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FINAL

FEASIBILITY STUDY

OPERABLE UNIT NO. 9
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0312

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	area of concern
ARARs	applicable or relevant and appropriate requirements
AST	aboveground storage tank
Baker	Baker Environmental, Inc.
bgs	below ground surface
BOD	biochemical oxygen demand
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
COC	contaminant of concern
COD	chemical oxygen demand
COPC	contaminant of potential concern
CSF	carcinogenic slope factor
CWA	Clean Water Act
1,2-DCE	1,2-dichloroethene
DoN	Department of the Navy
DOT	Department of Transportation
ESE	Environmental Science and Engineering, Inc.
FFA	Federal Facilities Agreement
FS	Feasibility Study
gpm	gallons per minute
GSI	Groundwater Technology Government Services, Inc.
HI	hazard index
IAS	Initial Assessment Study
ICR	incremental lifetime cancer risk
IDW	investigation-derived waste
IRP	Installation Restoration Program
kg	kilograms
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
µg/L	microgram per liter
µg/kg	microgram per kilogram

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

mg/kg	milligram per kilogram
mg/L	milligram per liter
MW	monitoring well
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCAC	North Carolina Administrative Code
NCP	National Contingency Plan
NCWQS	North Carolina Water Quality Standards
ND	nondetect
NPL	National Priorities List
NPW	net present worth
O&M	operation and maintenance
OU	operable unit
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
POL	petroleum, oil, and lubricant
POTW	publicly owned treatment works
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PVC	polyvinyl chloride
QI	quotient index
RA	risk assessment
RAA	remedial action alternative
RAB	Restoration Advisory Board
RAO	remediation action objective
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RGO	remediation goal option
RI/FS	Remedial Investigation/Feasibility Study
RI	Remedial Investigation
RL	remediation level
RME	responsible maximum exposure
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SD	sediment
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level
SMP	Site Management Plan

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

SSSV	surface soil screening value
SSV	sediment screening value
STP	sewage treatment plant
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SW	surface water
SWSV	surface water screening value
TAL	target analyte list
TBC	to be considered
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristics leaching procedure
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRV	terrestrial reference value
TSS	total suspended solids
UBK	uptake biokinetic
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.

EXECUTIVE SUMMARY

INTRODUCTION

This report documents the Feasibility Study (FS) conducted for Operable Unit (OU) No. 9, Site 73 - the Amphibious Vehicle Maintenance Facility at Marine Corps Base (MCB), Camp Lejeune, North Carolina. Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0312 under the Department of the Navy (DoN) Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS has been primarily based on data collected during the Remedial Investigation (RI) for Site 73, which was conducted in two phases between 1995 and 1996.

SITE DESCRIPTION AND HISTORY

Site 73 encompasses the Amphibious Vehicle Maintenance Facility located in the Courthouse Bay Area of MCB, Camp Lejeune. The site is roughly bounded by State Route 172 (Sneads Ferry Road). to the north, Courthouse Bay to the south, and unnamed tributaries to Courthouse Bay to the east and west. Courthouse Bay Road, which bisects the study area, is used to enter the complex.

Site 73 contains numerous buildings, aboveground storage tanks (ASTs), underground storage tanks (USTs), vehicle wash racks, and oil/water separators. From 1946 to the present, the site has been used as an Amphibious Vehicle Maintenance Facility. An estimated 400,000 gallons of waste oil were reportedly discharged directly onto the ground surface at this facility, primarily near Building A47. In addition to the waste oil, approximately 20,000 gallons of waste battery acid were also reportedly disposed in the area northeast of Building A47. The waste battery acid was poured into shallow hand-shoveled holes which were then backfilled. There is currently no visual evidence of these disposal areas; the areas are currently covered by concrete, buildings and/or roads. Solvents may have also been disposed at the site although no specific disposal locations or dates have been identified.

NATURE AND EXTENT OF CONTAMINATION

According to the RI, volatile organic compounds (VOCs) in the surficial and deep groundwater aquifers were the most significant contaminants detected at Site 73. These VOCs included benzene, trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride.

Benzene detected in the surficial aquifer was located within the Building A47 complex. The contamination appears to be restricted to the surficial aquifer because of the natural tendency of benzene to reside in the upper portions of any water-bearing zones. Low levels of benzene were also detected in a deep monitoring well that was installed in the upper portion of the Castle Hayne aquifer. However, it is possible that this contamination was introduced during deep monitoring well installation.

Chlorinated organic contamination residing in the uppermost portion of the surficial aquifer consists of TCE and its degradation byproducts - vinyl chloride and cis-1,2-DCE. Although TCE was detected in a number of surficial groundwater samples collected across the site, the concentrations were relatively low compared to a deep groundwater sample collected within the Building A47 complex. This deep sample was collected in the upper portion of the Castle Hayne aquifer. No VOCs were detected in the mid- to lower-portions of the Castle Hayne aquifer.

It appears as though the fuel-related and chlorinated solvent contamination is naturally attenuating. This is because TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected in both the surficial aquifer and the upper portion of the Castle Hayne aquifer. In addition, the spatial arrangement of the TCE, cis-1,2-DCE, and vinyl chloride plumes suggests that the cis-1,2-DCE and vinyl chloride are a direct result of TCE degradation.

The groundwater flow model conducted during the RI concluded that groundwater in the vicinity of Site 73 flows downward from the surficial aquifer into the upper portion of the Castle Hayne aquifer. Groundwater continues its downward progression as it heads toward Courthouse Bay until at some undetermined depth it begins to travel upward and discharge into the bay.

HUMAN HEALTH RISK ASSESSMENT

As part of the RI, a human health risk assessment (RA) was conducted to identify contaminants of potential concern (COPCs) and to assess potential human health risks associated with these COPCs. These COPCs included pesticides and inorganics in surface and subsurface soil, VOCs and inorganics in groundwater, inorganics in surface water and sediment, and VOCs and inorganics in fish and crab tissue. Table ES-1 presents the total incremental lifetime cancer risk (ICR) and hazard index (HI) values that were generated for each environmental medium and relevant receptor. ICR values that exceed the USEPA acceptable limit of 1E-04, and HI values that exceed the USEPA acceptable limit of 1.0, are shaded in Table ES-1. These unacceptable values correspond to groundwater exposure under the future child and adult residential scenarios and surface water and sediment exposure under the future residential child scenario.

ECOLOGICAL RISK ASSESSMENT

During the RI, an ecological RA was conducted to address the impacts that COPCs may be having on the aquatic and terrestrial ecosystems at Site 73.

For the aquatic ecosystem, benthic species in Courthouse Bay and its tributaries exhibited lower indices than benthic species in the background stations. However, significant contaminant levels were not detected in the sediment of the tributaries. One sediment sample in Courthouse Bay exhibited significant pesticide levels, but these pesticides are considered to be remnants of past Base-wide pesticide application rather than site-related contaminants. Several contaminants detected in fish and crab tissues appeared to be slightly elevated above background studies. However, based on the relatively abundant and diverse fish population at Site 73, these contaminants do not appear to be significantly impacting the fish community. Tissue concentrations of arsenic, chromium, lead, and zinc were below toxicity concentrations available in the published literature for aquatic and piscivorous wildlife.

For the terrestrial ecosystem, several inorganics (aluminum, chromium, iron, and vanadium) in the surface soil exceeded soil toxicity benchmark values. Although most of the values exceeded were plant benchmark values, the flora community did not appear to be adversely impacted during the site investigation. In addition, it should be noted that there is much uncertainty associated with the surface soil screening values (SSSVs). Using the terrestrial intake model, the chronic daily intake (CDI) value exceeded the terrestrial reference value (TRV) for several species. The greatest risk was identified for the raccoon. Aluminum, antimony, arsenic, and cadmium drove the terrestrial model risks.

MEDIA OF CONCERN, CONTAMINANTS OF CONCERN, AND REMEDIATION LEVELS

The media of concern at Site 73 are groundwater (in both the surficial and deep aquifer), and fish and crab tissue. These media pose a concern because they generated unacceptable carcinogenic and noncarcinogenic risks during the human health RA. Table ES-2 presents the final set of contaminants of concern (COCs) and remediation levels (RLs) that were developed for groundwater and fish and crab tissue, respectively.

REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) were developed to address the VOCs that exceeded RLs in the surficial and deep groundwater aquifers. Although aluminum, barium, chromium, and vanadium in groundwater also exceeded RLs, they are not addressed by the RAOs. This is because each inorganic contributed no more than five percent to the total noncarcinogenic risk for exposure to groundwater.

Thus, two RAOs were developed for VOCs in the surficial and deep groundwater aquifers:

- RAO #1:
  Mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater.

- RAO #2:
  Remediate the groundwater to the specified remediation levels.

Separate remedial action alternatives (RAAs) were developed for the surficial and deep aquifers to achieve these RAOs.

SURFICIAL AQUIFER ALTERNATIVES

RAA 1S: No Action

- Capital Cost: $0
- Annual Operation and Maintenance (O&M) Cost: $0
- Net Present Worth (NPW): $0
- Time to Implement: 0

Under the no action alternative, contaminated groundwater in the surficial aquifer will remain untreated in its in situ state. No active remedial actions will be implemented.

RAA 2S: Natural Attenuation, Monitoring, and Aquifer-Use Restrictions

- Capital Cost: $275,000
- Annual Monitoring O&M Cost (Years 1-5): $185,000
- Annual Monitoring O&M Cost (Years 6-30): $94,000
- NPW: $2,068,000
- Time to Implement: 30 years of monitoring

Under RAA 2S, natural attenuation will be relied upon to decrease contaminant levels. The main component of RAA 2S is a long-term groundwater and surface water monitoring program. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicate the type of biodegradation that is occurring, and the kind and amount of contaminant reduction that can be expected. All surface water samples will be analyzed for VOCs to ensure that the contaminant plumes are not adversely affecting Courthouse Bay. In addition to the monitoring program, RAA 2S will include aquifer-use restrictions that will prohibit future use of the surficial and deep aquifers, within a 1,500-foot radius of Site 73, as potable water sources. RAA 2S may also include a contaminant fate and transport model and a laboratory microcosm study to provide further evidence that natural attenuation is occurring.

RAA 3S: Groundwater Extraction and Treatment

- Capital Cost: $1,194,000
- Annual Monitoring O&M Cost (Years 1-5): $185,000
- Annual Monitoring O&M Cost (Years 6-30): $94,000
- Annual System O&M Cost (Years 1-30): $45,000
- NPW: $3,725,000
- Time to Implement: 30 years of monitoring and 30 years of system operation

Under RAA 3S groundwater from the most contaminated areas (hot areas) of the upper portion of the surficial aquifer will be extracted, treated and discharged to Courthouse Bay. In areas where groundwater contamination is lower, natural attenuation will be relied upon to reduce contaminant levels. In addition , aquifer-use restrictions will be implemented that will prohibit the future use of the surficial aquifer within 1,500 feet of Site 73.

A total of three extraction wells will be installed to collect contaminated groundwater. Two extraction wells will be installed in hot areas of the upper portion of the surficial aquifer and one will be installed to extract groundwater from underneath the concrete structure near 73-MW09. Groundwater will be conveyed to a small on-site treatment plant where it will receive suspended solids /metals pretreatment, VOC removal via air stripping and liquid-phase carbon absorption.

In addition, a long-term groundwater and surface water monitoring program similar to the program described under RAA 2S will be implemented. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicated the type of biodegradation that is occurring and the kind and amount of contaminant reduction that can be expected. All surface waters will be analyzed for VOCs to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

RAA 4S: Air Sparging and Soil Vapor Extraction

- Capital Cost: $1,086,000
- Annual Monitoring O&M Cost (Years 1-5): $185,000
- Annual Monitoring O&M Cost (Years 6-30): $94,000
- Annual Monitoring O&M Cost (Years 1-30): $49,000
- NPW: $3,678,000
- Time to Implement: 30 years of monitoring and 10 years of system operation

Under RAA 4S horizontal in situ air sparging (IAS) and soil vapor extraction (SVE) systems will be installed in hot areas of the upper portion of the surficial aquifer in order to remove dissolved phase VOC contamination. In areas where groundwater contamination levels are lower, natural attenuation will be relied upon to reduce contaminant levels. In addition, aquifer-use restrictions will be implemented to that will prohibit the future use of the surficial aquifer within 1,500 feet of Site 73.

A total of three separate IAS/SVE systems will be installed to treat contaminated groundwater. Two systems will be installed in hot areas near Courthouse Bay and a third system will be installed near Building A-47. Contaminated off-gas collected by SVE systems will be treated by vapor phase carbon adsorption units located near each IAS/SVE system.

In addition, a long-term groundwater and surface water monitoring program similar to the program described under RAA2S will be implemented. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicated the type of biodegradation that is occurring and the kind and amount of contaminant reduction that can be expected. All surface waters will be analyzed for VOCs to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

RAA 5S: Groundwater Extraction and Treatment - Expanded System

- Capital Cost: $1,507,000
- Annual Monitoring O&M Cost (Years 1-5): $142,000
- Annual Monitoring O&M Cost (Years 6-30): $73,000
- Annual System O&M Cost (Years 1-30): $65,000
- NPW: $3,927,000
- Time to Implement: 30 years of monitoring and 30 years of system operation

Under RAA 5S groundwater from all areas of the upper portion of the surficial aquifer with contaminant concentrations that exceed remediation levels be will be extracted, treated and discharged to Courthouse Bay. Aquifer-use restrictions will be implemented to that will prohibit the future use of the surficial aquifer within 1,500 feet of Site 73.

A total of seven extraction wells will be installed to collect contaminated groundwater. Groundwater will be conveyed to a single on-site treatment plant where it will receive suspended solids/metals pretreatment, VOC removal via air stripping and liquid-phase carbon absorption.

In addition, a long-term groundwater and surface water monitoring program will be implemented. This program is not similar to the monitoring program summarized in RAA 2S, RAA 3S and RAA 4S in that all groundwater and surface water samples will be analyzed for only VOCs. Natural attenuation parameters are not included in this alternative. Surface water samples will be collected and analyzed to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

DEEP AQUIFER ALTERNATIVES

RAA 1D: No Action

- Capital Cost: $0
- Annual O&M Cost: $0
- NPW: $0
- Time to Implement: 0

Under the no action alternative, contaminated groundwater in the deep aquifer will remain untreated in its in situ state. No active remedial actions will be implemented.

RAA 2D: Natural Attenuation, Monitoring, and Aquifer-Use Restrictions

- Capital Cost: $231,000
- Annual Monitoring O&M Cost (Years 1-5): $123,000
- Annual Monitoring O&M Cost (Years 6-30): $64,000
- NPW: $1,470,000
- Time to Implement: 30 years of monitoring

Under RAA 2D, natural attenuation will be relied upon to decrease contaminant levels. The main component of RAA 2D is a long-term groundwater and surface water monitoring program. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicate the type of biodegradation that is occurring, and the kind and amount of contaminant reduction that can be expected. All surface water samples will be analyzed for VOCs to ensure that the contaminant plumes are not adversely affecting Courthouse Bay. In addition to the monitoring program, RAA 2D will include aquifer-use restrictions that will prohibit future use of the surficial and deep aquifers, within a 1,500-foot radius of Site 73, as potable water sources. RAA 2S may also include a contaminant fate and transport model and a laboratory microcosm study to provide further evidence that natural attenuation is occurring.

RAA 3D: Groundwater Extraction and Treatment

- Capital Cost: $1,064,000
- Annual Monitoring O&M Cost (Years 1-5): $123,000
- Annual Monitoring O&M Cost (Years 6-30): $64,000
- Annual System O&M Cost (Years 1-30): $46,000
- NPW: $3,010,000
- Time to Implement: 30 years of monitoring and 30 years of system operation

Under RAA 3D groundwater from the hot areas of the lower portion of the surficial aquifer and the upper portion of the Castle Hayne will be extracted, treated and discharged to Courthouse Bay. In areas where groundwater contamination is lower, natural attenuation will be relied upon to reduce contaminant levels. In addition, aquifer-use restrictions will be implemented to that will prohibit the future use of the surficial aquifer within 1,500 feet of Site 73.

A total of two extraction wells will be installed to collect contaminated groundwater. One will be installed near monitoring well 73-MW11 and the other near well 73-MW13. Groundwater will be

conveyed to a small on-site treatment plant where it will receive suspended solids/metals pretreatment, VOC removal via air stripping and liquid phase carbon absorption.

In addition, a long-term groundwater and surface water monitoring program similar to the program described under RAA 2D will be implemented. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicated the type of biodegradation that is occurring and the kind and amount of contaminant reduction that can be expected. All surface waters will be analyzed for VOCs to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

RAA 4D: In-Well Aeration

- Capital Cost: $1,079,000
- Annual Monitoring O&M Cost (Years 1-5): $123,000
- Annual Monitoring O&M Cost (Years 6-30): $64,000
- Annual System O&M Cost (Years 1-10): $43,000
- NPW: $2,979,000
- Time to Implement: 30 years of monitoring and 10 years of system operation

Under RAA 4D three in-well aeration wells will be installed in the hot areas of the lower portion of the surficial aquifer and the upper portion of the Castle Hayne. In areas where groundwater contamination is lower, natural attenuation will be relied upon to reduce contaminant levels. In addition, aquifer use restrictions will be implemented to that will prohibit the future use of the lower surficial aquifer and upper portion of the Castle Hayne aquifer within 1,500 feet of Site 73.

A total of two in-well aeration wells will be installed between monitoring wells 73-MW14 and existing wash racks. A third well will be installed near monitoring well 73-MW11. Separate treatment units containing a vapor/liquid separation unit, a vapor-phase carbon adsorption unit, an air blower and a vacuum pump will be located at each aeration well.

In addition, a long-term groundwater and surface water monitoring program similar to the program described under RAA 2D will be implemented. All groundwater samples will be analyzed for natural attenuation parameters and VOCs to indicated the type of biodegradation that is occurring and the kind and amount of contaminant reduction that can be expected. All surface waters will be analyzed for VOCs to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

Total annual O&M costs for RAA 4D ($230,000) exceeds total annual O&M costs for RAA 5D ($213,000) even though RAA 5D is a much more extensive system. Annual treatment plant O&M costs for RAA 5D ($104,000) exceed annual treatment costs for RAA 4S ($38,000), as would be expected. However, total annual monitoring O&M costs for RAA 4D for years one through five ($123,000) and years six through thirty ($64,000) exceed the total annual monitoring O&M costs for RAA 5D during the same time period ($71,000 and $38,000, respectively).

The O&M cost difference mirrors the differences in monitoring programs proposed for RAA 4D and RAA 5D. The annual monitoring program under RAA 5D includes only volatile organic compound (VOC) analysis. However, because natural attenuation is included as a process option under RAA 4D, analytical costs associated with this alternative are approximately five times greater than the analytical costs associated with RAA 5D. In addition to higher analytical costs, North Carolina

regulations require the development and maintenance of a groundwater fate and transport model to support natural attenuation.

RAA 5D: In-Well Aeration

- Capital Cost: $1,602,000
- Annual Monitoring O&M Cost (Years 1-5): $71,000
- Annual Monitoring O&M Cost (Years 6-30): $38,000
- Annual System O&M Cost (Years 1-10): $104,000
- NPW: $3,928,000
- Time to Implement: 30 years of monitoring and 10 years of system operation

Under RAA 5D eleven in-well aeration wells will be installed in all areas where contamination levels exceed remediation levels. Aquifer-use restrictions will be implemented that will prohibit the future use of the lower surficial aquifer and upper Castle Hayne aquifer within 1,500 feet of Site 73.

A total of eleven in-well aeration wells will be installed. Eight aeration wells will be installed within the limits of the groundwater plume that is between monitoring well 73-DW03 and 73-DW04. The remaining three aeration wells will be installed in contaminant plumes located in the vicinity of monitoring wells 73-MW01B, 73-MW02B and 73-MW11B. Separate treatment units containing a vapor/liquid separation unit, a vapor-phase carbon adsorption unit, an air blower and a vacuum pump will be located at each aeration well.

In addition, a long-term groundwater and surface water monitoring program will be implemented. This program is not similar to the program summarized in RAA-2D, RAA-3D and RAA-4D in that all groundwater and surface water samples will be analyzed for only VOCs. Natural attenuation parameters are not included in this alternative. Surface water samples will be collected and analyzed to ensure that contaminant plumes are not adversely affecting Courthouse Bay.

TABLE ES-1

TOTAL SITE RISK
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptors	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water/Sediment		Fish/Crab Tissue		Total (Phase I Groundwater)		Total (Phase II Groundwater)	
	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Current Military Personnel	1.3E-07	0.01	NA	NA	NA	NA	NA	NA	2.7E-07	0.5	NA	NA	4.0E-07	0.5	4.0E-07	0.5
Current Adolescent Trespasser	9.3E-08	<0.01	NA	NA	NA	NA	NA	NA	5.3E-07	0.4	NA	NA	6.2E-07	0.4	6.2E-07	0.4
Current Adult Trespasser	2.0E-07	<0.01	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	NA	NA	1.3E-06	0.3	1.3E-06	0.3
Current Adult Fisherman	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	4.3E-06	0.1	5.5E-06	0.35	5.5E-06	0.35
Biota Ingestion-Child Receptor	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.0E-06	0.4	4.0E-06	0.4	4.0E-06	0.4
Future Child Resident (RME)	1.6E-06	0.2	NA	NA	1.6E-05	2.0	7.1E-05	2.1	1.6E-06	1.1	NA	NA	1.9E-05	3.3	7.4E-05	3.4
Future Adult Resident (RME)	1.6E-06	0.02	NA	NA	3.7E-05	0.87	1.6E-04	1.0	1.1E-06	0.3	NA	NA	4.0E-05	1.1	1.6E-04	1.3
Future Construction Worker	3.4E-08	0.02	6.7E-08	0.02	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-07	0.04	1.0E-07	0.04

Notes:

Shading indicates an ICR value that exceeds the acceptable limit of 1E-04, or an HI value that exceeds the acceptable limit of 1.0.
ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
Total = Soil + Groundwater + Surface Water/Sediment + Fish/Crab Tissue
NA = Not Applicable

TABLE ES-2

REMEDIATION LEVELS AND FINAL COCs
GROUNDWATER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	RL[1]	Basis of RL	Corresponding Risk
1,2-Dichloroethane	0.38	NCWQS[2]	
1,2-Dichloroethene (total)	70	MCL[3]	
cis-1,2-Dichloroethene	70	NCWQS	
Benzene	1	NCWQS	
Vinyl Chloride	0.015	NCWQS	
Trichloroethene	2.8	NCWQS	
Aluminum	50/200	NCWQS	
Barium	2,000	NCWQS	
Chromium	50	NCWQS	
Iron	300	NCWQS	
Manganese	50	NCWQS	
Vanadium	110	Risk-Ingestion and dermal contact	THI[4] = 1.0

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 Contaminant Level
(4) THI = Total Hazard Index

1.0 INTRODUCTION TO THE FEASIBILITY STUDY

Marine Corps Base (MCB), Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) on October 4, 1989 (54 Federal Register 41015, October 4, 1989). The United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of the Environment, Health, and Natural Resources (NC DEHNR), and the United States Department of the Navy (DoN) then entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune. The primary purpose of the FFA is to ensure that environmental impacts associated with past and present activities at MCB, Camp Lejeune are thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect public health and the environment (Camp Lejeune FFA, 1989).

The Fiscal Year 1997 Site Management Plan (SMP) for MCB, Camp Lejeune (Baker, 1996a), a primary document identified in the FFA, identifies 34 sites at the Base that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 34 sites have been grouped into 18 Operable Units (OUs) to simplify RI/FS activities. OU No. 9 contains two sites: Site 65 - the Engineer Area Dump, and Site 73 - the Amphibious Vehicle Maintenance Facility. This report documents the FS conducted for Site 73. Based on the results of the RI conducted for Site 65 (Baker, 1995a), an FS is not required for this site (see Section 1.3).

Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0312 under the DoN, Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS has been conducted in accordance with the requirements delineated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) for remedial actions [40 Code of Federal Regulations (CFR) 300.430]. These NCP regulations were promulgated under CERCLA, commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA) signed into law on October 17, 1986. In addition, the USEPA document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988) was used as a guidance in preparing this study.

The FS has been primarily based on the RI that Baker conducted for Site 73. Field investigations for the RI were conducted from April 1995 through May 1996 and included surface soil, subsurface soil, groundwater, surface water, and sediment investigations; an ecological investigation; and a site survey. Results of these field investigations are summarized in the Site 73 RI report under separate cover (Baker, 1996b).

1.1 Purpose of the FS

The purpose of the FS for Site 73 is to identify remedial action alternatives that are protective of human health and the environment, attain federal and state requirements that are applicable or relevant and appropriate, and are cost-effective. In general, the FS process under CERCLA serves to ensure that appropriate remedial alternatives are developed and evaluated, such that relevant 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
2) Detailed Analysis of Remedial Action Alternatives

The first phase includes the following major activities: (1) developing remediation levels and remedial action objectives; (2) identifying volumes or areas of affected media; (3) developing general response actions; (4) identifying and screening potential technologies and process options; (5) evaluating process options; (6) assembling alternatives; (7) defining alternatives; and (8) screening and evaluating alternatives.

Section 121(b)(1) of CERCLA requires that an assessment of permanent 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 be conducted. 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 of alternatives, 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 major phase of the FS consists of: (1) evaluating the potential alternatives in detail with respect to nine evaluation criteria to address statutory requirements and preferences of CERCLA; and (2) performing a comparative analysis of the evaluated alternatives.

1.2 Report Organization

This FS report is divided into eight main sections. Section 1.0 is an introductory section that presents an overview of the FS process. Section 2.0 provides background information describing conditions (e.g., a site description and history, geology, and hydrogeology) at Site 73. Section 3.0 presents the development of remediation goal options, remediation levels, and remedial action objectives. This section also identifies the media of concern and contaminants of concern at the site. Section 4.0 presents the identification and screening of applicable remediation technologies and process options. Based on the results of this technology screening, Section 5.0 identifies remedial action alternatives that may be appropriate for the surficial and deep groundwater aquifers at Site 73. Sections 6.0 and 7.0 present detailed evaluations of the remedial action alternatives developed for the surficial and deep aquifers, respectively. Finally, Section 8.0 contains references for the entire report. Please note that tables and figures are located at the end of each section.

1.3 Results of the Site 65 RI

As part of the RI (Baker, 1995a), human health and ecological risk assessments (RAs) were conducted for Site 65. The results of the human health RA indicated that, under current and future land-use scenarios, there are no unacceptable human health risks associated with soil and groundwater at the site. With the exception of a child fisherman exposed to fish tissue, there were also no unacceptable human health risks associated with surface water and sediment. For the child fisherman, the calculated hazard index (HI) was 1.3 which slightly exceeds the acceptable limit of 1.0. However, the elevated HI was primarily due to mercury which does not appear to be a site-related contaminant. (The mercury was only detected in fish tissue, not any other medium; the ponds are located near the heavy equipment training area which prevents them from being affected

by Site 65 surface water runoff; and the ponds are stocked with fish from off-site sources.) The results of the ecological RA indicated that there are no significant risks impacting the aquatic and terrestrial ecosystems at Site 65.

Based on this information, conditions at Site 65 appear to be protective of human health and the environment, and no remedial response actions are justifiable. Therefore, no FS was conducted for Site 65. Instead, Site 65 will be addressed in a Proposed Remedial Action Plan (PRAP) prepared jointly for Sites 65 and 73 (i.e., OU No. 9).

2.0 BACKGROUND INFORMATION

Section 2.0 presents background information that describes conditions at Site 73. This information includes an operable unit description, a site description and history, a summary of the previous investigations conducted at Site 73, a summary of the field activities associated with the Remedial Investigation, the physical characteristics of the study area, the nature and extent of contamination, the results of the human health risk assessment, and the results of the ecological risk assessment. This background information is a summary of more comprehensive information that can be found in the RI Report (Baker, 1996b).

2.1 Operable Unit Description

Figure 2-1 presents a map of MCB, Camp Lejeune. Located in Onslow County, North Carolina, the Base covers approximately 234 square miles and is bisected by the New River. As shown in Figure 2-1, the New River flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The borders of MCB, Camp Lejeune are defined by U. S. Route 17 and State Route 24 to the west and northwest, respectively. The eastern and southern borders are defined by the Atlantic Ocean shoreline, and the northern border is defined by the City of Jacksonville, North Carolina. More extensive background information on MCB, Camp Lejeune is located in the RI report (Baker, 1996b).

Operable units at MCB, Camp Lejeune were formed as an incremental step toward addressing individual site concerns. The purpose of an operable unit is to simplify the specific problems associated with a site or group of sites. There are currently 34 Installation Restoration Program (IRP) sites at MCB, Camp Lejeune which have been grouped into 18 OUs.

OU No. 9 contains two sites: Site 65 - the Engineer Dump Area, and Site 73 - the Amphibious Vehicle Maintenance Facility. Figure 2-1 depicts the location of Sites 65 and 73 within MCB, Camp Lejeune. As shown, both sites are located in the Courthouse Bay area of the Base. The area is accessible via Marine's Road and North Carolina Route 172.

2.2 Site Description and History

Figure 2-2 presents a map of Site 73. The site encompasses the Amphibious Vehicle Maintenance Facility located in the Courthouse Bay Area of MCB, Camp Lejeune. The site is referred to as either the Courthouse Bay Liquids Disposal Area or the Amphibious Vehicle Maintenance Facility. Within the Base, the site is more commonly referred to as the latter and, consequently, this report refers to Site 73 as the Amphibious Vehicle Maintenance Facility.

Site 73 is roughly bounded by State Route 172 (Sneads Ferry Road) to the north, Courthouse Bay to the south, and unnamed tributaries to Courthouse Bay to the east and west. Courthouse Bay Road, which bisects the study area, is used to enter the complex.

The study area consists of numerous buildings, aboveground storage tanks (ASTs), underground storage tanks (USTs), vehicle wash racks, and oil/water separators. Most of the USTs are or were located (some USTs have been removed) within the fenced area around Building A47. Non-petroleum type wastes are routinely handled at an active Hazmat Storage Area located near UST A47/3. Other USTs are or were located near Buildings A1, A2, and A10. The RI/FS Work

Plan (Baker, 1995b) contains profiles of the various USTs. Figure 2-3 depicts the approximate locations of the USTs.

The Amphibious Vehicle Maintenance Facility started operations in 1946 and is currently active. Available information indicates that an estimated 400,000 gallons of waste oil were discharged directly onto the ground surface at this facility, primarily near Building A47. In addition to the waste oil, approximately 20,000 gallons of waste battery acid were also reportedly disposed in the area northeast of Building A47. The waste battery acid was poured into shallow hand-shoveled holes which were then backfilled. Neither area is visually apparent with respect to its history of waste disposal. Moreover, most of the area where waste disposal reportedly took place is covered with concrete, buildings and/or roads. A previous report (Law-Catlin, 1993) indicated that solvents may have also been disposed at this site although no specific disposal locations or dates were identified.

2.3 Previous Investigations

Previous environmental investigations conducted at Site 73 include: an Initial Assessment Study (IAS), a Confirmation Study, five separate UST investigations, and a preliminary investigation.

The IAS was conducted in 1983 by Water and Air Research, Inc. (WAR, 1983). The IAS identified a number of sites at MCB, Camp Lejeune, including Site 73, as potential sources of contamination. A Confirmation Study was recommended to evaluate the necessity of conducting mitigating actions or cleanup operations.

The Confirmation Study was conducted in 1990 by Environmental Science and Engineering, Inc. (ESE, 1990). Upon completion of the Confirmation Study, a Site Summary Report was written to summarize the results of the study. The report recommended that further characterization of the site be performed to complete the RI/FS process.

The five UST investigations at Site 73 were conducted by various consultants between 1991 and 1993. The first UST investigation was conducted in 1991 by ATEC Environmental Consultants and focused on UST SA-21. In 1992 and 1993, Baker performed additional investigations on the same UST. UST A47/3 was investigated by Groundwater Technology Government Services, Inc. (GSI) in April 1993 and Law-Catlin in October 1993. Both USTs were reported to be leaking. UST SA-21 was a 30,000-gallon capacity steel tank which contained both gasoline and diesel fuel. This tank was installed in 1959 and subsequently removed in 1991. UST A47/3 was a 30,000-gallon capacity steel tank which contained diesel fuel. Available information indicates that this UST was installed in 1986. A hydrostatic test was performed on A47/3 in late 1992; this tank was subsequently replaced with a fiberglass tank.

The preliminary investigation was conducted by Baker in 1994. Groundwater and soil gas samples were collected across the site to provide additional data prior to developing the RI project plans.

Using the results of the previous investigations, Baker subdivided Site 73 into nine distinct areas of concern (AOCs), in order to segregate potential sources of contamination and identify future ecological sampling zones. These AOCs are identified in Figure 2-4 and are described below.

AOC #1 The general area identified in the Camp Lejeune Site Summary Report (ESE, 1990) where over 400,000 gallons of petroleum, oil, and lubricant (POL) waste may have been disposed. A previous report also indicated that

solvents may have been disposed in this area. USTs A-47/1, A-47/5, and A-47/4 are located within this AOC.

AOC #2 — A vehicle roadway/ditch area at the extreme southwestern edge of the site which leads into Courthouse Bay. During a Pre-RI site visit, Baker observed two distinct areas of random discharge into the road/ditch from seeps located on both sides of the road/ditch. Although the seeps were brownish in appearance, samples obtained during the preliminary investigation indicated no detectable levels of volatile organic compounds (VOCs) were present.

AOC #3 — Former location of UST SA-26, a 550-gallon waste oil tank. This UST was removed after it was determined to be leaking. Adjacent to this former UST is a vehicle washdown area that is connected to an oil/water separator.

AOC #4 — UST SA-21 area that previously contained a 30,000-gallon UST for the storage of diesel fuel and gasoline. This area was previously investigated by ATEC and Baker.

AOC #5 — The general area identified in the Camp Lejeune Site Summary Report (ESE, 1990) where over 20,000 gallons of waste battery acid may have been disposed. This area is also part of the area where waste oil may have been disposed.

AOC #6 — UST A47/3 area that previously contained a 30,000-gallon UST used to store diesel fuel. This UST area was previously investigated by GSI and Law-Catlin.

