until destroyed may include COCs and daughter products such as cis- 1,2- DCE and vinyl chloride. Daughter products of TCE such as vinyl chloride can be more toxic than the parent compound. However, if organic carbon source is adequate complete dechlorination can continue. In addition, vinyl chloride can be degraded to nontoxic byproducts aerobically, as well as, anaerobically

Natural attenuation addresses and can potentially reduce the principle threats to human health and the environment. Therefore, this RAA satisfies the statutory preference for treatment alternatives.

Short-Term Effectiveness: Because there are no engineered remedial actions associated with RAA 3, no increase of short-term potential risks to the community or site workers are anticipated. Additional environmental impacts resulting from long-term monitoring activities are unlikely. Construction personnel working on the U.S. Highway 17 Bypass in the vicinity of Site 35 may be required to wear personal protective equipment to avoid exposure to contaminated groundwater or airborne contaminants.

An estimation of the time frame required for achieving remediation levels can be determined upon completion of the treatability study. As data is gathered through long-term monitoring a more accurate estimate of the time required for completion can be developed. For the purpose of developing a cost estimate long-term monitoring in support of natural attenuation was assumed to continue for 30 years.

Implementability: RAA 3 can be implemented relatively easier than engineered remedial alternative systems because no design and construction activities are required. The Base Master Plan will be relatively easy to modify. However, a substantial effort will be required to implement a groundwater monitoring plan in support of natural attenuation. A treatability study will be needed to initially assess the capacity and time frame of the natural system to achieve remediation levels. Included in the proposed treatability study are a microcosm study, the development of a contaminant fate and transport model, and gathering sufficient data to determine a baseline of biochemical activity in the natural system. The proposed treatability study will require the development and submission of project plans an a final treatability study report. Upon completion of the treatability study report a long-term monitoring program can then be developed for natural attenuation at Site 35.

Cost: Total direct and indirect capital costs for RAA 3 are associated with drilling activities and the initial treatability study. These costs are estimated to total $290,000. Annual O&M costs for RAA 3 are associated with sampling and analysis activities and monitoring well replacement. These annual costs are estimated to be $251,000 for years one through five and $142,000 for years six through thirty. Considering these costs, a 30-year service life and a discount rate of 5%, the present worth value of RAA 3 is estimated to be $2,470,000. Backup for these cost estimates are included in Table 5-3.

5.2.4 RAA 4: Extraction and Ex Situ Treatment

<u>Description</u>

RAA 4 is a conventional extraction and treatment alternative in which groundwater will be collected by extraction wells and conveyed to an on-site facility for treatment (i.e., primarily VOC removal). Once treated, the groundwater will then be discharged to Brinson Creek via an upgraded storm drain. In addition, sludge and spent activated carbon generated from the treatment process will be properly disposed.

RAA 4 includes the installation of seven, six-inch diameter extraction wells and the construction of a 40 gallon per minute (gpm) groundwater treatment facility. Four extraction wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. The combined capture zones of these extraction wells will intercept the contaminant plume and mitigate the horizontal migration of contaminants. In addition to the extraction wells along the eastern edge of the contaminant plume, three more extraction wells will be installed in a "hot spot" area near MW-10 where solvent-related contamination was on the order of 1,000 µg/L. These hot spot extraction wells are intended to reduce the overall contaminant mass in these areas.

Extracted groundwater will be pumped from the wellhead to the on-site treatment facility. At the treatment facility, the groundwater will undergo suspended solids removal via coagulation/ flocculation, clarification/sedimentation, and filtration units. Primary VOC removal will be accomplished by an air stripper with secondary treatment provided by a liquid-phase granular activated carbon (GAC) filter. VOC emissions from the air stripper will be treated with a vapor-phase GAC filter.

Bench-scale tests will be performed to estimate coagulant usage, sludge generation, and carbon usage. A pump test would be required to accurately determine the pumping rates and capture radii that could be expected at the site. Data from the pump test will then be utilized to develop a traditional groundwater flow and transport model (three-dimensional) to further evaluate the number and placement of extraction wells. It is assumed that this model will not have the capacity to assess natural attenuation processes.

In addition, RAA 4 includes long-term groundwater monitoring for COCs and the implementation of site controls that include aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: RAA 4, provides for the overall protection of human health and the environment through the implementation of site controls and long-term groundwater monitoring for COCs, and the construction of a groundwater extraction/treatment system. Site controls consist of restricting new supply well construction within the vicinity of Site 35 and identifying restricted aquifer use areas in the Base Master Plan. Implementation of these actions will reduce the potential for human exposure to contaminated surficial groundwater at Site 35.

Under long-term monitoring for COCs, groundwater samples will be collected from the surfical aquifer, as well as the Castle Hayne aquifer, and analyzed for Target Compound List (TCL) VOCs quarterly for the first five years and semiannually thereafter. The results of long-term monitoring for COCs can be used to assess the effectiveness and efficiency of the remedial actions. Results can also identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as, any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

The long-term monitoring for COCs can also help identify contaminant reductions that may be occurring as a result of natural attenuation processes. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the time frame for achieving remediation levels through the natural attenuation processes cannot be established. Analysis for COCs alone is insufficient for assessing natural attenuation processes.

The extraction/treatment system attempts to mitigate the potential human health risks by decreasing the overall contaminant mass in the "hot spot" area, and intercepting the horizontal migration of the contaminant plume along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. It is anticipated that natural remedial processes will also continue to occur as active remediation is pursued.

Although this alternative does provide for the protection of the environment, actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 (Baker, 1995) are currently being implemented that will mitigate the migration of site related COCs into Brinson Creek. This RAA can provide evidence of the natural attenuation processes that appear to be occurring in the wetlands adjacent to Brinson Creek.

Compliance With ARARs: Under RAA 4, reductions of organic contamination in the surficial aquifer within the capture zone of the extraction well system may meet state federal and chemical-specific ARARs. Contaminant concentrations upgradient may continue to decrease as groundwater transports contamination towards the treatment area. However, it is uncertain if contaminant concentrations in the upgradient areas will meet state and federal chemical-specific ARARs.

Long-Term Effectiveness and Permanence: This treatment technology is designed to permanently remove organic contamination from the surficial aquifer. Remediation levels presented in Section 2.3 may be met within the capture zones of the extraction well system. However, it is uncertain if contamination levels upgradient will meet remediation levels.

Additional reductions in contaminants may occur upgradient as a result of ongoing natural attenuation, but these reductions will be much slower than those within the capture zone. Without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Long-term management activities associated with RAA 4 will consist of the following:

- Monitoring groundwater for COCs, quarterly for the first five years and semiannually thereafter.
- Monitoring discharge and off-gas effluent for VOCs.
- Monitoring the operations of the treatment system.
- Maintaining a data base of groundwater and effluent analytical results.
- Controlling laboratory and materials costs.
- Identifying and implementing the most up-to-date sampling equipment and techniques.
- Recording changes in site conditions or land use.
- Recording any accidental spills of fuel or chlorinated solvents.
- Routine assessment of the data to determine if the treatment system is performing as expected, contaminant migration is occurring and natural processes are occurring.
- Communicating the results of sampling efforts and data assessment with the appropriate regulatory agency.

Treatment plant O&M includes: replacement of vapor and liquid phase carbon filter; routine equipment inspection/cleaning; adjustment of air flows associated with the air stripper; adjustment of chemical mixing equipment; and minor repair of equipment. For costing purposes it was assumed that treatment plant equipment would be replaced once during the 30-year service life.

A potential operational problem that could occur is the development of inorganic precipitates that clog well screens. Some inorganic precipitates that form on well screens can be treated by adding a dissolving agent. Excessive inorganic precipitation on well screens could result in extraction well reinstallation.

Monitoring well O&M includes: the replacement of PVC monitoring wells every five years; the occasional painting of "stick-up" wells in visible areas; redevelopment of sediment laden wells; changing rusted locks on wells; and trimming vegetation around well pads.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years. In the event that this RAA is no longer effective in recovering COCs, the extraction/treatment system can be replaced.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 4 includes: coagulation/ flocculation; clarification/sedimentation; and filtration for suspended solids removal; air stripping for VOC removal from groundwater; and vapor phase carbon adsorption for VOC removal from air stripper emissions; and liquid phase carbon adsorption as a polishing step for groundwater prior to discharge. This process is designed to reduce the volume of contaminant in the groundwater prior to discharge

Extraction wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. The combined capture zones of these extraction wells will intercept the contaminant plume and mitigate the horizontal migration of contaminants. Extraction wells will also be installed in a "hot spot" area near MW-10 where solvent-related contamination was on the order of 1,000 μg/L in order to reduce the overall contaminant mass in these areas.

Contamination reduction will primarily occur in the capture zone of the extraction well system. Additional reductions may occur upgradient as a result of ongoing natural attenuation, but will be much slower than those reductions within the capture zone. Without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Residuals remaining after treatment may include sludge from suspended solids removal, spent carbon, and treated groundwater. The sludge is expected to be non-hazardous, but will require proper disposal. Spent liquid and vapor phase carbon will require regeneration or proper disposal. Once treated, groundwater is expected to be within acceptable limits and discharged to Brinson Creek.

This treatment addresses and potentially reduces the principle threats to human health and the environment, and therefore, this RAA satisfies the statutory preference for treatment alternatives.

Short-Term Effectiveness: During groundwater extraction and treatment operations the potential exists for an accidental release of contaminated groundwater or off-gas due to mechanical failure or operator error. It is anticipated that such a release would result in a plant shutdown and the release would be minimal in duration. Risk to Activity personnel working in the immediate vicinity of the treatment plant from would potentially be minimal. The environmental impact of such a release would also be potentially minimal.

Additional risks to the surrounding community resulting from long-term monitoring activities are unlikely. However, the installation of monitoring wells in the vicinity of Brinson Creek will require some disturbance of the wetland adjacent to Brinson Creek.

Personnel associated with the construction of the proposed U. S. Highway 17 Bypass, drilling operations, treatment plant O&M, and sampling activities may require some type of personnel protective equipment (PPE). This will include some type of protection against dermal contact with the groundwater. During all excavation operations air quality in the work zone should be monitored.

Under RAA 4, it is difficult to estimate a time frame for achieving site-wide remediation through treatment and natural attenuation processes. However, for the purpose of developing a cost estimate comparable to other RAAs a 30 year project life was assumed.

Implementability: The technology and materials required to install extraction wells and a groundwater treatment plant are readily available from multiple vendors. To support the design of such a system the following items are recommended: a pump test to accurately determine a radius of influence; the development of a traditional groundwater flow/transport mode to locate extraction wells; and performance of a bench-scale to estimate plant operating parameters.

No special problems are anticipated during construction and operation. However dissolved inorganics can precipitate onto well screens reducing efficiency and effectiveness.

The construction of monitoring wells adjacent to Brinson Creek will result in the disturbance of wetland areas. To minimize damage from heavy drilling equipment a plank road will be constructed where monitoring wells are to be installed. Permission will be required from the Army Corp of Engineers to install additional monitoring wells in wetland areas.

Some effort will be required to modify the Base Master Plan and prepare a long-term monitoring plan. The latter document will be subjected to review and some agency interaction can be expected. Analytical data from the long-term monitoring effort will be presented in a report prepared semiannually for agency review.

Cost: Total direct and indirect capital costs for RAA 4 are associated with drilling activities and the construction of the treatment plant. These costs are estimated to total $1,268,000. Annual O&M costs for RAA 4 are associated with sampling and analysis activities, monitoring well replacement, and treatment plant O&M. These annual costs are estimated to be $ 113,000 for years one through five, and $63,000 for years six through thirty. Considering these costs, a 30 year service life and a discount rate of 5%, the present worth value of RAA 4 is estimated to be $3,760,000. Backup for these costs are included in Table 5-4.

5.2.5 RAA 5: In Situ Passive Treatment/Slurry Cut-Off Wall

Description

RAA 5 includes the construction of two separate sections of an in situ passive treatment/slurry cut-off wall. Groundwater at the site generally flows in a northeasterly direction toward Brinson Creek. However, in the southern portion of the site, evidence suggests that a break potentially occurs where groundwater flows in a southeasterly direction. It is estimated that the northern treatment/cut-off wall will be approximately 1,300 feet in length, will consist of approximately 1,170 feet of slurry cut-off wall and 150 feet of gate, and will be positioned to intercept groundwater flowing toward Brinson Creek . It is estimated that the southern treatment/cut-off wall will be approximately 1,000 feet in length, will consist of approximately 900 feet of slurry cut-off wall and 100 feet of gate, and will be positioned to intercept groundwater flowing in a southeasterly direction.

This type of technology is referred to as a "funnel and gate" system. The slurry wall directs or funnels groundwater flow to gate sections that are packed with gravel and iron filings. The iron filings facilitate the dechlorination of solvent-contaminated groundwater into non-toxic byproducts. Gates consist of a vertical section of iron filings sandwiched between two vertical gravel sections. The gate would extend from the semiconfining unit, located about 40 feet bgs, to approximately 20 feet bgs. A slurry wall would be constructed on top of the gate from 20 foot bgs to the surface. It is assumed for this RAA that three gate sections will be constructed in the northern wall and two gate sections in the southern wall. The exact location and number of gate section would be determined by a groundwater flow model during the design phase. A bench-scale test would be required to determine the exact formulation of the iron material.