AOC #7 — Unnamed stream which borders Site 73 on the east. This surface water body may be a receptor of shallow groundwater and/or surface water run-off.

AOC #8 — The area of Courthouse Bay which could be impacted by Site 73 shallow groundwater recharge and surface water run-off.

AOC #9 — Unnamed stream which borders Site 73 on the west. This surface water may be a possible receptor of surface groundwater and/or surface soil run-off.

2.4 Remedial Investigation

Baker conducted an RI at Site 73 to evaluate the nature and extent of the threat to public health and the environment resulting from the potential release of hazardous substances, pollutants, or contaminants. The RI field activities were conducted in two phases. The objective of the first phase was to detail the extent of soil and groundwater contamination based on historical information and previous investigations. At the completion of the initial phase, the analytical data was evaluated to determine whether the extent of soil and groundwater contamination had been delineated. With the concurrence of LANTDIV, USEPA, NC DEHNR, and Camp Lejeune, it was concluded that an

additional phase of field work was necessary to further define the vertical and horizontal extent of soil and groundwater contamination detected at the site.

The first phase was initiated in the field on April 3 and concluded May 25, 1995. Additional work associated with the first phase (primarily investigation-derived waste [IDW] management, surveying, and groundwater elevation measurements) was conducted between May 26 and August 21, 1995. The second phase of the field investigation commenced on February 16, and concluded March 27, 1996. IDW management, groundwater elevation measurements, and a geophysical survey associated with the second phase of field work was conducted between May 13 and 16, 1996. The field programs consisted of soil and groundwater investigations, surface water and sediment investigations, an ecological investigation, a site survey, and IDW handling.

Figure 2-5 identifies the soil, groundwater, surface water, sediment, and fish and crab sampling locations associated with the RI. Tables 2-1, 2-2, 2-3, and 2-4 summarize the contamination that was detected in soil, groundwater, surface water, and sediment, respectively.

Soil samples collected were analyzed for one or more of the following: Target Compound List (TCL) organics; Target Analyte List (TAL) metals; or Total Petroleum Hydrocarbons (TPH). Soil samples collected in the vicinity of the UST systems within the site may have had multiple analytical methods for volatile analyses as well as other analytical requirements stipulated by NC DEHNR regulations.

Groundwater samples collected during the first phase of field work were analyzed for VOCs via Method 601/602, TCL semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs) via Contract Laboratory Program (CLP) protocols. In addition, all monitoring wells were analyzed for total suspended solids (TSS) and TAL metals (total metals plus five percent of the samples for dissolved metals) via CLP protocols, and an additional sample was collected from monitoring wells 73-MW13 and A47/3-08 and analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total dissolved solids (TDS), total phosphorous, microbial count, and alkalinity. Samples collected in the vicinity of the USTs were analyzed for parameters in accordance with requirements mandated by NC DEHNR. An additional round of groundwater samples was collected during the second phase of field work. Samples collected during this phase were analyzed for TCL volatiles via CLP protocols only.

Surface water and sediment samples were analyzed for TCL organics, TAL metals, and TOC. Additionally, the 0- to 6- inch sediment samples were analyzed for grain size distribution. Fish and crab samples were analyzed for TCL organics and TAL metals only.

The remaining portions of Section 2.0 summarize the results and findings of the RI. Section 2.5 briefly describes the physical characteristics of Site 73. Section 2.6 describes the nature and extent of contamination. Finally, Sections 2.7 and 2.8 summarize the results of the human health and ecological risk assessments, respectively. More detailed information is located in the RI report (Baker, 1996b).

2.5 Physical Characteristics of the Study Area

The physical characteristics of the study area include the site's topography, surface water hydrology, and drainage features; geology; hydrogeology; and nearby potable water supply wells.

2.5.1 Topography, Surface Water Hydrology, and Drainage Features

The terrain at Site 73 is primarily flat. Stormwater runoff tends to drain directly south to Courthouse Bay or to two small unnamed tributaries located east and west of the facility which ultimately discharge to Courthouse Bay. A broad marshy area is associated with the western tributary. Directly north of the site is another large marshy area and a stream that discharges north into the New River. This marshy area is separated from the site by State Route 172 which represents a local topographic high and a surface water runoff divide.

2.5.2 Geology

The subsurface soils at the site consist of unconsolidated deposits of sand and silty sand separated by a discontinuous clay layer that thickens and thins across the site. The sands are fine to medium grained and contain varied amounts of silt and clay.

Underlying the sands described in the previous paragraph is a loose to very dense, greenish-gray, fine sand containing varying amounts of silt and shell fragments, trace clay and cemented sand nodules. This soil unit constitutes the Belgrade Formation typically referred to as the semi-confining unit separating the surficial and Castle Hayne aquifers. It appears that this unit is not acting as a confining or semi-confining unit at Site 73. Based on hydraulic head differentials, it does not appear that this unit is restricting flow from the surficial aquifer to the Castle Hayne aquifer.

Cross-sections indicate that a much larger tributary existed where the eastern unnamed tributary presently exists. This tributary may have connected the New River, north of the site, with Courthouse Bay. The evidence for this theory is the highly angular, geologically younger sands encountered at depths more typical of the River Bend Formation; the surficial clay (mentioned in the first paragraph) and the Belgrade and upper units of the River Bend Formations are missing; and topographical maps provided by the United States Geological Survey (USGS) indicate that wetlands/marshlands located north of State Route 172 have the same surficial topography as the area surrounding the unnamed tributary on the eastern portion of the site. The significance of this observation is that contamination has a potential pathway into deeper groundwater zones without impediment by less permeable geologic units.

2.5.3 Hydrogeology

Shallow groundwater flow is radial from a topographical high centered near Buildings A-8 through A-11. Flow patterns in the eastern portion of the site are influenced by the underlying clay. The absence of the clay in the eastern portion of the site allows the surficial groundwater to combine with the underlying groundwater zones causing change in the direction of groundwater flow.

Groundwater flow in the upper portion of the Castle Hayne aquifer is influenced by Courthouse Bay. A groundwater divide is present north of the site in the area of State Route 172. Flow direction in the mid to lower portion of the Castle Hayne aquifer is influenced by the New River.

Groundwater elevations collected from the monitoring wells indicate that groundwater located on the southeastern side of the bay flows toward Courthouse Bay as does groundwater on the northwestern side.

A pathline analysis was conducted as part of an overall modeling effort conducted at the site. The analysis indicated that as groundwater in the surficial aquifer begins to descend, it changes course heading toward Courthouse Bay, however continuing its descent. As groundwater nears the bay, the vertical gradient reverses and both surficial and deep groundwater begin to recharge Courthouse Bay.

During the RI, hydraulic conductivity tests were performed at Site 73. For the upper portion of the surficial aquifer, the hydraulic conductivity was determined to be 1.3 feet/day (4.6×10^{-4} cm/sec). For the lower portion of the surficial aquifer, the hydraulic conductivity was determined to be 3.6 feet/day (1.3×10^{-3} cm/sec). A study of data from other aquifer tests (pump tests) at MCB, Camp Lejeune was conducted to further evaluate the surficial aquifer characteristics and production capacity that may be expected at Site 73. Based on these other tests, pumping rates for the surficial aquifer (both the upper and lower portions) are expected to range from 0.5 to 3 gallons per minute (gpm), transmissivity is expected to range from 7.1 to 7,100 ft^2/day, and hydraulic conductivity is expected to range from 0.5 to 1.4 ft/day.

2.5.4 Potable Water Supply Wells

Potable water at MCB, Camp Lejeune is supplied entirely from the Castle Hayne aquifer. In the MCB, Camp Lejeune area, the Castle Hayne is a highly permeable, semiconfined aquifer capable of yielding several hundred to 1,000 gpm. The water retrieved is typically hard, calcium bicarbonate type.

Figure 2-6 depicts the locations of potable water supply wells in the vicinity of Site 73. As shown, three active wells (BB-44, BB-47, and BB-220) are located within a one-mile radius of the site, and two active wells (BB-218 and BB-221) are located just beyond a mile. Production well BB-44 is located approximately 4,225 feet from the site. The total depth of this well is 62 feet bgs and is screened from 32 to 62 feet bgs. This well is suspected to have been impacted by surficial groundwater infiltration due to its relatively shallow screen. Additionally, contamination was detected in samples collected from this well during the study conducted by Greenhorne and O'Mara in 1992. Trichloroethene (TCE) was detected in the sample from supply well BB-44 at a concentration of 1 microgram per liter (ug/L). Site 73 was listed as one of the possible sources for the TCE contamination. The supply well was resampled during the RI, but no VOCs were detected.

Production wells BB-47, BB-218, BB-220, and BB-221 have total depths of 150, 185, 150, and 200 feet, respectively. The screen intervals for the wells (measured in feet below ground surface [bgs]) are as follows:

- BB-47 - 40-53 feet; and 102-125 feet
- BB-218 - 64-94 feet; and 148-168 feet
- BB-220 - 55-70 feet; 85-95 feet; and 130-145 feet
- BB-221 - 60-80 feet; and 135-155 feet

2.6 Nature and Extent of Contamination

Tables 2-1, 2-2, 2-3, and 2-4 summarize the analytical results from the soil, groundwater, surface water, and sediment investigations conducted during the RI. These tables present concentration ranges for positively detected contaminants, and a comparison of contaminant concentrations to relevant comparison criteria (i.e., federal, state, and/or local standards, or background

concentrations). The following paragraphs briefly describe the nature and extent of contamination in each environmental medium.

2.6.1 Soil

Eleven VOCs were detected in surface and subsurface soils collected at Site 73. However, none of the VOCs exceeded the USEPA's Soil Screening Levels for protection of groundwater.

High SVOC concentrations were detected in surface soil sample 73-AC2-MW07-00, and in subsurface soil samples collected from soil boring locations 73-MW15B, 73-MW14, 73-SB01 and 73-SB06. Soil sample 73-AC2-MW07-00 was collected from an area where evidence of waste disposal had been observed during field operations. Soil borings 73-MW15B, 73-MW14, 73-SB01 and 73-SB06 were drilled in areas located near USTs and oil/water separators which may have been the source of the elevated SVOCs. 2,4-Dinitrophenol and benzo(a)anthracene were detected in the soils at concentrations exceeding applicable soil screening levels for groundwater protection.

Pesticides were detected in the surface and subsurface soils throughout the site. The most commonly detected compound was 4,4'-DDD. An equal number of compounds were detected in both the surface and subsurface samples. Pesticides detected in the subsurface soils were observed in areas where the soils have been either disturbed by excavation, construction, or training exercises and the reworked soil may have contained pesticide contamination. The scattered detections of pesticides and the relatively low concentrations observed in the samples provide evidence that the contamination is probably the result of surface pesticide application rather than disposal.

PCBs were detected in the surface and subsurface soils. Detections were observed in a surface soil sample collected from 73-MW20 and a subsurface soil sample from boring 73-SB07. The frequency, location and concentration of PCB detections suggest that the contamination is the result of POL spills and releases.

The distribution of detected inorganic analytes among both the surface and subsurface soils followed no pattern and was observed throughout the site at varying concentrations, suggesting that the former and current site operations have not resulted in noticeable inorganic contamination.

2.6.2 Groundwater

Benzene contamination was detected in the shallow groundwater within the A-47 complex. It was defined horizontally by monitoring wells A47/3-09, A47/3-11, 73-MW27 and 73-MW29. A former UST, reportedly located in the vicinity of the A-47 complex, is the suspected source of this contamination. The contamination is, for the most part, restricted to the surficial aquifer which is consistent with the contaminants' natural tendency to reside in the upper portions of any water-bearing zone.

The highest concentration of TCE was detected in intermediate monitoring well 73-DW03 (screened from approximately -51.7 to -61.7 feet mean sea level), located in the central portion of the Building A-47 complex. The horizontal extent of contamination is defined by monitoring wells 73-DW06, 73-DW07, and 73-DW08 to the west, 73-DW09 and 73-DW10 to the north, 73-DW13 to the east and Courthouse Bay to the south. The vertical extent lies between 63 feet and 146.5 feet mean sea level based on the lack of VOCs detected in the mid to lower portions of the Castle Hayne aquifer.

Inorganic contamination in the groundwater mainly consisted of iron and manganese; however, these analytes are commonly detected in groundwater at Camp Lejeune at levels exceeding the North Carolina Water Quality Standard (NCWQS) values. Therefore, these inorganic constituents are not considered to be the result of past waste disposal practices at Site 73.

2.6.3 Surface Water and Sediment

VOCs were detected in Courthouse Bay, but this surface water body appears to be unaffected by them. Polynuclear aromatic hydrocarbons (PAHs) detected in the sediments are suspected as the result of fossil fuel combustion due to the high amount of boat and amphibious traffic occurring in the bay on a daily basis.

The concentrations and distribution of pesticides in sediments sampled in Courthouse Bay indicate that the occurrence of these compounds is probably the result of erosion and possible aerial pesticide application, and not from spills or disposal events.

2.6.4 Fish and Crab

VOCs detected in the fish and crab samples were restricted to common laboratory contaminants and are suspected to be the result of sample preparation. Endrin (a pesticide) was detected in a fillet sample collected from sampling station F/C-02 located in Courthouse Bay. This same compound was detected in sediments and surface and subsurface soils and is suspected to have originated from Base-wide aerial application.

A number of inorganics were detected in the fish and crab samples collected from Courthouse Bay. Three of the inorganics detected (mercury, molybdenum and selenium) were not detected in any other media sampled at the site and are not considered to be related to past waste disposal activities at Site 73.

2.7 Human Health Risk Assessment

As part of the RI, a human health RA was conducted to assess the potential risks associated with the contaminants of potential concern (COPCs) at Site 73. Table 2-5 summarizes the risk values (i.e., incremental cancer risk [ICR] and hazard index [HI] values) calculated with respect to each environmental medium and relevant receptor. ICR values exceeding the USEPA limit of 1E-04, and HI values exceeding the USEPA limit of 1.0, are considered to represent unacceptable risks. ICR and HI values indicating unacceptable risks are shaded in Table 2-5.

The unacceptable risk values include exposure to groundwater under the future child and adult residential scenario and exposure to surface water and sediment under the future residential child scenario.

2.8 Ecological Risk Assessment

During the RI, an ecological RA was conducted to address the impacts that COPCs may be having on the ecological integrity of Site 73. The following sections describe the potential risks that were evaluated for the aquatic and terrestrial ecosystems.

2.8.1 Aquatic Ecosystem

The first measurement endpoint is lower benthic macroinvertebrate species diversity and richness in the Site 73 stations when compared to an ecologically similar background location. The benthic species at the stations located in the tributaries to Courthouse Bay (73-BN01, 73-BN11, and 73-BN12) and several stations within the bay (73-BN02, 73-BN04, and 73-BN09) had lower indices than the background stations. This indicates that the benthic community at these stations may be adversely impacted by contaminants detected in the sediment. However, the shallow nature and tidal conditions of the tributary stations may also contribute a significant stress to the benthic community. In particular, the tributaries had no significant levels of contaminants detected in the sediment collected, indicating other stresses are contributing to poor benthic community. Of the stations within Courthouse Bay, only station 73-BN04 had high levels of pesticides detected in the sediment that may impact the benthic communities.

The second measurement endpoint is determining if the contaminant levels in the Site 73 biota tissue samples are elevated when compared to tissue samples collected at off-site background stations or in the literature. Several of the contaminants detected in the fish and crab tissues appeared to be slightly elevated above background studies and the NC Study. However, based on the relatively abundant and diverse fish population at Site 73, these contaminants do not appear to be significantly impacting the fish community.

The third measurement endpoint is determining if the contaminant levels in the Site 73 fish tissue samples exceed toxicity values in the literature. Tissue concentrations of arsenic, chromium, lead, and zinc were below toxicity concentrations located in the literature for aquatic and piscivorous wildlife. However, there are several inorganics detected in the fish tissue that there are no toxicological data available to evaluate the detected concentrations.

The last measurement endpoint is determining if the contaminant concentrations in the surface water and sediment exceed the contaminant-specific surface water and sediment effect concentrations (i.e., surface water screening values [SWSVs], and sediment screening values [SSVs]). The inorganics in the surface water and sediment appear to have a low potential to adversely impact the aquatic receptor population.

The significant risk posed by the sediment is from pesticides detected at several stations within Courthouse Bay. The pesticides are not considered to be site-related contaminants, but they are most likely remnants of past Base-wide pesticide application.

2.8.2 Terrestrial Ecosystem

Several inorganics (aluminum, chromium, iron, and vanadium) in the surface soil collected at Site 73 exceeded soil toxicity benchmark values. Most of the values exceeded were plant benchmark values. However, the flora community did not appear to be adversely impacted during the site investigation.

The chronic daily intake (CDI) value exceeds the terrestrial reference value (TRV) for all five terrestrial species. However, the risk is higher for the raccoon. The risks in the terrestrial models were driven by aluminum, antimony, arsenic, and cadmium.

Overall, some potential impacts to soil invertebrates and plants may occur as a result of site-related contaminants. It should be noted that there is much uncertainty associated with the surface soil

screening values (SSSVs). There is a slight potential for a decrease in the terrestrial vertebrate population from site-related contaminants based on the terrestrial intake model. It is noted that aluminum concentrations detected in the surface soil exceed flora and fauna values, as well as contribute to risks in terrestrial models.

SECTION 2.0 TABLES

TABLE 2-1

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil,Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Surface Soil	Volatile (µg/kg)	1,1,1-Trichloroethane	900	1,668	NA	2 J	2 J	73-DW09	1/35	0	0	NA	north, N.C. HWY 172
		1,2-Dichloroethane	10	1.84	NA	2 J	2 J	73-SB07	1/27	0	1	NA	adjacent to SA-42
		1,2-Dichloropropane	20	2.88	NA	1 J	1 J	73-SB07	1/35	0	0	NA	adjacent to SA-42
		2-Butanone	NE	692	NA	2 J	4.2 J	73-DW03	4/35	NA	0	NA	north and east
		Acetone	8,000	2,810	NA	24	29 J	73-MW20	2/35	0	0	NA	north
		Chlorobenzene	600	438	NA	1 J	1 J	73-MW14	1/35	0	0	NA	adjacent to 73-DW03
		Ethylbenzene	5,000	241	NA	8 J	8 J	73-MW20	1/35	0	0	NA	adjacent to 73-DW05
		Styrene	2,000	2,242	NA	2 J	2 J	73-MW18	1/35	0	0	NA	near Courthouse Road
		Toluene	5,000	7,275	NA	1 J	1 J	73-DW01	1/35	0	0	NA	north, near 73-MW01
		Trichloroethene	20	18.30	NA	2 J	2 J	73-MW05	1/35	0	0	NA	near Building A8
		Xylenes (total)	74,000	4,958	NA	1 J	4 J	73-MW36	10/30	0	0	NA	scattered
	Semivolatile (µg/kg)	2,4-Dinitrophenol	100	NE	NA	56 J	200 J	73-MW23	4/34	2	NA	NA	scattered
		4-Chloro-3-Methylphenol	NE	NE	NA	36 J	36 J	73-SB09	1/35	NA	NA	NA	near 73-MW37
		Acenaphthene	200,000	8,160	NA	40 J	40 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Anthracene	4,300,000	995,000	NA	50 J	50 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Benzo(a)anthracene	700	343	NA	220 J	220 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Benzo(a)pyrene	4,000	NE	NA	160 J	160 J	73-MW07	1/35	0	NA	NA	south, near 73-MW06
		Benzo(b)fluoranthene	4,000	NE	NA	260 J	330 J	73-SB07	2/35	0	NA	NA	east and south
		Benzo (g,h,i)perylene	NE	6,720,000	NA	140 J	140 J	73-SB04	1/35	NA	0	NA	southeast, near 73-MW15
		Bis(2-ethylhexyl)phthalate	11,000	NE	NA	42 J	84 J	73-SB12	9/35	0	NA	NA	scattered, north and west
		Butyl Benzyl Phthalate	68,000	27,800	NA	110 J	110 J	73-SB11	1/35	0	0	NA	northwest, near 73-MW21
		Chrysene	1,000	38,150	NA	60 J	190 J	73-MW07	3/35	0	0	NA	scattered
		Di-n-butyl Phthalate	120,000	24,800	NA	110 J	510	73-MW05	11/35	0	0	NA	north, west and east
		Fluoranthene	980,000	276,080	NA	42 J	380 J	73-MW07	4/35	0	0	NA	scattered
		Phenanthrene	NE	59,640	NA	260 J	260 J	73-MW07	1/35	NA	0	NA	west, near 73-MW06
		Pyrene	1,400,000	286,440	NA	41 J	450	73-MW07	5/35	0	0	NA	southwest and east
	Pesticide (µg/kg)	4,4'-DDD	700	NE	NA	7	82	73-MW14	7/29	0	NA	NA	scattered
		4,4'-DDE	500	NE	NA	3.9 NJ	11 J	73-MW20	3/29	0	NA	NA	scattered
		4,4'-DDT	1,000	NE	NA	2.8 NJ	15 J	73-MW20	2/29	0	NA	NA	north and east
		Alpha-Chlordane	NE	NE	NA	2.5 NJ	2.5 NJ	73-SB09	1/29	NA	NA	NA	near 73-MW37
		Endrin Ketone	NE	NE	NA	7 NJ	7 NJ	73-MW20	1/29	NA	NA	NA	near 73-DW05
		Gamma-Chlordane	NE	NE	NA	3.3 J	6.8 J	73-SB09	2/29	NA	NA	NA	north and east
	PCB (µg/kg)	Aroclor-1060	NE	NE	NA	140 NJ	140 NJ	73-MW20	1/29	NA	NA	NA	near 73-DW05
		Aroclor-1260	NE	NE	NA	170 J	170 J	73-MW20	1/29	NA	NA	NA	near 73-DW05

TABLE 2-1

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Surface Soil (continued)	TPH (mg/kg)	Diesel Range Organics	NE	NE	NA	11	160	73-MW12	28/46	NA	NA	NA	scattered
		Gasoline Range Organics	NE	NE	NA	16	16	73-SB02	1/49	NA	NA	NA	adjacent to 73-MW08
		HBPH, as motor oil	NE	NE	NA	130	160	73-MW19	3/3	NA	NA	NA	northeast, southwest
		Oil and Grease	NE	NE	NA	860	13,800	73-MW28	8/26	NA	NA	NA	west, south and southeast
	Metal (1) (mg/kg)	Aluminum	NE	NE	5,856.1	147	10,600	73-SB03	35/35	NA	NA	1	scattered
		Barium	32	848	17.3	2.3	46.3	73-MW20	35/35	4	0	1	scattered
		Cadmium	6	2.72	0.7	1.1	1.9	73-MW14	5/35	0	0	5	scattered
		Chromium	NE	27.20	6.6	2.3	13.5 J	73-SB05	27/35	NA	0	8	scattered
		Cobalt	NE	NE	2	4.4	7.2	73-MW29	4/35	NA	NA	4	central and southeast
		Copper	NE	704	7.1	2.4	9.2	73-MW28	15/35	NA	0	2	scattered
		Iron	NE	151.20	3,702	174	8,310 J	73-SB05	35/35	NA	35	3	scattered
		Lead	NE	270.06	23.4	1.2	38.2	73-MW07	35/35	NA	0	7	scattered
		Magnesium	NE	NE	203	14	789	73-SB05	35/35	NA	NA	10	scattered
		Manganese	NE	65.20	18.5	0.97	38.8	73-SB05	35/35	NA	0	1	scattered
		Vanadium	NE	NE	11.4	2.6	14.8	73-SB03	21/35	NA	NA	1	scattered
		Zinc	42,000	1100.40	13.8	2.9 J	197	73-MW12	30/35	0	0	16	scattered
Subsurface Soil	Volatile (µg/kg)	1,1,1-Tricloroethane	900	1,668	NA	21	21	73-DW09	1/28	0	0	NA	north, N.C. HWY 172
		2-Butanone	NE	692	NA	2 J	9 J	73-SB07	7/27	NA	0	NA	scattered
		4-Methyl-2-Pentanone	NE	220,000 (4)	NA	11	11	73-SB07	1/28	NA	0	NA	adjacent to SA-42
		Acetone	8,000	2,810	NA	22 J	530	73-DW10	13/28	0	0	NA	scattered
		Carbon Disulfide	14,000	4,940	NA	2 J	2 J	73-DW09	1/28	0	0	NA	north, N.C. HWY 172
		Ethylbenzene	5,000	241	NA	1 J	1 J	73-MW37	2/28	0	0	NA	north and northeast
		M-Xylene & P-Xylene	240,000	4,958	NA	1.8 J	1.8 J	73-DW03	1/2	0	0	NA	central, near 73-MW13
		O-Xylene	150,000	4,958	NA	0.89 J	3 J	73-MW14	2/3	0	0	NA	central
		Tetrachloroethene	40	7.40	NA	1 J	1 J	73-SB01	1/28	0	0	NA	west, near 73-MW02
		Tricloroethene	20	18.30	NA	6 J	6 J	73-MW23	1/28	0	0	NA	west, near 73-MW30
		Xylenes (Total)	74,000	4,958	NA	1 J	11 J	73-SB13	5/25	0	0	NA	scattered
	Semivolatile (µg/kg)	2-Methylnaphthalene	NE	NE	NA	250 J	9,400	73-SB01	2/27	NA	NA	NA	west and central
		2,4-Dinitrophenol	100	NE	NA	140 J	180 J	73-MW23	2/26	2	NA	NA	west and northeast
		Acenaphthene	200,000	8,160	NA	51 J	830 J	73-SB01	3/27	0	0	NA	scattered
		Anthracene	4,300,000	995,000	NA	2000 J	2000 J	73-MW15B	1/27	0	0	NA	southeast, near 73-DW04
		Benzo(a)antracene	700	343	NA	120 J	880 J	73-MW15B	2/27	1	1	NA	southeast
		Benzo(a)pyrene	4,000	NE	NA	140 J	140 J	73-SB06	1/27	0	NA	NA	southeast, near 73-MW15
		Benzo(b)fluoranthene	4,000	NE	NA	230 J	690 J	73-MW15B	2/27	0	NA	NA	southeast
		Bis(2-ethylhexyl)phthalate	11,000	NE	NA	62 J	360 J	73-MW14	11/27	0	NA	NA	scattered
		Chrysene	1,000	38,150	NA	120 J	930 J	73-MW15B	2/27	0	0	NA	southeast

TABLE 2-1

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Subsurface Soil (continued)	Semivolatile (µg/kg) (continued)	Di-n-butyl Phthalate	120,000	24,800	NA	110 J	430	73-MW02	10/27	0	0	NA	scattered
		Fluoranthene	980,000	276,080	NA	44 J	4000	73-MW15	3/27	0	0	NA	southeast and central
		Fluorene	160,000	44,297	NA	100 J	1200 J	73-SB01	2/27	0	0	NA	west and central
		Phenanthrene	NE	59,640	NA	140 J	1600 J	73-SB01	3/27	NA	0	NA	scattered
		Pyrene	1,400,000	286,440	NA	100 J	3100 J	73-MW15B	3/27	0	0	NA	southeast and central
	Pesticide (µg/kg)	Dieldrin	1	NE	NA	6.6 J	6.6 J	73-SB07	1/27	1	NA	NA	east, adjacent to SA-42
		4,4'-DDE	500	NE	NA	4.8 J	50	73-MW15	5/27	0	NA	NA	scattered
		4,4'-DDD	700	NE	NA	6.5 J	9100	73-MW28	9/27	1	NA	NA	south, west and southeast
		4,4'-DDT	1,000	NE	NA	17 J	17 J	73-SB07	1/27	0	NA	NA	east, adjacent to SA-42
		Alpha-Chlordane	NE	NE	NA	2.4 J	2.4 J	73-SB07	1/27	NA	NA	NA	east, adjacent to SA-42
		Endosulfan I	3,000	NE	NA	4.1 J	4.1 J	73-SB07	1/27	0	NA	NA	east, adjacent to SA-42
		Endrin Aldehyde	NE	NE	NA	3.9	3.9	73-MW15B	1/27	NA	NA	NA	south, near 73-DW04
	PCB (µg/kg)	Aroclor-1254	NE	NE	NA	35 J	56 NJ	73-SB07	2/27	NA	NA	NA	central and southeast
	TPH (mg/kg)	Diesel Range Organics	NE	NE	NA	13	1,000	73-MW28	12/35	NA	NA	NA	scattered
		HBPH, as motor oil	NE	NE	NA	27	10,000	73-MW28	4/4	NA	NA	NA	scattered
		Oil and Grease	NE	NE	NA	730	7200	73-MW28	8/31	NA	NA	NA	scattered
	Metal (1) (mg/kg)	Aluminum	NE	NE	5,856.1	141	17,200	73-MW21	29/29	NA	NA	2	scattered
		Barium	32	848	17.3	2	26.3	73-MW21	28/29	0	0	5	scattered
		Cadmium	6	2.72	0.7	1.3	1.6	73-SB07	2/29	0	0	2	south and southeast
		Chromium	NE	27.20	6.6	2.3	28.7	73-MW21	23/29	NA	1	10	scattered
		Cobalt	NE	NE	2	4.9	5.3	73-MW28	3/29	NA	NA	3	south and southeast
		Copper	NE	704	7.1	2.7	9.5	73-MW06	7/29	NA	0	1	south, central and east
		Iron	NE	151.20	3,702	200	9,620	73-MW21	29/29	NA	29	3	scattered
		Lead	NE	270.06	23.4	0.91	71.8	73-MW06	29/29	NA	0	3	scattered
		Magnesium	NE	NE	203	16.6	1090	73-MW21	29/29	NA	NA	8	scattered
		Manganese	NE	65.20	18.5	0.65	20 J	73-SB06	29/29	NA	0	1	scattered
		Vanadium	NE	NE	11.4	2.5	30.1	73-MW21	20/29	NA	NA	2	scattered
		Zinc	42,000	1100.40	13.8	1.4 J	87.7	73-MW12	24/29	0	0	9	scattered

Notes:
(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for aluminum, barium, iron, manganese cadmium, chromium, cobalt, copper, lead, magnesium, vandium and zinc.
(2) Soil Screening Level - USEPA Region III Soil Screening Levels for Protection of Groundwater, established by the Office of Solid Waste Emergency Response: R.L. Smith (October 4, 1995).
(3) Soil Target Concentrations - North Carolina Risk Analysis Framework methods for determining contaminant target concentrations in soil and groundwater, Method I, S3: G-1.
(4) No concentration was provided under S3: G-1 classification therefore the concentration for the S3: G-2 classification was used for comparison.
- Concentrations are presented µg/kg for organics (parts per billion), metal concentrations for soils are presented in mg/kg (parts per million).
NE - Not Established
NA - Not applicable

TABLE 2-2

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Uppermost Portion of the Surficial Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.3	0.7 J	A47/3-08	9/38	7	0	scattered
		Benzene	1	5	2.2 J	18 J	A47/3-08	7/38	7	3	central and east
		Chloroform	0.19	100	0.7	0.7	73-MW07	1/38	1	0	south, near 73-MW06
		Cis-1,2-Dichloroethene	70	70	1.3	74	73-MW13	9/38	2	2	central, east and south
		Ethylbenzene	29	700	3.1	3.1	MW-13	1/38	0	0	north, near DW-02
		Toluene	1000	1000	3.1 J	3.1 J	A47/3-08	1/38	0	0	east, near A47/3-09
		Trans-1,2,-Dichloroethene	100	70	1.7	4.5 J	A47/3-09	4/38	0	0	central and east
		Trichloroethene	2.8	5	1.4	24	73-MW27	13/38	6	4	scattered
		Vinyl Chloride	0.015	2	1.8 J	23 J	A47/3-08	3/38	3	2	central, east and south
		Xylenes (total)	530	10,000	1.2	5.5	MW-13	4/37	0	0	central and north
	Volatiles via CLP Method (µg/l) (Phase II)	Vinyl Chloride	0.015	2	22	43 J	A47/3-08	2/20	2	2	east
		Acetone	700	NE	2 J	2 J	73-MW27	1/20	0	NA	central, near Building A-47
		1,2-Dichloroethene (total)	NE	70	2 J	44	A47/3-08	5/20	NA	0	central, east and west
		Trichloroethene	2.8	5	1 J	46	73-MW27	3/20	2	1	central and northwest
		Benzene	1	5	3 J	27	A47/3-08	3/20	3	1	central and southeast
		Toluene	1000	1000	2 J	2 J	A47/3-08	1/20	0	0	east, near SA-42
	Semivolatile (µg/l) (Phase I)	Phenol	300	NE	2 J	2 J	A47/3-22	1/42	0	NA	east, near SA-42
		Bis(2-Ethylhexyl)phthalate	3	6	1 J	50	73GW-03	3/43	1	1	scattered
		Acenaphthene	800	NE	2 J	4 J	73-MW15	2/43	0	NA	south and southeast
		Di-n-butyl Phathalate	700	NE	1 J	6 J	73-MW25	10/43	0	NA	scattered
		Fluorene	280	NE	1 J	1 J	73-MW15	1/43	0	NA	southeast, near 73-DW04
		Naphthalene	21	NE	6 J	6 J	73-MW29	1/43	0	NA	central, within parking area
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l)	Aluminum	NE	NE	49.9	29,700 J	73-MW09	37/44	NA	NA	scattered
		Antimony	6	NE	55.8	55.8	73-MW30	1/44	1	NA	west, near 73-MW02
		Barium	2,000	2,000	10.2	116	A47/3-22	44/44	0	0	scattered
		Chromium	50	100	10.6	39.7	73-MW09	3/44	0	0	central
		Cobalt	NE	NE	26.1	53.4	A47/3-22	9/44	NA	NA	scattered
		Copper	1,000	1,300	13.8	14.3	73-MW09	2/44	0	0	south and central
		Iron	300	NE	171	38,800	A47/3-22	44/44	43	NA	scattered
		Lead	15	15	3.6	14.9	73-MW09	3/44	0	0	scattered
		Magnesium	NE	NE	629	25,900	73-MW15	44/44	NA	NA	scattered
		Manganese	50	NE	4.8	310	A47/3-13	43/44	14	NA	scattered
		Thallium	2	NE	10.8	10.8	A47/3-22	1/44	1	NA	east, near SA-42