In addition, RAA 5 includes long-term groundwater monitoring for COCs and the implementation of site controls that include aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: RAA 5 provides for the overall protection of human health and the environment through the implementation of site controls and long-term groundwater monitoring for COCs and the construction of a funnel and gate system. Site controls consist of restricting new supply well construction within the vicinity of Site 35 and identifying restricted aquifer-use areas in the Base Master Plan. Implementation of these actions will reduce the potential for human exposure to contaminated surficial groundwater at Site 35.

Under long-term monitoring for COCs, groundwater samples will be collected from the surfical aquifer, as well as the Castle Hayne aquifer, and analyzed for Target Compound List (TCL) VOCs quarterly for the first five years and semiannually thereafter. The results of long-term monitoring for COCs can be used to assess the effectiveness and efficiency of the remedial actions. Results can also identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

The long-term monitoring for COCs can also help identify contaminant reductions that may be occurring as a result of natural attenuation processes. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the time frame for achieving remediation levels through the natural attenuation processes cannot be established. Analysis for only COCs alone is insufficient for fully assessing natural attenuation processes.

The funnel and gate wall attempts to reduce the potential human health risks by intercepting the horizontal migration of the contaminant plume along the eastern and southern limits of the plume in an area where contaminant concentrations slightly exceed regulatory levels. It is anticipated that natural remedial processes will also continue to occur as active remediation is pursued.

Although this alternative does provide for the protection of the environment, actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 (Baker, 1995) are currently being implemented that will mitigate the migration of site-related COCs into Brinson Creek.

Compliance With ARARs: Under RAA 5, reductions of organic contamination in the surficial aquifer in the vicinity of the treatment gates may meet state federal and chemical-specific ARARs. Contaminant concentrations upgradient may continue to decrease as groundwater transports contamination towards the treatment area. However, it is uncertain if contaminant concentrations in the upgradient areas will meet state and federal chemical-specific ARARs.

Long-Term Effectiveness and Permanence: This treatment technology is designed to permanently remove organic contamination from the surficial aquifer. Remediation levels presented in Section 2.3 may be met in the vicinity of the treatment gates. However, it is uncertain if contamination levels upgradient will meet remediation levels.

Additional reductions may occur upgradient as a result of ongoing natural attenuation, but will be much slower than reductions in the vicinity of the treatment gates. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Long-term management activities associated with RAA 5 will consist of the following:

- Monitoring groundwater for COCs, quarterly for the first five years and semiannually thereafter.
- Monitoring the effectiveness of the treatment system.
- Maintaining a data base of groundwater analytical results.
- Controlling laboratory and materials costs.
- Identifying and implementing the most up-to date sampling equipment and techniques.
- Recording changes in site conditions or land use.
- Recording any accidental spills of fuel or chlorinated solvents.
- Routine assessment of the data to determine if the treatment system is performing as expected, contaminant migration is occurring and natural processes are occurring.

- Communicating the results of sampling efforts and data assessment with the appropriate regulatory agency.

O&M for this RAA includes: the replacement of PVC monitoring wells every five years; the occasional painting of "stick-up" wells in visible areas; redevelopment of sediment laden wells; changing rusted locks on wells; and trimming vegetation around well pads.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years. In the event that this RAA is no longer effective in recovering COCs, the extraction/treatment system can be replaced.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment process associated with RAA 5 includes reductive dechlorination. Chlorine atoms are stripped from chlorinated solvent molecule and replaced with a hydrogen atom. The reaction is facilitated in an iron enriched environment.

The funnel and gate wall attempts to reduce the potential human health risks by intercepting the horizontal migration of the contaminant plume along the eastern and southern limits of the plume in an area where contaminant concentrations slightly exceed regulatory levels.

Contamination reduction will primarily occur in the vicinity of the treatment gates. Reductions may occur upgradient as a result of ongoing natural attenuation, but will be much slower than reductions in the vicinity of the treatment gate. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Residuals that will remain after the action is complete include spent iron filings and about 2,200 lineal feet of slurry cut-off wall.

This treatment addresses and potentially reduces the principle threats to human health and the environment. Therefore, this RAA satisfies the statutory preference for treatment alternatives.

Short-Term Effectiveness: Additional risks to the surrounding community resulting from the construction and operation of the treatment gate, and long-term monitoring activities are unlikely. Additional environmental impacts resulting from the construction and operation of the treatment gate are also unlikely. However, the installation of monitoring wells in the vicinity of Brinson Creek may require some disturbance of the adjacent wetlands. Permission will be required from the Army Corp of Engineers to construct monitoring wells in the wetland

Construction personnel working on the U.S. Highway 17 Bypass in the vicinity of Site 35 may be required to wear personal protective equipment to avoid exposure to contaminated groundwater or airborne contaminants. Construction personnel installing the gate section may be required to don level B personal protective equipment. The subsurface gate construction area is considered a confined space.

Under RAA 5, it is difficult to estimate a time frame for achieving site-wide remediation through treatment and natural attenuation processes. However, for the purpose of developing a cost estimate comparable to other RAAs a 30-year service life was assumed.

Implementability: Construction of an passive treatment/slurry cut off wall will require a specialty contractor. Gate treatment is proprietary and limited number of vendors exist. The installation process is time consuming and hazardous. Discussions with vendors indicate that delays in construction are likely.

A traditional groundwater flow/transport model should be developed to support the design of the project. In addition, bench-scale tests will be needed to formulate gate and slurry wall material.

The construction of monitoring wells adjacent to Brinson Creek will result in the disturbance of wetland areas. To minimize damage from heavy drilling equipment a plank road will be constructed where monitoring wells are to be installed. Permission will be required from the Army Corp of Engineers on the wetland.

Some effort will be required to modify the Base Master Plan and prepare a long-term monitoring plan. The latter document will be subjected to review and some agency interaction can be expected. Analytical data from the long-term monitoring effort will be presented in a report prepared semiannually for agency review.

Cost: Total direct and indirect capital costs for RAA are associated with drilling activities and the construction of the passive treatment/slurry cut-off wall. These costs are estimated to total $5,976,000. Annual O&M costs for RAA 5 are associated with sampling and analysis activities, and monitoring well replacement. These annual costs are is estimated to be $130,300 for years one through five and $71,700 for years six through thirty. Considering these costs, a 30 year service life and a discount rate of 5%, the present worth value of RAA 5 is estimated to be $7,330,000. Backup for these costs are included in Table 5-5.

5.2.6 RAA 6: In-Well Aeration and Off-Gas Carbon Adsorbtion

<u>Description</u>

RAA 6 consists of the installation and operation of ten in-situ aeration wells. Seven aeration wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. These wells will intercept the contaminant plume and mitigate horizontal migration. Assuming a conservative capture radius of approximately 100 feet, the combined capture zones of the "interceptor wells" will extend over a distance of approximately 1,400 feet. To reduce the contaminant mass in the hot spot area near MW-10, where solvent-related contamination is on the order of 1,000 μg/L, three additional aeration wells will be installed.

During the operation of an in-well aeration system, air is injected into a groundwater well creating an in-well air-lift pump effect. This pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out the top of the well. As the groundwater circulates through the well, the injected air stream strips away VOCs. The VOCs are captured at the top of the well and treated via a carbon adsorption unit.

Each aeration well will be flush mounted and equipped with the appropriate down-hole seals, piping and valves, well screens, and filter packs. VOCs generated by this technology will be treated by trailer mounted unit that will include a blower, knockout tank, vacuum pump and vapor phase carbon adsorption units. Two or three aeration wells will be serviced by a single trailer mounted blower/off-gas treatment unit. To assess the effectiveness of each in-well aeration unit, a pair of monitoring wells screened in the upper and lower portion of the surficial aquifer will be constructed.

Currently, an in-well aeration pilot test is being conducted at Camp Lejeune Site 69, Rifle Range Chemical Dump. The results are anticipated sometime during 1997. Once data becomes available regarding system operations and remedial success, RAA 6 may be modified.

In addition, RAA 6 includes a long-term groundwater monitoring for COCs and the implementation of site controls that include aquifer-use restrictions.

Overall Protection of Human Health and the Environment: RAA 6 provides for the overall protection of human health and the environment through the implementation of site controls and long-term groundwater monitoring for COCs and the construction of an in-well aeration system. Site controls consist of restricting new supply well construction within the vicinity of Site 35 and identifying restricted aquifer-use areas in the Base Master Plan. Implementation of these actions will reduce the potential for human exposure to contaminated surficial groundwater at Site 35.

Under long-term monitoring for COCs, groundwater samples will be collected from the surfical aquifer, as well as the Castle Hayne aquifer, and analyzed for Target Compound List (TCL) VOCs quarterly for the first five years and semiannually thereafter. The results of long-term monitoring for COCs can be used to assess the effectiveness and efficiency of the remedial actions. Results can also identify vertical migration of contamination, if any, into the Castle Hayne aquifer, as well as any horizontal migration of the contaminant plume. Once migration is identified the appropriate action can be taken, if necessary, to limit human exposure.

The long-term monitoring for COCs can also help identify contaminant reductions that may be occurring as a result of natural attenuation processes. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the time frame for achieving remediation levels through the natural attenuation processes cannot be established. Analysis for COCs alone is insufficient for assessing natural attenuation processes.

The in-well aeration system attempts to reduce the potential human health risks by decreasing the reduce the overall contaminant mass in the "hot spot" area and intercepting the horizontal migration of the contaminant plume along the eastern limit of the plume in an area where contaminant concentrations slightly exceed regulatory levels. It is anticipated that natural remedial processes will also continue to occur as active remediation is pursued.

Although this alternative does provide for the protection of the environment, actions directed by the Interim ROD for Surficial Groundwater for a Portion of Operable Unit No. 10 (Baker, 1995) are currently being implemented that will mitigate the migration of site-related COCs into Brinson

Creek. This RAA can provide evidence of the natural attenuation processes that appear to be occurring in the wetlands adjacent to Brinson Creek.

Compliance With ARARs: Under RAA 6, reductions of organic contamination in the surficial aquifer within the zone of influence of the aeration well system may meet state federal and chemical-specific ARARs. Contaminant concentrations upgradient may continue to decrease as groundwater transports contamination towards the treatment area. However, it is uncertain if contaminant concentrations in the upgradient areas will meet state and federal chemical-specific ARARs.

Long-Term Effectiveness and Permanence: This treatment technology is designed to permanently remove organic contamination from the surficial aquifer. Remediation levels presented in Section 2.3 may be met within the zone of influence of the aeration well system. However, it is uncertain if contamination levels upgradient will meet remediation levels.

Additional reductions may occur upgradient as a result of ongoing natural attenuation, but will be much slower than reductions within the influence zone. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Long-term management activities associated with RAA 6 will consist of the following:

- Monitoring groundwater for COCs, quarterly for the first five years and semiannually thereafter.
- Monitoring off-gas effluent for VOCs.
- Monitoring the operations of the treatment system.
- Maintaining a data base of groundwater and effluent analytical results.
- Controlling laboratory and materials costs.
- Identifying and implementing the most up-to date sampling equipment and techniques.
- Recording changes in site conditions or land use.
- Recording any accidental spills of fuel or chlorinated solvents.
- Routine assessment of the data to determine if the treatment system is performing as expected, contaminant migration is occurring and natural processes are occurring..

- Communicating the results of sampling efforts and data assessment with the appropriate regulatory agency.

Treatment plant O & M includes: replacement of vapor phase carbon filter; routine equipment inspection/cleaning; adjustment of air flows; and minor repair of equipment. For costs purposes it was assumed that treatment plant equipment would be replaced once during the 30-year service life.

A potential operational problem that could occur is the development of inorganic precipitates that clog well screens. Some inorganic precipitates that form on well screens can be treated by adding a dissolving agent. Excessive inorganic precipitation on well screens could result in aeration well reinstallation.

Monitoring well O&M includes: the replacement of PVC monitoring wells every five years; the occasional painting of "stick-up" wells in visible areas; redevelopment of sediment laden wells; changing rusted locks on wells; and trimming vegetation around well pads.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative at least once every five years. In the event that this RAA is no longer effective in recovering COCs, the extraction/treatment system can be replaced.

Reduction of Toxicity, Mobility, or Volume Through Treatment: During the operation of an in-well aeration system, air is injected into a groundwater well creating an in-well air-lift pump effect. This pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out the top of the well. As the groundwater circulates through the well, the injected air stream strips away VOCs. The VOCs are captured at the top of the well and treated via a carbon adsorption unit.

Aeration wells will be located in a line along the eastern limit of the contaminant plume in an area where contaminant concentrations slightly exceed regulatory levels. The combined capture zones of these extraction wells will intercept the contaminant plume and mitigate the horizontal migration of contaminants. Extraction wells will be installed in "hot spot" areas near MW-10 where solvent-related contamination was on the order of 1,000 µg/L are intended to reduce the overall contaminant mass in these areas.