TABLE 2-2

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Upper Surficial (continued)	Metals (mg/l) (continued)	Vanadium	NE	NE	10.7	10.7	73-MW09	2/44	NA	NA	east and south
		Zinc	2,100	NE	8.6	186	73-MW29	38/44	0	NA	scattered
Lower Surficial Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.4	0.4	73-MW15B	1/5	1	0	southeast, near 73-DW04
		Chloroform	0.19	100	0.6	0.7	73-MW11B	2/5	2	0	central and south
		Cis-1,2-Dichloroethene	70	70	11	11	73-MW11B	1/5	0	0	central, near 73-MW16
		Ethylbenzene	29	700	1.3 J	1.3 J	73-MW15B	1/5	0	0	southeast, near 73-DW04
		Trichloroethene	2.8	5	1.4	31	73-MW11B	3/5	2	2	scattered
		Xylenes (total)	530	10,000	1.4	31	73-MW15B	1/5	0	0	southeast, near 73-DW04
	Volatiles via CLP (µg/l) (Phase II)	1,2-Dichloroethene (total)	70	NE	3 J	35	73-MW02B	2/4	0	0	west and central
		Trichloroethene	2.8	5	9 J	9 J	73-MW01B	2/4	2	2	central and north
	Semivolatile (µg/l) (Phase I)	1,2,4-Trichlorobenzene	NE	70	1 J	1 J	73-MW01B	1/6	NA	0	north
		Naphthalene	21	NE	2 J	3 J	73-MW15B	2/6	0	NA	north and southeast
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l) (Phase I)	Aluminum	NE	NE	67.6 J	192	73-MW02B	3/6	NA	NA	
		Barium	2,000	2,000	6.3	23.8	73-MW02B	6/6	0	0	scattered
		Cobalt	NE	NE	26.8	26.8	DW-02	1/6	NA	NA	north, near 73-MW18
		Iron	300	NE	766	2010	73-MW02B	6/6	6	NA	scattered
		Magnesium	NE	NE	687	2230	73-MW11B	5/6	NA	NA	scattered
		Manganese	50	NE	13.8	356	73-MW02B	6/6	3	NA	scattered
		Zinc	2,100	NE	11.6	46.8	73-MW15B	5/6	0	NA	scattered
Uppermost Portion of the Castle Hayne Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.6	0.7	73-DW03	2/5	2	0	
		Benzene	1	5	2.4	2.4	73-DW03	1/5	1	0	central, near 73-MW13
		Chloroform	0.19	100	1 J	5.5 J	73-DW04	3/5	3	0	
		Cis-1,2-Dichloroethene	70	70	67	67	73-DW03	1/5	0	0	central, near 73-MW13
		Trans-1,2,-Dichloroethene	100	70	1.8	1.8	73-DW03	1/5	0	0	central, near 73-MW13
		Trichloroethene	2.8	5	3.2	110	73-DW03	5/5	5	3	scattered
	Volatiles via CLP Method (µg/l) (Phase II)	Vinyl Chloride	0.015	2	4 J	4 J	73-DW03	1/14	1	1	central, near 73-MW13
		Chloroethane	NE	NE	3 J	3 J	73-DW03	1/14	NA	NA	central, near 73-MW13
		1,2-Dichloroethene (total)	NE	70	120	120	73-DW03	1/14	NA	1	central, near 73-MW13
		Chloroform	0.19	100	1 J	2 J	73-DW11	4/14	4	0	
		Trichloroethene	2.8	5	320	320	73-DW03	1/14	1	1	central, near 73-MW13
	Semivolatile (µg/l) (Phase I)	1,2,4-Trichlorobenzene	NE	70	2 J	5 J	73-DW02	2/5	NA	0	south and north
		Di-n-Butyl Phthalate	700	NE	2 J	2 J	73-DW02	1/5	0	NA	south
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--

TABLE 2-2

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Uppermost Portion of the Castle Hayne Aquifer (continued)	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l) (Phase I)	Aluminum	NE	NE	52.1	2240	73-DW01	4/5	NA	NA	scattered
		Antimony	6	NE	457	457	73-DW01	1/5	1	NA	north, near 73-MW01
		Barium	2,000	2,000	11.2	2050	73-DW01	5/5	1	1	scattered
		Beryllium	NE	4	52.3	52.3	73-DW01	1/5	NA	1	north, near 73-MW01
		Cadmium	5	5	50.7	50.7	73-DW01	1/5	1	1	north, near 73-MW01
		Chromium	50	100	210	210	73-DW01	1/5	1	1	north, near 73-MW01
		Cobalt	NE	NE	530	530	73-DW01	1/5	NA	NA	north, near 73-MW01
		Copper	1,000	1,300	269	269	73-DW01	1/5	0	0	north, near 73-MW01
		Iron	300	NE	74.4	2070	73-DW01	4/5	3	NA	scattered
		Magnesium	NE	NE	64.3	4190	73-DW01	5/5	NA	NA	scattered
		Manganese	50	NE	2.2	534	73-DW01	4/5	2	NA	scattered
		Nickel	100	100	520	520	73-DW01	1/5	1	1	north, near 73-MW01
		Silver	18	NE	54.2	54.2	73-DW01	1/5	1	NA	north, near 73-MW01
		Vanadium	NE	NE	518	518	73-DW01	1/5	NA	NA	north, near 73-MW01
		Zinc	2,100	NE	11.4 J	541	73-DW01	5/5	0	NA	scattered
Mid/Lower Portions of Castle Hayne Aquifer	Volatiles via CLP (µg/l) (Phase II)	Acetone	700	NE	2 J	2 J	73-GW05	1/6	0	NA	across Courthouse Bay
		Chloroform	0.19	100	2 J	2 J	73-GW01	1/6	1	0	central, near 73-DW11
	Semivolatile (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	Pesticide (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	Metals (mg/l)	Not Requested	--	--	--	--	--	--	--	--	--

Notes:
- Organic concentrations are presented µg/l for liquids (parts per billion), metal concentrations for liquids are presented in mg/l (parts per million).
- Positively detected compounds were compared to North Carolina Water Quality Standards (NCWQS) and the Federal Maximum Contaminant Levels (MCLs) established by the

NE - Not Established

NA - Not applicable

TABLE 2-3

SUMMARY OF SURFACE WATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS (2)	Average Reference Station Conc.					NCWQS	Average Reference Station Conc.	
Surface Water	Volatiles via CLP Method (µg/l)	Acetone	NE	ND	2 J	5 J	73-SW01	3/11	NA	3	scattered
		Chloroform	NE	ND	50	50	73-SW01	1/11	NA	1	east trib.
		Toluene	NE	ND	3 J	3 J	73-SW06	1/11	NA	1	Courthouse Bay
	Metal (1) (mg/l)	Aluminum	NE	ND	74.6	500	73-SW11	4/11	NA	4	scattered
		Antimony	NE	ND	116	216	73-SW06	10/11	NA	10	scattered
		Barium	NE	24.3	6.7	10.5	73-SW01	10/11	NA	0	scattered
		Iron	NE	317.8	245	4,540	73-SW01	11/11	NA	9	scattered
		Magnesium	NE	511,200	1550	1,390,000	73-SW06	11/11	NA	10	scattered
		Manganese	NE	ND	5.8	37.7	73-SW02	11/11	NA	11	scattered
		Silver	0.1	19.1	6.4	6.4	73-SW06	1/11	1	0	Courthouse Bay
		Zinc	86	ND	12	103	73-SW04	10/11	1	10	scattered

Notes: - Organic concentrations are presented in µg/l (parts per billion), metal concentrations are presented in mg/l (parts per million).

(1) Metals were compared to North Carolina Water Quality Standards and Average Reference Station Concentrations for aluminum, antimony, barium, iron, mangesium manganese, silver and zinc.

(2) NC DEHNR, 1994 (North Carolina Water Quality Standards)

NE - Not Established

ND - Not Detected

NA - Not applicable

TABLE 2-4

SUMMARY OF SEDIMENT CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Depth (inches)	Detection Frequency	Detections Above		Distribution of Positive Detections
			ER-L (2)	ER-M (3)						ER-L (1)	ER-M (2)	
Sediment	Volatile (µg/kg)	Methylene Chloride	NE	NE	7 J	7 J	73-SD11	6-12	1/22	NA	NA	west trib.
		Acetone	NE	NE	5 J	280	73-SD09	0-6	7/22	NA	NA	scattered
		Carbon Disulfide	NE	NE	2 J	75	73-SD09	6-12	13/22	NA	NA	scattered
		2-Butanone	NE	NE	4 J	13 J	73-SD01	6-12	2/22	NA	NA	east trib. & Courthouse Bay
		Toluene	NE	NE	1 J	12 J	73-SD11	6-12	2/22	NA	NA	west trib. & Courthouse Bay
		Xylenes (total)	NE	NE	9 J	9 J	73-SD11	6-12	1/22	NA	NA	west trib.
	Semivolatile (µg/kg)	Bis(2-ethylhexyl)phthalate	1,300	NE	51 J	1900 J	73-SD06	6-12	8/22	1	NA	scattered
		Di-n-butyl Phthalate	1,400	NE	240 J	680 J	73-SD11	0-6	11/22	0	NA	scattered
		Fluoranthene	600	5100	1000 J	1000 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
		Phenanthrene	240	1500	940 J	940 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
		Phenol	NE	420	150 J	150 J	73-SD07	6-12	1/22	NA	0	Courthouse Bay
		Pyrene	665	2600	880 J	880 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
	Pesticide (µg/kg)	4,4'-DDD	2	20	4.2 J	28	73-SD01	0-6	6/22	6	1	east trib. & Courthouse Bay
		4,4'-DDE	2	27	5.6 J	17 J	73-SD06	6-12	5/22	5	0	east trib. & Courthouse Bay
		Endrin	0.02	45	4.7	7.5 J	73-SD06	0-6	2/22	2	0	east trib. & Courthouse Bay
	PCB (µg/kg)	Aroclor-1260	22.7	180	120 J	120 J	73-SD06	6-12	1/22	1	0	Courthouse Bay
	Metal (1) (mg/kg)	Aluminum	NE	NE	431	28,100	73-SD09	6-12	21/22	NA	NA	scattered
		Arsenic	8.2	70	3.3	14.1	73-SD09	0-6	9/22	2	0	scattered
		Barium	500	NE	1.3	27.8	73-SD09	6-12	21/22	0	NA	scattered
		Cadmium	1.2	9.6	2.7 J	6.1 J	73-SD06	6-12	2/22	2	0	Courthouse Bay
		Chromium	81	370	3.3	55.9	73-SD09	6-12	17/22	0	0	scattered
		Cobalt	NE	NE	7.68	11.5	73-SD08	0-6	3/22	NA	NA	Courthouse Bay
		Copper	34	270	3.2	20.5	73-SD09	0-6	14/22	0	0	scattered
		Iron	27,000	NE	3.7	27,400	73-SD09	0-6	22/22	1	NA	scattered
		Lead	46.7	218	3.3	47.7 J	73-SD06	6-12	22/22	1	0	scattered
		Magnesium	NE	NE	140	9430	73-SD09	0-6	21/22	NA	NA	scattered
		Manganese	230	NE	3.4	137	73-SD09	0-6	21/22	0	NA	scattered
		Nickel	20.9	51.6	6	19.7	73-SD09	6-12	5/22	0	0	scattered
		Vanadium	NE	NE	2.6	50.8	73-SD09	6-12	16/22	NA	NA	scattered
		Zinc	150	410	8	100	73-SD09	6-12	21/22	0	0	scattered

Notes: - Organic concentrations are presented in µg/kg (parts per billion), metal concentrations for sediments are presented in mg/kg (parts per million).

(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for aluminum, cobalt, barium, arsenic, cadmium, chromium, copper, lead, iron, manganese, magnesium, nickel, vanadium, zinc.

(2) NOAA ER-L - USEPA Region IV Sediment Effects-Range Low Screening Values, established by the National Oceanic and Atmospheric Administration.

(3) NOAA ER-M - USEPA Region IV Sediment Effects-Range Medium Screening Values, established by the National Oceanic and Atmospheric Administration.

NE - Not established

NA - Not applicable

ND - Not detected

TABLE 2-5

TOTAL SITE RISK
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptors	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water/Sediment		Fish/Crab Tissue		Total (Phase I Groundwater)		Total (Phase II Groundwater)	
	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Current Military Personnel	1.3E-07	0.01	NA	NA	NA	NA	NA	NA	2.7E-07	0.5	NA	NA	4.0E-07	0.5	4.0E-07	0.5
Current Adolescent Trespasser	9.3E-08	<0.01	NA	NA	NA	NA	NA	NA	5.3E-07	0.4	NA	NA	6.2E-07	0.4	6.2E-07	0.4
Current Adult Trespasser	2.0E-07	<0.01	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	NA	NA	1.3E-06	0.3	1.3E-06	0.3
Current Adult Fisherman	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	4.3E-06	0.1	5.5E-06	0.35	5.5E-06	0.35
Biota Ingestion-Child Receptor	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.0E-06	0.4	4.0E-06	0.4	4.0e-06	0.4
Future Child Resident (RME)	1.6E-06	0.2	NA	NA	1.6E-05	2.0	7.1E-05	2.1	1.6E-06	1.1	NA	NA	1.9E-05	3.3	7.4E-05	3.4
Future Adult Resident (RME)	1.6E-06	0.02	NA	NA	3.7E-05	0.87	1.6E-04	1.0	1.1E-06	0.3	NA	NA	4.0E-05	1.1	1.6E-04	1.3
Future Construction Worker	3.4E-08	0.02	6.7E-08	0.02	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-07	0.04	1.0E-07	0.04

Notes:

Shading Indicates an ICR value that exceeds the acceptable limit of 1E-04, or an HI value that exceeds the acceptable limit of 1.0.
ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
Total = Soil + Groundwater + Surface Water/Sediment + Fish/Crab Tissue
NA = Not Applicable

SECTION 2.0 FIGURES

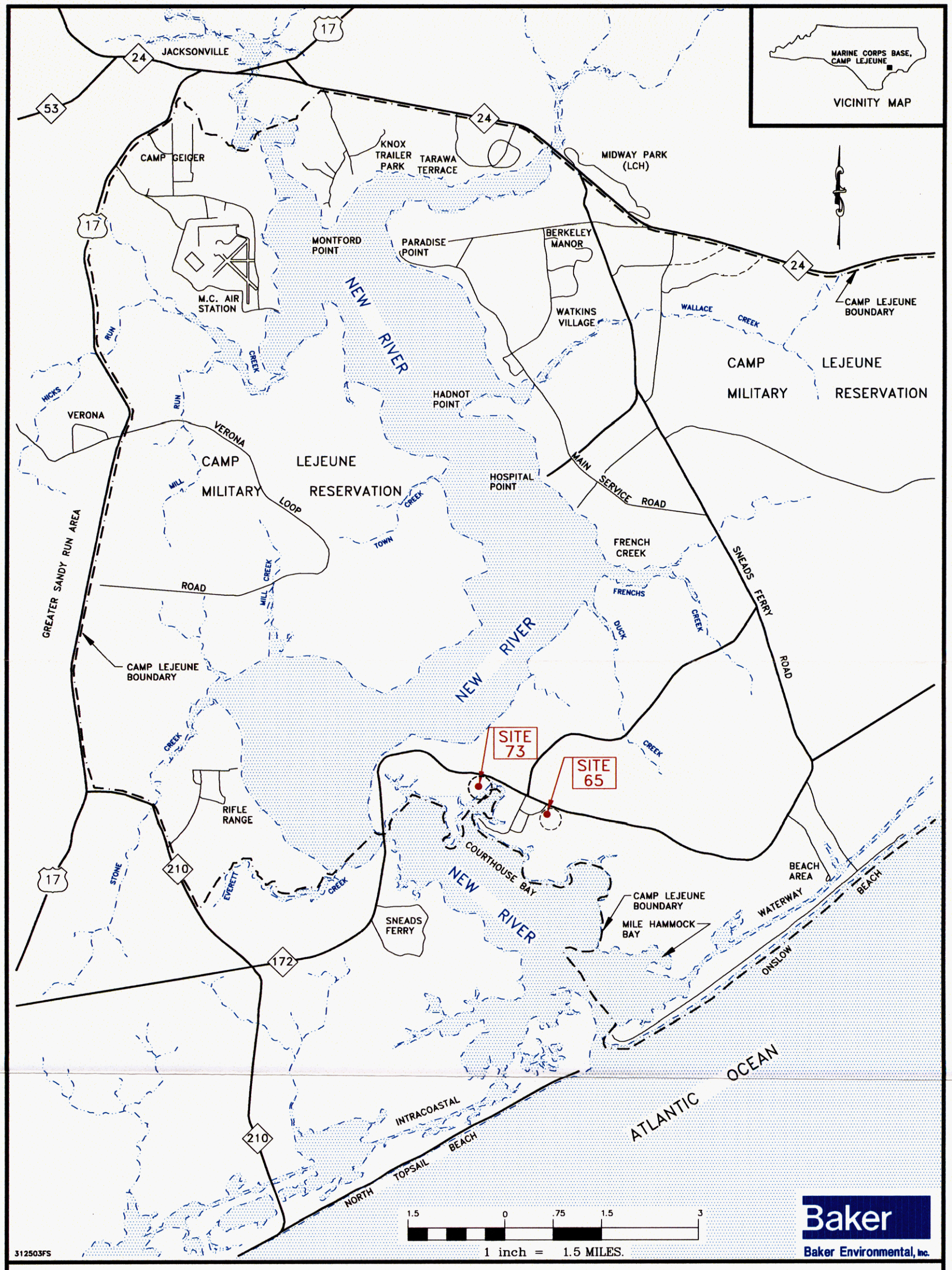


FIGURE 2-1
LOCATION MAP
SITE 65 – ENGINEER AREA DUMP AND
SITE 73 – AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GG01Y

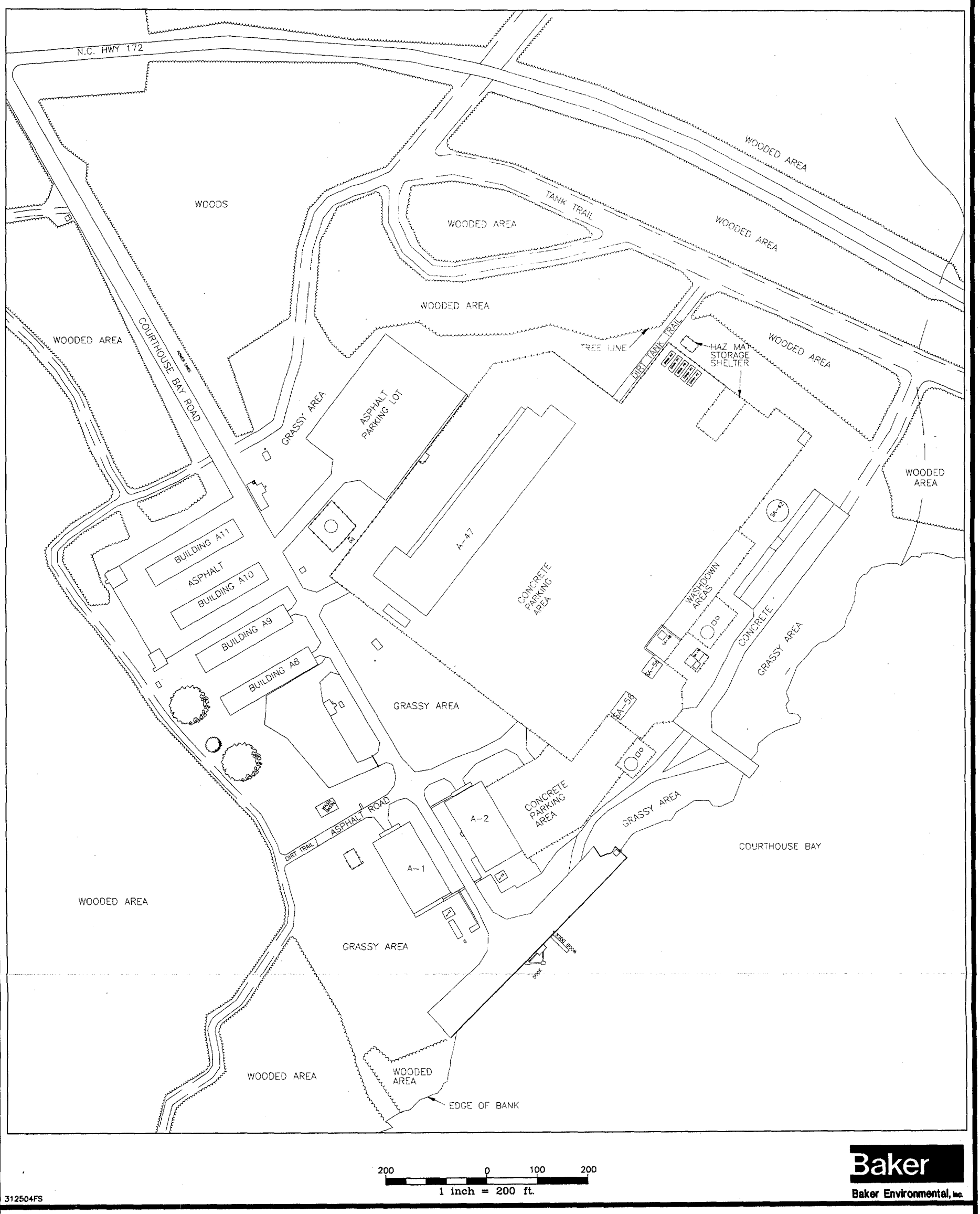
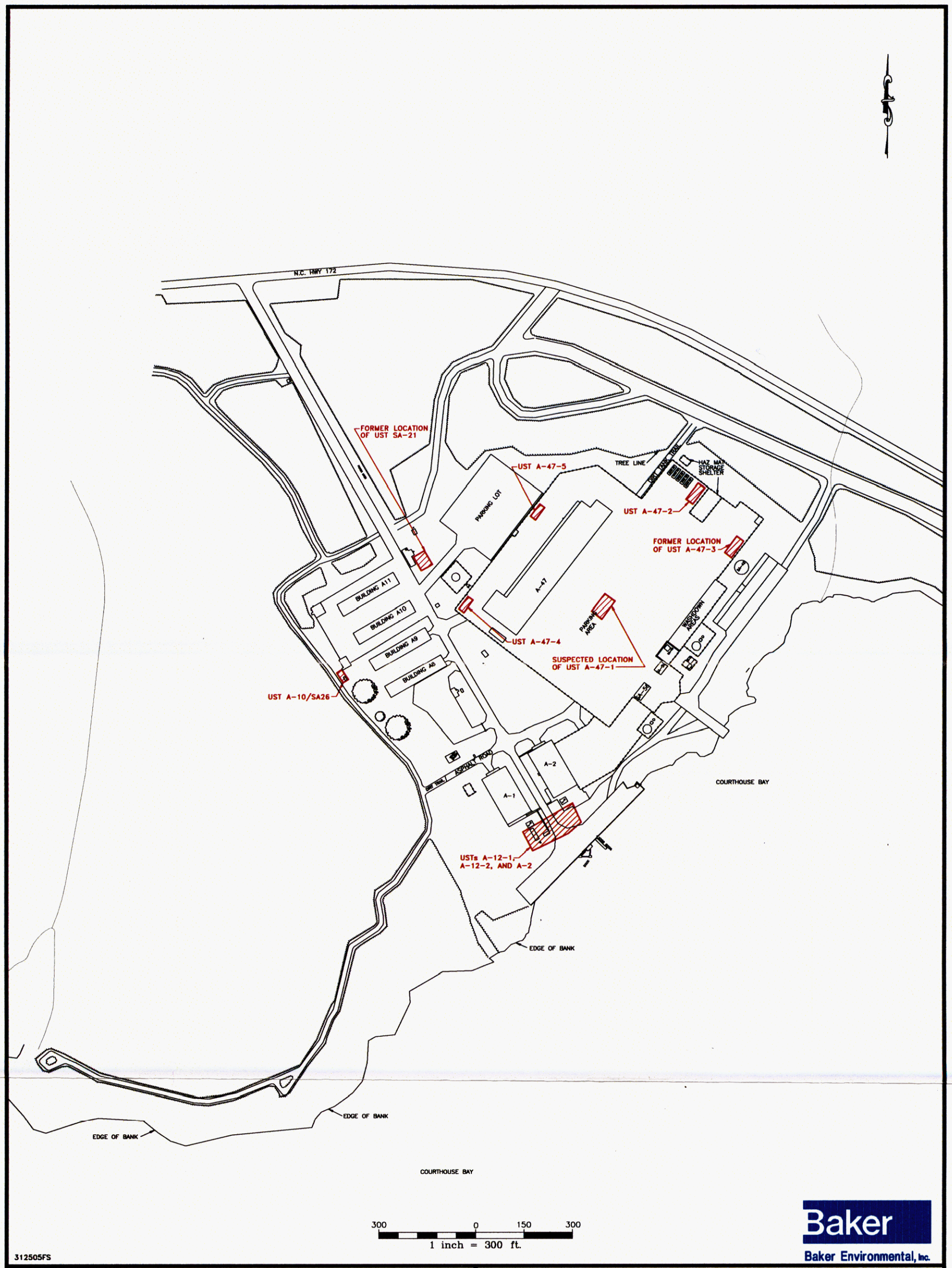


FIGURE 2-2
SITE MAP
SITE 73 – AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GG02Z



APPROXIMATE LOCATION OF UST

FIGURE 2-3
UST LOCATION MAP
SITE 73 -
AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GGB1Y

312506FS

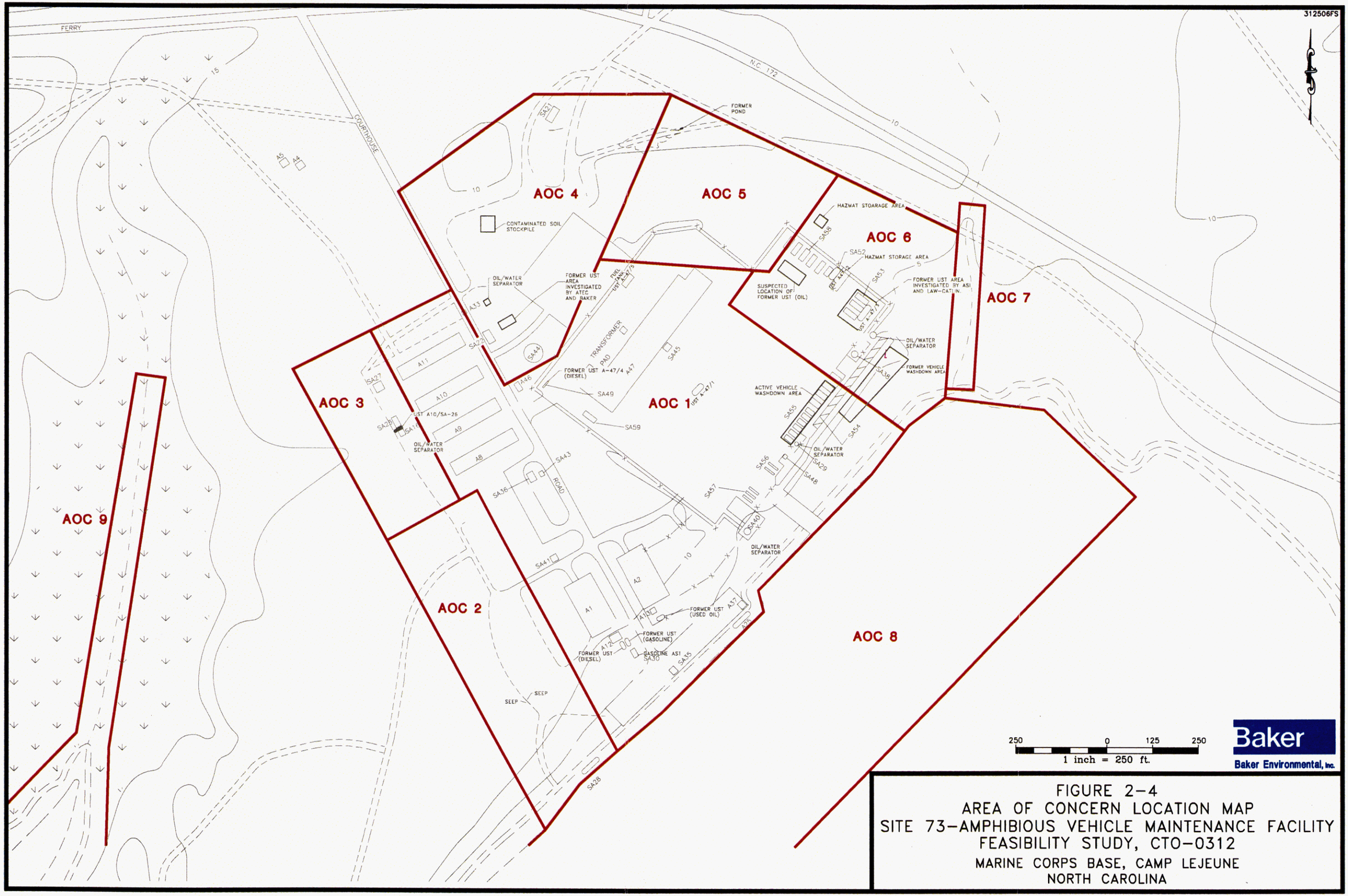
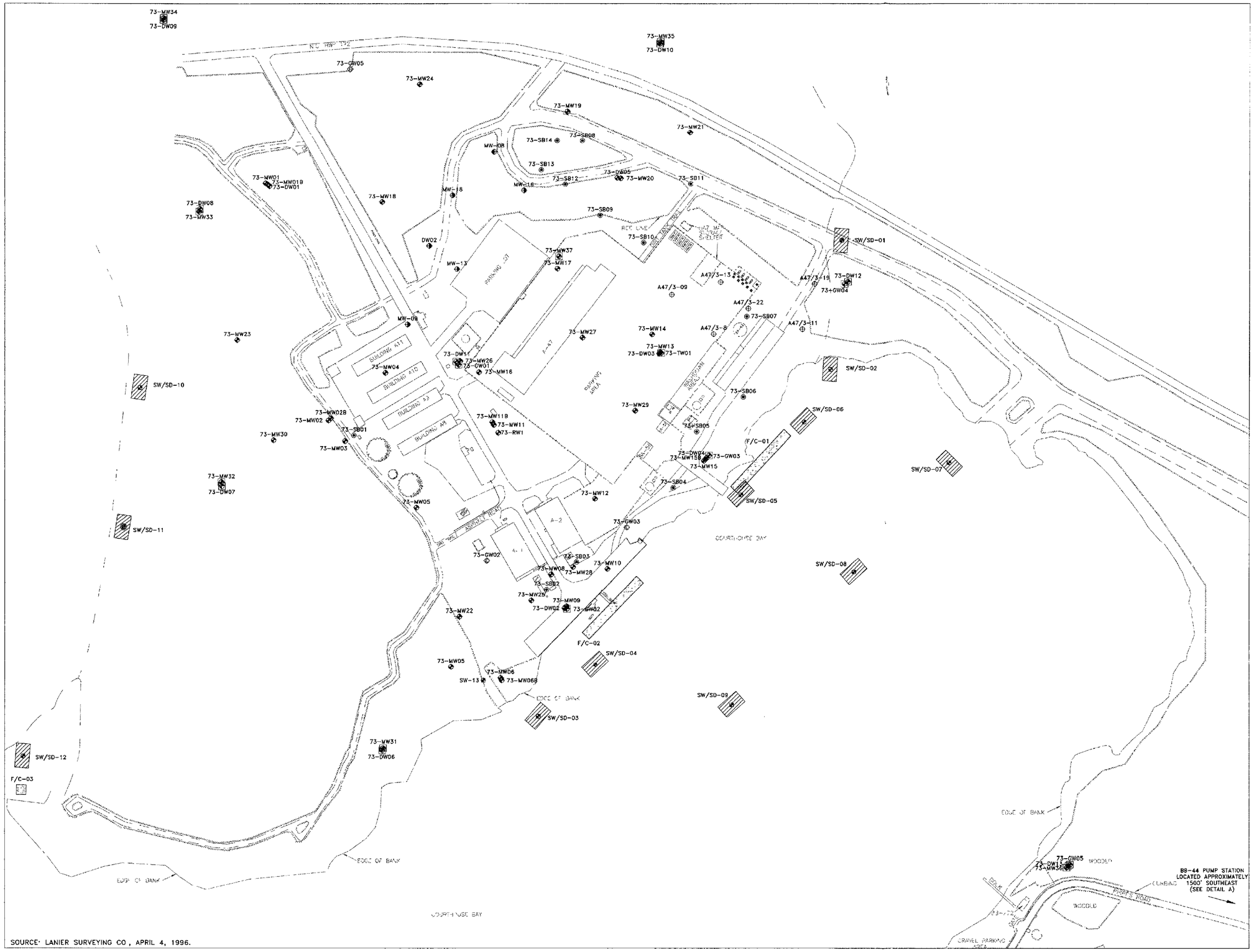


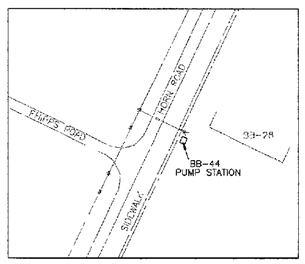
FIGURE 2-4
AREA OF CONCERN LOCATION MAP
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
SW/SD-01	SURFACE WATER/SEDIMENT LOCATION SAMPLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
F/C-01	FISH/CRAB LOCATION SAMPLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)



DETAIL A

REVISIONS			
	DRAWN WJH REVIEWED JSC S O # 62470-312-0000-07000 CADD# 312507FS	NORTH	

SITE 73 – AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc

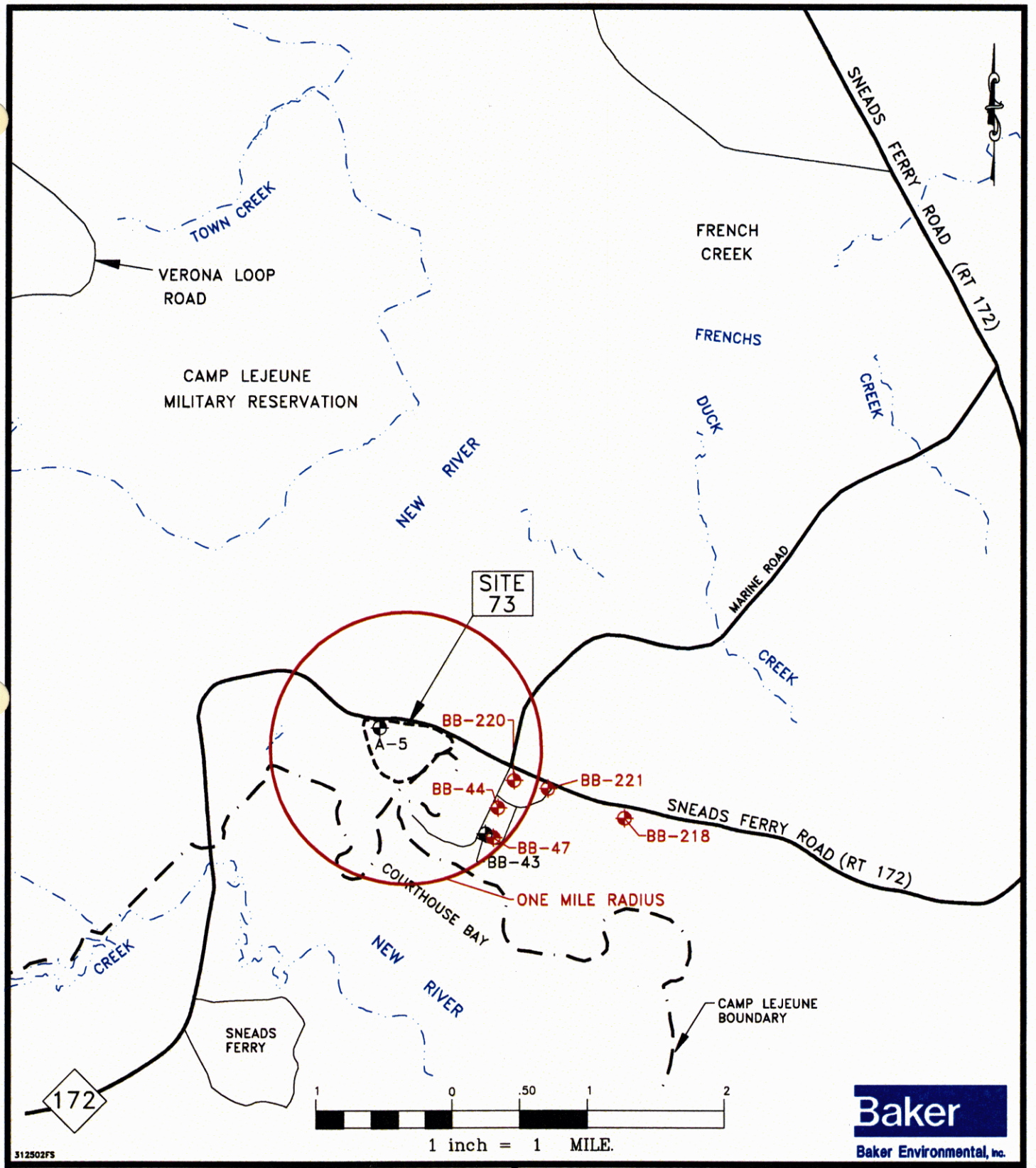
SAMPLE LOCATION MAP
(RI PHASE I AND PHASE II)

SCALE 1" = 150'

DATE JANUARY 1997

FIGURE NO.
2-5

02590GG03X



LEGEND

- SITE
- BB-221 – ACTIVE SUPPLY WELL
- BB-43 – DEACTIVATED SUPPLY WELL (1991)

SOURCE: GEOPHEX, 1983.