Contamination reduction will primarily occur in the capture zone of the extraction well system. Reductions may occur upgradient as a result of ongoing natural attenuation, but will be much slower than reductions within the capture zone. However, without a predictive model that estimates natural attenuation processes, and a monitoring program that includes parameters that quantify specific natural attenuation processes, the capacity of the natural system and time frame for achieving remediation levels through natural attenuation processes cannot be established. Analysis for COCs is insufficient for a complete assessment of natural attenuation processes. However, long-term monitoring for COCs may provide some indication that natural attenuation processes are occurring by measuring the decreasing levels of BTEX and TCE in groundwater, and increasing levels of cis-1,2-DCE and vinyl chloride in groundwater.

Residuals remaining will include spent vapor phase carbon that will require regeneration or proper disposal.

This treatment addresses and potentially reduces the principle threats to human health and the environment, and therefore, this RAA satisfies the statutory preference for treatment alternatives.

Short-Term Effectiveness: During treatment operations the potential exists for an accidental release contaminated off-gas due to mechanical failure or operator error. It is anticipated that such a release would result in a plant shutdown, and the release would be minimal in duration. Risk to Activity personnel working in the immediate vicinity of the treatment plant from would potentially be minimal. The environmental impact of such a release would also be potentially minimal.

Additional risks to the surrounding community resulting from long-term monitoring activities are unlikely. However, the installation of monitoring wells in the vicinity of Brinson Creek will require some disturbance of the wetland adjacent to Brinson Creek.

Personnel associated with the construction of the U. S. Highway 17 Bypass, drilling operations, treatment plant O&M, and sampling activities may require some type of personnel protective equipment (PPE). This will include some type of protection against dermal contact with the groundwater. During all excavation operations air quality in the work zone should be monitored.

Under RAA 6 it is difficult to estimate a time frame for achieving site-wide remediation through treatment and natural attenuation processes. However, for the purpose of developing a cost estimate comparable to other RAAs a 30-year service life was assumed.

Implementability: Several types of in-well aeration systems are available in the United States. These systems are proprietary in nature and the number of vendors is limited. This technology has been commercially applied in Germany, but is still relatively new in this country. No special problems are anticipated during construction and additional system components can be added to increase capacity. As with any in situ process, dissolved inorganics can precipitate onto well screens reducing efficiency and effectiveness.

The results of a field pilot-scale field test currently being conducted at Site 69 at Camp Lejeune will be sufficient and applicable to Site 35 and should be available during 1997. In addition, aeration wells should be located based on the results of a groundwater flow/contaminant fate and transport model. Design and construction of this RAA should not begin until these results are reviewed.

The construction of monitoring wells adjacent to Brinson Creek will result in the disturbance of wetland areas. To minimize damage from heavy drilling equipment a plank road will be constructed where monitoring wells will be installed. Permission will have to be obtained from the Army Corp of Engineers to install monitoring wells in the wetlands adjacent to Brinson Creek.

Some effort will be required to modify the Base Master Plan and prepare a long-term monitoring plan. The latter document will be subjected to review and some agency interaction can be expected. Analytical data from the long-term monitoring effort will be presented in a report prepared semiannually for agency review.

Cost: Total direct and indirect capital costs for RAA 6 are associated with drilling activities and the installation of the treatment units. These costs are estimated to total $1,060,000. Annual O&M costs for RAA 6 are associated with sampling and analysis activities, equipment replacement, and monitoring well replacement. These annual costs are is estimated to be $113,000 for years one through five and $63,000 for years six through thirty. Considering these costs, a 30-year service life and a discount rate of 5%, the present worth value of RAA 6 is estimated to be $3,350,000. Backup for these costs are included in Table 5-6.

5.3 Comparative Analysis

This section presents a comparative analysis of the six RAAs for groundwater presented for Site 35. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA. Seven of the nine previously introduced criteria used for the detailed analysis will be the basis for the following comparative analysis.

5.2.1 Protection of Human Health and the Environment

RAA 1 (No Action), RAA 2 (Site Controls with Long-Term Monitoring), and RAA 3 (Natural Attenuation) are similar in that each involves no engineered treatment and relies on natural attenuation to achieve remediation levels presented in Section 2.3. However, RAA 1 does not provide for the overall protection of human health and the environment. RAA 2 and RAA 3 provide for the overall protection of human health and the environment through site controls and monitoring.

RAA 2 and RAA 3 differ in the manner in which natural attenuation processes are monitored and assessed. Under RAA 3, natural attenuation processes are monitored using protocols that were specifically developed for natural attenuation. Under RAA 2, groundwater samples are analyzed for only the COCs using CLP methods. In addition, RAA 3 employs an appropriate model that can be used to predict the effectiveness of natural attenuation. RAA 2 does not include model development.

RAA 4 (Extraction Wells and Ex Situ Treatment), RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall), and RAA 6 (In-Well Aeration and Off-Gas Adsorption) are all similar in that each applies an active treatment systems to mitigate off-site migration of the contaminant plume. RAA 4 and 6 also include provisions to reduce contaminant mass through treatment near monitoring well MW10.

5.3.2 Compliance with ARARs

Under RAA 1 (No Action), RAA 2 (Site Controls with Long-Term Monitoring), and RAA 3 (Natural Attenuation) no active effort is made to reduce contaminant levels below federal and state ARARs. However, RAAs 1, 2, and 3 have the potential to meet federal and state ARARs over time. Under RAA 1 and 2, the time frame for completion of the action is indefinite. After the initial assessment has been preformed, RAA 3 can provide a time frame for achieving remediation levels.

RAA 4 (Extraction Wells and Ex Situ Treatment), RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall), and RAA 6 (In-Well aeration and Off-Gas Adsorption) may meet federal and state ARARs within the particular zone of influence of each system. All of these RAAs rely on natural attenuation to reduce contamination levels upgradient of the particular zone of influence.

Installation of additional monitoring wells in the wetlands adjacent to Brinson Creek is required under RAAs 2, 3, 4, 5, and 6.

Treated air discharges are provisions of RAA 4 and 6. Treated groundwater discharge is associated with RAA 4.

5.3.3 Long-Term Effectiveness and Permanence

In the case of all six RAAs, contamination will remain at the site and require a USEPA review on a five year basis. RAA 1 (No Action), RAA 2 (Site Controls with Long-Term Monitoring), and RAA 3 (Natural Attenuation) provide no active means of contaminant reduction, but rely on natural attenuation processes. Aquifer-use restrictions and groundwater monitoring associated with RAA 2 and 3 provide a permanent means against direct human exposure.

RAA 4 (Extraction Wells and Ex Situ Treatment), RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall), and RAA 6 (In-Well Aeration and Off-Gas Adsorption) provide an active means for permanently reducing contamination in the surficial aquifer within the particular zone of influence of each system. The effectiveness of these three RAAs is roughly similar. RAAs 4, 5, and 6 assume natural attenuation may be reducing upgradient groundwater contamination.

Long-term management issues and O&M activities associated with monitoring and well maintenance are similar for RAAs 2, 3, 4, 5, and 6. RAAs 4 and 6 are similar in that both rely on mechanical systems and as such, have similar maintenance issues. Both RAAs 4 and 6 are potentially subject to clogging problems caused by inorganic precipitates . Both RAAs 4 and 6 will require equipment replacement over the 30-year life of the project. The need for replacement of treatment components of RAA 5 during a 30-year project life is uncertain because the technology is relatively new.

5.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

RAA 1 (No Action), RAA 2 (Site Controls with Long-Term Monitoring), and RAA 3 (Natural Attenuation) provide no active means for the reduction of toxicity, mobility, or volume through treatment. RAAs 1, 2, and 3 all rely on the natural attenuation processes to reduce contaminant levels in groundwater.

RAA 4 (Extraction Wells and Ex Situ Treatment), RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall), and RAA 6 (In-Well Aeration and Off-Gas Adsorption) provide an active means for permanently reducing the toxicity, mobility or volume through treatment. RAAs 4, 5, and 6 intercept the contaminant plume and mitigate the horizontal migration contamination in the surficial aquifer. RAAs 4 and 6 reduce overall contaminant mass in the "hot spot" area.

5.3.5 Short-Term Effectiveness

Under RAA 1 (No Action), RAA 2 (Site Controls with Long-Term Monitoring), RAA 3 (Natural Attenuation), RAA 4 (Extraction Wells and Ex Situ Treatment), RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall), and RAA 6 (In-Well Aeration and Off-Gas Adsorption) workers associated with sampling activities, installation of treatment systems, and the construction of U. S. Highway 17 Bypass, should be provided with protection against dermal contact with contaminated groundwater. During all drilling and excavation activities associated with RAA 4, 5, and 6 air quality should be monitored. Gate construction activities associated with RAA 5 will require construction personnel to work in level B personnel protective equipment. The excavation where the gate is constructed is considered a confined space.

Under RAAs 1, 2, 3, and 5 there will be no increase in risk to the community during implementation of the remedial action. Under, RAAs 4 and 6 contaminated media could be accidentally discharged.

Plant controls are expected to limit such a release. RAA 5 will be the most disruptive to the Activity, due to the extensive excavation required to implement the action. Some disturbance of the wetlands adjacent to Brinson Creek will occur during the installation of monitoring wells under RAA 2, 3, 4, 5, and 6.

5.3.6 Implementability

When assessing implementability RAAs fall into two categories, those that involve engineered remedial actions, and those that involve no engineered remedial actions. The RAAs that do not include engineered remedial actions and rely solely on natural attenuation include: RAA 1 (No Action); RAA 2 (Site Controls with Long-Term Monitoring); and RAA 3 (Natural Attenuation). The most difficult of these RAAs to implement is RAA 3, because it requires a treatability study to be performed prior to implementing a long-term monitoring plan.

The RAAs that include engineered remedial actions include: RAA 4 (Extraction Wells and Ex Situ Treatment); RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall); and RAA 6 (In-Well Aeration and Off-Gas Adsorption). Technologies associated with RAA 5 and 6 are proprietary. As such, a limited number of vendors can provide the equipment/materials. Of the three engineered remedial actions, RAA 4 will be the easiest to implement. The equipment used for groundwater treatment plants is readily available.

5.3.7 Cost

The present worth values of the RAAs from least expensive to most expensive are as follows:

RAA 1 (No Action)	$ 0
RAA 2 (Site Controls with Long-Term Monitoring)	$1,220,000
RAA 3 (Natural Attenuation)	$2,470,000
RAA 6 (In-Well Aeration and Off-Gas Adsorption)	$3,350,000
RAA 4 (Extraction Wells and Ex Situ Treatment)	$3,760,000
RAA 5 (In Situ Passive Treatment/Slurry Cut-Off Wall)	$7,330,000

5.4 References

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

Baker. 1995. Baker Environmental Inc. Interim Record Of Decision for Surficial Groundwater for a Portion of Operable Unit No. 10. Marine Corp Base, Camp Lejeune, North Carolina.

Wiedemeier, Todd; et al. 1995. Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater Volumes I and II. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

Wiedemeier, Todd; et al. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

SECTION 5.0 TABLES

TABLE 5-1

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
OVERALL PROTECTIVENESS						
Human Health	• Reduction in risks associated with the natural remedial processes cannot be determined. • Current receptors are not at risk.	• Site controls and long-term monitoring (LTM) for COCs will reduce potential future human health risks. • Horizontal and vertical migration of the contaminant plume toward receptors can be identified and remedial action can be taken to limit exposure • Reduction in risks associated with the natural remedial processes can be determined to a limited extent. • Current receptors are not at risk.	• Site controls and LTM in support of natural attenuation (NA)will reduce potential future human health risks. • Horizontal and vertical migration of the contaminant plume toward receptors can be predicted with the aid of a contaminant fate and transport model and additional remedial action can be taken, if necessary, to avoid exposure. • Reduction in risks associated with the natural remedial processes can be determined. • Current receptors are not at risk.	• Site controls, LTM for COCs, and groundwater extraction/ treatment will reduce potential future human health risks. • Horizontal migration of the contaminant plume toward potential receptors is mitigated by collection system. • Vertical migration of contaminant plume can be identified and additional remedial action taken if to avoid exposure. • Current receptors are not at risk.	• Site controls, LTM for COCs, and passive treatment/slurry cut-off wall will reduce potential future human health risks. • Horizontal migration of the contaminant plume toward potential receptors is mitigated by in situ treatment system. • Vertical migration of contaminant plume can be identified and remedial action taken to avoid exposure. • Current receptors are not at risk.	• Site controls, LTM for COCs, and in-well aeration will reduce potential future human health risks. • Horizontal migration of the contaminant plume toward potential receptors is mitigated by in situ treatment system. • Vertical migration of contaminant plume can be identified and remedial action taken to avoid exposure. • Current receptors are not at risk.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
OVERALL PROTECTIVENESS (continued)						
Environmental Protection	• No measurable reduction in potential risks to ecological receptors. • Remedial actions in Interim ROD mitigate COC migration toward Brinson Creek.	• LTM for COCs can provide evidence of wetlands ability to limit migration towards Brinson Creek. • Remedial actions in Interim ROD mitigate such migration.	• LTM in support of NA will identify and quantify natural mechanisms that limit contaminant migration towards Brinson Creek. • Remedial actions in Interim ROD also mitigate such migration.	• Site controls, LTM for COCs, and groundwater extraction/ treatment will reduce potential risks to ecological receptors. "Hot spot" wells will collect contaminant mass upgradient of Brinson Creek. • Remedial actions in Interim ROD also mitigate such migration.	• Site controls and LTM for COCs and passive treatment/slurry wall will reduce migration of contamination toward Brinson Creek. • Remedial actions in Interim ROD also mitigate such migration.	• Site controls, LTM for COCs, and in-well aeration will reduce potential risks to ecological receptors. "Hot spot" wells will collect contaminant mass up-gradient of Brinson Creek. • Remedial actions in Interim ROD also mitigate such migration.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
COMPLIANCE WITH ARARs						
Chemical-Specific ARARs	• Regulatory levels may be reached through natural remedial processes. However, this cannot be demonstrated in this RAA.	• Regulatory levels may be reached through natural remedial processes. LTM for COCs can demonstrate progress toward reaching regulatory levels.	• Regulatory levels may be reached through natural remedial processes. LTM for NA can identify and quantify natural remedial mechanisms, demonstrate and predict progress toward reaching regulatory levels.	• Regulatory levels may be reached in the vicinity of the wells. Reductions upgradient will be less. • LTM for COCs can demonstrate progress toward reaching regulatory levels.	• Regulatory levels may be reached in the downgradient of the wall. • LTM for COCs can demonstrate progress toward reaching regulatory levels.	• Regulatory levels may be reached in the vicinity of the wells. • LTM for COCs can demonstrate progress toward reaching regulatory levels.
Location-Specific ARARs	• Not applicable.	• Approval will be required to install additional monitoring wells in Brinson Creek wetland area.	• Approval will be required to install additional monitoring wells in Brinson Creek wetland area.	• Potential construction of discharge line through wetlands will require permission. • Approval will be required to install additional monitoring wells in Brinson Creek wetland area.	• Approval will be required to install additional monitoring wells in Brinson Creek wetland area.	• Approval will be required to install additional monitoring wells in Brinson Creek wetland area.
Action-Specific ARARs	• Not applicable.	• Not applicable.	• Not applicable.	• Can be designed to meet action-specific ARARs.	• Can be designed to meet action-specific ARARs.	• Can be designed to meet action-specific ARARs.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERMANENCE						
Magnitude of Residual Risk	• No active treatment process applied.	• No active treatment process applied.	• No active treatment process applied.	• Residuals will include sludge from solids removal and spent carbon. These will be disposed of properly.	• Nontoxic byproducts of dechlorination will remain in the aquifer.	• Residuals will include spent carbon, which will be disposed of properly.
Adequacy and Reliability of Controls	• There are no measurable controls associated with this alternative. Natural processes are not quantified as a part of this RAA.	• The LTM for COCs is adequate and reliable for identifying plume migration, but not adequate for predicting migration and change in chemical nature of the plume. • Sampling events will occur quarterly (5 years) and semiannually thereafter. • Monitoring wells will require replacement. • Site controls are adequate and reliable for preventing human exposure to groundwater.	• The presence of daughter products of TCE, and reduced concentrations of contamination downgradient of the source areas are indicators that natural attenuation may be occurring. To determine how reliable, adequate, and efficient NA requires a treatability study. • LTM in support of NA will require sampling and analysis for an extensive list of NA parameters.	• Once designed in accordance with site-specific conditions, extraction/ treatment should be both adequate and reliable. • LTM for COCs is adequate and reliable for determining the alternative's effectiveness, but not for predicting plume migration and chemical changes. • LTM sampling events will occur quarterly (5 years) and semiannually thereafter.	• Once designed in accordance with site-specific conditions, passive treatment/slurry cut-off wall should be both adequate and reliable. • LTM for COCs is adequate and reliable for determining the alternative's effectiveness, but not for predicting plume migration and chemical changes. • LTM sampling events will occur quarterly (5 years) and semiannually thereafter. • Monitoring wells will require replacement.	• Once designed in accordance with site-specific conditions, in-well aeration systems should be both adequate and reliable. • LTM for COCs is adequate and reliable for determining the alternative's effectiveness, but not for predicting plume migration and chemical changes. • LTM sampling events will occur quarterly (5 years) and semiannually thereafter. • Monitoring wells will require replacement.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERFORMANCE (continued)						
Adequacy and Reliability of Controls (continued)			• Sampling will occur quarterly (5 years) and semiannually thereafter. • The development of a contaminant fate. and transport model will be required • The concentrations of COCs downgradient of the source area appear to be substantially reduced. This indicates dispersion, dilution, or sorption may be occurring.	• Monitoring wells will require replacement. • Extraction wells and pumps may require replacement due to metals precipitation. • LTM for COCs is adequate and reliable for determining the alternative's effectiveness. • If enforced over time, site controls are adequate and reliable for preventing human exposure to groundwater.	• Gates may experience loss of efficiency from metals precipitate. • Maintenance is minimal. • Because the technology is new the in situ service life is uncertain. Gate may require replacement in 12-15 years. • Changes in hydraulic conditions created by channeling groundwater flow could result in migration of contamination across the semiconfining unit. • Current receptors could be at risk under this scenario.	• Down-hole equipment may require replacement due to metals precipitation. • Maintenance includes regeneration of carbon , routine cleaning, adjustment of air flows and pressures, and minor repair of equipment. These items must be performed on four systems • In a 30-year service life treatment equipment will need replacing. • Current receptors are not at risk due to system failure. • Additional aeration wells can be added if necessary.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERFORMANCE (continued)						
Adequacy and Reliability of Controls (continued)			• The presence of daughter products such as cis-1,2-DCE and vinyl chloride are indications of microbial activity. Reduced concentrations along the centerline of the plume indicates natural attenuation of groundwater contaminants may be occurring.	• Maintenance items include regeneration of carbon, monitoring chemical mixing processes, effluent monitoring, and routine, and minor repairs of equipment. • In a 30-year service life treatment equipment will need replacing. • Current receptors are not at risk due to system failure. • Additional treatment components and wells can be added, if necessary, to address problems that may arise.	• Additional gates and slurry walls can be added, if necessary. • Site controls are adequate and reliable for preventing human exposure to groundwater.	• Site controls are adequate and reliable for preventing human exposure to groundwater.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERFORMANCE (continued)						
Adequacy and Reliability of Controls (continued)			• LTM in support of NA is adequate and reliable for identifying and predicting migration and change in the chemical nature of the plume. • Monitoring wells will require replacement. • The collection of NA parameters and the contaminant fate and transport model will give the capability of predicting plume mobility and changes in the chemical nature of the plume. • Additional action can be taken at any time to reduce risks if contaminant migration occurs.	• Site controls are adequate and reliable for preventing human exposure to groundwater.		

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERFORMANCE (continued)						
Adequacy and Reliability of Controls (continued)			• Site controls are adequate and reliable for preventing human exposure to groundwater.			
Need for 5-year Review	• Review will be required to ensure adequate protection of human health and the environment.	• Review will be required to ensure adequate protection of human health and the environment.	• Review will be required to ensure adequate protection of human health and the environment.	• Review will be required to ensure adequate protection of human health and the environment.	• Review will be required to ensure adequate protection of human health and the environment.	• Review will be required to ensure adequate protection of human health and the environment.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT						
Treatment Process Use	• Natural remedial processes are associated with this alternative. However, the exact processes cannot be determined or predicted. No monitoring is preformed.	• Natural remedial processes are associated with this alternative. Some limited evidence of the natural attenuation processes can be determined through LTM for COCs.	• Natural remedial processes are associated with this alternative. LTM for NA can identify the natural attenuation processes that are occurring. These processes potentially include: ▸ microbial degradation ▸ abiotic chemical reduction ▸ adsorption ▸ dilution ▸ volatilization	• The treatment process includes: ▸ coagulation/ flocculation, ▸ sedimentation/ clarification ▸ filtration ▸ air stripping for VOC removal ▸ secondary treatment of air emission via carbon adsorption ▸ secondary treatment of groundwater via carbon adsorption • Discharge to Brinson Creek	• The treatment process includes: ▸ Slurry cut-off wall to direct groundwater flow towards gates ▸ In situ passive gate that dechlorinates dissolved contaminants	• The treatment process includes: ▸ in-well air stripping of VOCs ▸ off-gas carbon adsorption