FIGURE 2-6
SUPPLY WELL LOCATION MAP
SITE 73 – AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GG04Y

3.0 DEVELOPMENT OF REMEDIATION GOAL OPTIONS, REMEDIATION LEVELS, AND REMEDIAL ACTION OBJECTIVES

This section presents remediation goal options (RGOs), remediation levels (RLs), and remedial action objectives (RAOs) for the contaminated groundwater at Site 73. Section 3.1 describes the media and contaminants of concern based on findings presented in the RI Report (Baker, 1996b). Section 3.2 presents the exposure routes and receptors evaluated in the human health risk assessment conducted for Site 73. In Section 3.3, RGOs and final RLs are developed. Section 3.3 also includes a final set of contaminants of concern (COCs) for the FS. Based on the RLs, remedial action objectives and areas of concern are identified in Section 3.4.

3.1 Media of Concern/Contaminants of Concern

The results of the human health RA presented in the RI Report indicate that the total carcinogenic and noncarcinogenic risk exceed the USEPA acceptable risk range. The media of concern at Site 73 is groundwater. Exposure to groundwater generated unacceptable carcinogenic and noncarcinogenic human health risks. Calculated risks from exposure to surface soil, subsurface soil, surface water, sediment, fish tissue, and crab tissue were within acceptable risk levels. Consequently, these media were not considered to be of concern from a human health standpoint.

The criteria for the selection of COPCs for constituents detected during field sampling included in the Final RI were:

- Comparison to USEPA Region III Risk-Based Concentrations (RBCs).
- Historical Information.
- Comparison to field and laboratory data blanks.
- Prevalence (frequency of detection).

Site 73 groundwater data was separated into two phases for evaluation under the RA. The first round of sampling (Phase I) was to evaluate the nature and extent of groundwater contamination at Site 73. These samples were analyzed for VOCs, SVOCs, pesticides/PCBs, and inorganics. The second round of groundwater samples (Phase II) were collected to delineate the VOC contamination and were analyzed for VOCs only. For the purposes of this FS, the COPCs selected for Phase I and Phase II will be combined, and the maximum concentration of a contaminant between phases will be used for comparison purposes.

The groundwater COPCs that contributed to unacceptable risks were considered COCs for this FS and are presented in Table 3-1. In addition, those COPCs in groundwater that exceeded federal and/or state criteria were included in the evaluation.

Lead was identified as a COC in fish and crab tissue. Currently, there are no criteria available for lead in fish or crab tissue. However, in the RI Report the lead uptake biokinetic (UBK) model was used to evaluate the concentrations of lead found in fish and crab tissue. Based on the results of the lead model, it was determined that there were no unacceptable human health risks from exposure to lead in fish or crab tissue.

Detected concentrations of the COCs will be compared to the remediation levels developed in Section 3.3.4 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.

3.2 Exposure Routes and Receptors

To determine risk-based action levels in media of concern at the site, all possible exposure pathways were considered for each medium. For Site 73, the following exposure scenarios were evaluated:

- Groundwater ingestion, dermal contact, and inhalation for a future adult resident
- Groundwater ingestion and dermal contact for a future child resident

Potential exposure pathways and receptors used to determine RGOs were site-specific and consider the future land use of this site. For this FS, all groundwater exposure pathways, ingestion, dermal contact, and inhalation of volatile contaminants while showering were used in the development of RGOs for the future adult receptor. Inhalation of volatile contaminants was included in the development of RGOs due to the presence of VOCs in the groundwater. The inhalation pathway is not assessed for the future child receptor since it is unlikely that a young child would shower.

3.3 Remediation Goal Options and Remediation Levels

RGOs are established based on federal and state criteria and risk-based RGOs. Section 3.3.1 presents the definition of applicable or relevant and appropriate federal and state requirements (ARARs) and "to be considered" (TBC) requirements. Section 3.3.2 provides an evaluation of federal and state criteria applicable to the COCs at Site 73. Development of site-specific risk-based RGOs for the COCs at Site 73 are provided in Section 3.3.3. 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.

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

Under Section 121(d)(1) of 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:

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

There are three types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include requirements which set health or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants. Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act (SDWA) are examples of chemical-specific ARARs.

Location-specific ARARs set restrictions on activities based upon the characteristics of the site and/or the nearby suburbs. Examples include federal and state siting laws for hazardous waste facilities and sites on the National Register of Historic Places.

The third classification of ARARs, action-specific, refers to requirements that set controls or restrictions on particular activities related to the management of hazardous substances, pollutants, or contaminants. RCRA regulations for closure of hazardous waste storage units, RCRA incineration standards, and pretreatment standards under the Clean Water Act (CWA) for discharges to publicly owned treatment works (POTWs) are examples of action-specific ARARs.

Subsection 121(d) of CERCLA requires that the remedial action meet a level or standard which at least attains federal and state substantive requirements that qualify as ARARs. Federal, state, or local permits are not necessary for removal or remedial actions to be implemented on-site, but their substantive requirements or ARARs must be met. "On-site" is interpreted by the USEPA to include the areal extent of contamination and all suitable areas in reasonable proximity to the contamination necessary for implementation of the response action.

ARARs can be identified only on a site-specific basis. They depend on the detected contaminants at a site, site-specific characteristics, and particular remedial actions proposed for the site. Potential ARARs identified for Site 73 are presented in Section 3.3.2.

The preamble to the proposed rule in 40 CFR Part 300.400(g)(3) states that "advisories, criteria, or guidance to-be-considered that do not meet the definition of ARAR may be necessary to determine what is protective or may be useful in developing Superfund remedies. The ARARs preamble described three types of TBCs: health effects information with a high degree of credibility, technical information on how to perform or evaluate site investigations or remedial actions, and policy" (USEPA, 1990).

3.3.2 Potential ARARs and TBCs Identified for Site 73

A set of chemical-specific, location-specific, and action-specific ARARs were identified and evaluated for Site 73 and are discussed below.

3.3.2.1 Chemical-Specific ARARs and TBCs

Potential chemical-specific ARARs and TBCs that are potentially applicable to Site 73 are listed in Table 3-2. The federal MCLs and NC WQSs (groundwater) applicable to the COCs at Site 73 are listed in Table 3-3. A brief description of federal MCLs and NC WQSs (groundwater) are presented below.

Federal Maximum Contaminant Levels - MCLs are enforceable standards for public water supplies promulgated under the SDWA and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. These standards are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply. As shown in Table 3-3, MCLs have been established for most of the groundwater COPCs.

North Carolina Water Quality Standards (Groundwater) - Under the North Carolina Administrative Code (NCAC), Title 15A, Subchapter 2L, Section .0200, (15A NCAC 2L.0200) the NC DEHNR has established groundwater standards (NCWQSs) for three classifications of groundwater within the state: GA, GSA, and GC. Class GA waters are those groundwaters in the state naturally containing 250 milligram per liter (mg/L) or less of chloride. These waters are an existing or potential source of drinking water supply for humans. Class GSA waters are those groundwaters in the state naturally containing greater than 250 mg/L of chloride. These waters are an existing or potential source of water supply for potable mineral water and conversion to fresh water. Class GC water is defined as a source of water supply for purposes other than drinking. The NCAC T15A:02L.0300 has established sixteen river basins within the state as Class GC ground waters (15A NCAC 2L.0201 and 2L.0300).

The water quality standards for groundwater are the maximum allowable concentrations resulting from any discharge of contaminants to the land or water of the state, which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for its intended best usage. If the water quality standard of a substance is less than the limit of detectability, the substance shall not be permitted in detectable concentrations. If naturally occurring substances exceed the established standard, the standard will be the naturally occurring concentration as determined by the state. Substances which are not naturally occurring and for which no standard is specified are not permitted in detectable concentrations for Class GA or Class GSA groundwaters (15A NCAC 2L.0202).

The NCWQS for substances in Class GA and Class GSA groundwaters are established as the lesser of:

- Systemic threshold concentration (based on reference dose and average consumption)
- Concentration which corresponds to an incremental lifetime cancer risk of $1x10^{-6}$
- Taste threshold limit value
- Odor threshold limit value
- MCL
- National Secondary Drinking Water Standard

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 Site 73 groundwater COCs are listed in Table 3-3. The NCWQS will be considered an ARAR for Site 73.

3.3.2.2 Location-Specific ARARs

Potential location-specific ARARs identified for Site 73 are listed in Table 3-3. An evaluation determining the applicability of these location-specific ARARs with respect to Site 73 is also presented and summarized in Table 3-4. Based on this evaluation, specific sections of the following location-specific ARARs may be applicable to Site 73:

- 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
- NC Hazardous Waste Management Rules
- NC Solid Waste Management Rules
- NC Coastal Management Rules

Please note that the citations listed in Table 3-4 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.

3.3.2.3 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 73. A set of potential action-specific ARARs is presented in Table 3-5. These ARARs are based on RCRA, CWA, SDWA, and Department of Transportation (DOT) requirements. Note that the citations listed in Table 3-5 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 73. Additional action-specific ARARs may also be identified and evaluated at that time.

3.3.3 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 73 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, 1989; USEPA, 1991). For noncarcinogenic effects, concentrations were calculated to correspond to an HI of 3.0, 1.0, and 0.1. 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 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 $1x10^{-6}$ and $1x10^{-4}$. 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.

3.3.3.1 Risk Evaluation Assessment

Medium-specific risk-based RGOs were determined in accordance with USEPA guidance (USEPA, 1989). Reference doses (RfDs) were used to evaluate noncarcinogenic RGOs, while carcinogenic slope factors (CSFs) were used to evaluate carcinogenic RGOs. These toxicity values were dermally-adjusted when evaluating the dermal contact exposure scenario.

Consistent with USEPA guidance, noncarcinogenic health effects were estimated using an average annual exposure. The action level 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, 1989; 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:

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

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 (days)
ATnc	=	averaging time noncarcinogens (days)
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, 1989). Table 3-6 summarizes the input parameters used to estimate the groundwater ingestion RGOs.

Dermal Contact with Groundwater

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

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

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 (days)
ATnc	=	averaging time noncarcinogens (days)
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 ($0.001 L/cm^3$)

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, 1989). Table 3-6 summarizes the input parameters used to estimate the groundwater exposure RGOs.

Inhalation of Volatile Contaminants as Vapor

Groundwater inhalation RGOs can be characterized using the following equation:

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

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (days)
ATnc	=	averaging time noncarcinogens (days)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
IR	=	inhalation rate (m^3/hour)
k	=	volatilization factor (0.5 L/m^3)
ET	=	exposure time (0.25 hours)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)

Under the residential use scenario, the following input parameters were used to estimate RGOs: adult inhalation rate was assumed to be 0.6 m^3/hour, and exposure frequency was assumed to be 350 days per year over a 30 year exposure duration (USEPA, 1989). The volatilization factor for VOCs is 0.5 L/m^3. Table 3-6 summarizes the input parameters used to estimate the groundwater ingestion RGOs.

3.3.3.2 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 for future residential children. Ingestion, dermal contact, and inhalation of volatile contaminants while showering were assessed

for future residential adults. Tables 3-7 and 3-8 present the risk-based RGOs calculated for the carcinogenic and noncarcinogenic COCs in the groundwater.

3.3.3.3 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 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 3-9 for the future scenarios.

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.

3.3.3.4 Uncertainty Analysis

Uncertainties associated with calculating risk-based RGOs are summarized below. The action level 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 action level 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 action level 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 err conservatively, thus adequately protecting human health and allowing establishment of reasonable cleanup goals.

3.3.4 Summary of RLs and Final COCs

RLs associated with the COCs at Site 73 are presented in Table 3-9. This list was based on a comparison of chemical-specific standards and the site-specific risk-based RGOs identified throughout Sections 3.3.2 and 3.3.3. If a COC had a 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 in Table 3-9.

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 Table 3-9. 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 73: 1,2-dichlorethane; 1,2-dichloroethene (total); cis-1,2-dichloroethene; benzene; vinyl chloride; trichloroethene; aluminum; barium; chromium; iron; manganese; and vanadium in groundwater. The final set of COCs and the associated RLs are presented in Table 3-10.

3.4 Remedial Action Objectives

Remedial action objectives are medium-specific goals established for protecting human health and the environment. At Site 73, the medium to be addressed by a remedial action is contaminated groundwater in the surficial and deep aquifers. Two RAOs were developed for the contaminated groundwater:

- RAO #1: Mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater.

- RAO #2: Remediate groundwater to the specified remediation levels.

These RAOs apply to the VOCs that exceeded remediation levels in both the surficial and deep aquifers. Figures 3-1 and 3-2 show the VOC areas of concern (AOCs) in the surficial and deep aquifers, respectively.

Although aluminum, barium, chromium, and vanadium in groundwater exceeded remediation levels, they are not addressed by the RAOs since each contributed no more than five percent to the total noncarcinogenic risk for exposure to groundwater.

SECTION 3.0 TABLES

TABLE 3-1

CONTAMINANTS OF CONCERN FOR THE FS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminants of Concern [1]
Groundwater	1,2-Dichloroethane 1,2-Dichloroethene (total) cis-1,2-Dichloroethene Benzene Vinyl Chloride Trichloroethene Aluminum Barium Chromium Copper Iron Manganese Vanadium

Notes:

[1] This list includes contaminants of potential concern evaluated in the RI (Baker, 1996).

TABLE 3-2

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Chemical;-Specific ARAR	General Citation	Comment
NC Drinking Water Act	130A NCAC 311-327	Regulates water systems and the aquifers that supply them. These requirements may be an applicable ARAR.
NC Water Quality Standards	15A NCAC 2B .0100-.0400	Establishes a series of classifications and water quality standards for surface waters. These requirements may be an applicable ARAR if the selected remedial actions result in the discharge of water to Courthouse Bay.
NC Water Quality Standards Applicable to Groundwater	15A NCAC 2L .0200	Establishes a series of classifications and standards for groundwater. These requirements are an applicable ARAR.
NC Air Pollution Control Regulations	15A NCAC 2D, 2H .0600, 2Q	Regulates ambient air quality and establishes air quality standards for hazardous air pollutants. These requirements may be an applicable ARAR if the selected remedial action includes the discharge of off-gas.
NC Hazardous Waste Management Rules	15A NCAC 13A, .0009 and .0012	Establishes standards for hazardous waste that is excavated and stored or treated as a part of a remedial action. These requirements may be applicable if the selected remedial action requires excavation and that material is found to be hazardous.
Safe Drinking Water Act		Establishes Federal Maximum Contaminant Levels (MCLs) for drinking water. These requirements are an applicable ARAR.

TABLE 3-3

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs FOR GROUNDWATER COCs SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY FEASIBILITY STUDY, CTO-0312 MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Federal MCL (µg/L)	NCWQS (µg/L)
1,2-Dichloroethane	5	0.38
1,2-Dichloroethene (total)	70	NE
cis-1,2-Dichloroethene	70	70
Benzene	5	1
Vinyl Chloride	2	0.015
Trichloroethene	5*	2.8
Aluminum	50/200	NE
Barium	2,000	2,000
Chromium	100	50
Copper	1,300	1,000
Iron	300*	300
Manganese	50*	50
Vanadium	NE	NE

Notes:

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

TABLE 3-4

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
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©	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. 9, 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	Courthouse Bay (New River) is located adjacent to the operable unit boundaries. If remedial actions are implemented that modify the bay, 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 3-4 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
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, Site 73 is surrounded by wetland areas. 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, the majority of Site 73 is within the 500-year flood plain. Areas immediately adjacent to Courthouse Bay are within the 100 year floodplain. Therefore, these requirements may be an ARAR for Site 73.
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 3-4 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	Comment
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.
NC Hazardous Waste management Rules	15A NCAC 13A .0009 and .0012	These requirements may be applicable if the remedial actions for the operable unit include on-site storage or treatment. Therefore, these requirements may be an applicable ARAR for the operable unit.
NC Solid Waste management Rules	15A NCAC 13B .1600	These requirements are applicable if remedial actions generate solid waste. Therefore, these requirements may be an applicable ARAR for the operable unit.

TABLE 3-4 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	Comment
NC Costal Management	15NCAC 7H	This guideline provides guidelines for areas of environmental concern such as Courthouse Bay. Therefore, these ARARs will be considered applicable.
NC Groundwater Corrective Action	15A NCAC 2L .0106	Regulations for cleanup of contaminated groundwater. Therefore, these ARARs will be considered applicable.
NC 15A NCAC 2L Implementation Guidance	Division of Water Quality Guidance Document	Explains implementation of corrective action at groundwater contamination sites. Therefore, these ARARs will be considered applicable.
NC Well Construction Standards	15A NCAC 2C .0100	Construction and abandonment requirements for wells. These requirements will be considered applicable ARARs.
NC Injection Well Construction Standards	15A NCAC 2C .0200	Construction requirements for injection wells. These requirements will be applicable ARARs.
NC Water Quality Discharge Requirements	15A NCAC 2H .0100 and .0200	Waste water requirements for discharges and infiltration galleries. These requirements may be applicable ARARs depending on the remedial action selected.
NC Sedimentation Control Rules	15A NCAC 2H .1000	Establishes requirements for storm water management. These requirements may be applicable ARARs depending on the remedial action selected.
NC Hazardous Waste Management Rules	15A NCAC 13A	Design and treatment requirements for hazardous waste TSDs. These requirements may be applicable ARARs depending on the remedial action selected.

TABLE 3-4 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	Comment
NC Solid Waste Management Rules	15A NCAC 13B	Design and monitoring requirements for solid waste disposal. These requirements may be applicable ARARs depending on the remedial action selected.
NC Air Pollution Control Requirements	15A NCAC 2D, 2H .0600 2Q	Regulates air quality and establishes emissions standards. These requirements may be applicable ARARs depending on the remedial action selected.
NC Inactive Hazardous Substance or Waste Disposal Sites	NCGS 130A-310.3 E-310.8	Land use restrictions and recordation of inactive sites. These requirements will be considered applicable ARARs

TABLE 3-5

POTENTIAL ACTION-SPECIFIC ARARs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential ARAR	Action	General Citation
Resource Conservation Recovery Act	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
Clean Water Act	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
Clean Air Act (NAAQS)[1]	Discharge to Air	40 CFR 50
Safe Drinking Water Act	Underground Injection Control	40 CFR 144, 146, 147, 268
Toxic Substance Act	PCB Regulations	40 CFR 761
DOT Rules for Transportation[2]	Transportation of Hazardous Waste	49 CFR 107

Notes:

(1) NAAQS = National Ambient Air Quality Standards
(2) DOT = Department of Transportation

TABLE 3-6

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor			
		Future Residential Child	Future Residential Adult	Current Adult Fisherman	Child Receptor
Groundwater					
Ingestion Rate, IR	L/d	1	2	NA	NA
Surface Area, SA	cm^2	10,000	23,000	NA	NA
Exposure Frequency, EF	d/y	350	350	NA	NA
Exposure Duration, ED	y	6	30	NA	NA
Exposure Time, ET	h/d	0.25	0.25	NA	NA
Averaging Time, Noncarc., ATnc	d	2,190	10,950	NA	NA
Averaging Time, Carc., ATc	d	25,550	25,550	NA	NA
Conversion Factor, CF	L/cm^3	0.001	0.001	NA	NA
Body Weight, BW	kg	15	70	NA	NA
PC, Permeability Constant	cm/hr	chemical-specific	chemical-specific	NA	NA
Respiration Rate, RR	m^3/hr	NA	0.6	NA	NA
Volatilization Factor, k	L/m^3	NA	chemical-specific	NA	NA
Cancer Slope Factor, CSF	$(mg/kg\text{-}day)^{-1}$	chemical-specific	chemical-specific	NA	NA
Reference Dose, RfD	mg/kg-day	chemical-specific	chemical-specific	NA	NA

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 3-7

GROUNDWATER CARCINOGENIC RGOs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
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
1,2-Dichloroethane	89	150	8.9	15	0.89	1.5
Benzene	260	570	26	57	2.6	5.7
Vinyl Chloride	4.3	1.1	0.43	0.11	0.043	0.011
Trichloroethene	720	1,590	72	159	7.2	15.9

TABLE 3-8

GROUNDWATER NONCARCINOGENIC RGOs
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Noncarcinogenic Risk-Based RGOs (µg/L) Future Residents					
	Target Hazard Quotient 0.1		Target Hazard Quotient 1.0		Target Hazard Quotient 3.0	
Contaminant of Concern	Adult	Child	Adult	Child	Adult	Child
1,2-Dichloroethene (total)	32	14	320	140	960	420
cis-1,2-Dichloroethene	35	16	350	160	1,050	480
Benzene	170	NA	1,700	NA	5,100	NA
Trichloroethene	21	9	210	90	630	270
Aluminum	3,600	1,564	36,000	15,640	108,000	46,920
Barium	250	110	2,500	1,100	7,500	3,300
Chromium	18	8	180	80	540	240
Cobalt	216	94	2,160	940	6,480	2,820
Copper	140	63	1,400	630	4,200	1,890
Iron	1,100	470	11,000	4,700	33,000	14,100
Manganese	83	36	830	360	2,490	1,080
Vanadium	25	11	250	110	750	330

TABLE 3-9

COMPARISON OF SITE GROUNDWATER MAXIMUM LEVEL TO CRITERIA
FUTURE RESIDENTS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Maximum Groundwater Concentration	NCWQS[1]	Federal MCL[2]	RGO[4]	
				Adult	Child
1,2-Dichloroethane	0.7	0.38	5	0.89	1.5
1,2-Dichloroethene (total)	120	NE	70	320	140
cis-1,2-Dichloroethene	74	70	70	350	160
Benzene	27	1	5	2.6 [5] 1,700 [6]	5.7 [5] NA [6]
Vinyl Chloride	43	0.015	2	0.043	0.011
Trichloroethene	320	2.8	5	7.2 [5] 210 [6]	15.9 [5] 90 [6]
Aluminum	29,700	NE	50/200[3]	36,000	15,640
Barium	2,050	2,000	2,000	2,500	1,100
Chromium	210	50	100	180	80
Cobalt	530	NE	NE	2,160	940
Copper	269	1,000	1,300	1,400	600
Iron	38,800	300	300[3]	11,000	4,700
Manganese	534	50	50[3]	830	360
Vanadium	158	NE	NE	250	110

Notes:

Shaded blocks contain the remediation level for that contaminant.
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) Secondary MCL
(4) RGO = Risk-based Remediation Goal Option
Carcinogenic Target Risk Level - $1x10^{-6}$
Noncarcinogenic Target Hazard Quotient - 1.0
(5) Carcinogenic RGO
(6) Noncarcinogenic RGO
NE = No Criteria Established

TABLE 3-10

REMEDIATION LEVELS AND FINAL COCs
GROUNDWATER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

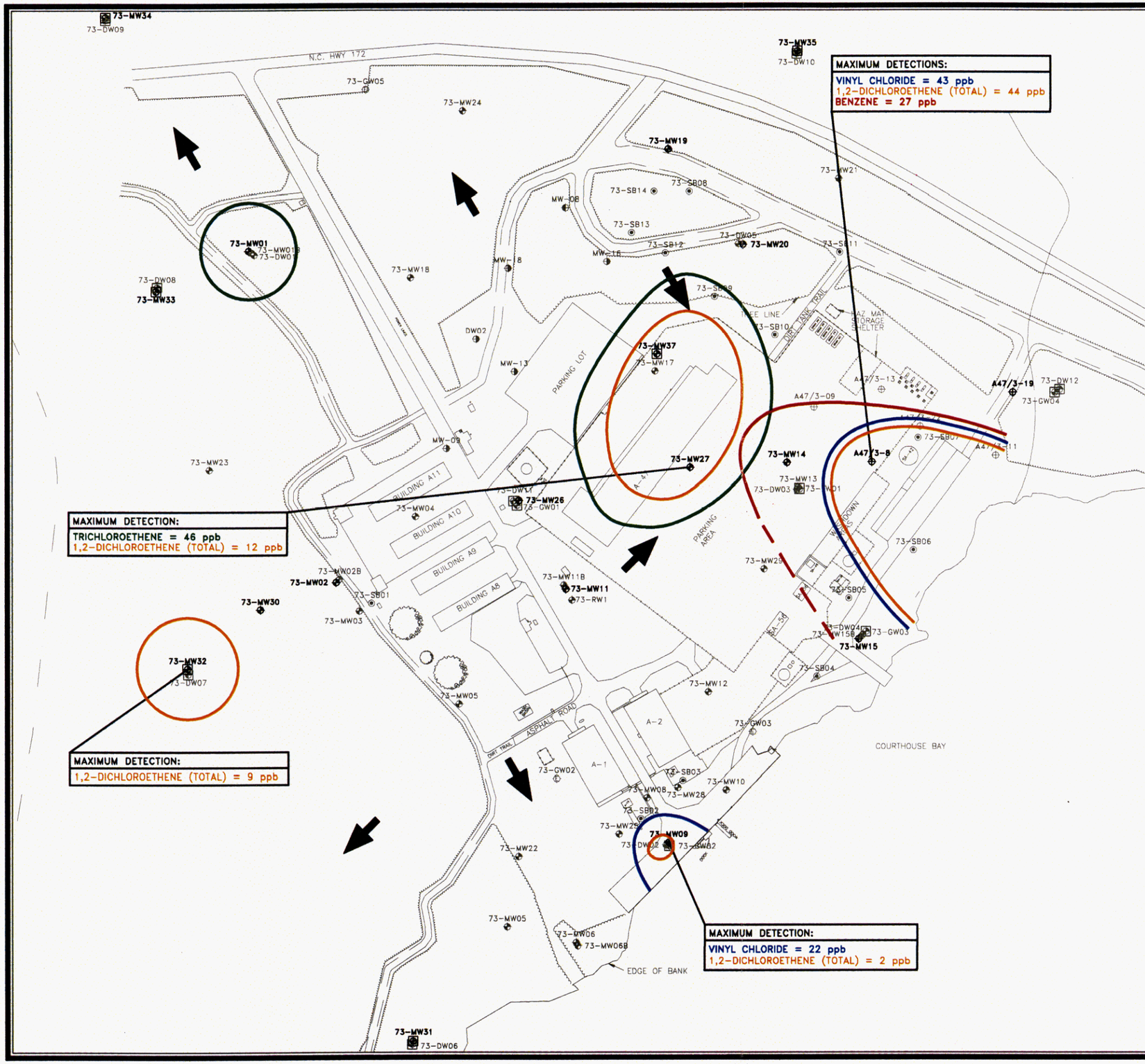
Contaminant of Concern	RL[1]	Basis of RL	Corresponding Risk
1,2-Dichloroethane	0.38	NCWQS[2]	
1,2-Dichloroethene (total)	70	MCL[3]	
cis-1,2-Dichloroethene	70	NCWQS	
Benzene	1	NCWQS	
Vinyl Chloride	0.015	NCWQS	
Trichloroethene	2.8	NCWQS	
Aluminum	50/200	NCWQS	
Barium	2,000	NCWQS	
Chromium	50	NCWQS	
Iron	300	NCWQS	
Manganese	50	NCWQS	
Vanadium	110	Risk-Ingestion and dermal contact	THI[4] = 1.0

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 Contaminant Level
(4) THI = Total Hazard Index

SECTION 3.0 FIGURES

312604FS



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
→	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb
- BENZENE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE SURFICAL AQUIFER WAS USED TO DEVELOP ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250
1 inch = 250 ft.

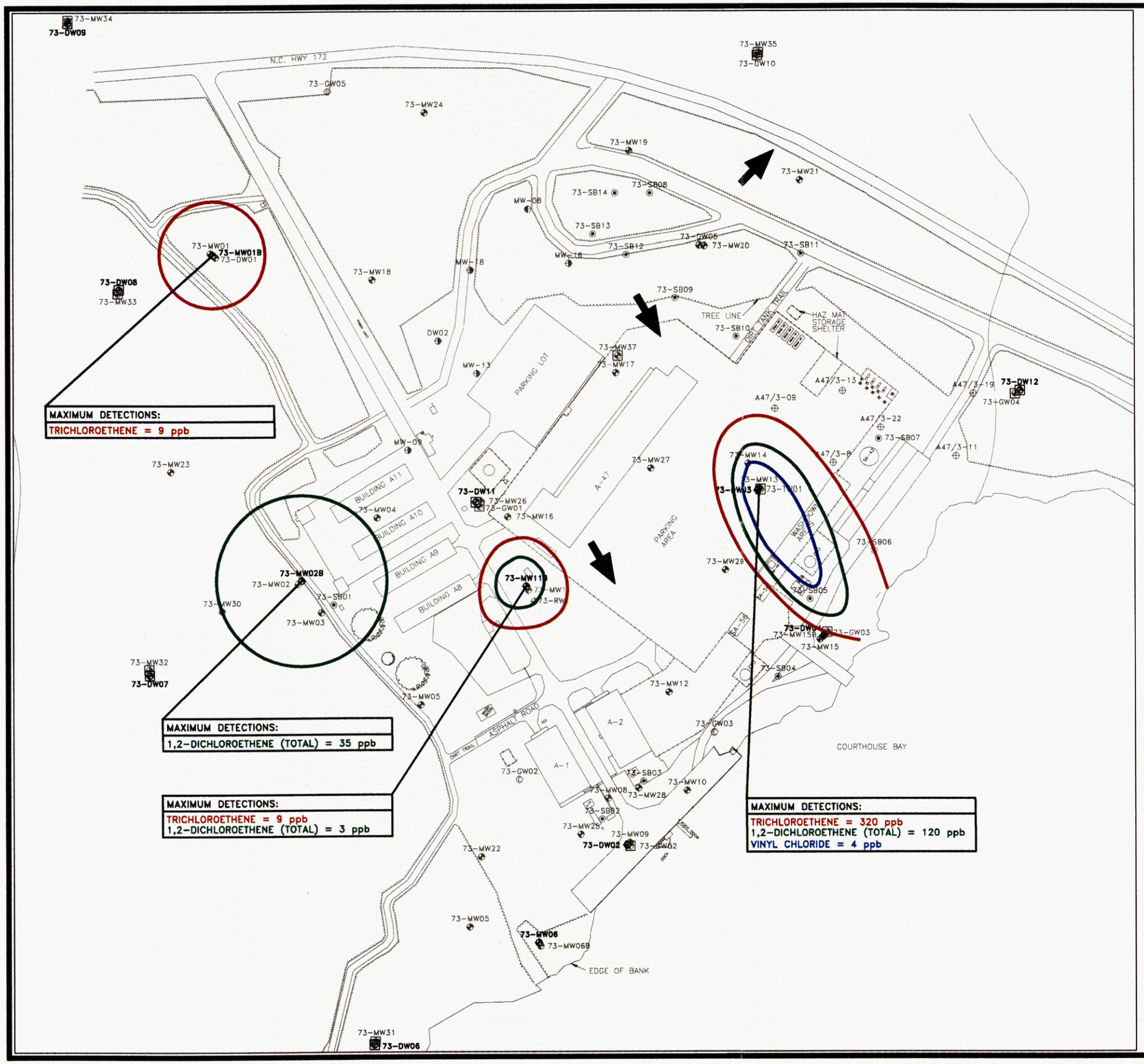
Baker
Baker Environmental, Inc.

FIGURE 3-1
AREAS OF CONCERN IN THE SURFICIAL AQUIFER
SITE 73 -
AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GGB2Y

312605FS



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
→	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- 1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE CASTLE HAYNE AQUIFER AND LOWER PORTION OF THE SURFICIAL AQUIFER. WAS USED TO DEVELOP THE ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250
1 inch = 250 ft.

Baker
Baker Environmental, Inc.

FIGURE 3-2
AREAS OF CONCERN IN THE DEEP AQUIFER
SITE 73 -
AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

4.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Section 4.0 presents the identification and preliminary screening of remedial action technologies and process options. More specifically, Section 4.1 identifies a set of general response actions that apply to both the surficial and deep aquifers at Site 73, Section 4.2 identifies remedial action technologies and process options for each general response action, and Section 4.3 presents the preliminary screening of remedial action technologies and process options. After this preliminary screening, the remaining technologies/process options undergo a process option evaluation in Section 4.4. Section 4.5 presents the final set of remedial action technologies and process options. These final technologies/process options will be combined in Section 5.0 to form remedial action alternatives for the surficial and deep aquifers.

4.1 General Response Actions

General response actions are broad-based, medium-specific categories of remedial action technologies and process options. The following response actions were identified to satisfy the remedial action objectives of this FS.

- No Action

The NCP requires the evaluation of a no action response as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that have 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 itself.

- Institutional Controls

Institutional controls are various "administrative restrictions" actions that can be implemented as part of a complete remedial action alternative to minimize exposure to potential hazards. With respect to groundwater, institutional controls may include aquifer-use restrictions, deed restrictions, and monitoring programs.

- Containment/Collection Actions

Containment/collection actions include subsurface barriers and extraction well systems that may isolate or prevent the migration of contaminated groundwater. The same subsurface barriers may also collect the contaminated groundwater for further treatment as they contain the contamination.

- Ex Situ Treatment

Ex situ treatment actions include physical/chemical, biological, and thermal treatment technologies that are implemented after the contaminated groundwater has been extracted from the subsurface. These treatment actions may be conducted at an off site facility, an on site facility, or a mobile facility.

- In Situ Treatment

In situ treatment actions include physical/chemical, biological, and passive remediation technologies that are implemented while the contaminated groundwater remains in an in situ state.

- Discharge Actions

Discharge actions are usually implemented after groundwater has been treated to acceptable remediation levels. They specify the location where the groundwater will ultimately be disposed. These actions include on site and off site discharge options.

4.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable technologies and process options will be identified for each general response action. The term "technology type" will refer to general categories of technologies such as physical/chemical treatment, biological treatment, and thermal treatment. The term "process option" will refer to specific processes, or technologies, within each generalized technology type. For example, carbon adsorption, solvent extraction, and chemical oxidation are process options that fall under the technology type known as physical/chemical treatment. Several technology types may be identified for each general response action, and numerous process options may exist within each generalized technology type.

Remedial action technology types that are potentially applicable for soil and groundwater are listed in Table 4-1. Each technology type is listed with respect to its corresponding general response action. (These technology types are listed in the column titled "Remedial Action Technology".) Also identified on the table are applicable process options associated with each of the listed technology types.

4.3 Preliminary Screening of Remedial Action Technologies and Process Options

In this step, the set of remedial action technologies and process options identified in the previous section will be screened (or reduced) by evaluating the technologies with respect to technical implementability and site-specific factors. This screening step will be accomplished by using readily available information from the RI (with respect to contaminant types, contaminant concentrations, and on-site characteristics) to screen out technologies and process options that cannot be effectively implemented at the site (USEPA, 1988). In general, all technologies and process options which appear to be applicable to the site contaminants and to the site conditions will be retained for further evaluation. This preliminary screening is presented in Table 4-2. Following the preliminary screening, each remaining process option will be evaluated in Section 4.4.

As shown in Table 4-2, several technologies and/or process options were eliminated from further evaluation because they were determined to be inappropriate for the site-specific characteristics and/or contaminant-specific characteristics. The technologies/process options that were eliminated include:

- Vertical Barriers
- Horizontal Barriers
- Capping
- Chemical Dechlorination
- Chemical Reduction
- Ion Exchange
- Electrochemical Ion Generation
- Distillation
- Oil/Water Separation
- Incineration

- Pyrolysis, Plasma Arc Torch
- Off-Site Treatment
- Discharge to a POTW
- Discharge to a Sewage Treatment Plant

The technologies/process options that passed this preliminary screening are listed in Table 4-3.

4.4 Process Option Evaluation

The objective of the process option evaluation is to select only one process option for each applicable remedial technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. More than one process option may be selected for a technology type if the processes are sufficiently different in their performance that one would not adequately represent the other. In addition, an entire response action may be eliminated if all of the process options listed under the response are eliminated. The representative process options that are retained provide a basis for developing performance specifications during preliminary design. However, the specific process options used to implement the remedial action may not be selected until the remedial design phase.

The process options listed in Table 4-3 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 will be when addressing 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 cost evaluation played a limited role in this screening. Only relative capital and operation and maintenance (O&M) costs were used instead of detailed estimates. As per the USEPA guidance, the cost analysis was made on the basis of engineering judgement.

A summary of the process option evaluation is presented in Table 4-4. It is important to note that the elimination of a process option does not mean that the process option/technology 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.

4.5 Final Set of Remedial Action Technologies and Process Options

Table 4-5 identifies the final set of feasible technologies/process options for the surficial and deep aquifers. This final set will be used to develop remedial action alternatives in Section 5.0.

SECTION 4.0 TABLES

TABLE 4-1

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Site Restrictions	Aquifer Use Restrictions
		Monitoring	Monitoring
	Containment/ Collection Actions	Vertical Barriers	Slurry Wall, Sheet Piling, Grout Curtain, Rock Grouting
		Horizontal Barriers	Grout Injection, Jet Grouting
		Capping	Clay/Soil Cap, Asphalt Cap, Synthetic Membrane, Composite Cap, Multilayered Cap, Soil Cover
		Extraction	Extraction Wells
			Extraction/Injection Wells
		Subsurface Drains	Interceptor Trenches
	Ex Situ Treatment	Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			Chemical Dechlorination
			Chemical Reduction
			Chemical Oxidation
			Membrane Separation
			Ion Exchange
			Electrochemical Ion Generation
			Distillation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
			Oil/Water Separation
		Biological Treatment	Aerobic Bioremediation (Aerated Lagoon, Activated Sludge, Trickling Filter, Rotating Biological Contactor)
			Anaerobic Bioremediation

TABLE 4-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater (Continued)	Ex Situ Treatment (Continued)	Thermal Treatment	Incineration (Liquid Injection, Rotary Kiln, Circulating Fluidized Bed, Multiple Hearth, Molten Salt)
			Pyrolysis, Plasma Arc Torch
		Off-Site Treatment	POTW
			RCRA Facility
			Sewage Treatment Plant
			Site 82 or HPIA Treatment System
	In Situ Treatment	Air Stripping	Air Sparging and Soil Vapor Extraction
			In-Well Aeration
		Dual Phase Extraction	Dual Phase Extraction
		Biological Treatment	Aerobic Biodegradation
			Anaerobic Biodegradation
		Natural Attenuation	Natural Attenuation
		Passive Remediation	Passive Treatment Wall
	Discharge Actions	On Site Discharge	Reinjection (Injection Wells, Infiltration Galleries)
		Off Site Discharge	POTW
			Sewage Treatment Plant
			Surface Water
			Deep Well Injection

TABLE 4-2

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No action - contaminated groundwater remains as is.	Potentially applicable to any site; required by the NCP.	Retained
Institutional Controls	Ordinances	Aquifer Use Restrictions	Restrictions that prohibit use of the contaminated aquifer as a potable water source.	Potentially applicable.	Retained
	Legal Restrictions	Deed Restrictions	Restrictions that limit the future use of land, including placement of wells.	Potentially applicable.	Retained
	Monitoring	Monitoring	Periodic sampling and analysis.	Potentially applicable.	Retained
Containment/Collection Actions	Vertical Barriers	Slurry Wall, Sheet Piling, Grout Curtain, Rock Grouting	A subsurface, impervious, vertical barrier is constructed to restrict the horizontal migration of a contaminated area.	No continuous confining layer under the site for the wall to adjoin to.	Eliminated
	Horizontal Barriers	Grout Injection, Jet Grouting	A subsurface, impervious, horizontal barrier is constructed to restrict the vertical migration of a contaminated area.	Technique is in the experimental stage.	Eliminated
	Capping	Clay/Soil Cap, Asphalt Cap, Synthetic Membrane, Composite Cap, Multilayered Cap, Soil Cover	Capping of contaminated areas to restrict water infiltration.	A cap alone will not prevent water infiltration; the majority of the site is already capped with paved parking areas.	Eliminated
	Extraction	Extraction Wells	Series of extraction wells used to pump contaminated groundwater to the surface.	Potentially applicable.	Retained
		Extraction/Injection Wells	Injection of uncontaminated groundwater to enhance collection of contaminated groundwater via extraction wells. Injection wells can also inject material into an aquifer to remediate groundwater.	Potentially applicable.	Retained
	Subsurface Drains	Interceptor Trenches	Perforated pipe installed in trenches backfilled with porous media to collect contaminated groundwater. Generally limited to shallow depths.	Potentially applicable.	Retained

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment	Physical/Chemical Treatment	Air Stripping	Mixing large volumes of air with water in a packed volume to promote transfer of volatile organics to air.	Potentially applicable to the volatile organic contaminants of concern.	Retained
		Steam Stripping	Mixing large volumes of steam with water in a packed column to promote transfer of volatile organics to air.	Potentially applicable to the volatile organic contaminants of concern.	Retained
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through a carbon column. Effective for a wide range of organics.	Potentially applicable to the volatile organic contaminants of concern.	Retained
		Chemical Dechlorination	Use of specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them into other harmless compounds. Primarily effective for PCB/dioxin/furan and halogenated phenol/creosol groups.	Not applicable to the volatile organic contaminants of concern.	Eliminated
		Chemical Reduction	Use of reducers, such as sulfur dioxide, sulfite compounds, or ferrous iron compounds, to chemically decrease contaminants' oxidation states. Effective for inorganics, particularly chromium, mercury, and lead.	Not applicable to the volatile organic contaminants of concern.	Eliminated
		Chemical Oxidation	Use of oxidizers, such as ozone, hydrogen peroxide, chlorine, and permanganate, to chemically increase contaminants' oxidation states. Ultraviolet light, or high pressures and temperatures may enhance the oxidation process. Effective for organics and inorganics.	Potentially applicable to the volatile organic contaminants of concern.	Retained
		Membrane Separation (Reverse Osmosis, Electrodialysis, Ultrafiltration)	Groundwater passes through a membrane that separates contaminants from the liquid phase. Effective for dissolved solids (organic and inorganic).	Potentially applicable to the volatile organic contaminants of concern.	Retained

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment (Continued)	Physical/Chemical Treatment (Continued)	Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Effective for inorganics.	Not applicable to the volatile organic contaminants of concern.	Eliminated
		Electrochemical Ion Generation	Electrical currents are used to put ferrous and hydroxyl ions into solution for subsequent removal via precipitation. Effective for inorganics.	Not applicable to the volatile organic contaminants of concern.	Eliminated
		Distillation	Contaminated water is heated so it evaporates leaving contaminants behind. The water vapor is then cooled resulting in a condensate of purified water. Highly energy intensive.	Because it is highly energy intensive, this method is only appropriate for treating groundwater with high contaminant concentrations.	Eliminated
		Neutralization	Addition of an acid or a base to waste stream in order to adjust its pH. Ex situ systems may require the removal of certain dissolved metals that can foul treatment equipment. To remove dissolved metals lime or sodium sulfide is added to the groundwater stream to precipitate the dissolved metals out of solution. This is a pH sensitive process and neutralization is needed as a process option if pH adjustment is required. Typically this process is use as a pretreatment technology.	Potentially applicable as a pretreatment technology.	Retained
		Precipitation	Materials in solution are transferred to the solid phase. As previously noted dissolved metals are precipitated out of solution to avoid equipment fouling. Typically this process is used as a pretreatment technology.	Potentially applicable as a pretreatment technology.	Retained

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment (Continued)	Physical/Chemical Treatment (Continued)	Filtration	Removal of suspended solids from solution by forcing the liquid through a porous medium. Applicable to suspended solids. Typically this process is used to remove residual levels of suspended solids that did not settle out during sedimentation.	Potentially applicable as a pretreatment technology.	Retained
		Flocculation	Flocculating agents such as alum, ferric chloride or ferric sulfate may be added to groundwater to enhance the agglomeration of precipitate particles or naturally suspended solids. As the smaller particles agglomerate settling occurs. Typically this process is used as a pretreatment technology.	Potentially applicable as a pretreatment technology.	Retained
		Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation. Insoluble precipitants or flocculents generated by metals or suspended solids removal are separated from the groundwater. This is achieved by allowing the flocculent or precipitate to "settle out". Typically this process is used as a pretreatment technology.	Potentially applicable as a pretreatment technology.	Retained
		Oil/Water Separation	Petroleum hydrocarbon materials in solution are separated for removal.	Oil and grease were not encountered in the groundwater at Site 73.	Eliminated
	Biological Treatment	Aerobic Bioremediation (Aerated Lagoon, Activated Sludge, Trickling Filter, Rotating Biological Contractor)	Degradation of organic contaminants via microorganisms in an aerobic (oxygen-sufficient) environment. Nutrients may be added and oxygen, pH, and temperature may be adjusted to optimize contaminant removal.	Potentially applicable to the volatile organic contaminants of concern, particularly benzene.	Retained
		Anaerobic Bioremediation	Degradation of organic contaminants via microorganisms in an anaerobic (oxygen-deficient) environment.	Potentially applicable to the volatile organic contaminants of concern, particularly the chlorinated organics.	Retained

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Ex Situ Treatment (Continued)	Thermal Treatment	Incineration (Liquid Injection, Rotary Kiln, Circulating Fluidized Bed, Multiple Hearth, Molten Salt)	Use of high temperatures and oxygen to volatilize and combust contaminants. Effective for a wide range of organics and inorganics.	Incineration is a relatively expensive alternative for groundwater.	Eliminated
		Pyrolysis, Plasma Arc Torch	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.	Incineration is a relatively expensive alternative for groundwater.	Eliminated
	Off-Site Treatment	POTW	Extracted groundwater discharged to the Jacksonville POTW for treatment.	Not applicable since this POTW will not accept contaminated groundwater.	Eliminated
		RCRA Facility	Extracted groundwater transported to a licensed RCRA facility for treatment and/or disposal.	Distance to nearest RCRA Facility, and the volume of groundwater that must be transported, make this option impractical.	Eliminated
		Sewage Treatment Plant	Extracted groundwater discharged to Base STP for treatment.	Not applicable since this STP will not accept highly contaminated groundwater.	Eliminated
		Site 82 or HPIA Treatment Systems	Extracted groundwater discharged to the Site 82 treatment system or the HPIA treatment system which include air stripping and carbon adsorption units.	The distance to these treatment systems (approximately 8 miles), and the volume of groundwater that must be transported, make this option impractical.	Eliminated

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
In Situ Treatment	Air Stripping	Air Sparging and Soil Vapor Extraction	"In situ air stripping"; air is injected into the aquifer creating an underground air stripper; air injection wells used in conjunction with soil vapor extraction to capture volatilized contaminants.	Potentially applicable to the volatile organic contaminants of concern.	Retained
		In-Well Aeration	"In-well air stripping". Process of inducing air into a well by applying a vacuum. The result is an in-well air lift pump effect that serves to strip volatiles from groundwater inside the well.	Potentially applicable to the volatile organic contaminants of concern.	Retained
	Dual Phase Extraction	Dual Phase Extraction	A high vacuum placed in a well to remove liquid and volatilized contaminants; applicable to volatile organics in low permeability or heterogeneous formations.	Potentially applicable to the volatile organic contaminants of concern.	Retained
	Biological Treatment	Aerobic Biodegradation	Degradation of organic contaminants via microorganisms in an aerobic (oxygen-sufficient) environment. Nutrients may be added and oxygen, pH, and temperature may be adjusted to optimize contaminant removal.	Potentially applicable to the volatile organic contaminants of concern, particularly benzene.	Retained
		Anaerobic Biodegradation	Degradation of organic contaminants via microorganisms in an anaerobic (oxygen-deficient) environment.	Potentially applicable to the volatile organic contaminants of concern, particularly the chlorinated organics.	Retained
	Natural Attenuation	Natural Attenuation	Natural subsurface processes - such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials - are allowed to reduce contaminant concentrations to acceptable levels.	Potentially applicable to the volatile organic contaminants of concern.	Retained

TABLE 4-2 (Continued)

PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
In Situ Treatment (Continued)	Passive Remediation	Passive Treatment Wall	A permeable reaction wall is installed across the flow path of a contaminant plume, treating the plume as it passively moves through the wall. Effective for volatile organics and inorganics.	Potentially applicable to the volatile organic contaminants of concern.	Retained
Discharge Actions	On-Site Discharge	Reinjection (Injection Wells, Infiltration Galleries)	Treated water is reinjected into the site aquifer using shallow infiltration galleries (trenches) or injection wells.	Potentially applicable.	Retained
	Off-Site Discharge	POTW	Treated water discharged to Jacksonville POTW.	The distance to the nearest POTW, and the volume of groundwater that must be transported, make this option impractical.	Eliminated
		Sewage Treatment Plant	Treated water discharged to Hadnot Point STP.	The distance to the STP, and the volume of groundwater that must be transported, make this option impractical.	Eliminated
		Surface Water	Treated water discharged to a nearby stream channel, or Courthouse Bay.	Potentially applicable.	Retained
		Deep Well Injection	Treated water is reinjected into the brine aquifer located under the Castle Hayne aquifer.	Potentially applicable.	Retained

TABLE 4-3

TECHNOLOGIES AND PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY FEASIBILITY STUDY, CTO-0312 MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Site Restrictions	Aquifer Use Restrictions
		Monitoring	Monitoring
	Containment/ Collection Actions	Extraction	Extraction Wells
			Extraction/Injection Wells
		Subsurface Drains	Interceptor Trenches
	Ex Situ Treatment	Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			Chemical Oxidation
			Membrane Separation (Reverse Osmosis, Electrodialysis, Ultrafiltration)
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		Biological Treatment	Aerobic Bioremediation (Aerated Lagoon, Activated Sludge, Trickling Filter, Rotating Biological Contactor)
			Anaerobic Bioremediation
	In Situ Treatment	Air Stripping	Air Sparging
			In-Well Aeration
		Dual Phase Extraction	Dual Phase Extraction
		Biological Treatment	Aerobic Biodegradation
			Anaerobic Biodegradation
		Natural Attenuation	Natural Attenuation
		Passive Remediation	Passive Treatment Wall
	Discharge Actions	On-Site Discharge	Reinjection (Injection Wells, Infiltration Galleries)
		Off-Site Discharge	Surface Water
			Deep Well Injection

TABLE 4-4

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
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 as per the requirements of the NCP
Institutional Controls	Site Restrictions	Aquifer Use Restrictions	• Will effectivly prevent future exposure to groundwater • Effectiveness dependent on continued future implementation	• Easily implemented • Legal requirements	• Negligible cost	Retained because of its effectiveness and negligible cost
	Monitoring	Monitoring	• Surface water monitoring will effectively mitigate the potential for exposure via Courthouse Bay • Groundwater monitoring will effectively track the contaminant plumes' migration over time; groundwater monitoring will also effectively mitigate the potential for exposure • Monitoring will help to determine 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 and low cost

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Containment/ Collection Actions	Extraction	Extraction Wells	• Effective for collecting and/or containing a contaminated groundwater plume • Extraction wells may not collect contaminants that are sorbed to soil particles or trapped in subsurface pore spaces and fissures • Inorganics may precipitate and clog well screens; this necessitates frequent maintenance and equipment replacement • Conventional, widely demonstrated technology	• Easily implemented • Uses standard equipment that is readily available • Current site operations may complicate implementation	• Moderate capital • Moderate O&M	Retained because it is a conventional technology and more easily implemented than an interceptor trench
		Extraction/ Injection Wells	• Effective for collecting and/or containing a contaminated groundwater plume • At Site 73, reinjection may facilitate contaminant migration toward Courthouse Bay • Inorganics may precipitate and clog well screens; this necessitates frequent maintenance and equipment replacement • Conventional, widely demonstrated technology	• Easily implemented • Uses standard equipment that is readily available • Current site operations may complicate implementation	• Moderate capital • Moderate O&M	Eliminated because it may further spread the contamination

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Containment/ Collection Actions (Continued)	Subsurface Drains	Interceptor Trenches	• Effective for collecting and/or containing a contaminated groundwater plume • More effective for shallow groundwater plumes • Slower recovery than extraction wells • Potential exposures during installation • Water pressure from Courthouse Bay may affect the integrity of nearby trenches	• Requires extensive trenching and dewatering which will be difficult due to paved areas and current site operations • Requires more surface area than extraction wells • There is no continuous confining layer under the site for the trench to adjoin to • Requires an experienced specialty contractor • Equipment readily available	• High capital • Moderate O&M	Eliminated because trenches require more surface area and are less cost effective than extraction wells
Ex Situ Treatment	Physical/ Chemical Treatment	Air Stripping	• Effective for a wide range of volatile organic compounds • More effective for low concentrations of wastes that are highly volatile and have low water solubility (e.g., TCE) • Contaminant transfer technology (rather than a contaminant destruction technology) • Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • Commercially proven and widely used technology	• Readily available, conventional technology • Mobile units available • May require bench-scale testing • May require off-gas and/or tower scale treatment • May require air emissions permit	• Low to moderate capital • Low to moderate O&M	Retained because of its effectiveness for treating volatile organic compounds

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Steam Stripping	• Effective for a wide range of volatile organic compounds • More effective for contaminants that are more water soluble and relatively less volatile • Contaminant transfer technology (rather than a contaminant destruction technology) • Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • Commercially proven technology	• Readily available, but not as common as air stripping • May require off-gas and/or tower scale treatment • May require air emissions permit	• Moderate capital • Moderate to high O&M	Eliminated because it is less effective than air stripping for contaminants that are highly volatile with low water solubility (i.e., the chlorinated solvent contaminants of concern)

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Carbon Adsorption	• Effective for a wide range of volatile organic compounds • Loses efficiency for compounds with low molecular weight • Loses efficiency for compounds with high polarity • Loses efficiency for compounds that are water-soluble • Contaminant transfer technology (rather than a contaminant destruction technology) • Suspended solids, inorganics, and oil and grease can foul the system • Commercially proven and widely used technology • Less cost effective if used as the primary treatment on a wastestream 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, oil and grease, and unstable chemical compounds • For waste with mixed contaminants, bench tests should be conducted to estimate carbon usage • Requires groundwater extraction	• 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

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemcial Treatment (Continued)	Chemical Oxidation	• Effectively treats liquids containing oxidizable contaminants • Contaminant destruction technology • Incomplete oxidation or formation of intermediate contaminants may occur depending upon the contaminants and oxidizing agents used • Chemical oxidants are non-selective; they may oxidize other compounds prior to the contaminants of concern (increasing treatment time) • Conventional, well-demonstrated technology for disinfecting drinking water and wastewater; not well demonstrated for environmental remediation • Not cost-effective for high contaminant concentrations because of the large amounts of oxidizing agents required • UV-enhanced oxidation does not work well for turbid water and slurries due to reduced light transmission	• Treatability tests should be conducted • Extensive air pollution control is usually not required, although the process may volatilize contaminants • Employs standard equipment that is readily available; mobile units are available • Requires groundwater extraction	• Moderate to high capital; high capital for ozonation because an ozone generator and an ozone decomposition unit are required • Moderate O&M	Eliminated because of its expense compared to air stripping and the non-selective nature of chemical oxidants (which may indefinitely increase the treatment time)

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemcial Treatment (Continued)	Membrane Separation (Reverse Osmosis, Electrodialysis, Ultrafiltration)	• Effective for polar organic compounds • Contaminant concentration/ separation technology (rather than a contaminant destruction technology) • Inability to handle fluctuations in organic concentrations	• Separated contaminants will require further treatment • Requires groundwater extraction	• High capital • Moderate O&M	Eliminated because of its high cost compared to other contaminant separation/ concentration technologies and its inability to handle fluctuations in contaminant concentrations
		Neutralization	• Can be used in a treatment train for pH adjustment • Many treatment technologies for organics require neutralization as pretreatment	• Widely used and well demonstrated • Simple and readily available equipment/materials	• Low capital • Low to moderate O&M	Retained because it may be necessary as pretreatment
		Precipitation	• Effective, reliable, permanent, and conventional technology for inorganics removal • Typically used for removal of heavy metals • Followed by solids-separation methods	• Widely used and well demonstrated • Equipment is basic and easily designed • Compact, single units that are deliverable to the site • Generates sludge which can be voluminous, difficult to dewater, and may require treatment	• Low capital • Moderate O&M	Retained because it may be necessary as pretreatment

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Filtration	• Conventional, proven method of removing suspended solids from wastewater • Does not remove contaminants other than suspended solids	• Equipment is relatively simple to install and no chemicals are required • Package units available • Pretreatment for oil and grease required • Generates a sludge which requires proper handling	• Low capital • Moderate O&M	Retained because it may be necessary as pretreatment
		Flocculation	• Conventional, proven technology • Applicable to any aqueous waste stream where particles must be agglomerated into larger more settleable particles prior to other types of treatment • Performance depends on the variability of the composition of the waste being treated	• Equipment is readily available and easy to operate • Can be easily integrated into more complex treatment systems	• Low capital • Moderate O&M	Retained because it may be necessary as pretreatment

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Sedimentation	• Conventional, proven technology • Effective for removing suspended solids and precipitated materials from wastewater • 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 reinjection time • Feasible for large volumes of water to be treated	• Effluent streams include the effluent water, scum, and settled solids	• Low capital • Moderate O&M	Retained because it may be necessary as pretreatment

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Biological Treatment	Aerobic Bioremediation (Aerated Lagoon, Activated Sludge, Trickling Filter, Rotating Biological Contactor)	• Contaminant destruction technology • Highly effective for fuel contaminants (e.g., benzene) • Contaminants with low water solubility are more difficult to degrade • Compounds may degrade into intermediate compounds that are more toxic or more mobile • Technology is still under development so it is not widely demonstrated • Very slow process • Effectiveness is susceptible to variation in waste stream characteristics and environmental parameters • Rotating Biological Contactors are susceptible to excessive biomass growth which may damage the equipment	• Low contaminant concentrations may make operation difficult • Treatability study is required • Pretreatment may be required for for heavy metals, highly chlorinated organics, pesticides, herbicides, and inorganic salts • Must dispose of wastewater and possibly treat process off-gases • Methane gas is produced and must be utilized or disposed • Mobile units are available • Requires groundwater extraction	• Moderate capital • Moderate O&M	Eliminated because it is a very slow process for groundwater remediation and it is not widely demonstrated

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Ex Situ Treatment (Continued)	Biological Treatment (Continued)	Anaerobic Bioremediation	• Contaminant destruction technology • Highly effective for chlorinated solvent contaminants (e.g., TCE) • Contaminants with low water solubility are more difficult to degrade • Compounds may degrade into intermediate compounds that are more toxic or more mobile • Technology is still under development so it is not widely demonstrated • Very slow process • Effectiveness is susceptible to variation in waste stream characteristics and environmental parameters • Rotating Biological Contactors are susceptible to excessive biomass growth which may damage the equipment	• Low contaminant concentrations may make operation difficult • Treatability study is required • Pretreatment may be required for for heavy metals, highly chlorinated organics, pesticides, herbicides, and inorganic salts • Must dispose of wastewater and possibly treat process off-gases • Methane gas is produced and must be utilized or disposed • Mobile units are available • Requires groundwater extraction	• Moderate capital • Moderate O&M	Eliminated because it is a very slow process for groundwater remediation and it is not widely demonstrated

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment	Air Stripping	Air Sparging and Soil Vapor Extraction	• Effective for volatile organic compounds • Effective for the surficial aquifer, but not the deep aquifer (the semiconfining layer that overlies the deep aquifer will prohibit contaminant removal) • In addition to volatilizing contaminants, natural biodegradation processes can be enhanced by this technology due to the addition of air and oxygen to the aquifer • Contamination of the vadose zone may occur as contaminated groundwater passes through it • Contaminant transfer technology (rather than a contaminant destruction technology) • Fouling of the system may occur by oxidized constituents in the groundwater • If soil vapor extraction wells (in addition to air injection wells) are not employed, a net positive subsurface pressure could induce contaminant migration • A water table located at a shallow depth increases the difficulty of recovering vapors with SVE wells	• May require secondary treatment of off-gas • Treatability study is required • May require air emissions permit • Underground utilities may complicate the construction of a manifold system • Groundwater does not need to be lifted above ground surface in order to be treated • Current site operations may complicate implementation • Near the Bay, the thickness of the vadose zone may decrease	• Moderate to high capital • Low to moderate O&M	Retained for the upper portion of the surficial aquifer because of its effectiveness at treating volatile organic compounds; eliminated for the lower portion of the surficial aquifer and the deep aquifer because of the overlying semiconfining unit

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Air Stripping (Continued)	In-Well Aeration	• Effective for volatile organic compounds • Effective for both the surficial and the deep aquifers • In addition to volatilizing contaminants, natural biodegradation processes can be enhanced by this technology due to the addition of air and oxygen to the aquifer • Compared to air sparging with soil vapor extraction, contamination of the vadose zone is less likely to occur • Contaminant transfer technology (rather than a contaminant destruction technology) • Fouling of the system may occur by oxidized constituents in the groundwater • Unlike air sparging and soil vapor extraction, in-well aeration will not increase pressure in the vadose zone thus allowing vapors into building basements	• May require secondary treatment of off-gas • Treatability study is required • May require air emissions permit • Underground utilities may complicate the construction of a manifold system • Groundwater does not need to be lifted above ground surface in order to be treated • The aquifer thickness must be large enough to develop a groundwater circulation flow pattern • Current site operations may complicate implementation	• Moderate to high capital • Low to moderate O&M	Retained for the deep aquifer because of its effectiveness at treating volatile organic compounds; eliminated for the surficial aquifer due to insufficient aquifer thickness

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Dual Phase Extraction	Dual Phase Extraction	• Effective for volatile organic compounds • The maximum suction lift is approximately 30 feet bgs • Requires both water and vapor treatment	• Emerging technology • Equipment and materials should be readily available • Groundwater must be lifted above the ground surface in order to be treated • Current site operations may complicate implementation	• Low to moderate capital • Low to moderate O&M	Eliminated because treatment of both water and vapor is required

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Biological Treatment	Aerobic Biodegradation	• Contaminant destruction technology • Highly effective for fuel contaminants (e.g., benzene) • Most likely, intrinsic aerobic biodegradation is already occurring at the site as a natural attenuation process • Contaminants with low water solubility are more difficult to degrade • Compounds may degrade into intermediate compounds that are more toxic or more mobile • The presence of heavy metals, highly chlorinated organics, pesticides, herbicides, and inorganic salts can inhibit microbial metabolism demonstrated • Highly dependent on soil characteristics; cleanup goals may not be attained if the soil matrix prohibits contaminant-microorganism contact • Less certainty about treatment results because of subsurface variability and difficulties in monitoring at depth	• Requires a treatability study • If intrinsic aerobic biodegradation (i.e., natural attenuation) is occurring, no microbe or nutrient addition will be required • Very little control over the system compared to ex situ technologies • Microbes may colonize and clog injection wells • Injection of substrate and nutrients into groundwater may require a permit • Equipment readily available	• Moderate capital if microbe or nutrient addition is required • Low to moderate O&M	Retained provided it is occurring as a natural attenuation process and no O&M will be required

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Biological Treatment (Continued)	Anaerobic Bioremediation	• Contaminant destruction technology • Highly effective for chlorinated solvent contaminants (e.g., TCE) • Most likely, intrinsic anaerobic biodegradation is already occurring at the site as a natural attenuation process; this is evident in the TCE degradation products (1,2-DCE and vinyl chloride) that have been detected at the site • Contaminants with low water solubility are more difficult to degrade • Compounds may degrade into intermediate compounds that are more toxic or more mobile • Highly dependent on soil characteristics; cleanup goals may not be attained if the soil matrix prohibits contaminant-microorganism contact • Less certainty about treatment results because of subsurface variability and difficulties in monitoring at depth	• Requires a treatability study • If intrinsic anaerobic biodegradation (i.e., natural attenuation) is occurring, no microbe or nutrient addition will be required • Very little control over the system compared to ex situ technologies • Microbes may colonize and clog injection wells • Injection of substrate and nutrients into groundwater may require a permit • Equipment readily available	• Moderate capital if microbe or nutrient addition is required • Moderate O&M	Retained provided it is occurring as a natural attenuation process and no O&M will be required

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Natural Attenuation	Natural Attenuation	• Effective for both fuel contaminants and chlorinated solvent contaminants • Widely accepted as a treatment for fuel-related contamination • Less accepted as a treatment for chlorinated solvent contamination • The existence of TCE degradation daughter products (1,2-DCE and vinyl chloride) suggest that natural attenuation is occurring at Site 73 • There are currently no unacceptable risks associated with the contaminated groundwater • Surface water monitoring in Courthouse Bay may be required since the contaminant plumes discharge directly into this surface water body	• Requires a treatability study • Requires a long-term monitoring program • No other O&M requirements besides long-term monitoring	• Negligible to low capital • Low O&M	Retained because it appears to be occurring at Site 73, and it is effective for the contaminants of concern

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
In Situ Treatment (Continued)	Passive Remediation	Passive Treatment Wall	• Iron filings are highly effective at treating chlorinated solvent contaminants • Contaminant destruction technology • Contaminants may be degraded into more mobile or more toxic compounds	• Requires a field pilot study • Requires extensive excavation trenching and dewatering • Requires a large surface area • There is no continuous confining layer under the site for the wall to adjoin to • Requires an experience specialty contractor • No mechanical O&M requirements • Iron filings will become eventually be exhausted (after 10-15 years) and will need to be replaced • Current site operations may complicate implementation	• High capital • Low O&M	Eliminated because of the difficulties associated with construction and the high capital costs
Discharge Actions	On-Site Discharge	Reinjection (Injection Wells, Infiltration Galleries)	• Conventional and widely demonstrated discharge option • Reinjection may spread contamination further	• Requires the construction of an injection well system or an infiltration gallery • Materials and equipment are readily available	• Moderate capital • Moderate O&M	Eliminated because it may spread contamination further

TABLE 4-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Discharge Actions (Continued)	Off-Site Discharge	Surface Water	• Conventional and widely demonstrated discharge option • Water may be discharged into the nearby stream channel that empties into Courthouse Bay, or directly into the bay itself • Only effective if water receives treatment before it is discharged; otherwise, contamination may spread	• Discharge permits required • Requires transportation of water via a pipeline	• Moderate capital • Low O&M	Retained because it is a conventional and widely demonstrated discharge option
		Deep Well Injection	• Injection wells' effectiveness is highly dependent on site geology/ hydrogeology • Wells may clog due to inorganics precipitation over time • Reinjection may spread contamination further	• Discharge permit required • Injection wells must be installed	• Moderate capital • Moderate O&M	Eliminated because it may spread contamination further

TABLE 4-5

FINAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Site Restrictions	Aquifer Use Restrictions
		Monitoring	Monitoring
	Containment/ Collection Actions	Extraction	Extraction Wells
	Ex Situ Treatment	Physical/Chemical Treatment	Air Stripping
			Carbon Adsorption
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
	In Situ Treatment	Air Stripping	Air Sparging and Soil Vapor Extraction
			In-Well Aeration
		Biological Treatment	Aerobic Biodegradation
			Anaerobic Biodegradation
		Natural Attenuation	Natural Attenuation
	Discharge Actions	Off Site Discharge	Surface Water

5.0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

In this section, potentially applicable remedial technologies and process options are combined to form remedial action alternatives (RAAs) for the surficial and deep aquifers at Site 73. Section 5.1 presents the development of surficial aquifer alternatives which will be designated with the letter "S", and Section 5.2 presents the development of deep aquifer alternatives which will be designated with the letter "D". Detailed evaluations of these surficial and deep aquifer alternatives (with respect to nine USEPA evaluation criteria) will be presented in Sections 6.0 and 7.0, respectively.