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (continued)						
Amount Destroyed or Treated	• Destruction of COCs occurs through natural processes. The amount of contamination destroyed is not quantified under this RAA.	• Destruction of COCs occurs through natural processes. The amount of contamination destroyed can be estimated through mass balance calculation.	• Destruction of COCs occurs through natural processes. The amount of contamination destroyed can be estimated through mass balance calculation.	• Contamination is transferred not destroyed. The amount of contamination recovered can be estimated. • Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be recovered.	• Contamination is destroyed. The amount of contamination destroyed can be estimated. • Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be destroyed.	• Contamination is transferred not destroyed. The amount of contamination recovered can be estimated. • Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be recovered.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (continued)						
Reduction of Toxicity, Mobility, or Volume Through Treatment	• Through microbial activity the original mass of contamination can be reduced to non-toxic by products. • Soils with high humic content can adsorb contaminants reducing mobility. • COC concentrations can be reduced by natural dilution and volatilization processes.	• Through microbial activity the original mass of contamination can be reduced to non- toxic by products. • Soils with high humic content can adsorb contaminants reducing mobility. • COC concentrations can be reduced by natural dilution and volatilization processes.	• Through microbial activity the original mass of contamination can be reduced to nontoxic by products. • Soils with high humic content can adsorb contaminants reducing mobility. • COC concentrations can be reduced by natural dilution and volatilization processes.	• The groundwater treatment processes are expected to reduce volume of contaminants in the groundwater. • Extraction wells will reduce the mobility of the contaminant plume.	• Chemical reduction processes occurring in the gate are expected to reduce toxicity and volume of contaminants in the groundwater. • Slurry cut-off wall will reduce mobility of contaminant plume.	• The in-well aeration system is expected to reduce the volume of contaminants in the groundwater. • Aeration wells will reduce the mobility of the contaminant plume.
Irreversibility of the Treatment	• Contamination destroyed/ removed by natural processes is permanent and irreversible.	• Contamination destroyed/ removed by natural processes is permanent and irreversible.	• Contamination destroyed/ removed by natural processes is permanent and irreversible.	• Air stripping will have irreversible results.	• Passive treatment/slurry cut-off wall will have irreversible results.	• In-situ air stripping and off-gas carbon adsorption will have irreversible results.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT *(continued)*						
Residuals Remaining After Treatment	• No monitoring is proposed under this RAA so residuals cannot be determined.	• To predict asymptotic levels of COCs will require the development of a contaminant fate and transport model that considers natural attenuation mechanisms. LTM for COCs does not provide sufficient data for the development of such a model. • Bioactivity will result in elevated levels of dissolved levels metabolic byproducts such as methane, ethane, ethene, nitrates, sulfates, and ferrous iron. • Where physical phenomena drive remediation COCs may be reduced below regulatory levels but some residual COCs will remain.	• To predict asymptotic levels of COCs will require the development of a contaminant fate and transport model that considers natural attenuation mechanisms. LTM in support of NA can provide data for the development of such a model. • Bioactivity will result in elevated levels of dissolved levels metabolic byproducts such as methane, ethane, ethene, nitrates, sulfates, and ferrous iron. • Where physical phenomena drives remediation , COCs may be reduced below regulatory levels but some residual COCs may remain.	• Treatment residuals may include sludge, spent carbon, and treated groundwater. The sludge should be non-hazardous, the spent carbon will require disposal or regeneration, and treated groundwater will be within acceptable groundwater discharge limits.	• After the aquifer is remediated only the non-toxic residuals of the slurry cut-off wall and iron gate will remain. • Elevated levels of byproducts associated with chemical reduction of chlorinated solvents will be observed in the groundwater near the gates sections. These include methane, ethene, ethane and chloride.	• Treatment residuals will include the small amount of liquid left in the knockout tanks and spent carbon. The liquid should be non-hazardous, but the spent carbon will contain adsorbed contaminants requiring disposal or regeneration.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (continued)						
Statutory Preference for Treatment	• Satisfied via natural remedial processes.	• Satisfied via natural remedial processes.	• Satisfied via natural remedial processes.	• Satisfied	• Satisfied	• Satisfied.
SHORT-TERM EFFECTIVENESS						
Community Protection	• Potential risks to the community will not be increased.	• Potential risks to the community will not be increased during implementation.	• Potential risks to the community will not be increased during implementation.	• Potential risks to the community will not be increased during implementation.	• Potential risks to the community will not be increased during implementation.	• Potential risks to the community will not be increased during implementation.
Worker Protection	• Not applicable to sampling technicians. • Highway construction personnel may require PPE.	• Sampling technicians will require Personnel Protective Equipment (PPE). • Highway construction personnel may require PPE.	• Sampling technicians will require PPE. • Highway construction personnel may require PPE.	• Sampling technicians will require PPE. • Highway construction personnel may require PPE. • Plant construction personnel will not require PPE	• Sampling technicians will require PPE. • Highway construction personnel may require PPE. • Level B PPE will be required during gate construction.	• Sampling technicians will require PPE. • Highway construction personnel may require PPE. • Plant construction personnel will not require PPE
Environmental Impact	• No additional environmental impacts.	• No additional environmental impacts.	• No additional environmental impacts.	• Placement of extraction wells must be based on a groundwater flow model. Incorrect placement could result in the migration of contamination.	• Length of slurry wall and placement of gates must be based on a groundwater flow and contaminant fate and transport model. Incorrect placement could result in contaminant migration.	• No additional environmental impacts.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
SHORT-TERM EFFECTIVENESS (continued)						
Time Until Action is Complete	• Unknown and unable to be determined.	• To predict when the asymptotic levels of COCs will be reached by natural processes will require the development of a contaminant fate and transport model that considers natural attenuation mechanisms. LTM for COCs does not provide sufficient data for the development of such a model. • 30 years has been assumed for cost estimating purposes.	• To predict when the asymptotic levels of COCs will be reached by natural processes will require the development of a contaminant fate and transport model that considers natural attenuation mechanisms. LTM for NA does provide sufficient data for the development of such a model. • 30 years has been assumed for cost estimating purposes.	• Unknown; 30 years has been assumed for cost estimating purposes.	• Unknown; 30 years has been assumed for cost estimating purposes.	• Unknown; 30 years has been assumed for cost estimating purposes.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
IMPLEMENTABILITY						
Ability to Construct and Operate	• Not applicable.	• A groundwater sampling effort can be implemented easily. • Restricting the construction of new wells in the vicinity of Site 35 should be easily accomplished. • Identification of restricted groundwater use areas in the Base Master Plan should be easily accomplished. • Routine updating of facility master plans does not always occur.	• A groundwater sampling effort can be implemented easily. • Restricting the construction of new wells in the vicinity of Site 35 should be easily accomplished. • Identification of restricted groundwater use areas in the Base Master Plan should be easily accomplished. • Routine updating of facility master plans does not always occur.	• Extraction/ treatment systems can be constructed with standard methods. • Treatment plant operations can be standardized • Organic precipitation on the well screens may reduce the efficiency and effectiveness of the collection system. • The treatment plant can be located at a site that does not impact Activity operations. • In the event the construction of U.S. Highway 17 Bypass is postponed the construction of an extensive discharge line to Brinson Creek may be required.	• Gate section construction to 40 foot depth will be difficult but achievable. • Inorganic precipitation may reduce the efficiency of the system. • Construction will be disruptive to Activity	• Based on past experience, an extraction/treatment system will generally be easy to construct and operate. • Inorganic precipitation on the well screens may reduce the efficiency and effectiveness of the treatment system. • The trailer mounted treatment unit can be located in an area that will minimally impact Activity operations.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
IMPLEMENTABILITY (continued)						
Reliability of Technology	• Natural remedial processes are ongoing.	• Natural remedial processes are ongoing. • Monitoring well installation and a groundwater water sampling effort are easy to implement. • Delays to implementation are unlikely.	• Natural remedial processes are ongoing. • Monitoring well installation and a groundwater sampling effort are easy to implement. . • Delays to implementation are unlikely	• The technology to construct groundwater treatment facilities is readily available. • In general, delays may be caused by following: ▸ Manufacturer does not provide equipment in a timely manner or provides defective equipment. Delays may range from weeks to months. ▸ Treatment system requires substantial adjustment during start-up. Delays may range from weeks to months.	• Slurry wall construction is a demonstrated construction method. Delays can be caused by uncertain subsurface conditions. • Gate construction is similar to cofferdam construction. The number of contractor with direct gate construction experience is limited. • Delays are likely due to contractor inexperience and uncertain subsurface conditions.	• The technology to construct is available, but vendors are limited. Typically a vendor provide and install equipment, including wells. • In general delays may be caused by following: ▸ Manufacturer does not provide equipment in a timely manner or provides defective equipment. Delays may range from weeks to months. ▸ Treatment system requires substantial adjustment during start-up. Delays may range from weeks to months.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
IMPLEMENTABILITY (continued)						
Ease of Undertaking Additional Remedial Actions	• Additional remedial actions can be easily implemented.	• Additional remedial actions can be easily implemented.	• Additional remedial actions can be easily implemented.	• Additional actions may require groundwater flow modeling and contaminant fate and transport modeling.	• Additional remedial actions can be easily implemented.	• Additional actions may require groundwater flow modeling and contaminant fate and transport modeling.
Ability to Monitor Effectiveness	• No monitoring plan. Failure to detect contamination could result in human and/or environmental exposure.	• LTM for COCs can detect contaminant migration before significant exposure can occur.	• LTM for NA can: ▸ Detect contaminants before significant exposure can occur. ▸ Predict migration and chemical changes in the contaminant plume.	• LTM for COCs can: ▸ Adequately determine effectiveness of treatment system. ▸ Detect contaminants before significant exposure can occur.	• LTM for COCs can: ▸ Adequately determine effectiveness of treatment system. ▸ Detect contaminants before significant exposure can occur.	• LTM for COCs can: ▸ Adequately determine effectiveness of treatment system. ▸ Detect contaminants before significant exposure can occur.
Availability of Services and Equipment	• No services or equipment required.	• Services and equipment are readily available.	• Services and equipment are readily available.	• Services and equipment are readily available.	• Slurry-wall contractors are readily available. • Gate design is proprietary and a specialty contractor will be required.	• Services and equipment are available but the number of vendors are limited.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
OU NO. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Site Controls and Long-Term Monitoring	RAA 3 Natural Attenuation	RAA 4 Extraction and Ex Situ Treatment	RAA 5 In Situ Passive Treatment/ Slurry Cut-Off Wall	RAA 5 In-Well Aeration
IMPLEMENTABILITY (continued)						
Requirements for Agency Coordination	• May require a waiver of ARARs since contaminated groundwater will be left on site.	• Must submit semiannual reports to document sampling.	• Must submit semiannual reports to document sampling.	• Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.		• Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.
COST (Net Present Worth)	**$0**	**$1,220,000**	**$2,470,000**	**$3,760,000**	**$7,330,000**	**$3,350,000**

TABLE 5-2

ESTIMATED COSTS FOR GROUNDWATER RAA No. 2

GROUNDWATER RAA No. 2: CONTROLS AND LONG-TERM MONITORING
OU No. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 30 EXISTING & 4 NEW WELLS

Jan-97

ANNUAL DIRECT AND INDIRECT CAPITAL COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
MONITORING WELL INSTALLATION							
Well Replacement Due to Highway Construction	LS	1	$20,492	$20,492		Replacement of 5 shallow and 4 intermediate wells	Engineering Estimates - Table 5-2A
Additional Wells and Piezometers	LS	1	$15,511	$15,511		Installation of 4 intermediate wells and 3 piezometers	Engineering Estimates - Table 5-2B
Total Monitoring Well Installation Capital Costs					$36,002		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M							
Labor	Hours	312	$32	$9,984		2 sampling events/yr, 10 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Table 5-2C
Travel	Sample Event	1	$2,028	$2,028		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table 5-2C
Per Diem	Sample Event	1	$1,460	$1,460		*Includes lodging and meals for 2 people*	*Engineering Estimate* - Table 5-2C
Laboratory Analysis & Data Validation							
VOA	Sample	38	$179	$6,802		34 samples/3 duplicate samples /1 MS/MSD sample	Basic Ordering Agreement
Equipment & Supplies	Sample Event	1	$835	$835		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table 5-2C
Sample Shipping	Sample Event	1	$830	$830		1 cooler per day for 10 days; $83/cooler	Engineering Estimate - Table 5-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$12,938	$12,938		Equal annual cost of replacing 28 wells every 5 years for 30 years	Engineering Estimate - Table 5-2D
Total Groundwater Monitoring O&M Costs (1 - 5 Years)					$112,694	Annual cost for quarterly sampling events	
Total Groundwater Monitoring O&M Costs (6 - 30 Years)					$62,816	Annual cost for semi-annual sampling events	

TABLE 5-2 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 2

GROUNDWATER RAA No. 2: CONTROLS AND LONG-TERM MONITORING
OU No. 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 30 EXISTING & 4 NEW WELLS

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

Jan-97

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$36,000	
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)	$112,700 $62,800	Assuming 30 Years of Operation
PRESENT WORTH VALUE	$1,220,000	Based on a discount rate of 5%

TABLE 5-2A

COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT DUE TO HIGHWAY CONSTRUCTION

GENERAL ASSUMPTIONS

5 shallow monitoring wells (20-ft deep) will be replaced

4 intermediate monitoring wells (40-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$16.50	260	$4,290.00
2" PVC sch. 40 riser	LF	$1.25	190	$237.50
2" PVC sch. 40 screen	LF	$11.00	70	$770.00
Protective cover	Each	$400.00	9	$3,600.00
Drums	Each	$42.00	45	$1,890.00
Well development	Hour	$65.00	9	$585.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	10	$950.00
Geologist Labor	Hour	$40.00	130	$5,200.00
Geologist travel	Event	$1,339.00	1	$1,339.00
Geologist per deim	Day	$73.00	10	$730.00
Misc.		$200.00	1	$200.00
Well Installation Costs per Event				$20,492

TABLE 5-2B

COST ESTIMATE ASSUMPTIONS FOR ADDITIONAL MONITORING WELLS AND PIEZOMETERS

GENERAL ASSUMPTIONS

3 intermediate piezometers (40-ft deep)

4 intermediate monitoring wells (40-ft deep)

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$16.50	280	$4,620.00
1" PVC sch. 40 riser	LF	$0.75	105	$78.75
1" PVC sch. 40 screen	LF	$7.00	15	$105.00
2" PVC sch. 40 riser	LF	$1.25	140	$175.00
2" PVC sch. 40 screen	LF	$11.00	20	$220.00
Protective cover	Each	$400.00	7	$2,800.00
Drums	Each	$42.00	35	$1,470.00
Well development	Hour	$65.00	7	$455.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	6	$570.00
Geologist Labor	Hour	$40.00	60	$2,400.00
Geologist travel	Event	$1,079.00	1	$1,079.00
Geologist per deim	Day	$73.00	6	$438.00
Misc.	Event	$400.00	1	$400.00
Well Installation Costs per Event				$15,511

TABLE 5-2C

COST ESTIMATE ASSUMPTIONS FOR

GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS

- Groundwater will be sampled quarterly for years 1-5, and semiannually for years 6-30
- 28 wells will be sampled for VOCs

LABOR	312	hours/event
No. of people:	3	
Days required:	10	
Hours per day:	10	
Travel Time/person	4	
LABOR COST	$9,984	/event
TRAVEL	$2,028	/event
No. of people:	2	
Days required:	10	
Airfare (roundtrip PIT-OAJ, full fare)	$689.00	
Mini-van rental	$65.00	
PER DIEM	$1,460.00	/event
No. of people:	2	
Days required:	10	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

Item	**Unit Rate**	**Units**	**No. of Units**	**Total**
Conductivity Meter	$3.86	/Day	10	$38.60
pH Meter	$6.35	/Day	10	$63.50
Turbidity Meter	$9.67	/Day	10	$96.70
D.O. Meter	$13.23	/Day	10	$132.30
Perstaltic Pump	$6.62	/Day	10	$66.20
P.E. Tubing	$21.25	/100 feet	3	$63.75
Silicon Tubing	$2.75	/foot	3	$8.25
P.E. Squeeze Bottles	$.06	/Day	10	$.60
Garbage Bags	$.16	Each	8	$1.28
Inner Gloves	$8.97	/Box	1	$8.97
Paper Towels	$.81	Roll	4	$3.24
Markers	$.60	Each	2	$1.20
Equipment Shipping	$50.00	/Package	7	$350.00
			TOTAL:	$835

TABLE 5-2D
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT - SITE 35

GENERAL ASSUMPTIONS

13 shallow monitoring wells (20-ft deep) will be installed

19 intermediate monitoring wells (40-ft deep) will be installed

2 deep monitoring well (60-ft deep) will be installed

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Existing Well Abandonment	LF	$16.50	1140	$18,810.00
Type II Well installation	LF	$16.50	1020	$16,830.00
Type III Well installation	LF	$30.00	55	$1,650.00
2" PVC sch. 40 riser	LF	$1.25	785	$981.25
2" PVC sch. 40 screen	LF	$11.00	235	$2,585.00
Protective cover	Each	$400.00	18	$7,200.00
Drums	Each	$42.00	150	$6,300.00
Well development	Hour	$65.00	34	$2,210.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	30	$2,850.00
Geologist labor	Hour	$40.00	300	$12,000.00
Geologist per diem	Day	$70.00	30	$2,100.00
Geologist Travel	Event	$3,700.00	1	$3,700.00

Well Installation Costs per Event	$77,916
Total Present Worth (5% discount rate, 5 replacement events, 30yrs	$198,733
Equal Annual Cost (5% discount rate, 30 years)	$12,938

TABLE 5-3
ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: NATURAL ATTENUATION
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 45 EXISTING WELLS
Jan-97