In some cases, this section of the FS may contain a preliminary alternative screening, in which the alternatives are evaluated with respect to three criteria - effectiveness, implementability, and cost. The objective of this screening, which is an optional step in the FS process, is to preliminarily evaluate the alternatives and retain only the most promising ones for the detailed evaluation. Consequently, this screening is usually conducted when the number of RAAs is too large to be manageable. In the case of Site 73, the number of RAAs will be amenable to proceeding directly with detailed evaluations which are presented in Sections 6.0 and 7.0.

Note that the RAAs developed within this section are only meant to include conceptual system designs. The conceptual designs were based on information available to date and will be adequate for developing FS cost estimates. However, they are subject to change during the design phase based on new and/or more accurate information that may become available.

5.1 Surficial Aquifer Alternatives

Five alternatives, ranging from no action to limited action to full action, were developed for the surficial aquifer as follows:

- RAA 1S: No Action
- RAA 2S: Natural Attenuation
- RAA 3S: Groundwater Extraction and Treatment
- RAA 4S: Air Sparging and Soil Vapor Extraction
- RAA 5S: Groundwater Extraction and Treatment - Expanded System

These RAAs are briefly described below.

5.1.1 RAA 1S: No Action

Under RAA 1S, no remedial actions will be conducted to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 73. The AOCs identified in Figure 3-1 will remain in place under their current conditions. The no action alternative is required by the NCP to provide a baseline for comparison with other remedial action alternatives that provide a greater level of response.

Since contaminants will remain in the groundwater, 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.

5.1.2 RAA 2S: Natural Attenuation

Under RAA 2S, no active remedial actions will be conducted to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 73. Instead, natural attenuation, a passive-type remedial action, will be relied upon to decrease contaminant levels. 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" (Weidemeier, 1995).

Biodegradation may occur as an aerobic, anaerobic, or cometabolic process. Aerobic processes involve oxidation-reduction reactions in which oxygen is the electron receptor. Anaerobic processes involve iron-reducing, denitrifying, and sulfate-reducing reactions. Cometabolic processes involve carbon dioxide-reducing reactions and result in the accumulation of methane as a final product. The natural biodegradation of fuel-related contaminants (e.g., benzene) is more fully documented than the natural biodegradation of chlorinated solvent contaminants (e.g., TCE, 1,2-DCE, and vinyl chloride). Both fuel and chlorinated solvent contamination can undergo natural attenuation through one or more of the biodegradation processes mentioned (Wiedemeier, Todd, et al., 1995 and 1996). At Site 73, the following evidence suggests that natural attenuation processes are successfully degrading the chlorinated solvent contamination in the surficial aquifer:

- TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected.

- The suspected plume of cis-1,2-DCE is positioned downgradient from the suspected TCE plume; the suspected vinyl chloride plume is positioned downgradient from both the cis-1,2-DCE and TCE plumes (see Figure 3-1). The arrangement of these plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation.

Based on this information, the natural attenuation alternative may be a justifiable remedial option for the fuel and chlorinated solvent contamination detected in the surficial aquifer.

The main component of RAA 2S is a long-term monitoring program. The monitoring program will include periodic groundwater and surface water sampling at the locations identified in Figure 5-1. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. The natural attenuation parameters will indicate the type of biodegradation that is occurring (aerobic, iron-reducing, denitrifying, sulfate-reducing, or methanogenic) which will be used to predict the kind and amount of contaminant reduction that can be expected. All surface water samples will be analyzed for TCL VOCs. Additional sampling locations may be added to the monitoring program if necessary. If water quality improves, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

To provide further evidence that natural attenuation is occurring, RAA 2S may include two optional components: a contaminant fate and transport model and a laboratory microcosm study. The model will estimate contaminant concentrations over time assuming natural attenuation processes are occurring in the surficial aquifer. Periodic updating of the model will be conducted as new

analytical results become available. The laboratory microcosm study will be conducted to more definitively determine if indigenous microbes are degrading the contamination, and to estimate the degradation rates. For cost estimating, it was assumed that RAA 2S will include these two optional components and that the modeling updates will be conducted on a quarterly basis for five years.

RAA 2S also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater, 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.

5.1.3 RAA 3S: Groundwater Extraction and Treatment

RAA 3S is a conventional pump and treat alternative which incorporates extraction wells for collection of the contaminated groundwater, and air stripping and liquid-phase carbon adsorption for VOC removal. Figure 5-2 presents the conceptual system layout. The well placement shown was based on the pump and treat model presented under separate cover in "Groundwater Modeling at Operable Unit No. 9 - The Amphibious Vehicle Maintenance Facility (Site 73)" (Baker, 1997). According to the model, an approximate radius of influence between 100 and 150 feet may be expected for each extraction well installed in the surficial aquifer. The pumping rates for each well range from 0.25 to 2 gpm; the treatment plant capacity will be 3.25 gpm. Two extraction wells will be positioned to collect the hot portions of the contaminated plumes, and one extraction well will be positioned to collect contamination that is trapped underneath the concrete structure near 73-MW09. Contaminated areas that do not receive active treatment are assumed will experience contaminant reduction through natural attenuation.

Once extracted, the contaminated groundwater will be conveyed by underground piping to the treatment facility shown in Figure 5-2. Treatment will consist of neutralization, precipitation, filtration, flocculation, and sedimentation for metals/suspended solids removal, and air stripping and liquid-phase carbon adsorption for VOC removal. Figure 5-3 presents a typical process flow diagram. Once treated, the groundwater will be discharged to Courthouse Bay.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. The program will include periodic sampling at the locations identified in Figure 5-1, which are the same sampling locations that are associated with RAA 2S. Additional sampling locations may be added to this monitoring program if necessary. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. All surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 3S also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

5.1.4 RAA 4S: Air Sparging and Soil Vapor Extraction

Air sparging involves the injection of air into a well that is screened at the base of the contaminated aquifer. The injected air exits through the well screen and moves outward and upward through the saturated zone. As the air moves through the aquifer, it volatilizes dissolved contaminants and enhances natural subsurface biodegradation. The volatilized contaminants may then be captured in the vadose zone by a soil vapor extraction (SVE) well and treated via vapor-phase activated carbon.

Figure 5-4 depicts the conceptual layout for the surficial aquifer air sparging/SVE system. Because chlorinated solvent contamination tends to sink, horizontal air injection wells will be installed at the base of the upper surficial aquifer which is located at approximately 10 to 15 feet bgs. For each horizontal air injection well, a horizontal SVE well will be installed within the vadose zone of the upper surficial aquifer which is located from approximately 0 to 5 feet bgs. Each SVE well will be installed directly above each air injection well. According to technology vendors, an average radius of influence of about 20 feet can be expected for each air injection well. Each SVE well will have an average radius of influence of about 40 feet which is twice the radius for an air injection well (Bausmith et. al., 1996). Contaminated areas that are not actively treated by the air sparging/SVE system are assumed will experience contaminant reductions through natural attenuation.

Volatilized contaminants that are captured by the SVE wells will be conveyed by underground piping to the treatment facilities identified in Figure 5-4. At the treatment facilities, the volatilized contaminants will undergo vapor-phase carbon adsorption treatment. The treatment facilities will also contain the necessary air and vacuum blowers and vapor-water separation units. Figure 5-5 presents a typical process flow diagram.

Because air sparging and SVE are relatively new and innovative technologies, RAA 4S requires that a field pilot test be conducted prior to the system design. The pilot test will determine the loss of efficiency over time as a result of inorganics precipitation and oxidation on the well screen, the radius of influence of the air injection and SVE wells under various heads of pressure, the rate of off-gas organic contaminant removal via carbon adsorption, and carbon breakthrough times. The field pilot test will also determine the off-gas concentrations that can be expected prior to vapor extraction. If these concentrations are low, off-gas treatment may not be necessary.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. The program will include periodic sampling at the locations identified in Figure 5-1, which are the same sampling locations that are associated with RAAs 2S and 3S. Additional sampling locations may be added to this monitoring program if necessary. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. All surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 4S also includes aquifer use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500 foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

5.1.5 RAA 5S: Groundwater Extraction and Treatment - Expanded System

RAA 5S is a conventional pump and treat alternative that expands upon the extraction/treatment system presented in RAA 3S by attempting to treat all of the groundwater contamination that exceeds remediation levels, as opposed to only the most highly contaminated (i.e., hot) areas. Figure 5-6 presents a conceptual system layout. This alternative was developed so that a full range of remedial action alternatives (from no action to limited action to full action) could be evaluated.

Under RAA 5S, seven extraction wells will be installed in the surficial aquifer, as shown in Figure 5-6, in an attempt to collect all of the contamination that exceeds remediation levels. This well placement was based on the pump and treat model presented under separate cover in "Groundwater Modeling at Operable Unit No. 9 - The Amphibious Vehicle Maintenance Facility (Site 73)" (Baker, 1997). The pumping rates for each well range from 0.25 to 2 gpm; the treatment plant capacity will be 11.5 gpm.

Once extracted, the contaminated groundwater will be conveyed by underground piping to the treatment facility shown in Figure 5-6. Treatment will consist of neutralization, precipitation, filtration, flocculation, and sedimentation for metals/suspended solids removal, and air stripping and liquid-phase carbon adsorption treatment for VOC removal. Figure 5-3 presents a typical process flow diagram. Once treated, the groundwater will be discharged to Courthouse Bay.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. This program will include periodic sampling at the locations identified in Figure 5-1, which are the same sampling locations that are associated with RAAs 2S, 3S, and 4S. Additional sampling locations may be added to this monitoring program if necessary. All groundwater and surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 5S also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

5.2 Deep Aquifer Alternatives

Five alternatives, ranging from no action to limited action to full action, were developed for the deep aquifer as follows:

- RAA 1D: No Action
- RAA 2D: Natural Attenuation
- RAA 3D: Groundwater Extraction and Treatment
- RAA 4D: In-Well Aeration
- RAA 5D: In-Well Aeration - Expanded System

These RAAs are briefly described below.

5.2.1 RAA 1D: No Action

Under RAA 1D, no remedial actions will be conducted to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 73. The AOCs identified in Figure 3-2 will remain in place under their current conditions. The no action alternative is required by the NCP to provide a baseline for comparison with other remedial action alternatives that provide a greater level of response.

Since contaminants will remain in the groundwater, 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.

5.2.2 RAA 2D: Natural Attenuation

Under RAA 2D, no active remedial actions will be conducted to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 73. Instead, natural attenuation, a passive-type remedial action, will be relied upon to decrease contaminant levels. Both fuel and chlorinated solvent contamination can undergo natural attenuation (Wiedemeier, Todd, et al., 1995 and 1996). (Natural attenuation processes are described in more detail in Section 5.1.2.) At Site 73, the following evidence suggests that natural attenuation processes are successfully degrading the chlorinated solvent contamination in the deep aquifer:

- TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected in the deep aquifer.

- The suspected plumes of cis-1,2-DCE and vinyl chloride are positioned underneath the suspected TCE plume (see Figure 3-2). The arrangement of these plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation.

Based on this information, the natural attenuation alternative may be a justifiable remedial option for the fuel and chlorinated solvent contamination detected in the deep aquifer.

The main component of RAA 2D is a long-term monitoring program. The monitoring program will include periodic groundwater and surface water sampling at the locations identified in Figure 5-7. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. The natural attenuation parameters will indicate the type of biodegradation that is occurring (aerobic, iron-reducing, denitrifying, sulfate-reducing, or methanogenic) which will be used to predict the kind and amount of contaminant reduction that can be expected. All surface water samples will be analyzed for TCL VOCs. Additional sampling locations may be added to the monitoring program if necessary. If water quality improves, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

To provide further evidence that natural attenuation is occurring, RAA 2D may include two optional components: a contaminant fate and transport model and a laboratory microcosm study. The model will estimate contaminant concentrations over time assuming natural attenuation processes are occurring in the deep aquifer. Periodic updating of the model will be conducted as new analytical results become available. The laboratory microcosm study will be conducted to more definitively

determine if indigenous microbes are degrading the contamination, and to estimate the degradation rates. For cost estimating, it was assumed that RAA 2D will include these two optional components and that the modeling updates will be conducted on a quarterly basis for five years.

RAA 2D also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater, 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.

5.2.3 RAA 3D: Groundwater Extraction and Treatment

RAA 3D is a conventional pump and treat alternative which involves extractions wells for collection of the contaminated groundwater, and air stripping and liquid-phase carbon adsorption for VOC removal. Figure 5-8 presents the conceptual system layout. As shown, one extraction well will be positioned to collect the hot portion of the contaminated plumes, and one extraction well will be positioned to collect the contamination that is trapped by the concrete structure near 73-MW09. This well placement was based on the pump and treat model presented under separate cover in "Groundwater Modeling at Operable Unit No. 9 - The Amphibious Vehicle Maintenance Facility (Site 73)" (Baker, 1997). According to the model, a pumping rate of 10 gpm may be expected for each extraction well installed in the deep aquifer; the treatment plant capacity will be 20 gpm. Contaminated areas that are not actively treated by the pump and treat system are assumed will experience contaminant reductions through natural attenuation.

Once extracted, the contaminated groundwater will be conveyed by underground piping to an on site treatment facility. Treatment will consist of neutralization, precipitation, filtration, flocculation, and sedimentation for metals removal, and air stripping and liquid-phase carbon adsorption for VOC removal. Figure 5-3 presents a typical process flow diagram. Once treated, the groundwater will be discharged to Courthouse Bay.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. The program will include periodic sampling at the locations identified in Figure 5-7, which are the same sampling locations associated with RAA 2D. Additional wells may be added to the monitoring program if necessary. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. All surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 3D also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

5.2.4 RAA 4D: In-Well Aeration

In-well aeration is a type of air sparging in which air is injected into a 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 of the top of the well. As the groundwater circulates through the well, the injected air stream strips volatiles. (As a result, in-well aeration is often referred to as in-well air stripping.) The volatiles are captured at the top of the well and then treated. The wells may be connected by manifold piping to a treatment plant, or an individual treatment unit may be located on the ground surface by each well.

Figure 5-9 depicts the conceptual system layout for the surficial aquifer in-well aeration system. As shown, three aeration wells will be installed to collect the hot portions of the contaminated plumes. Figure 5-10 presents a typical well detail and process flow diagram. The approximate radius of influence for each aeration well has been estimated to be 110 feet, which is 2 times the saturated thickness of the contaminated aquifer (Buermann and Bott-Breuning, 1994). Contaminated areas that are not actively treated by the in-well aeration system will experience contaminant reductions through natural attenuation.

Because in-well aeration is a relatively new and innovative technology, a field pilot test is recommended prior to initiating the system design. The pilot test will determine the loss of efficiency over time as a result of inorganics precipitation and oxidation on the well screens, the radius of influence of the aeration wells under various heads of injection pressure, the rate of off-gas contaminant removal via carbon adsorption, and the carbon breakthrough times.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. The program will include periodic sampling at the locations identified in Figure 5-7, which are the same sampling locations associated with RAAs 2D and 3D. Additional samples may be added to the monitoring program if necessary. All groundwater samples will be analyzed for TCL VOCs and the natural attenuation parameters listed in Table 5-1. All surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 4D also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

5.2.5 RAA 5D: In-Well Aeration - Expanded System

RAA 5D expands upon the in-well aeration system presented in RAA 4D by attempting to treat all of the contaminated groundwater that exceeds remediation levels, as opposed to only the most highly contaminated (i.e., hot) areas. Figure 5-11 presents a conceptual system layout. This alternative was developed so that a full range of remedial action alternatives (from no action to limited action to full action) could be evaluated.

Under RAA 5D, 11 aeration wells will be installed in the deep aquifer in an attempt to collect all of the contamination that exceeds remediation levels. A separate treatment unit, blower, and vacuum pump will be located by each aeration well. Figure 5-10 presents a typical well detail and process flow diagram. The approximate radius of influence for each aeration well has been estimated to be 110 feet, which is 2 times the saturated thickness of the contaminated aquifer (Buermann and Bott-Bruening, 1994).

Because in-well aeration is a relatively new and innovative technology, a field pilot test is recommended prior to initiating the system design. The pilot test will determine the loss of efficiency over time as a result of inorganics precipitation and oxidation on the well screens, the radius of influence of the aeration wells under various heads of injection pressure, the rate of off-gas contaminant removal via carbon adsorption, and the carbon breakthrough times.

To measure the effects of this alternative, a groundwater and surface water monitoring program will be implemented. The program will include periodic sampling at the locations identified in Figure 5-7, which are the same sampling locations that are associated with RAAs 2D, 3D, and 4D. Additional samples may be added to the monitoring program if necessary. All groundwater and surface water samples will be analyzed for TCL VOCs. If water quality improves over time, the program may be refined to include fewer sampling locations or less frequent sampling events. (For cost estimating purposes, 5 years of quarterly sampling followed by 25 years of semiannual sampling will be assumed.)

RAA 5D also includes aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources.

Since contaminants will remain in the groundwater indefinitely, 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.

SECTION 5.0 TABLES

TABLE 5-1

NATURAL ATTENUATION PARAMETERS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the aquifer matrix.	Fixed-Base Laboratory
Water	VOCs	Contract Laboratory Protocol	Method of analysis includes BTEX and chlorinated solvents/byproducts, which are the primary target analytes for monitoring natural attenuation.	Fixed-Base Laboratory
Water	Oxygen	Dissolved oxygen meter	Concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Field
Water	Nitrate	IC Method E300	Substrate for microbial respiration if oxygen is depleted.	Fixed-Base Laboratory
Water	Iron (II) (Fe^{2+})	Colorimetric Hach Method #8146	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Field
Water	Sulfate (SO_4^{2-})	IC Method E300	Substrate for anaerobic microbial respiration.	Fixed-Base Laboratory
Water	Methane, ethane, and ethene	Kampbell et al., 1989 or SW3810 Modified	The presence of CH_4 suggests BTEX degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing biological transformation.	Fixed-Base Laboratory

TABLE 5-1 (Continued)

NATURAL ATTENUATION PARAMETERS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	Alkalinity	Hach alkalinity test kit model AL AP MG-L	General water quality parameter used (1) to measure the buffering capacity of groundwater, and (2) as a marker to verify that all site samples are obtained from the same groundwater system.	Field
Water	Oxidation-reduction potential (ORP)	A2580B	The ORP of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the ORP of groundwater may range from more than 800 mV to less than -400 mV.	Field
Water	pH	Field probe with direct reading meter	Aerobic and anaerobic processes are pH-sensitive.	Field
Water	Temperature	Field probe with direct reading meter	Well development.	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Field
Water	Major cations	SW6010	Can be used to evaluate other remedial actions.	Field

TABLE 5-1 (Continued)

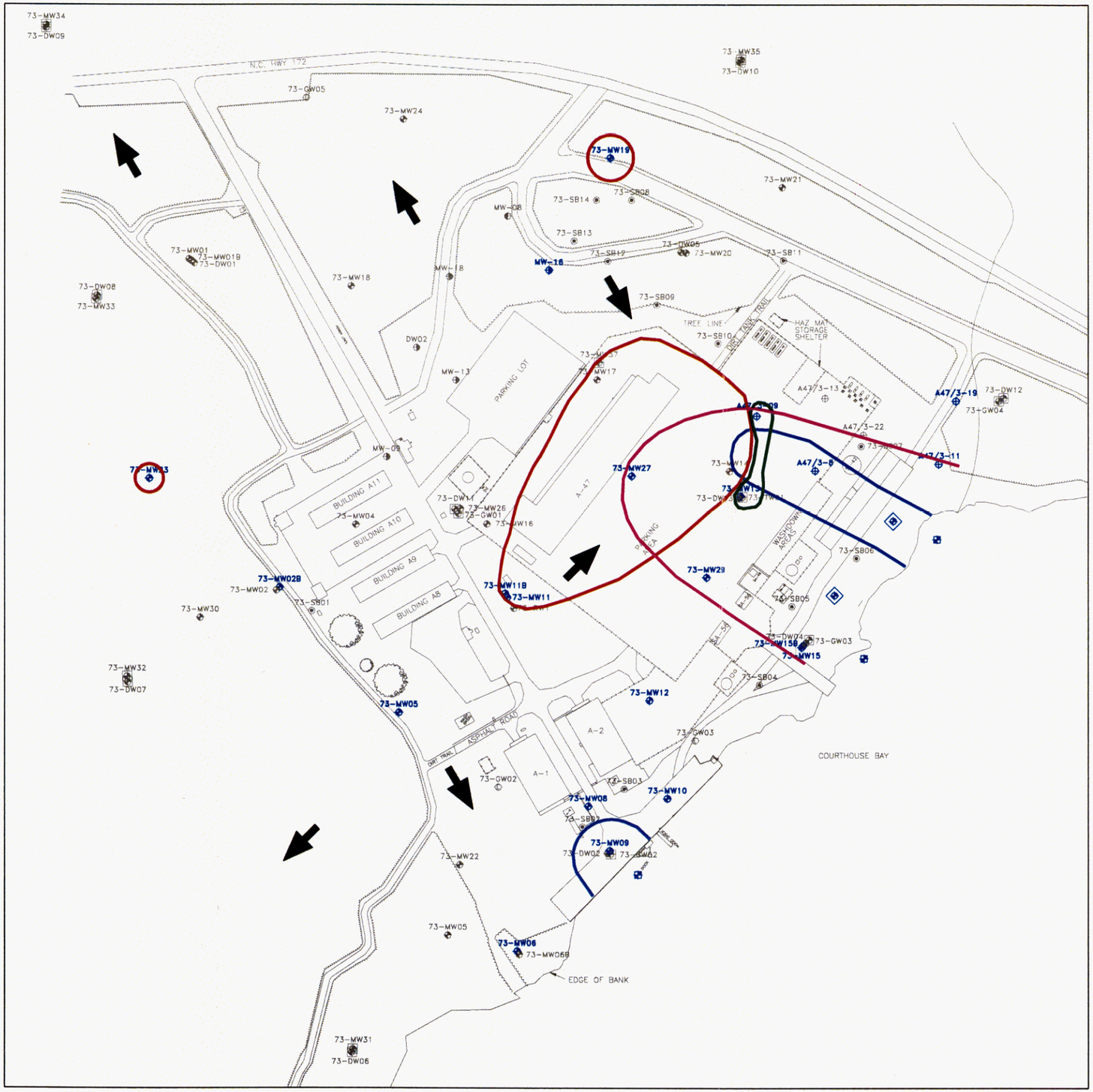
NATURAL ATTENUATION PARAMETERS
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0232
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	Chloride	IC Method E300	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system. Final product of chlorinated solvent reduction.	Fixed-Base Laboratory
Water	Total Organic Carbon	SW9060	Used to classify plume and to determine if cometabolism is possible in the absence of anthropogenic carbon.	Fixed-Base Laboratory
Water	Hydrogen (H_2)[a/]	Equilibration with gas in the field. Determined with a reducing gas detector.	Determine terminal electron accepting process. Predicts the possibility for reductive dechlorination.	Field

Reference: 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 FIGURES

312518FS



SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW
	SURFACE WATER MONITORING LOCATION
	PROPOSED SHALLOW MONITORING WELL LOCATION

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 2.8 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE = 70 ppb
- VINYL CHLORIDE = 0.015 ppb
- BENZENE = 1 ppb

HIGHLIGHTED WELLS ARE INCLUDED IN THE MONITORING PROGRAM.

500 0 250 500
1 inch = 500 ft.

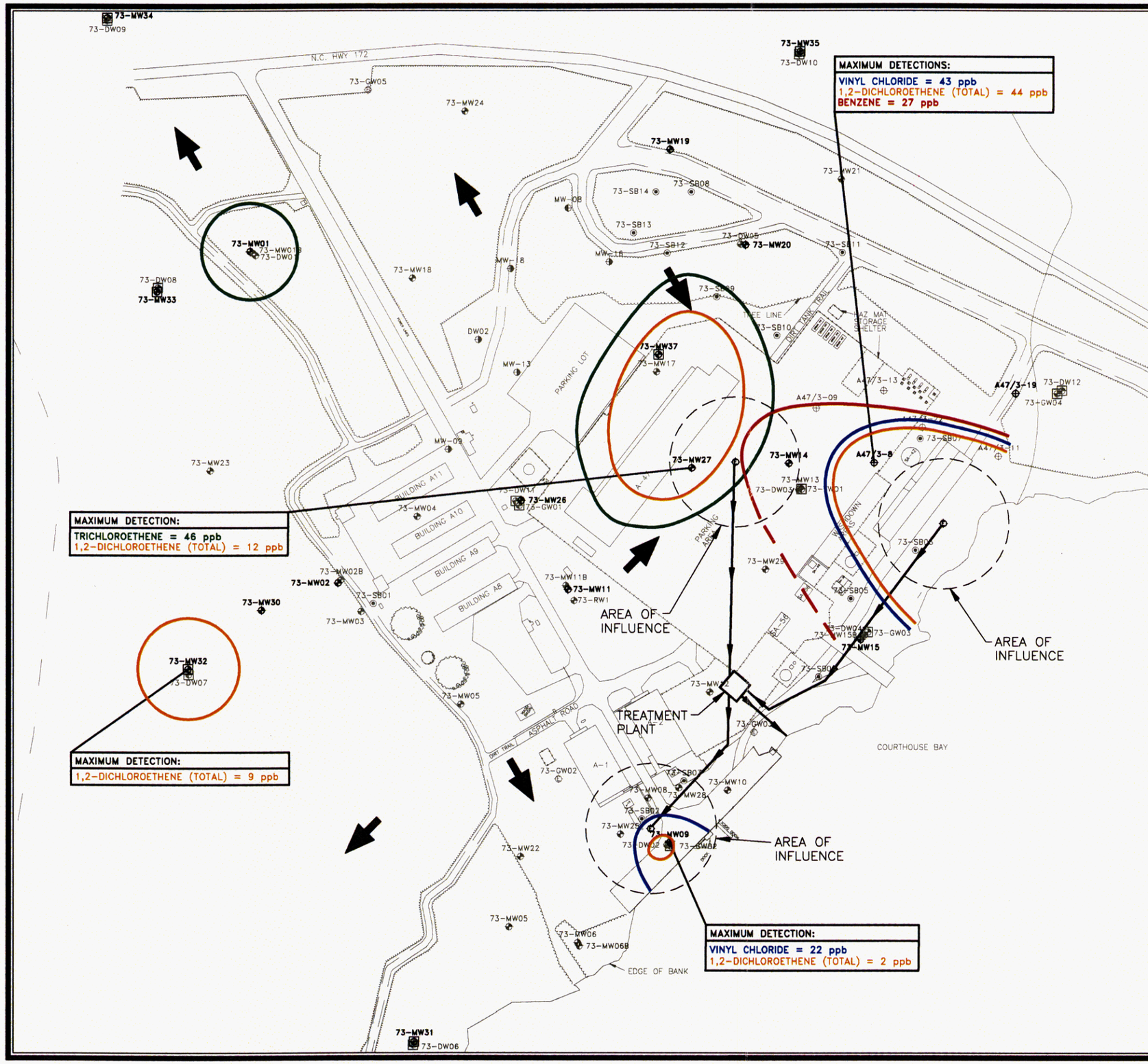
Baker
Baker Environmental, Inc.

FIGURE 5-1
RAA 2S: NATURAL ATTENUATION
SITE 73 -
AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GGB3Y

312066RI



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
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MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	EXTRACTION WELL
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb
- BENZENE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE SURFICAL AQUIFER WAS USED TO DEVELOP ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

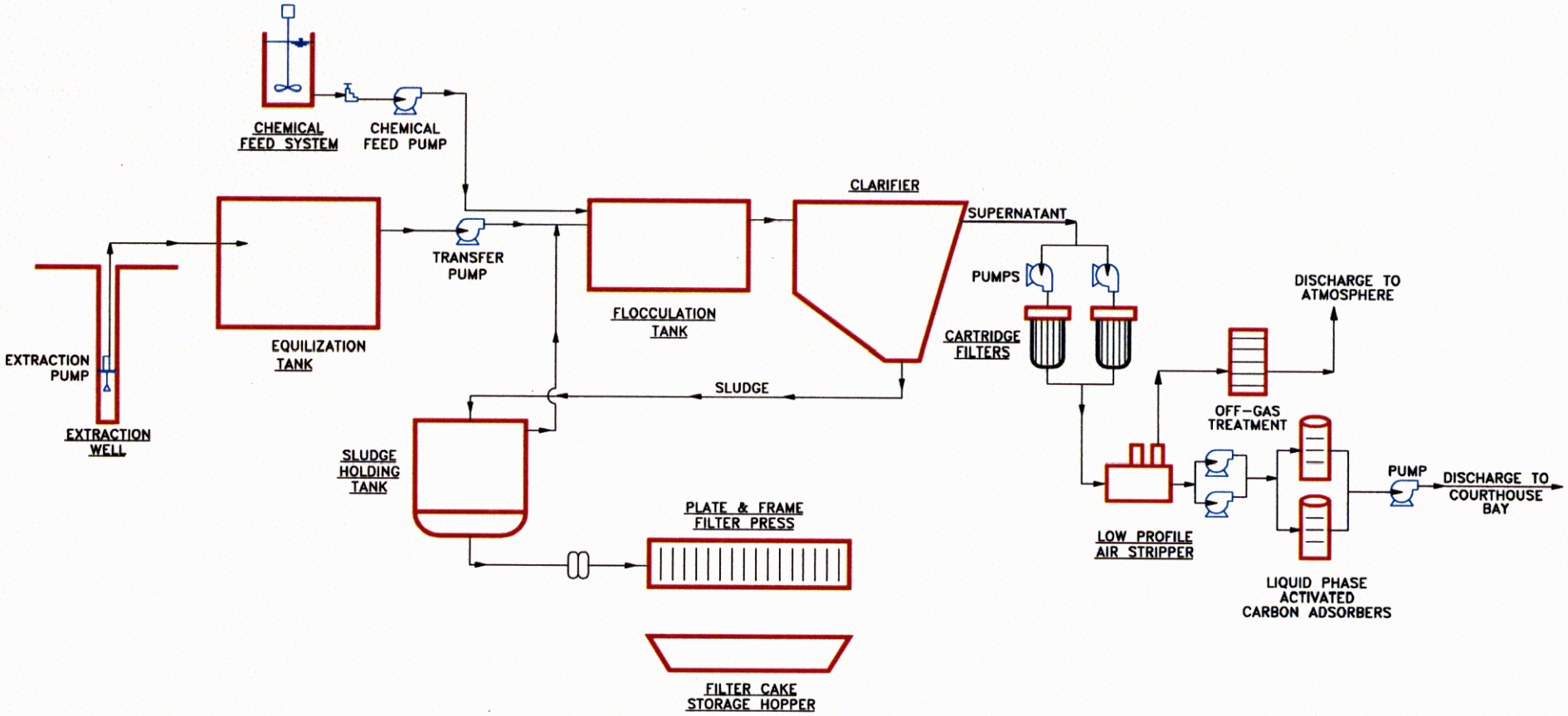
SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250
1 inch = 250 ft.

Baker
Baker Environmental, Inc.

FIGURE 5-2
RRA 3S: GROUNDWATER EXTRACTION AND TREATMENT
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

FIGURE 5-3
GROUNDWATER EXTRACTION AND TREATMENT – PROCESS FLOW DIAGRAM
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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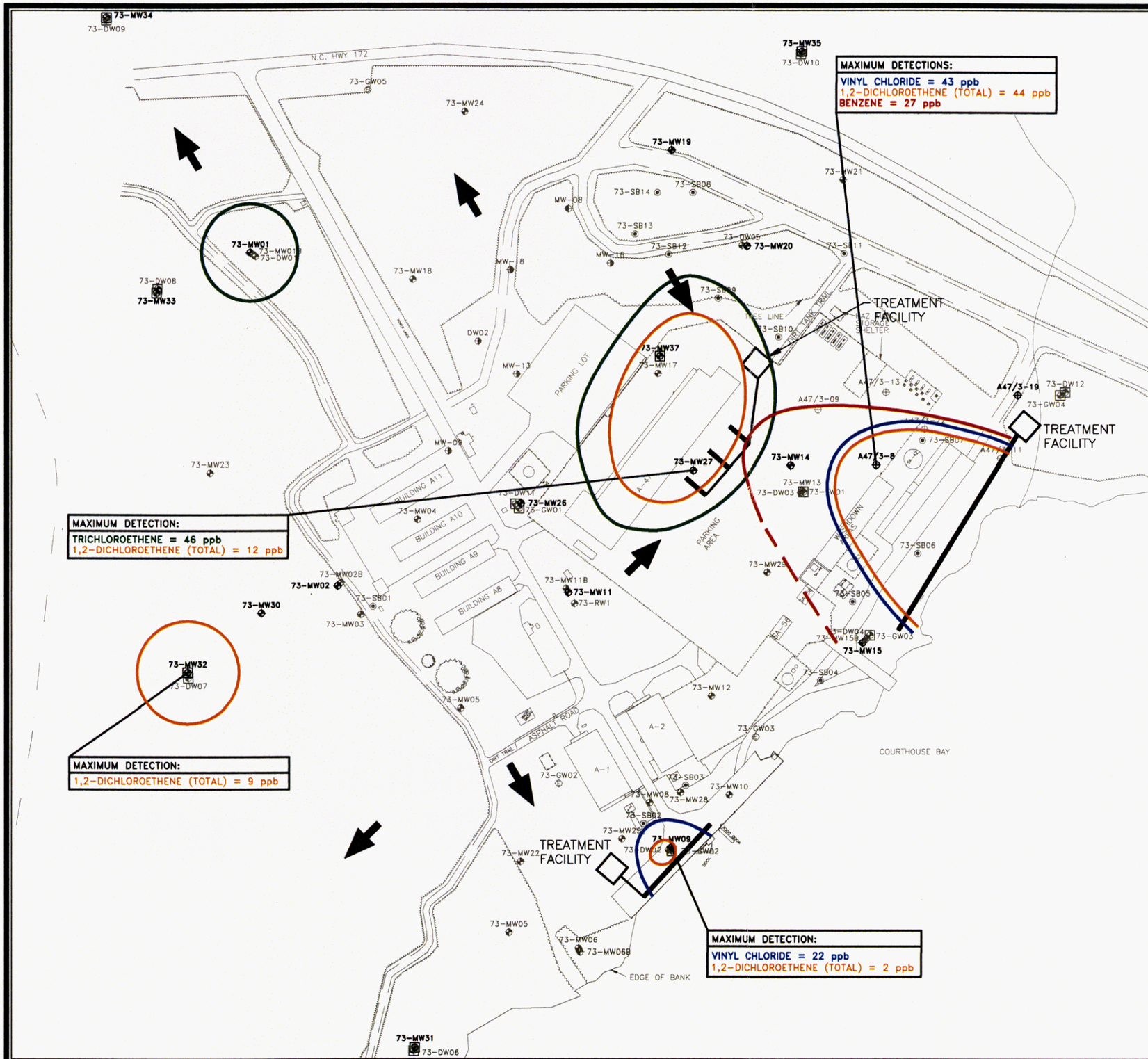
312069RI



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb
- BENZENE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE SURFICAL AQUIFER WAS USED TO DEVELOP ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250

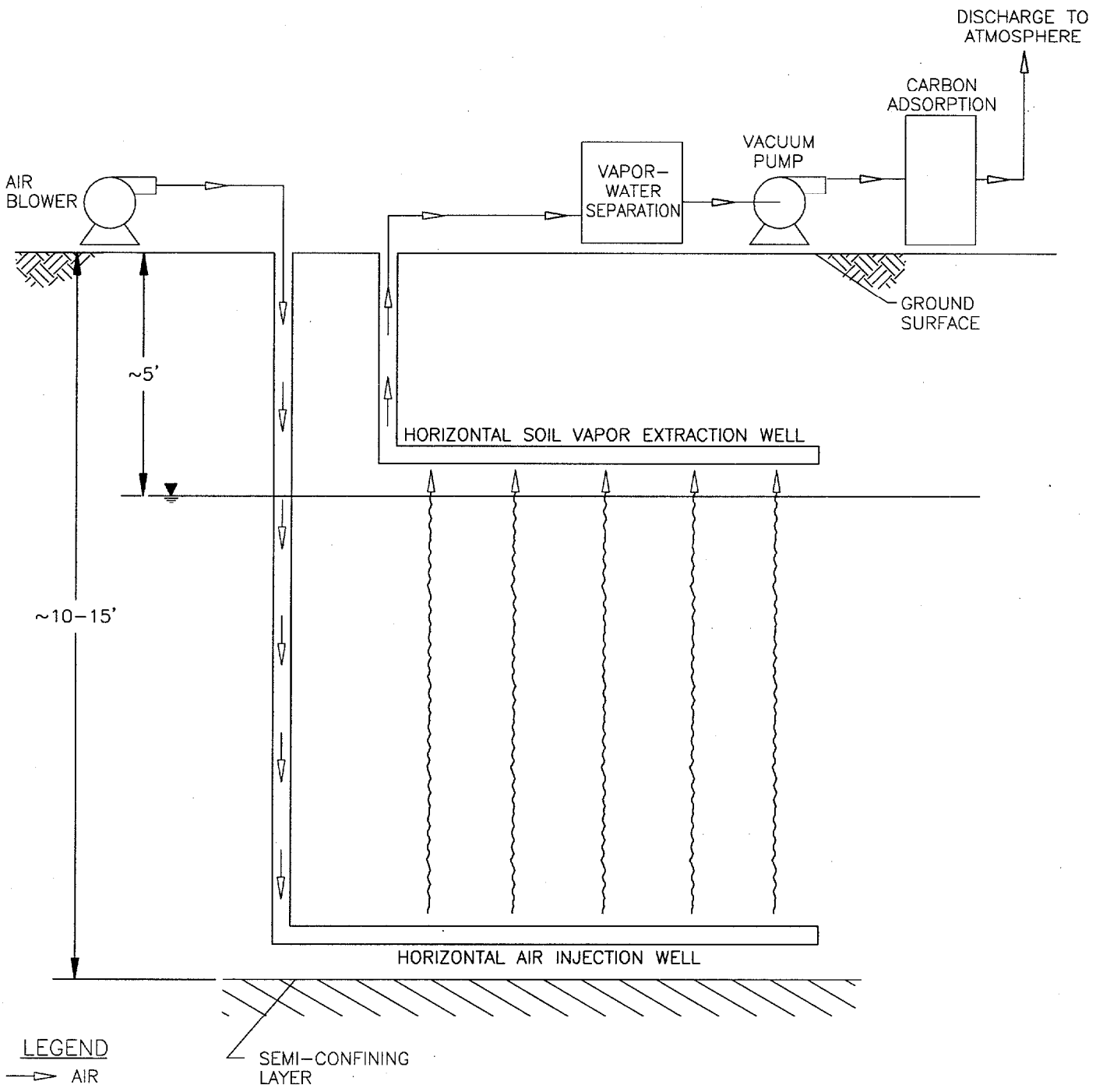
1 inch = 250 ft.

Baker

Baker Environmental, Inc.

FIGURE 5-4
RRA 4S: AIR SPARGING AND SOIL VAPOR EXTRACTION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



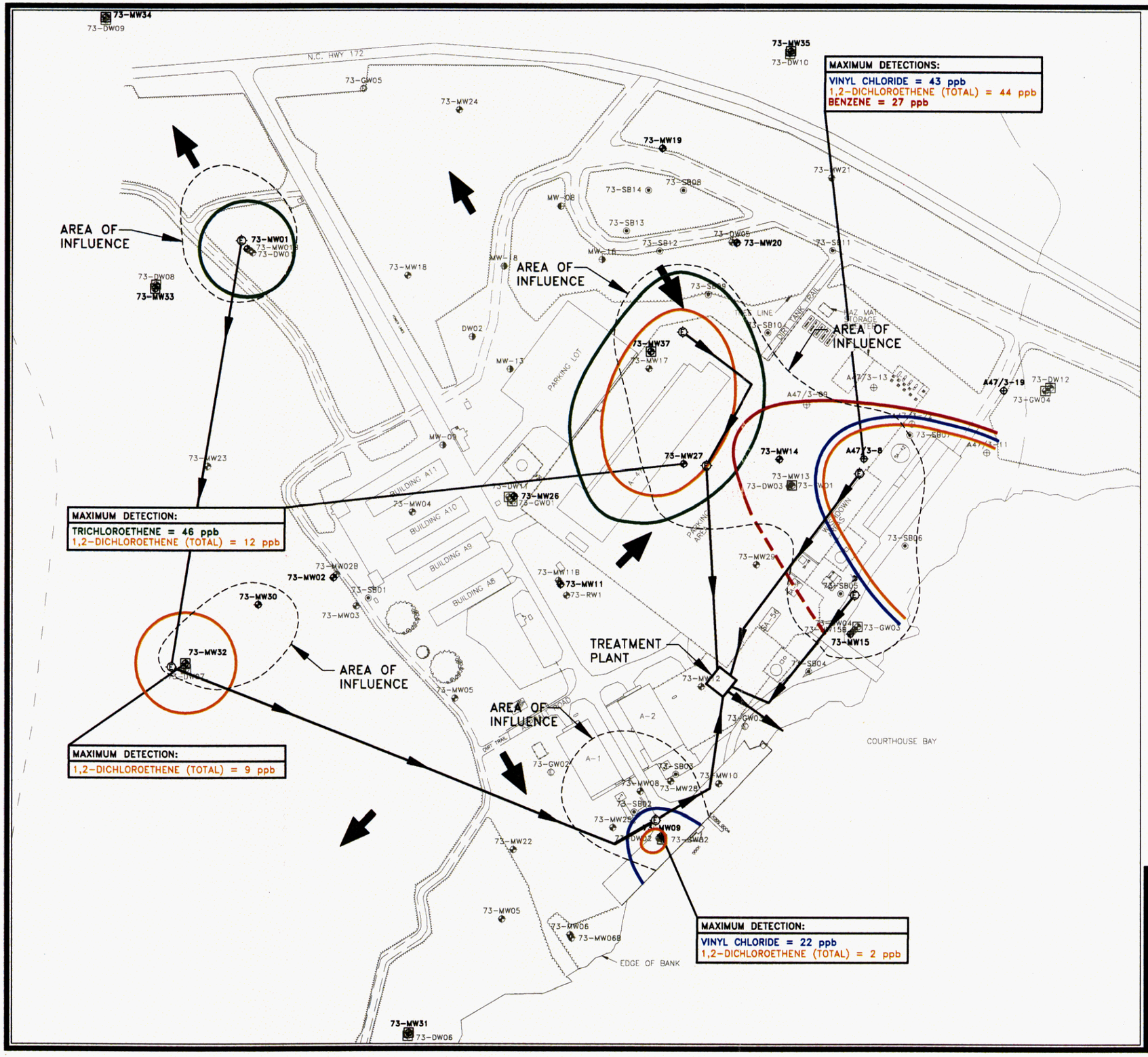
Baker

Baker Environmental, Inc.

312514FS

FIGURE 5-5
AIR SPARGING AND SOIL VAPOR EXTRACTION -
PROCESS FLOW DIAGRAM
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

312073RI



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	EXTRACTION WELL
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb
- BENZENE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE SURFICAL AQUIFER WAS USED TO DEVELOP ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250
1 inch = 250 ft.

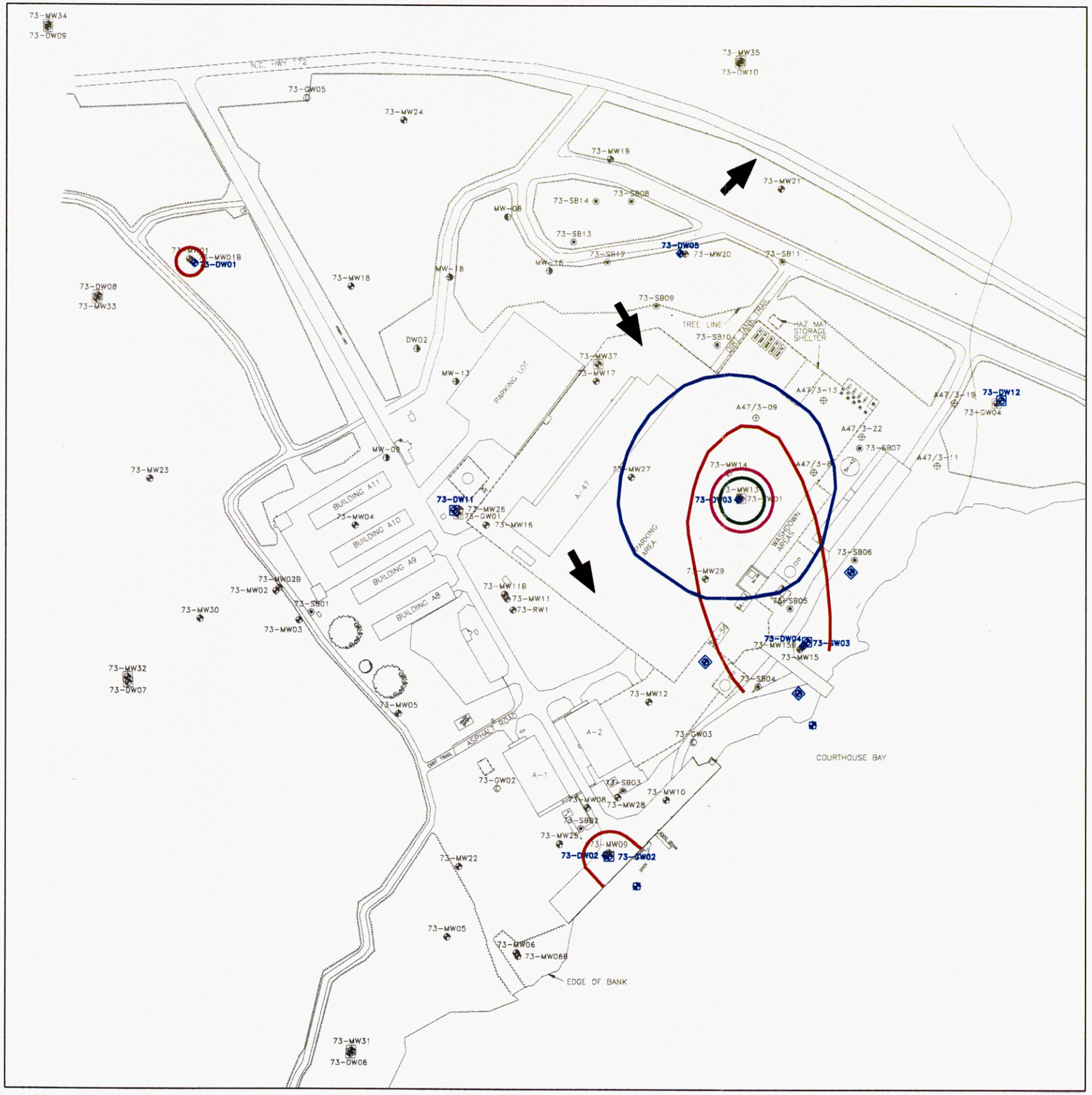
Baker
Baker Environmental, Inc.

FIGURE 5-6
RAA 5S: GROUNDWATER EXTRACTION AND TREATMENT - EXPANDED SYSTEM
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GGB4Y

312519FS



SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
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MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW
	SURFACE WATER MONITORING LOCATION.
	PROPOSED DEEP MONITORING WELL LOCATION.

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 2.8 PARTS PER BILLION (ppb)
- CIS-1,2-DICHLOROETHENE = 70 ppb
- VINYL CHLORIDE = 0.015 ppb
- BENZENE = 1 ppb

HIGHLIGHTED WELLS ARE INCLUDED IN THE MONITORING PROGRAM.

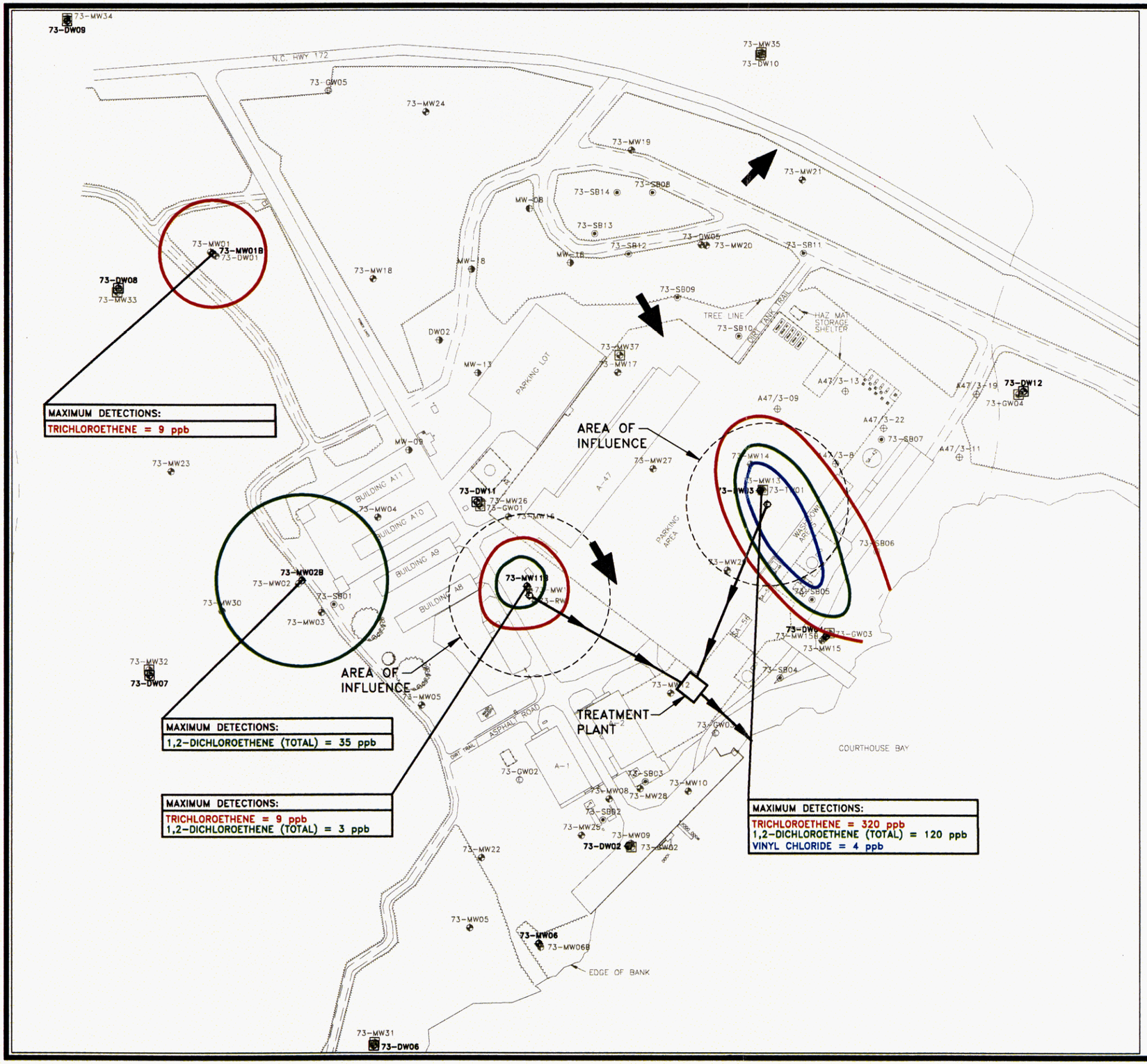
500 0 250 500
1 inch = 500 ft.

Baker
Baker Environmental, Inc.

FIGURE 5-7
RAA 2D: NATURAL ATTENUATION
SITE 73 -
AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

312068RI



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73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
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73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	EXTRACTION WELL
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- 1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE CASTLE HAYNE AQUIFER AND LOWER PORTION OF THE SURFICIAL AQUIFER. WAS USED TO DEVELOP THE ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

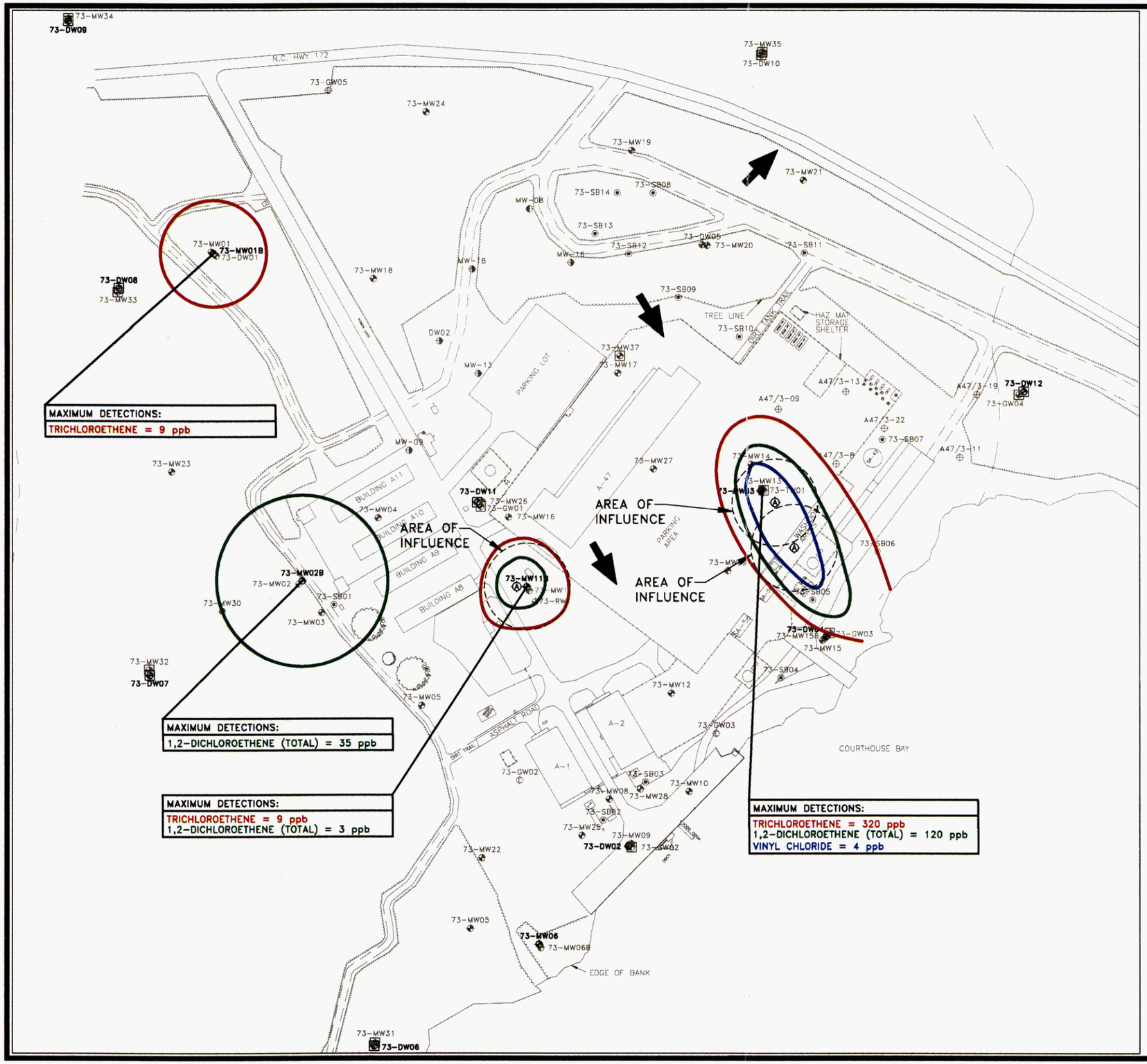
250 0 125 250
1 inch = 250 ft.

Baker
Baker Environmental, Inc.

FIGURE 5-8
RAA 3D: GROUNDWATER
EXTRACTION AND TREATMENT
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

312074RI



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
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73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	AERATION WELL
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- 1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE CASTLE HAYNE AQUIFER AND LOWER PORTION OF THE SURFICIAL AQUIFER. WAS USED TO DEVELOP THE ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250

1 inch = 250 ft.

Baker

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FIGURE 5-9
RAA 4D: IN-WELL AERATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

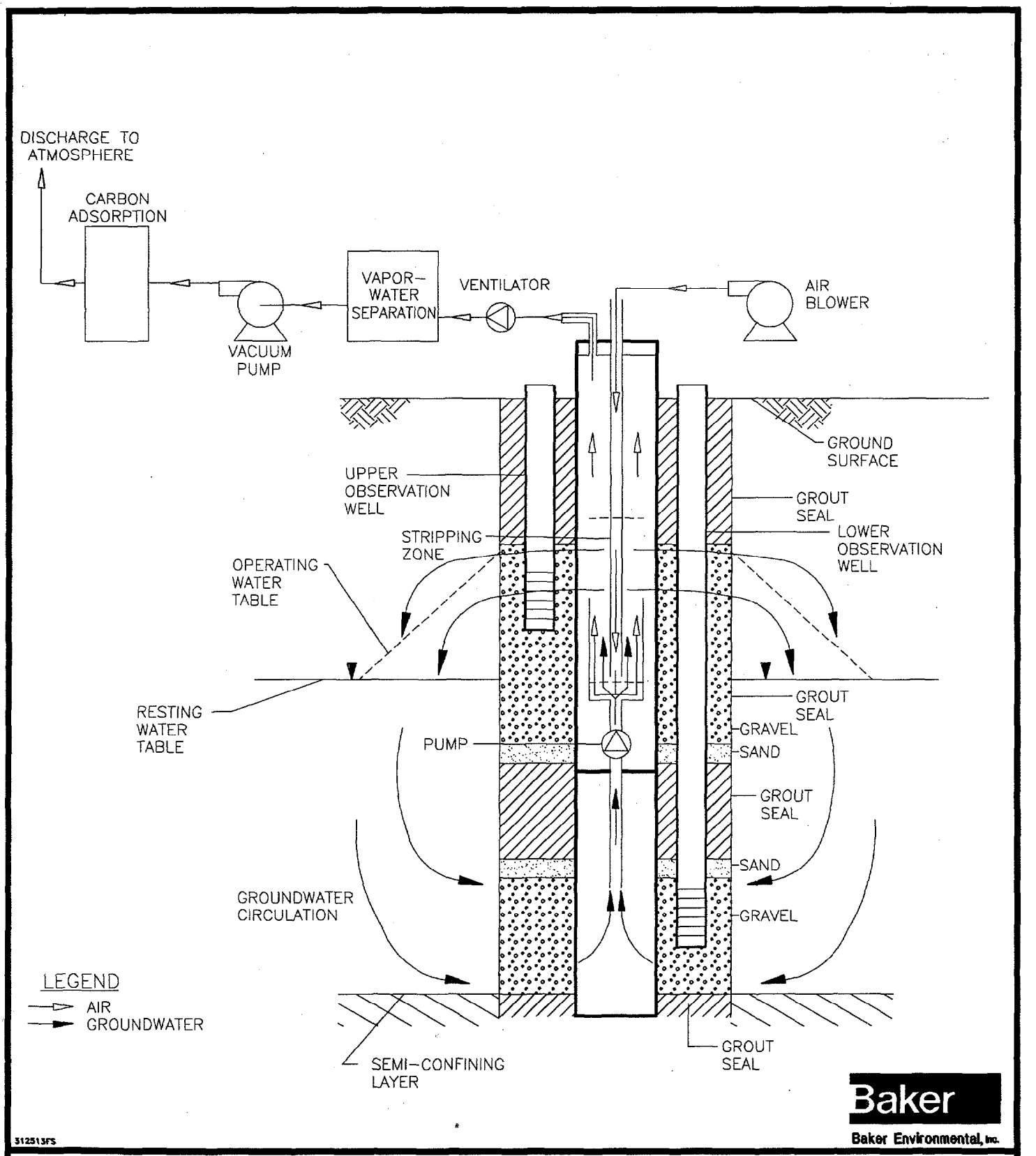
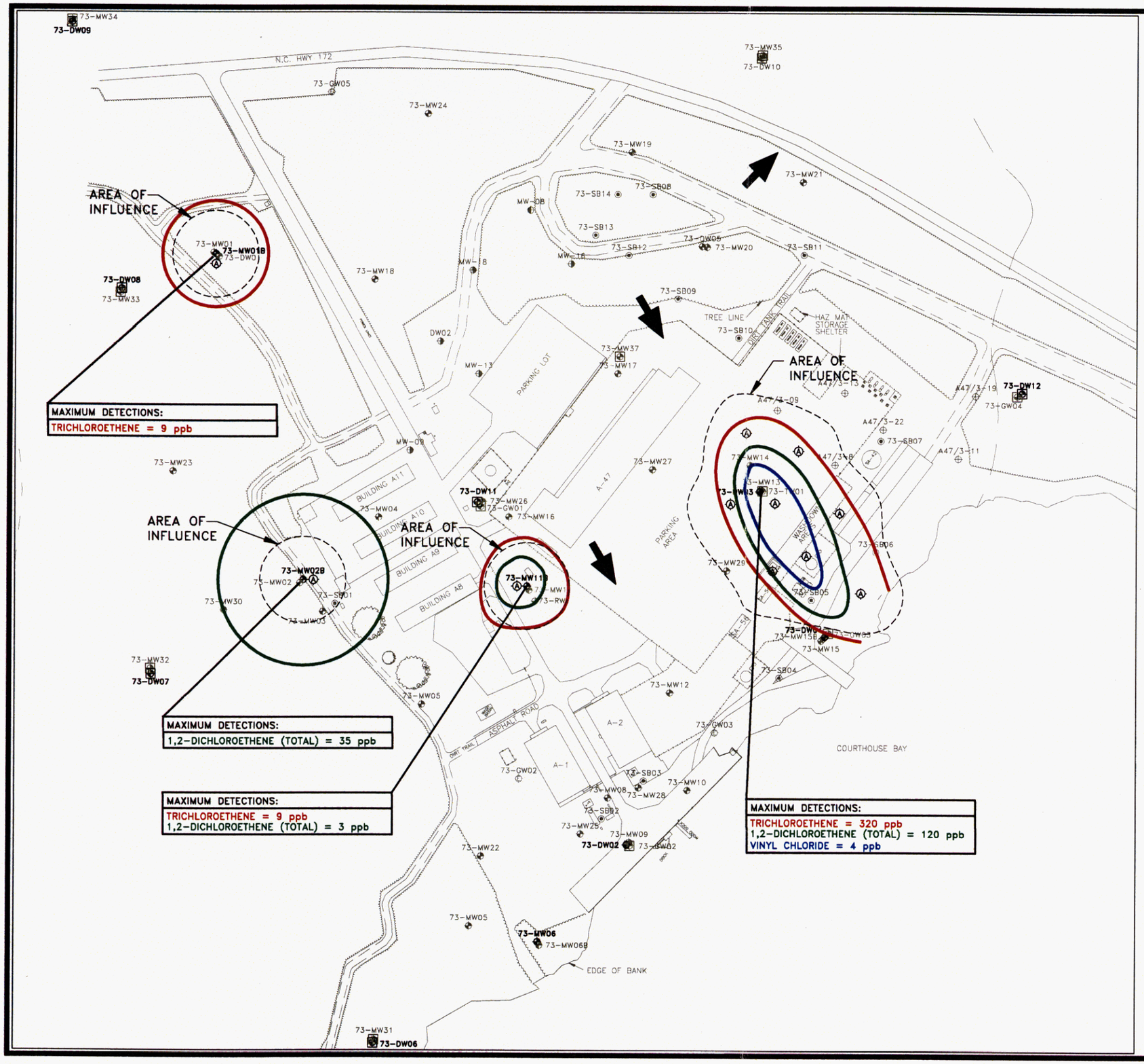


FIGURE 5-10
IN-WELL AERATION -
TYPICAL WELL DETAIL AND PROCESS FLOW DIAGRAM
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

312075RI



LEGEND

73-SB01	SOIL BORINGS ADVANCED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW01	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE I (APRIL-MAY, 1995)
73-MW31	MONITORING WELLS INSTALLED BY BAKER DURING REMEDIAL INVESTIGATION, PHASE II (FEBRUARY-MARCH, 1996)
A47/3-8	MONITORING WELLS INSTALLED DURING UST INVESTIGATION BY GSI AND LAW-CATLIN AND ASSOCIATES (1993)
MW-18	MONITORING WELLS INSTALLED BY BAKER DURING UST INVESTIGATION (1992 AND 1993)
MW-08	MONITORING WELLS INSTALLED DURING A UST INVESTIGATION BY ATEC AND ASSOCIATES (1991)
73GW-02	MONITORING WELLS INSTALLED BY ESE DURING CONFIRMATORY SAMPLING (1990)
	AERATION WELL
	APPROXIMATE DIRECTION OF GROUNDWATER FLOW

NOTES:

THE FOLLOWING ISOCONCENTRATION LINES DEFINE THE AREAS OF CONCERN:

- TRICHLOROETHENE = 1.0 PARTS PER BILLION (ppb)
- 1,2-DICHLOROETHENE (TOTAL) = 1.0 ppb
- VINYL CHLORIDE = 1.0 ppb

PHASE II DATA FROM THE UPPER PORTION OF THE CASTLE HAYNE AQUIFER AND LOWER PORTION OF THE SURFICIAL AQUIFER. WAS USED TO DEVELOP THE ISOCONCENTRATION LINES.

BOLDED WELLS WERE SAMPLED BUT NO CONTAMINATION WAS DETECTED.

SOURCE: LANIER SURVEYING CO., APRIL 4, 1996.

250 0 125 250
1 inch = 250 ft.

Baker
Baker Environmental, Inc.