DIRECT AND INDIRECT CAPITAL COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$15,282	$15,282		*Install 4 intermediate wells and 6 soil borings*	*Engineering Estimates - Table 5-3A*
Well Replacement Due to Highway Construction	LS	1	$25,489	$25,489		Replace 6 shallow and 6 intermediate wells	Engineering Estimates - Table 5-3A
Total Well & Boring Installation Capital Costs					$40,771		
NATURAL ATTENUATION STUDIES							
Initial Field Effort	LS	1	$ 73,010	$73,010			Engineering Estimates - Table 5-3B
Microcosm Study	LS	1	$50,000	$50,000			Engineering Estimates - Previous Projects
Modeling, Data Evaluation and Analysis	LS	1	$60,000	$60,000			Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000			Engineering Estimates - Previous Projects
Reporting	LS	1	$20,000	$20,000			Engineering Estimates - Previous Projects
Contingency	LS	1	$24,567	$24,567		15% of direct capital costs	Engineering Estimates - Previous Projects
Total Natural Attenuation Study Capital Costs					$247,577		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					$ 288,348		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M							
Labor	Hours	312	$32	$9,984		10 days/event, 10 hrs/day/person, 3 people	Engineering Estimate - Table 5-3C
Travel	Sample Event	1	$2,717	$2,717		Includes minivan rental and airfare for 3 people	Engineering Estimate - Table 5-3C
Per Diem	Sample Event	1	$2,190	$2,190		Includes lodging and meals for 3 people	Engineering Estimate - Table 5-3C
Laboratory Analysis & Data Validation							
Intrinsic Remed. Parameters	Sample	52	$ 631.79	$32,853		45 samples/5 duplicate samples /2 MS/MSD samples	Basic Ordering Agreement - Table 5-3D
Equip. & Supplies	Sample Event	1	$2,982	$2,982		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table 5-3C
Shipping	Sample Event	1	$830	$830		2 coolers per day for 10 days; $83/cooler	Engineering Estimate - Table 5-3C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$13,204	$13,204		Equal annual cost of replacing 45 wells every 5 years for 30 years	Basic Ordering Agreement - Table 5-3E
Model Updates & Reporting	Year	1	$20,000	$20,000			
Total Groundwater Monitoring O&M Costs (1 to 5 years)					$251,427	Quarterly sampling will be performed for the first 5 years	
Total Groundwater Monitoring O&M Costs (6 to 30 years)					$142,315	Semi-annual sampling will be performed for the remaining 15 yrs	

TABLE 5-3 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: NATURAL ATTENUATION
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 45 EXISTING WELLS
Jan-97

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$ 290,000	
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)	$251,000 $142,000	
PRESENT WORTH VALUE	$2,470,000	Based on a discount rate of 5%

TABLE 5-3A
COST ESTIMATE ASSUMPTIONS FOR ADDITIONAL MONITORING WELLS AND SOIL BORINGS

GENERAL ASSUMPTIONS
6 soil borings (each 40-ft deep)
4 intermediate monitoring wells (each 40-ft deep)

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Soil Boring (3-1/4 in HSA)	LF	$15.00	240	$3,600.00
Type II Well installation	LF	$15.00	160	$2,400.00
2" PVC sch. 40 riser	LF	$1.25	140	$175.00
2" PVC sch. 40 screen	LF	$11.00	20	$220.00
Protective cover	Each	$400.00	4	$1,600.00
Drums	Each	$42.00	20	$840.00
Well development	Hour	$65.00	4	$260.00
Temp. decon. pad	Each	$200.00	1	$200.00
Misc. expenses	Each	$1,000.00	1	$1,000.00
Contractor per diem	Day	$95.00	6	$570.00
Geologist labor	Hour	$40.00	60	$2,400.00
Geologist travel	Each	$1,079.00	1	$1,079.00
Geologist per diem	Day	$73.00	6	$438.00
Well Installation Costs				$15,282

TABLE 5-3B
ESTIMATED COSTS FOR INITIAL FIELD EFFORT

Item	Units		Unit Cost	Quantity		Subtotal	Remarks
Geoprobe Rig	Day	$	1,500.00	1	$	1,500.00	Engineering Estimate
Equipment	LS	$	2,981.59	1	$	2,981.59	Table 5-3D
Water Analysis	LS	$	631.79	52	$	32,853.08	Table 5-3D
Soil Gas Analysis (1)	Day	$	10,000.00	1	$	10,000.00	Engineering Estimate
Labor	Hour	$	32.00	540	$	17,280.00	Engineering Estimate
Travel	LS	$	4,745.00	1	$	4,745.00	Engineering Estimate
Per Deim (5 people)	Day		$365.00	10	$	3,650.00	Engineering Estimate
				Total	$	73,010.00	

Notes:
(1) On site, mobile laboratory to provide the soil gas analysis.

TABLE 5-3C
COST ESTIMATE ASSUMPTIONS FOR
HIGHWAY CONSTRUCTION MONITORING WELL REPLACEMENT

GENERAL ASSUMPTIONS

6 shallow monitoring wells (20-ft deep) will be replaced

6 intermediate monitoring wells (40-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$16.50	360	$5,940.00
2" PVC sch. 40 riser	LF	$1.25	270	$337.50
2" PVC sch. 40 screen	LF	$11.00	90	$990.00
Protective cover	Each	$400.00	12	$4,800.00
Drums	Each	$42.00	60	$2,520.00
Well development	Hour	$65.00	12	$780.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	14	$1,330.00
Geologist labor	Hour	$40.00	140	$5,600.00
Geologist travel	Each	$1,469.00	1	$1,469.00
Geologist per diem	Day	$73.00	14	$1,022.00
Well Installation Costs				$25,489

TABLE 5-3D
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS
- Groundwater will be sampled semiannually for 30 years
- 12 wells will be sampled for intrinsic remediation parameters

LABOR	312	hours/event
No. of people:	3	
Days required:	10	
Hours per day:	10	
Travel Time/person	4	
LABOR COST	$9,984	/event
TRAVEL	$2,717	/event
No. of people:	3	
Days required:	10	
Airfare (roundtrip PIT-OAJ, full fare)	$689.00	
Mini-van rental	$65.00	
PER DIEM	$2,190.00	/event
No. of people:	3	
Days required:	10	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

ITEM	UNIT RATE	UNIT	No. OF UNITS	TOTAL
Conductivity Meter	$3.86	/Day	20	$77.20
pH Meter	$6.35	/Day	20	$127.00
Turbidity Meter	$9.67	/Day	20	$193.40
Hydrogen Ion Meter	$80.00	/Day	20	$1,600.00
D.O. Meter	$13.23	/Day	20	$264.60
Perstaltic Pump	$6.62	/Day	20	$132.40
P.E. Tubing	$21.25	/100 feet	3	$63.75
Silicon Tubing	$2.75	/foot	3	$8.25
P.E. Squeeze Bottles	$.06	/Day	5	$.30
Garbage Bags	$.16	Each	8	$1.28
Inner Gloves	$8.97	/Box	1	$8.97
Paper Towels	$.81	Roll	4	$3.24
Markers	$.60	Each	2	$1.20
Equipment Shipping	$50.00	/Package	10	$500.00
			TOTAL:	$2,981.59

TABLE 5-3E
ESTIMATED ANALYTICAL PARAMETER COSTS FOR INTRINSIC REMEDIATION MONITORING

Parameters	Unit Price(1)	Validation Price	Total
Diss. Oxygen	Field (2)	--	--
Nitrate & Nitrite	$ 20.03	$ 6.67	$ 26.70
Iron (II)	$ 45.00	$ 7.00	$ 52.00
Iron (III)	$ 45.00	$ 7.00	$ 52.00
Sulfate	$ 13.39	$ 6.33	$ 19.72
Sulfide	$ 17.41	$ 6.33	$ 23.74
Methane	$ 140.00	$ 13.50	$ 153.50
ReDox	Field	--	--
Major Cations	$ 55.00	$ 15.00	$ 70.00
pH	Field	--	--
Temperature	Field	--	--
TOC (water)	$ 24.13	$ 6.33	$ 30.46
Alkalinity	$ 9.93	$ 6.17	$ 16.10
Chloride	$ 12.84	$ 6.33	$ 19.17
VOAs (3)	147.73	20.67	$ 168.40
	TOTAL		$ 631.79

NOTES
(1) Costs based on laboratory quotes and LANTDIV bidding prices.
(2) The cost for field analysis is included in equipment and labor costs for groundwater sampling.
(3) Specific parameters include benzene, toluene, ethylbenzene, xlyenes, or perchloroethene, trichloroethene, and dichloroethene (cis & trans)

TABLE 5-3F
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REPLACEMENT

GENERAL ASSUMPTIONS

22 shallow monitoring wells (20-ft deep) will be replaced

23 intermediate monitoring wells (40-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$16.50	1360	$22,440.00
2" PVC sch. 40 riser	LF	$1.25	1025	$1,281.25
2" PVC sch. 40 screen	LF	$11.00	335	$3,685.00
Protective cover	Each	$400.00	45	$18,000.00
Drums	Each	$42.00	225	$9,450.00
Well development	Hour	$65.00	45	$2,925.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	30	$2,850.00
Geologist labor	Hour	$40.00	300	$12,000.00
Geologist travel	Each	$4,000.00	1	$4,000.00
Geologist per diem	Day	$73.00	30	$2,190.00

Well Installation Costs per Event	$79,521
Total Present Worth (5% discount rate, 5 replacement events, 30yrs)	$202,827
Equal Annual Cost (5% discount rate, 30 years)	$13,204

TABLE 5-4
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EX SITU TREATMENT
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

7 EXTRACTION WELLS
40 GPM TREATMENT FACILITY
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$30,000	$30,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$20,000	$20,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$18,000	$18,000			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$15,000	$15,000			Engineering Estimate- Previous Projects
Total General Costs					$93,000		
MONITORING WELL INSTALLATION							
Well Replacement Due to Highway Construction	LS	1	$20,492	$20,492		Replacement of 5 shallow and 4 intermediate wells	RAA No. 2
Additional Wells and Piezometers	LS	1	$15,511	$15,511		Installation of 4 intermediate wells and 3 piezometers	RAA No. 2
Total Monitoring Well Installation Costs					$36,003		
SITE WORK							
Site Work During System Installation:							
Demolish Bituminous Road w/ Power Equip	SY	50	$12	$600		Remove paving and base course	Means Environmental Restoration, 1996
Clearing for Discharge Line	Acre	0.25	$2,203	$551		Heavy brush, light trees, clear, grub, and haul	Means Environmental Restoration, 1996
Piping Trench for the Collection Line	LF	1900	$5.49	$10,431		Includes excavation, removal, backfill, and compaction	Engineering Estimate- Previous Projects
Piping Trench for the Discharge Line	LF	1100	$5.49	$6,039		Includes excavation, removal, backfill, and compaction	Engineering Estimate- Previous Projects
Excavation for Treatment Plant Slab	CY	70	$12	$840		Roughly 30' x 30' x 2'excavation	Means Site 1996, 022-200 & Estimate
Backfill Around Treatment Plant Slab	CY	50	$5	$250		Roughly 5' x 2' x 120' around plant	Means Site 1996, 022-226 & Estimate
Cut and Fill for Driveway to Treatment Plant	CY	300	$5	$1,500		Includes excavation, water wagon, backfill, and tamping	Means Site 1996, A12.1-214 & Estimate
Construct Asphalt Driveway	LF	20	$67	$1,340		Assuming asphalt is 8" thick	Means Site 1996, A12.5-111 & Estimate
Water Connection at Treatment Plant	LF	100	$8	$800		Includes trenching & laying a 1" copper line	Means Site 1996, 026-662 & 022-258
Overhead Electrical to Treatment Plant	LF	75	$25	$1,875		Includes overhead routing and poles	Means Site 1996, 167-100 & Estimate
Erosion Protection at Discharge Point	CY	5	$62	$310		For erosion protection around headwall	Engineering Estimate- Previous Projects
Site Restoration:							
Top Dressing Around Treatment Plant	CY	11	$40	$440		Roughly 5' x 0.5' x 120' around plant	Means Site 1996, 022-286 & Estimate
Fine Grading and Seeding for Revegetation	SY	600	$4	$2,442		Revegetation for 1 acre that was cleared	Means Site 1996, 022-286 & Estimate
Pavement Replacement Over Trench	SY	50	$46	$2,300		Assuming asphalt pavement 8" thick	Means Site 1996, 025-104 & Estimate
Total Site Work Costs					$29,718		

TABLE 5-4 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EX SITU TREATMENT
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

7 EXTRACTION WELLS
40 GPM TREATMENT FACILITY
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
CONCRETE/STRUCTURAL							
Pre-fab. Bldg. for VOCs Pretreatment Plant	EA	1	$30,000	$30,000		30' x 30' building, not including heating & ventilation	Engineering Estimate- Previous Projects
Installation of Building	EA	1	$7,500	$7,500			Engineering Estimate- Previous Projects
Concrete Slab Building	SF	900	$3.83	$3,447		6" thick, 30' x 30' on-grade slab	Means Environmental Restoration, 1996
Total Concrete/Structural Costs					$40,947		
EXTRACTION WELLS							
Extraction Well Installation	LF	280	$664	$186,050		6" stainless steel, incl installation of pumps and appurtenances	Engineering Estimate - Table 5-4A
Extraction Well Pumps	EA	7	$2,550	$17,850		Includes well pump, level tracking device, and regulator	Vendor Quote
Appurtenances	EA	7	$1,000	$7,000			Vendor Quote
Manholes (Materials & Installation)	EA	7	$1,754	$12,278		Includes materials, excavation, backfill, trim, and compaction	Means Site 1996, A12.3-710 & Estimate
Total Extraction Well Costs					$223,178		
PIPING SYSTEM							
2" PVC Line for Collection	LF	1900	$5	$9,500		Includes materials and installation	Means Site 1996, 026-678 & Estimate
2" PVC Line for Discharge	LF	1100	$5	$5,500		Includes materials and installation	Means Site 1996, 026-678 & Estimate
4" PVC Containment Line for Recovery	LF	3000	$8	$24,000		Includes materials and installation	Means Site 1996, 026-678 & Estimate
Fittings	LS	1	$2,250	$2,250		Assume 15% of Total Piping Cost	Engineering Estimate- Previous Projects
Total Piping System Costs					$41,250		
TREATMENT EQUIPMENT							
VOC and Solids Removal System	EA	1	$189,157	$189,157		VOC and Solids Removal System	Table 5-4B
Electrical System	EA	1	$32,600	$32,600			
HVAC System	EA	1	$11,500	$11,500			
Plumbing System	EA	1	$4,600	$4,600			
Total Treatment Plant Equipment Costs					$237,857		
TOTAL DIRECT CAPITAL COSTS					$701,952		

TABLE 5-4 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EX SITU TREATMENT
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

7 EXTRACTION WELLS
40 GPM TREATMENT FACILITY
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$84,234	$84,234		12% of Total Direct Cost	Engineering Estimate
Pump Test	LS	1	$150,000	$150,000		Min. 72-Hr test incl. planning, addt'l piezometers & data analysis	Engineering Estimate - Previous Projects
3D Groundwater Modeling	Hour	400	$40	$16,000			Engineering Estimate
Construction Administration	*LS*	1	*$105,293*	*$105,293*		*15% of Total Direct Cost*	Engineering Estimate
Contingency Allowance	LS	1	$105,293	$105,293		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$105,293	$105,293		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$566,113		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M (Based on quarterly sampling for years 1-5, and semiannual sampling for years 6-30)							
Labor	Hours	312	*$32*	*$9,984*		*38 samples, 10 days, 10 hrs/day/person, 3 people*	RAA No. 2
Travel	Sample Event	1	$2,028	$2,028		Includes travel-airfare for 3 people and truck rental	RAA No. 2
Per Diem	Sample Event	1	$1,460	$1,460		10 days/sample event, $73/day/person, 3 people	RAA No. 2
Laboratory Analysis & Data Validation							
VOCs	Sample	38	$179	$6,802		34 samples / 3 duplicate / 1 MS/MSD	Basic Ordering Agreement
Equipment and Supplies	*Sample Event*	1	*$835*	*$835*		*Ice, DI water, expendables, pump, meters, etc.*	RAA No. 2
Sample Shipping	Sample Event	1	$830	$830		1 cooler per day for 10 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$12,938	$12,938		Equal annual cost of replacing 28 wells every 5 yrs for 30 yrs	RAA No. 2
Total Groundwater Monitoring O&M Costs	1 - 5 Years				$112,694	Annual cost for quarterly sampling events	
Total Groundwater Monitoring O&M Costs	6 - 30 Years				$62,816	Annual cost for semi-annual sampling events	

TABLE 5-4 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EX SITU TREATMENT
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

7 EXTRACTION WELLS
40 GPM TREATMENT FACILITY
MONITORING 30 EXISTING & 4 NEW WELLS

ANNUAL O&M COSTS

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Labor for Plant O&M	Week	52	$240	$12,480		8 hrs/wk, 52 weeks/yr, at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$120	$1,440		4 hrs/month, 12 months/yr, at $30/hr	Engineering Estimate
Air Sampling - Analysis	Sample	24	$200	$4,800		Assume 2 samples per month	Engineering Estimate
Effluent Sampling - Analysis	Sample	24	$300	$7,200		Assume 2 samples per month	Engineering Estimate
Canister Filter Replacement	Cartridge	12	$180	$2,160		Monthly replacement of cartridges	Means Environmental Restoration - 1996
Carbon Replacement	Unit	1	$5,211	$5,211		Replacement of one unit per year	Engineering Estimate
Sludge Disposal	Month	12	$380	$4,560		1 drum/month at $380/drum; handling, transport & disposal	Means Environmental Restoration - 1996
Extraction Well Replacement	Year	1	$1,000	$1,000		Assume $1,000/year	Engineering Estimate
Equipment Maintenance (Repacement)	Year	1	$4,757	$4,757		Approximately 2% of direct capital costs for treatment equipment	Engineering Estimate
Electricity	Month	12	$150	$1,800		24 hr/day, 365 days/year operation	Means Site 1996, 010-034 & Estimate
Administration & Reports	HR	40	$50	$2,000		10 hrs/quarter at $50/hr	Engineering Estimate
Total Treatment System O&M Costs					$47,408		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$1,268,000	
TOTAL ANNUAL MONITORING O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL MONITORING O&M COSTS (6 - 30 YEARS) TOTAL ANNUAL TREATMENT SYSTEM O&M COSTS	$113,000 $63,000 $47,000	
PRESENT WORTH VALUE	$3,760,000	Based on a discount rate of 5 %

TABLE 5-4A
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER EXTRACTION WELLS

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Well installation	Hr	$125.00	280	$35,000.00
6" 304-Stainless steel riser	LF	$55.00	70	$3,850.00
10'- 6" 304-Stainless Steel screen	Each	$675.00	210	$141,750.00
Drums	Each	$42.00	35	$1,470.00
Well development	Hour	$65.00	7	$455.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	5	$475.00
Geologist	Hour	$40.00	50	$2,000.00
Geologist Per Diem	Day	$70.00	5	$350.00
Well Installation Cost				$186,050
COST PER LINER FOOT				$664

TABLE 5-4B
ESTIMATED CAPITAL COSTS FOR THE GROUNDWATER EXTRACTION SYSTEM
WATER TREATMENT PLANT

Item	Quantity	Units	Estimated Unit Cost	Estimated Total Cost	Source	Remarks
2,000-Gal Sump (Equalization Tank)	1	Ea	$2,028.00	$2,028.00	RS Means, Environmental Restoration - 1996	Steel tank, installed
1.5 Hp Sump Pump	2	Ea	$1,324.00	$2,648.00	RS Means, Environmental Restoration - 1996	Installed
30 gpm Vertical Plate Clarifier	2	Ea	$18,524.00	$37,048.00	RS Means, Environmental Restoration - 1996	Includes clarifier and mixing tank
0.5 Hp Mixer, Single Prop.	1	Ea	$1,434.00	$1,434.00	RS Means, Environmental Restoration - 1996	Installed
1.5 Hp Pump	2	Ea	$1,324.00	$2,648.00	RS Means, Environmental Restoration - 1996	Installed
Filter Press (3.1 SF Filter Area)	1	Ea	$29,554.00	$29,554.00	RS Means, Environmental Restoration - 1996	Installed
Canister Filtration						
45 gpm Filter Chamber	2	Ea	$1,100.00	$2,200.00	RS Means, Environmental Restoration - 1996	Installed
1-50 gpm Cartridge Filter Equip.	2	Ea	$1,816.00	$3,632.00	RS Means, Environmental Restoration - 1996	Installed
Air Stripper (8' dia x 16' high)	1	Ea	$2,978.00	$2,978.00	RS Means, Environmental Restoration - 1996	Installed
Internal Parts	402	SF	$77.30	$31,074.60	RS Means, Environmental Restoration - 1996	Dimensions (SF) = 2pr x height, installed
Packing	804	CF	$8.92	$7,171.68	RS Means, Environmental Restoration - 1996	Dimensions (CF) = pr2 x height, installed
Blower	1	Ea	$963.00	$963.00	RS Means, Environmental Restoration - 1996	Installed
Electrical Controls	1	Ea	$6,396.00	$6,396.00	RS Means, Environmental Restoration - 1996	Installed
1.5 Hp Pump	2	Ea	$1,324.00	$2,648.00	RS Means, Environmental Restoration - 1996	Installed
Canister Filtration						
45 gpm Filter Chamber	2	Ea	$1,100.00	$2,200.00	RS Means, Environmental Restoration - 1996	Installed
1-50 gpm Cartridge Filter Equip.	2	Ea	$1,816.00	$3,632.00	RS Means, Environmental Restoration - 1996	Installed
Carbon Units (50 gpm)	2	Ea	$5,211.00	$10,422.00	RS Means, Environmental Restoration - 1996	Installed
1.5 Hp Pump	2	Ea	$1,324.00	$2,648.00	RS Means, Environmental Restoration - 1996	Installed
Piping & Fittings	25% of above costs			$37,831.32	Previous Projects, Engineering Judgement	Installed
Estimated Total Capital Costs				$ 189,156.60		

Notes: Cost does not include treatment chemicals

TABLE 5-5
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: *IN SITU PASSIVE TREATMENT WALL/SLURRY CUT-OFF WALL*
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

2 PASSIVE TREATMENT WALLS
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$40,000	$40,000		Work Plan, E&S Control Plan, H&S Plan, Permits for Utility Relocation	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Stockpile Area	LS	1	$5,000	$5,000			Engineering Estimate- Previous Projects
Contract Administration	LS	1	$18,000	$18,000			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$15,000	$15,000			Engineering Estimate- Previous Projects
Bench-Scale Study	LS	1	$50,000	$50,000		Includes iron column bench-scale tests; groundwater modeling for funnel and gate configuration; testing for slurry wall formulation	Engineering Estimate- Vendor Quote
Total General Costs					$168,000		
MONITORING WELL INSTALLATION							
Well Replacement Due to Highway Construction	LS	1	$20,492	$20,492		Replacement of 5 shallow and 4 intermediate wells	RAA No. 2
Additional Wells and Piezometers	LS	1	$15,511	$15,511		Installation of 4 intermediate wells and 3 piezometers	RAA No. 2
Total Monitoring Well Installation Costs					$36,003		
SITE WORK							
Clearing and Grubbing	Acre	1.15	$2,203	$2,533		Assume 5' width across each wall	Means ECHOS 1996
Temporary Safety Fencing	LF	5000	$1.83	$9,150		Cost includes matl & labor; assume fencing in reused for subsequent construction phases	Means Site 1996, 028-320-4800
Asphalt Removal	SY	172	$12	$2,064		Assume 5' width across each wall	Means ECHOS 1996
Utility Relocation	LS	1	$188,157	$188,157		Assume 5% of direct capital costs for treatment/slurry wall	Engineering Estimate
Fine Grading and Seeding for Revegetation	SY	6417	$4	$26,117			Means Site 1996, 022-286 & Estimate
Asphalt Replacement	SY	172	$46	$7,912		Assuming 4" binder course & 3" wearing course	Means Site 1996, 025-104-0200 & -0460
Monitoring Well Replacement due to Highway Construction	EA	1	$5,421	$5,421		Replacement of 2 shallow and 1 intermediate wells	Engineering Estimate - See backup information
Total Site Work Costs					$241,355		

TABLE 5-5 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN SITU PASSIVE TREATMENT WALL/SLURRY CUT-OFF WALL
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

2 PASSIVE TREATMENT WALLS
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
TREATMENT/SLURRY WALLS							
Slurry Walls	SF	82000	$10	$820,000		*Cost includes materials & installation; 1050 LF, 30' deep, 3' wide*	*Vendor Quote & Engineering Estimate*
Iron Treatment Gates - Materials	Tons	4050	$425	$1,721,250		250 LF, 20' thick, 9' wide; iron is 0.09 tons/CF	Vendor Quote & Engineering Estimate
Iron Treatment Gates - Installation	LS	1	$1,200,000	$1,200,000			Vendor Quote & Engineering Estimate
Monitoring Well Installation	LS	1	$21,899	$21,899		10 newly installed wells: 1 upgradient & 1 downgradient of each treatment wall (see back-up information for details)	Engineering Estimate - Previous Projects
Total Treatment/Slurry Wall Costs					$3,763,149		
TOTAL DIRECT CAPITAL COSTS					$4,208,507		
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$505,021	$505,021		12% of Total Direct Cost	Engineering Estimate
Construction Administration	LS	1	$631,276	$631,276		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$631,276	$631,276		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$1,767,573		

TABLE 5-5 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN SITU PASSIVE TREATMENT WALL/SLURRY CUT-OFF WALL
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

2 PASSIVE TREATMENT WALLS
MONITORING 30 EXISTING & 4 NEW WELLS

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M (Assuming quarterly sampling for years 1-5, and semiannual sampling for years 6-30)							
Note: Costs include sampling for long-term monitoring (28 wells) and sampling for treatment/slurry wall O&M (10 wells).							
Labor	Hours	312	$32	$9,984		52 samples, 10 days, 10 hrs/day/person, 3 people	Engineering Estimate - Table 5-5A.B
Travel	Sample Event	1	$2,353	$2,353		Includes travel-airfare for 3 people and truck rental	Engineering Estimate - Table 5-5A.B
Per Diem	Sample Event	1	$2,190	$2,190		10 days/sample event, $73/day/person, 3 people	Engineering Estimate - Table 5-5A.B
Laboratory Analysis & Data Validation							
VOCs	Sample	52	$179	$9,308		44 samples & 8 QA/QC samples	Basic Ordering Agreement
Equipment and Supplies	Sample Event	1	$1,270	$1,270		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate - Table 5-5A.B
Sample Shipping	Sample Event	1	$1,245	$1,245		1 cooler per day for 15 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$12,938	$12,938		Equal annual cost of replacing 28 wells every 5 yrs for 30 yrs	RAA No. 2
Total Groundwater Monitoring O&M Costs	1 - 5 Years				$130,340	Annual cost for quarterly sampling events	
Total Groundwater Monitoring O&M Costs	6 - 30 Years				$71,639	Annual cost for semi-annual sampling events	

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$5,976,000	
TOTAL GROUNDWATER MONITORING COSTS (YEARS 1-5) TOTAL GROUNDWATER MONITORING COSTS (YEARS 6-30)	$130,340 $71,639	
PRESENT WORTH VALUE	$7,330,000	Based on a discount rate of 5 %

TABLE 5-5A
COST ESTIMATE ASSUMPTIONS FOR INSTALLATION OF TREATMENT/SLURRY WALL MONITORING WELLS

GENERAL ASSUMPTIONS
10 intermediate monitoring wells (each 40-ft deep)

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$15.00	400	$6,000.00
2" PVC sch. 40 riser	LF	$1.25	360	$450.00
2" PVC sch. 40 screen	LF	$11.00	40	$440.00
Protective cover	Each	$400.00	10	$4,000.00
Drums	Each	$42.00	50	$2,100.00
Well development	Hour	$65.00	10	$650.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	10	$950.00
Geologist labor	Hour	$40.00	120	$4,800.00
Geologist travel	Each	$1,079.00	1	$1,079.00
Geologist per diem	Day	$73.00	10	$730.00
Well Installation Costs per Event				$21,899

TABLE 5-5B
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS

- Groundwater will be sampled quarterly for years 1-5, and semiannually for years 6-30
- 28 wells will be sampled for VOCs under the long-term monitoring program, and 10 wells will be sampled for VOCs under the treatment/slurry wall O&M

LABOR	308	hours/event
No. of people:	2	
Days required:	15	
Hours per day:	10	
Travel Time/person	4	
LABOR COST	$9,856	/event
TRAVEL	$2,353	/event
No. of people:	2	
Days required:	15	
Airfare (roundtrip PIT-OAJ, full fare)	$689.00	
Mini-van rental	$65.00	
PER DIEM	$2,190.00	/event
No. of people:	2	
Days required:	15	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

Item	Unit Rate	Units	No. of Units	Total
Conductivity Meter	$3.86	/Day	15	$57.90
pH Meter	$6.35	/Day	15	$95.25
Turbidity Meter	$9.67	/Day	15	$145.05
D.O. Meter	$13.23	/Day	15	$198.45
Perstaltic Pump	$6.62	/Day	15	$99.30
P.E. Tubing	$21.25	/100 feet	4	$85.00
Silicon Tubing	$2.75	/foot	4	$11.00
P.E. Squeeze Bottles	$.06	/Day	15	$.90
Garbage Bags	$.16	Each	15	$2.40
Inner Gloves	$8.97	/Box	2	$17.94
Paper Towels	$.81	Roll	6	$4.86
Markers	$.60	Each	4	$2.40
Equipment Shipping	$50.00	/Package	11	$550.00
			TOTAL:	$1,270.45

TABLE 5-6
ESTIMATED COSTS FOR GROUNDWATER RAA No. 6

GROUNDWATER RAA No. 6: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

10 AERATION WELLS
MONITORING 30 EXISTING & 4 NEW WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jan-97

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$30,000	$30,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$20,000	$20,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$18,000	$18,000			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$15,000	$15,000			Engineering Estimate- Previous Projects
Pilot Study	LS	1	$300,000	$300,000			Engineering Estimate- Previous Projects
Total General Costs					$393,000		
MONITORING WELL INSTALLATION							
Well Replacement Due to Highway Construction	LS	1	$20,492	$20,492		Replacement of 5 shallow and 4 intermediate wells	RAA No. 2
Additional Wells and Piezometers	LS	1	$15,511	$15,511		Installation of 4 intermediate wells and 3 piezometers	RAA No. 2
Total Monitoring Well Installation Costs					$36,003		
SITE WORK							
Monitoring Well Replacement due to Highway Construction	EA	1	$12,000	$12,000		Replacement of 4 shallow and 2 intermediate wells	Engineering Estimate & BOA Pricing
Demolish Bituminous Road w/ Power Equip	SY	50	$12	$600		Remove paving and base course	Means Environmental Restoration, 1996
Piping Trench for Air Injection & Vacuum Lines	LF	1200	$5.49	$6,588		Includes excavation, removal, backfill, and compaction	Means Site 1996, 12.3-110 & Estimate
Pavement Replacement Over Trench	SY	50	$46	$2,300		Assuming asphalt pavement 8" thick	Means Site 1996, 025-104 & Estimate
Water Connection at Treatment Trailer	LF	100	$8	$800		Includes trenching & laying a 1" copper line	Means Site 1996, 026-662 & 022-258
Overhead Electrical to Treatment Trailer	LF	75	$25	$1,875		Includes overhead routing and poles	Means Site 1996, 167-100 & Estimate
Total Site Work Costs					$12,163		
AERATION SYSTEM							
In-Well Aeration Well Installation	LF	400	$230	$91,918		6" stainless steel, incl installation of pumps and appurtenances	Engineering Estimate- Table 5-4B.A
Appurtenances	EA	10	$1,000	$10,000			Engineering Estimate- Previous Projects
2" PVC Line for Air Injection	LF	1200	$4	$4,800		Includes materials and installation	Means Site 1996, 026-678 & Estimate
2" PVC Line for Air Vacuum	LF	1200	$4	$4,800		Includes materials and installation	Means Site 1996, 026-678 & Estimate
Fittings, Anchoring, and Supporting	LS	1	$3,360	$3,360		Assume 35% of Total Piping Cost	Engineering Estimate- Previous Projects
12.2 HP Air Injection Treatment System	EA	2	$46,611	$93,222			Engineering Estimate- Table 5-4B.B
25.4 HP Air Injection Treatment System	EA	2	$48,668	$97,336			Engineering Estimate- Table 5-4B.B
Total Aeration System Costs					$305,436		
TOTAL DIRECT CAPITAL COSTS:					$746,602		

TABLE 5-6
ESTIMATED COSTS FOR GROUNDWATER RAA No. 6

GROUNDWATER RAA No. 6: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

10 AERATION WELLS
MONITORING 30 EXISTING & 4 NEW WELLS

Jan-97

CAPITAL COSTS (DIRECT AND INDIRECT)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$89,592	$89,592		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$111,990	$111,990		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$111,990	$111,990		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$313,573		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	312	$32	$9,984		38 samples, 10 days, 10 hrs/day/person, 3 people	RAA No. 2
Travel	Sample Event	1	$2,028	$2,028		Includes travel-airfare for 3 people and truck rental	RAA No. 2
Per Diem	Sample Event	1	$1,460	$1,460		10 days/sample event, $73/day/person, 3 people	RAA No. 2
Laboratory Analysis & Data Validation							
VOCs	Sample	38	$179	$6,802		34 samples / 3 duplicate / 1 MS/MSD	Basic Ordering Agreement
Supplies & Equipment	Sample Event	1	$835	$835			RAA No. 2
Sample Shipping	Sample Event	1	$830	$830		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		1 cooler per day for 10 days; $83/cooler	Engineering Estimate
Monitoring Well Replacement	Year	1	$12,938	$12,938		Laboratory reports, administration, etc.	RAA No. 2
TOTAL GROUNDWATER MONITORING O&M COSTS (1 - 5 Years)					$112,694	*Equal annual cost of replacing 28 wells every 5 yrs for 30 yrs*	
TOTAL GROUNDWATER MONITORING O&M COSTS (6 - 30 Years)					$62,816		
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Utilities	Yr	3	$8,400	$25,200		Electric service at $0.10/Kwh and phone service	Vendor Quote
Maintenance	Yr	3	$1,000	$3,000		Routine repairs and preventative maintenance	Vendor Quote
Labor	Yr	3	$9,000	$27,000		Monthly inspections	Vendor Quote
Off-gas Treatment	Yr	3	$3,200	$9,600		Carbon replacement	Vendor Quote
Aeration Well Replacement	EA	1	$1,000	$1,000		Assume $ 1,000/yr	
Equipment Maintenance (Replacement)	Yr	1	$973	$973		Replacement of worn equipment - assume an annual 2% of total	Engineering Estimate
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL TREATMENT SYSTEM O&M COSTS					$71,773		

TABLE 5-6
ESTIMATED COSTS FOR GROUNDWATER RAA No. 6

GROUNDWATER RAA No. 6: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
OU No 10, SITE 35 - CAMP GEIGER AREA FUEL FARM
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

10 AERATION WELLS
MONITORING 30 EXISTING & 4 NEW WELLS

Jan-97

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$1,060,000	
TOTAL ANNUAL MONITORING O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL MONITORING O&M COSTS (6 - 30 YEARS) TOTAL ANNUAL TREATMENT SYSTEM O&M COSTS	$113,000 $63,000 $72,000	Assuming 30 Years of Operation
PRESENT WORTH VALUE	$3,350,000	Based on a discount rate of 5 %

TABLE 5-6A

COST ESTIMATE ASSUMPTIONS FOR 8" IN-WELL AERATION WELLS

ITEM	UNITS	COST	UNITS	TOTAL
Mobilization	Each	$500.00	1	$500.00
Well installation	LF	$25.00	1000	$25,000.00
8" PVC Outer Casing	LF	$9.01	200	$1,802.00
8" PVC Screen	LF	$25.14	200	$5,028.00
3" PVC Inner Casing	LF	$2.00	250	$500.00
2" PVC Outer Casing	LF	$1.00	450	$450.00
2" PVC Screen	LF	$5.19	200	$1,038.00
Packer	Each	$200.00	10	$2,000.00
Vault Box	Each	$2,780.00	10	$27,800.00
Drums	Each	$42.00	100	$4,200.00
Well development	Hour	$65.00	20	$1,300.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	12	$1,140.00
Geologist	Hour	$40.00	120	$4,800.00
Geologist Per Diem	Day	$70.00	12	$840.00
Subtotal				$76,598.00
20% Contingency				$15,319.60
Well Installation Cost				$91,918
Cost per Linear Foot				$230

TABLE 5-6B

IN-WELL AERATION OFF-GAS TREATMENT SYSTEM ESTIMATED COSTS

Item	Unit Cost	No. of Units	Total		Remarks
Air Injection Equipment					
12.2-HP Max. Blower	$4,444.69	1	$4,444.69		Means Environmental Restoration, 1996
25.4-HP Max. Blower	$6,090.57	1	$6,090.57		Means Environmental Restoration, 1996
Inlet Filter	$20.00	1	$20.00		Engineering Estimate
Bleed-off Muffler	$40.00	1	$40.00		Engineering Estimate
Pressure Relief Valve	$20.00	1	$20.00		Engineering Estimate
Venturi Flow Meter /Gauge	$200.00	1	$200.00		Engineering Estimate
Pressure Gauges	$120.00	1	$120.00		Engineering Estimate
Valves & Plumbing (20 HP)	25% of materials cost		$1,622.64		
Valves & Plumbing (10 HP)	25% of materials cost		$1,211.17		Engineering Estimate
25.4-HP Max. Blower				$8,113.21	
12.2-HP Max. Blower				$6,055.86	
Vacuum Equipment					
10-HP Blower	$5,000.00	1	$5,000.00		Means Environmental Restoration, 1996
Inlet Filter	$20.00	1	$20.00		Engineering Estimate
Bleed-off Muffler	$40.00	1	$40.00		Engineering Estimate
Pressure Relief Valve	$20.00	1	$20.00		Engineering Estimate
Venturi Flow Meter /Gauge	$200.00	1	$200.00		Engineering Estimate
Pressure Gauges	$120.00	1	$120.00		Engineering Estimate
Valves & Plumbing	25% of materials cost		$1,350.00		Engineering Estimate
Subtotal				$6,750.00	
Off-Gas Treatment Equipment					
Carbon Units	$8,000.00	2	$16,000.00		Means Environmental Restoration, 1996
Installation	$42.00	40	$1,680.00		
Subtotal				$ 17,680.00	
Mechanical/Electrical Equipment					
Equipment Trailer w/ lights	$6,400.00	1	$6,400.00		Means 015 900, 1996
Electrical Control Panel	$6,500.00	1	$6,500.00		Engineering Estimate - Previous Projects
Conduit & Wiring	25% of materials cost		$3,225.00		Engineering Estimate - Previous Projects
Subtotal				$ 16,125.00	
Total Estimated Cost for a 25.4 HP Injection System				$48,668.21	
Total Estimated Cost for a 12.2 HP Injection System				$46,610.86	