FIGURE 5-11
RAA 5D: IN-WELL AERATION - EXPANDED SYSTEM
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02590GG05Y

6.0 DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES

This section contains a detailed analysis of the surficial aquifer RAAs that were developed in Section 5.0. Section 6.1 presents an overview of the nine USEPA evaluation criteria that will be used in the detailed analysis. An individual analysis of each alternative, with respect to the evaluation criteria, is presented in Section 6.2, and a comparative analysis of the alternatives is presented in Section 6.3. (Please note that the detailed analysis of the deep aquifer RAAs will be conducted in Section 7.0.)

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). (An initial screening of alternatives was not conducted.)

The detailed analysis 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 restoration advisory board (RAB) has reviewed the FS and PRAP. The RAB includes participants from the NC DEHNR, USEPA Region IV, and the public.

6.1 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 criterion 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 3.0 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 in 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 O&M costs incurred over the life of the project. The focus during the detailed analysis is on the net present worth (NPW) of these costs. The selected remedy will be the most cost-effective alternative that is still capable of achieving the remedial action objectives.

As per the 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. For this FS, the NPW costs were calculated assuming a five percent discount factor and a zero percent inflation rate. Appendices C and D present the cost estimates developed for the surficial and deep aquifer RAAs, respectively.

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 comments 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.

6.2 Individual Analysis of Alternatives

The following subsections present the detailed analysis of the surficial aquifer 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 6-1 summarizes the individual, detailed analysis of alternatives.

6.2.1 RAA 1S: No Action

Description

Under the no action alternative, contaminated groundwater in the surficial aquifer will remain as it currently is. No active remedial actions will be implemented.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 1S, contaminants in the surficial aquifer will remain untreated and will continue to discharge into Courthouse Bay. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- According to the human health and ecological RAs, the fuel and chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- The groundwater contamination that is migrating into Courthouse Bay appears to be discharging at levels that will not adversely affect potential receptors. The North Carolina Framework Groundwater-Surface Water Model (located in Appendix B) was used to determine the maximum groundwater concentrations that can discharge into Courthouse Bay before unsafe surface water conditions develop. The contaminant concentrations that are currently discharging into the bay are far below

the acceptable discharge limits that were developed using the model. In addition, the maximum contaminant concentrations detected at the site are far below the acceptable discharge limits.

- According to The Technical Protocol for Evaluationg Natural Attenuation of chlorinated Solvents in Groundwater (Wiedemeyer, 1996) and the Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater (Wiedemeier, 1995) fuel and chlorinated solvent contaminants are capable of naturally attenuating provided the appropriate conditions are present at the site. The contamination at Site 73 appears to be naturally attenuating because TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected. The arrangement of the TCE, cis-1,2-DCE, and vinyl chloride plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation. Thus, the contamination in the surficial aquifer, if left untreated, is expected to naturally attenuate over time.

Based on this information, no action is a justifiable solution for the surficial aquifer. RAA 1S, however, fails to provide a means (such as a monitoring program or aquifer-use restrictions) for ensuring the protection of human health and the environment over time. The alternative also will not achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"). Based on this information, RAA 1S will not provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 1S, no active effort will be made to reduce contaminant levels to below chemical-specific ARARs. Natural attenuation processes, however, are expected to eventually achieve these ARARs. Thus, RAA 1S has the potential to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over an extended period of time. A waiver of the chemical-specific ARARs may be required before this alternative can be implemented. No action-specific or location-specific ARARs apply to this no action alternative.

Long-Term Effectiveness and Permanence: No action is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant both now and in the future; 2) the North Carolina Framework Groundwater-Surface Water Model indicates that the groundwater contamination is not adversely impacting Courthouse Bay; and 3) the fuel and chlorinated solvent contamination appears to be naturally attenuating. However, RAA 1S does not ensure the safety of potential receptors over time. The alternative provides no means for monitoring contaminant concentrations, prohibiting future potable use of the surficial aquifer, or proving that natural attenuation is indeed occurring. As a result, the safety of potential receptors will be uncertain and RAA 1S will not provide long-term effectiveness and permanence.

Under RAA 1S, 5-year reviews by the lead agency will be required. However, these reviews alone will not be sufficient for ensuring the safety of potential receptors.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The no action alternative does not provide a treatment process; there will be no toxicity, mobility, or volume reduction through active treatment. There may, however, be some toxicity, mobility, or volume reduction through passive treatment (i.e., natural attenuation processes). Thus, RAA 1S does not satisfy the statutory preference for treatment.

Short-Term Effectiveness: There are no remedial action activities associated with RAA 1S. As a result, short-term potential risks to the community and workers will not be increased, and there will be no additional environmental impacts.

Implementability: The no action alternative is implementable since no additional construction or operation activities will be conducted. In terms of administrative feasibility, RAA 1S should not require additional coordination with other agencies. The availability of services, materials, and/or technologies is not applicable to this alternative.

If groundwater quality appears to be deteriorating, additional remedial actions could easily be implemented under RAA 1S.

Cost: There are no capital costs or O&M costs associated with this alternative. The NPW is $0.

6.2.2 RAA 2S: Natural Attenuation

Description

Under RAA 2S, no active remedial actions will be implemented for the surficial aquifer contamination. Instead, passive treatment via natural attenuation processes will be relied upon to reduce contaminant levels. The main component of RAA 2S is a long-term groundwater and surface water monitoring program. Groundwater samples will be analyzed for TCL VOCs and natural attenuation parameters. These parameters will indicate the type of natural biodegradation that is occurring in the aquifer, and the amount of contaminant reduction that can be expected. Surface water samples will be analyzed for TCL VOCs. RAA 2S will also include aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources. To further support the occurrence of natural attenuation, RAA 2S may include two optional components: a contaminant fate and transport model and a laboratory microcosm study.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 2S, contaminants in the surficial aquifer will remain untreated and will continue to discharge into Courthouse Bay. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- According to the human health and ecological RAs, the fuel and chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- The groundwater contamination that is migrating into Courthouse Bay appears to be discharging at levels that will not adversely affect potential receptors. The North Carolina Framework Groundwater-Surface Water Model (located in Appendix B) was used to determine the maximum groundwater concentrations that can discharge into Courthouse Bay before unsafe surface water conditions develop. The contaminant concentrations that are currently discharging into the bay are far below the acceptable discharge limits that were developed using the model. In addition,

the maximum contaminant concentrations detected at the site are far below the acceptable discharge limits.

- Technical literature (see Section 8.0) indicates that fuel and chlorinated solvent contaminants are capable of naturally attenuating provided the appropriate conditions are present at the site. The contamination at Site 73 appears to be naturally attenuating because TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected. The arrangement of the TCE, cis-1,2-DCE, and vinyl chloride plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation. Thus, the contamination in the surficial aquifer, if left untreated, is expected to naturally attenuate over time.

Based on this information, no active groundwater treatment is a justifiable solution for the surficial aquifer. RAA 2S ensures the protection of human health and the environment through natural attenuation, monitoring, and aquifer-use restrictions. Thus, RAA 2S will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"), and the alternative will provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 2S, no active effort will be made to reduce groundwater contaminant levels below federal MCLs or NC WQSs (groundwater). However, a Natural Attenuation Evaluation Study (NAES) will be conducted at Site 73 to assess natural attenuation processes. It is anticipated that the results of this study will provide evidence that natural attenuation processes are reducing contaminant levels.

A review of the action-specific ARARs indicated that this alternative must comply with the requirements outlined in 15A NCAC 2L .0106 , section (l) and discussed in 15A NCAC 2L Implementation Guidance (Implementation Guidance). In order to comply with 15A NCAC 2L the ten following conditions (enumerated items) must be demonstrated. Following each of these items is an explanation of how each condition will be met.

- " (1) that all sources of contamination and free product have been removed or controlled;"

  No soil contamination associated with dissolved- phase groundwater contamination or free product was detected during either phase of the RI. The results of surface and subsurface soils analysis collected under the RI will be included in the Corrective Action Plan (CAP).

- " (2) that the contaminant has the capacity to degrade or attenuate under the site-specific conditions;"

  As a part of the NAES, the appropriate geochemical and contaminant data will be gathered and an assessment of the aquifer's ability to degrade and attenuate the COCs will be performed The data and results of the NAES will be used in the development of the Corrective Action Plan (CAP).

  The sample strategy plan that will support the NAES will be developed using the following documents: 15A NCAC 2L Implementation Guidance; Technical Protocol

For Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1996); Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation (Wiedemeier, 1995); and OSWER Directive 9200.4-17, Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.

- " (3) that the time and direction of contaminant travel can be predicted with reasonable certainty;"

  A three-dimensional groundwater model has been developed for this site and can be used to estimate the time and direction of contaminant travel. Multiple rounds of static water levels were collected during the RI that supported the development of this model. However, simple analytical calculations or a simple one-dimensional model may also be used to estimate travel time.

  The technical basis for determining the values of aquifer parameters used in any calculations or models will be discussed in the CAP.

- " (4) that contaminant migration will not result in any violation of applicable groundwater standards at any existing or foreseeable receptor;"

  The Implementation Guidance generally defines receptors as utility lines, basements, elevator shafts, surface waters, domestic supply wells and regions of groundwater that have been identified for development. The only known receptor at this time is Courthouse Bay. Potential receptors that have been identified include storm sewer and wash rack conveyance lines that discharge to an on-site oil water separator. Currently, no foreseeable (future) receptors have been identified. Currently there are no formal plans to develop the shallow groundwater resources in the vicinity of site 73.

  The extent of the shallow groundwater contamination at the Courthouse Bay shoreline has not been clearly delineated. Multiple surface water and sediment samples were obtained from Courthouse Bay during the RI. No site-related volatile organic compounds were detected in these samples. As a part of the NAES additional monitoring wells will be installed along the shoreline to determine if groundwater at the Courthouse Bay is in violation of MCLs or NC WQS (groundwater).

  Typically, storm sewer and wash rack conveyance lines, where possible, are installed above the water table and are therefore not exposed to shallow groundwater contamination. Using MCB Camp Lejeune Public Works records the elevations of storm sewer lines with respect to the water table will be determined.

  Currently the surficial aquifer at MCB Camp Lejeune is not typically used as a source of drinking water. However, to identify foreseeable receptors Planning and Public Works departments at MCB Camp Lejeune will be contacted to determine if formal plans exist for the development of the surficial aquifer in the vicinity of Courthouse Bay as a water resource.

All existing and potential receptors will be shown on a base figure that will be included in the CAP

- " (5) that contaminants have not and will not migrate onto adjacent properties, or that: (A) such properties are served by an existing public water system dependant on surface waters or hydraulically isolated groundwater, or (B) the owners of such properties have consented in writing to the request;"

  The limits of the Site 73 shallow contaminant plume are well inside the boundaries of MCB Camp Lejeune and are not immediately adjacent to other private or government-owned parcels of land. Therefore, off-site migration of shallow groundwater contamination is not an issue. A figure will be provided in the CAP that shows the relationship between Site 73 and the nearest private property.

  Existing data indicates that this plume is in a state of equilibrium. As a part of the NAES additional monitoring wells will be installed and sampled to more clearly define the extent of the contaminant plume and determine if the plume is migrating or shrinking. Contaminant data that will be gathered during the NAES will be compared to existing data in the CAP to further assess the status of the plumes equilibrium. The nearest supply well is located approximately 4,225 feet from Site 73. A figure will be included in the CAP that shows the relationship of the closest supply wells and the contaminant plume.

- " (6) that, if the contaminant plume is expected to intercept surface waters, the groundwater will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 2B .0200;"

  No site-related volatile organic compounds were detected in surface water or sediment samples collected during the RI. The analytical results of the sediment and surface water sampling will be included in the CAP.

- " (7) that the person making the request will put in place a groundwater monitoring program sufficient to track degradation and attenuation of contaminants and contaminant by-products within and down gradient of the plume and to detect contaminants and contaminant by-products prior to their reaching any existing or foreseeable receptor at least one year's travel time up gradient of the receptors and no greater than the distance the groundwater at the contaminated site is predicted to travel in five years;"

  Based on the results of the NAES a groundwater monitoring program will be developed and implemented that will meet the intent of Item (7). The monitoring program will be developed using the following documents 15A NCAC 2L Implementation Guidance; Technical Protocol For Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1996); Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation (Wiedemeier, 1995); and OSWER Directive 9200.4-17, Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites; and OSWER Directive 9200.4-17, Use of

- " (8) that all necessary access agreements needed to monitor groundwater quality have been or can be obtained"

  Site 73 and the surrounding area are part of MCB Camp Lejeune. No access agreements will be required in order to implement the groundwater monitoring program.

- " (9) that public notice of this request has been provided in accordance with Rule .0114 (b) of this Section;"

  Public notification and review of the selected remedy at Site 73 is required under CERCLA. Prior to the signing of the Record of Decision (ROD) a public notice will be placed in a local newspaper and a public meeting held. It is assumed that public notification under CERCLA meets the requirement of Item (9) and Rule .0114.

- " (10) that the proposed corrective action plan would be consistent with all other environmental laws."

  A review of ARARS will be performed to assure the corrective action plan is consistent with all environmental laws.

Long-Term Effectiveness and Permanence: Leaving the groundwater untreated is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant both now and in the future; 2) the North Carolina Framework Groundwater-Surface Water Model indicates that the groundwater contamination is not adversely impacting Courthouse Bay; and 3) the fuel and chlorinated solvent contamination appears to be naturally attenuating. Through monitoring and aquifer-use restrictions, RAA 2S provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the surficial aquifer, and proving that natural attenuation is indeed occurring. As a result, RAA 2S will ensure the safety of potential receptors over time and will provide long-term effectiveness and permanence.

Under RAA 2S, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 2S does not provide an active treatment process; there will be no toxicity, mobility, or volume reduction through active treatment. There may, however, be some reduction in toxicity, mobility, and volume through passive treatment (i.e., natural attenuation). Thus, RAA 2S satisfies the statutory preference for treatment.

Short-Term Effectiveness: Under RAA 2S, the only activities that may increase risks to the community and to workers are monitoring well installation and periodic groundwater and surface water sampling. However, proper materials handling procedures and personal protective equipment (PPE) should sufficiently protect against these risks. RAA 2S will not create any additional environmental impacts. The time required for the action to be complete cannot be estimated, but 30 years was assumed for cost estimating purposes.

Implementability: RAA 2S is a technically implementable alternative since monitoring well installation, groundwater and surface water monitoring, and ordinance procurement have been easily implemented in the past. If water quality appears to be deteriorating over time, additional remedial actions could easily be implemented under RAA 2S.

In terms of administrative feasibility, this alternative will not require additional coordination with other agencies. However, semiannual reports must be submitted to document sampling procedures. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 2S is $275,000. The projected annual O&M costs are approximately $185,000 for quarterly sampling in years 1-5, and $94,000 for semiannual sampling in years 6-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $2,068,000. Table C-2 (Appendix C) presents a cost estimate for RAA 2S.

6.2.3 RAA 3S: Groundwater Extraction and Treatment

Description

RAA 3S is a conventional pump and treat alternative which incorporates groundwater extraction wells and ex situ, on-site treatment. Under RAA 3S, extraction wells will be positioned to collect the hot portions of the contaminated plumes and to collect the contamination that is trapped underneath the concrete structure near 73-MW09. Portions of the plume that do not receive active treatment are assumed will experience contaminant reduction through natural attenuation. The extracted groundwater will be conveyed to an on-site treatment facility where it will receive suspended solids/metals pretreatment and air stripping for VOC removal. Once treated, the groundwater will be discharged to Courthouse Bay. In addition to a pump and treat system, RAA 3S includes a groundwater and surface water monitoring program and aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 3S, the hot areas of contamination will receive active treatment in the form of a pump and treat system. The remaining contamination will experience passive remediation through natural attenuation processes. To ensure the safety of potential receptors over time, monitoring and aquifer use restrictions are included under RAA 3S. Thus, RAA 3S will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The pump and treat system and natural attenuation processes associated with RAA 3S are expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 3S is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAA 3S can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 3S incorporates an active groundwater treatment system and natural attenuation processes to reduce contaminant levels in the surficial aquifer. Through monitoring and aquifer use restrictions, RAA 3S will ensure the safety of potential receptors over time. As a result, RAA 3S will provide long-term effectiveness and permanence.

Pump and treat systems, however, are only effective to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into pore spaces and fissures where they become difficult to extract. The potential for inorganics precipitation to clog well screens also limits the reliability of the extraction well technology.

Under RAA 3S, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The active treatment processes associated with RAA 3S include air stripping and liquid-phase carbon adsorption for VOC removal, and neutralization, precipitation, flocculation, sedimentation, and filtration for suspended solids/metals removal. RAA 3S also includes natural attenuation as a passive treatment process. These treatment processes will reduce the mobility, toxicity, and volume of contaminants. The time frame in which these reductions will occur is assumed to be 30 years.

RAA 3S satisfies the statutory preference for treatment. Residuals remaining after treatment may include sludge, spent carbon, and treated groundwater.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the pump and treat system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 3S may cause aquifer drawdown during groundwater extraction. Excessive drawdown could result in foundation settlement. However, through the proper placement of extraction wells and system operation the effects of aquifer drawdown can be minimized.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 30 years of system operation and monitoring have been assumed.

Implementability: RAA 3S is a technically implementable alternative. All of the associated technologies are conventional and well-demonstrated to be implementable. However, extraction well and piping installation will be difficult due to the pavement removal that will be required and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system will be energy-intensive and frequent maintenance and equipment replacement may be required. Dissolved metals will most likely precipitate out of solution and clog the extraction well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 3S.

In terms of administrative feasibility, RAA 3S will require extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of water discharge permits will have to be met. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 3S is $1,194,000. The projected annual O&M costs are $185,000 for quarterly sampling in years 1-5, $94,000 for semiannual sampling in

years 6-30, and $45,000 for treatment system O&M in years 1-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $3,725,000. Table C-3 (Appendix C) presents the cost estimate for RAA 3S.

6.2.4 RAA 4S: Air Sparging and Soil Vapor Extraction

Description

Under RAA 4S, horizontal air injection and soil vapor extraction wells will be installed to collect VOC contamination from the upper portion of the surficial aquifer. The wells will be positioned to treat the hot portions of the contaminated plumes and to treat the contamination that is trapped underneath the concrete structure near 73-MW09. Portions of the plumes that do not receive active treatment are assumed will experience contaminant reduction through natural attenuation. Volatilized contaminants that are captured by the SVE wells will be conveyed to on-site treatment facilities. The treatment facilities will contain vapor-phase carbon adsorption units and the necessary air blowers and vacuum pumps. In addition to an air sparging/SVE system, RAA 4S includes a groundwater and surface water monitoring program and aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 4S, the hot areas of contamination will receive active treatment in the form of an air sparging/SVE system. The remaining contamination will experience passive remediation through natural attenuation processes. To ensure the safety of potential receptors over time, monitoring and aquifer-use restrictions are included under RAA 4S. Thus, RAA 4S will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The air sparging/SVE system and natural attenuation processes associated with RAA 4S are expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 4S is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAA 4S can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 4S incorporates an active groundwater treatment system and natural attenuation processes to reduce contaminant levels in the surficial aquifer. Through monitoring and aquifer use restrictions, RAA 4S will ensure the safety of potential receptors over time. As a result, RAA 4S will provide long-term effectiveness and permanence.

Under RAA 4S, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The active treatment processes associated with RAA 4S include in situ air stripping and vapor-phase carbon adsorption. RAA 4S also includes natural attenuation as a passive treatment process. These treatment processes will reduce the toxicity, mobility, and volume of the contaminants. The time frame in which these reductions will occur is assumed to be 10 years based on technical literature (see Section 8.0).

RAA 4S satisfies the statutory preference for treatment. Residuals remaining after treatment may include spent carbon and separated water from the vapor-water separation unit.

Short-Term Effectiveness: Dust production during the underground piping and horizontal well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the air sparging/SVE system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 4S may result in vapor build up underneath foundations or paved areas. However, through adequate monitoring , vapor build up can be detected and the SVE system modified.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 10 years of system operation (based on technical literature referenced in Section 8.0) and 30 years of groundwater and surface water monitoring have been assumed.

Implementability: Although air sparging/SVE is a relatively new and innovative technology, RAA 4S appears to be a technically implementable alternative. However, horizontal well and piping installation will be difficult due to the trenching and pavement removal that will be required, and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system will be energy-intensive and frequent maintenance and equipment replacement may be required. Dissolved metals will most likely precipitate out of solution and clog the air injection well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 4S.

In terms of administrative feasibility, RAA 4S will require extensive coordination with the Base Public Works/Planning Department. However, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 4S is $1,086,000. The projected annual O&M costs are $185,000 for quarterly sampling in years 1-5, $94,000 for semiannual sampling in years 6-30, and $49,000 for treatment system O&M in years 1-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $3,678,000. Table C-4 (Appendix C) presents the cost estimate for RAA 4S.

6.2.5 RAA 5S: Groundwater Extraction and Treatment - Expanded System

Description

RAA 5S is a conventional pump and treat alternative that expands upon the extraction/treatment system presented in RAA 3S by attempting to treat all of the contamination that exceeds remediation levels, as opposed to only the most highly contaminated (i.e., hot) areas. Thus, extraction wells will be positioned to span the entire contaminated area. The extracted groundwater will be conveyed to an on-site treatment facility where it will receive suspended solids/metals pretreatment and air stripping for VOC removal. Once treated, the groundwater will be discharged to Courthouse Bay. In addition to a pump and treat system, RAA 5S includes a groundwater and surface water monitoring program and aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 5S, a pump and treat system will attempt to treat all of the contaminated groundwater in the surficial aquifer. To ensure the safety of potential receptors over time, monitoring and aquifer use restrictions are also included under RAA 5S. Thus, RAA 5S will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The pump and treat system associated with RAA 5S are expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 5S is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels"). RAA 5S can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 5S incorporates an active groundwater treatment system to reduce contaminant levels in the surficial aquifer. Through monitoring and aquifer use restrictions, RAA 5S will ensure the safety of potential receptors over time. As a result, RAA 5S will provide long-term effectiveness and permanence.

Pump and treat systems, however, are only effective to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into pore spaces and fissures where they become difficult to extract. The potential for inorganics precipitation to clog well screens also limits the reliability of the extraction well technology.

Under RAA 5S, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 5S include air stripping and liquid-phase carbon adsorption for VOC removal, and neutralization, precipitation, flocculation, sedimentation, and filtration for suspended solids/metals removal. These treatment processes will reduce the mobility, toxicity, and volume of contaminants collected by the extraction wells. The time frame in which these reductions will occur is assumed to be 30 years.

RAA 5S satisfies the statutory preference for treatment. Residuals remaining after treatment may include sludge, spent carbon, and treated groundwater.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the pump and treat system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 5S may cause aquifer drawdown during groundwater extraction. Excessive drawdown could result in foundation settlement. However through the proper placement of extraction wells and system operation the effects of aquifer drawdown can be minimized.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 30 years of system operation and monitoring have been assumed.

Implementability: RAA 5S is a technically implementable alternative. All of the associated technologies are conventional and well-demonstrated to be implementable. However, extraction well and piping installation will be difficult due to the pavement removal that will be required and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system will be energy-intensive and frequent maintenance and equipment replacement may be required. Dissolved metals will most likely precipitate out of solution and clog the extraction well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 5S.

In terms of administrative feasibility, RAA 5S will require extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of water discharge permits will have to be met. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 5S is $1,507,000. The projected annual O&M costs are $142,000 for quarterly sampling in years 1-5, $73,000 for semiannual sampling in years 6-30, and $65,000 for treatment system O&M in years 1-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $3,927,000. Table C-5 (Appendix C) presents the cost estimate for RAA 5S.

6.3 Comparative Analysis

This section presents a comparative analysis of the surficial aquifer alternatives. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA.

6.3.1 Overall Protection of Human Health and the Environment

With the exception of RAA 1S, all of the surficial aquifer alternatives will provide overall protection of human health and the environment. By monitoring natural attenuation parameters at the site, monitoring contaminant concentrations over time, and prohibiting future potable use of the surficial aquifer, RAAs 2S, 3S, 4S, and 5S will ensure the safety of potential receptors over time. RAA 1S provides no means for ensuring their safety. In addition, RAAs 3S, 4S, and 5S include active groundwater treatment systems which will provide additional protection to human health and the environment. Thus, RAAs 2S, 3S, 4S, and 5S will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"), RAA 1S will not.

Although RAAs 3S, 4S, and 5S provide additional protection by actively treating the contaminated groundwater, active treatment may not be necessary in order to provide adequate protection. Passive treatment via natural attenuation processes (i.e., RAA 2S) is expected to sufficiently protect human health and the environment. This is because the potential human health and ecological risks were insignificant, groundwater contamination is not adversely impacting Courthouse Bay, and the fuel and chlorinated solvent contamination appears to be naturally attenuating. As a result, it appears as though the groundwater may be left untreated without endangering potential receptors.

6.3.2 Compliance with ARARs

All five alternatives are expected to eventually achieve the chemical-specific ARARs through either passive or active treatment systems. All five alternatives are also expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAAs 1S and 2S will attempt to achieve it passively through natural attenuation processes, whereas RAAs 3S, 4S, and 5S will attempt to achieve it through a combination of natural attenuation and active groundwater treatment systems.

No location- or action specific ARARs are applicable to RAA 1S. In addition, a waiver of chemical-specific ARARs will be required if this alternative is implemented.

Considering the available data it is anticipated that treatment and/or monitoring programs described in RAAs 2S, 3S, 4S and 5S can be designed to meet location- and action-specific ARAS. Because the natural attenuation process option is included under RAAs 2S, 3S, and 4S 15A NCAC 2L .0106, section (l) and the Implementation Guidance are applicable ARARs. Under these RAAs sufficient data will gathered to meet the requirements of these ARARs.

6.3.3 Long-Term Effectiveness and Permanence

With the exception of RAA 1S, all of the surficial aquifer alternatives will be designed to provide long-term effectiveness and permanence. The common elements that RAAs 2S, 3S, 4S, and 5S share are a groundwater and surface water monitoring program and aquifer-use restrictions. These controls will be effective provided they are enforced over time. RAAs 2S, 3S, and 4S also share natural attenuation as a common passive treatment component. Based on current information, it appears as though natural attenuation can be an effective and permanent solution. RAAs 3S, 4S, and 5S include active groundwater treatment systems in addition to or in lieu of natural attenuation.

All five alternatives will require 5-year reviews by the lead agency. Once contaminant concentrations reach the specified remediation levels, these reviews will no longer be required.

6.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

RAAs 3S, 4S, and 5S will reduce the toxicity, mobility, and volume of contamination through active treatment. Although RAAs 1S and 2S do not involve active treatment systems, the contamination may experience toxicity, mobility, and volume reduction through passive treatment (i.e., natural attenuation).

Unlike RAAs 1S and 2S, RAAs 3S, 4S, and 5S will create treatment residuals. The residuals associated with RAAs 3S and 5S (sludge, spent carbon, and treated groundwater) will be voluminous and must be properly treated and/or disposed. The residuals associated with RAA 4S (spent carbon, a small amount of separated liquid, and treated vapor) will be more easily treated and/or disposed. Compared to RAA 3S, RAA 5S will create a larger volume of treatment residuals.

RAAs 2S, 3S, 4S, and 5S satisfy the statutory preference for treatment; RAA 1S does not.

6.3.5 Short-Term Effectiveness

Implementation of RAAs 1S and 2S does not pose substantial risks to the community or to workers. Implementation of RAAs 3S, 4S, and 5S does pose risks because these alternatives require extensive construction activities. In addition, RAAs 3S and 5S involve long-term operation and maintenance of an extraction well system and on site treatment facilities. For all of the alternatives, potential risks will be reduced through the use of proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. The treatment facilities will generate residual waste streams that must be properly treated and/or disposed. Potential environmental impacts that may be caused by excessive aquifer drawdown (RAAs 3S and 5S) and vapor build up (RAA 4S) can be eliminated during design or through system modification.

Under all five RAAs, the time for the action to be complete is unknown. Thirty years of groundwater and surface water monitoring was assumed for RAAs 2S, 3S, 4S, and 5S. Thirty years of treatment system O&M was assumed for RAAs 3S and 5S, and 10 years of treatment system O&M was assumed for RAA 4S.

6.3.6 Implementability

RAA 1S is the easiest alternative to implement, if not the most effective. RAA 2S is the next most implementable alternative followed by RAAs 3S, 4S, and 5S. RAAs 3S, 4S, and 5S have similar difficulties associated with their implementation. Pavement removal, underground utilities, and current site operations will complicate the construction of piping, extraction wells, and horizontal air injection and soil vapor extraction wells. Construction of RAA 5S will be more difficult than construction of RAAs 3S and 4S because RAA 5S involves a much larger treatment system.

RAA 1S requires no operation or maintenance. RAA 2S requires minimal operation and maintenance (groundwater and surface water samples will be collected periodically). RAA 3S requires extensive operation and maintenance. RAA 4S also requires extensive operation and maintenance, but for a shorter period of time than RAA 3S (10 years as opposed to 30 years). RAA 5S requires the most extensive operation and maintenance because it involves a much larger treatment system. RAA 4S involves the extraction of air rather than groundwater so it will be a less energy-intensive alternative compared to RAAs 3S and 5S. Under all five RAAs, additional remedial actions could easily be implemented.

RAAs 2S, 3S, 4S, and 5S involve conventional equipment and services that should be readily available. Compared to RAA 2S, RAAs 3S, 4S, and 5S will require more extensive coordination with the Base Public Works/Planning department. Unlike RAA 1S, RAAs 2S, 3S, 4S, and 5S will require semiannual submission of reports that document sampling results.

Under RAAs 1S and 2S no substantial reduction of contamination will occur immediately upon the implementation of RAAs 1S and 2S. Contaminants are being gradually degraded into nonhazardous nontoxic by-products via natural attenuative processes. Although under RAAs 1S and 2S contaminant levels may be above the remediation limits for a period time it is anticipated that in the long-term, remediation levels will be achieved under these RAAs.

Although RAAs 3S and 4S are removal systems they are primarily barriers against the movement contamination into Courthouse Bay. It is anticipated that groundwater contaminant levels in the immediate vicinity of air sparging or extraction system will meet remediation levels in the short

term. However, up gradient of the treatment systems contamination may remain above remediation levels until transported into the treatment systems' zone of influence.

Under RAAs 3S and 4S contamination that does not threaten Courthouse Bay will be allowed to degraded via natural attenuation. In these areas contaminant levels may be above the remediation limits for a period time. However, it is anticipated that in the long-term, remediation levels will be achieved under these RAAs.

Under RAA 5S the area of influence of the extraction system overlays the contaminant plumes. It is anticipated that groundwater contaminant levels in the immediate vicinity of the extraction system will meet remediation levels in the short term.

6.3.7 Cost

In terms of NPW, the no action alternative (RAA 1S) will be the least expensive RAA to implement, followed by RAA 2S, RAA 4S, RAA 3S, and RAA 5S. The estimated NPW values in increasing order are $0 (RAA 1S), $2,068,000 (RAA 2S), $3,678,000 (RAA 4S), $3,725,000 (RAA 3S), and $3,927,000 (RAA 5S).

SECTION 6.0 TABLES

TABLE 6-1

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
OVERALL PROTECTIVENESS					
• Human Health	Does not provide overall protection of human health.	Provides overall protection of human health through natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through a pump and treat system, natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through an air sparging/SVE system, natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through a pump and treat system, monitoring, and aquifer use restrictions.
• Environmental Protection	Does not provide overall protection of the environment.	Provides overall protection of the environment through natural attenuation and monitoring.	Provides overall protection of the environment through a pump and treat system, natural attenuation, and monitoring.	Provides overall protection of the environment through an air sparging/SVE system, natural attenuation, and monitoring.	Provides overall protection of the environment through a pump and treat system, monitoring, and aquifer use restrictions.
COMPLIANCE WITH ARARs					
• Chemical-Specific ARARs/TBCs	Eventually, natural attenuation is expected to achieve the ARARs over an extended period of time.	Eventually, natural attenuation is expected to achieve the ARARs over an extended period of time.	Eventually, natural attenuation and pump and treat are expected to achieve the ARARs.	Eventually, natural attenuation and air sparging/SVE are expected to achieve the ARARs.	Eventually, pump and treat is expected to achieve the ARARs.
• Location-Specific ARARs	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	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 6-1 (Continued)

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	Minimal.	Minimal.	Minimal.	Minimal.	Minimal.
• Adequacy and Reliability of Controls	Not applicable - no controls.	Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the pump and treat system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the air sparging/SVE system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the pump and treat system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.
• 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.

TABLE 6-1 (Continued)

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	No active treatment process. Natural Attenuation is a passive treatment process.	No active treatment process. Natural Attenuation is a passive treatment process.	Extraction wells, air stripping, liquid-phase carbon adsorption treatment, metals pretreatment, and natural attenuation.	Air injection wells, soil vapor extraction wells, vapor-phase carbon adsorption, and natural attenuation.	Extraction wells, air stripping, liquid-phase carbon adsorption treatment, metals pretreatment, and natural attenuation.
• Amount Destroyed or Treated	Expected to treat and/or destroy the majority of the contamination through natural attenuation.	Expected to treat and/or destroy the majority of the contamination through natural attenuation.	Expected to treat and/or destroy the majority of the contamination.	Expected to treat and/or destroy the majority of the contamination.	Expected to treat and/or destroy the majority of the contamination.
• Reduction of Toxicity, Mobility, or Volume Through Treatment	Some reduction in toxicity, mobility, and volume through natural attenuation.	Some reduction in toxicity, mobility, and volume through natural attenuation.	Some reduction in toxicity, mobility, and volume.	Some reduction in toxicity, mobility, and volume.	Some reduction in toxicity, mobility, and volume.
• Residuals Remaining After Treatment	Not applicable - no active treatment.	Not applicable - no active treatment.	Treatment residuals will include sludge, spent carbon, and treated groundwater.	Treatment residuals will include spent carbon, separated water, and treated vapor.	Treatment residuals will include sludge, spent carbon, and treated groundwater.
• Statutory Preference for Treatment	Not satisfied.	Satisfied through passive treatment.	Satisfied through active treatment.	Satisfied through active treatment.	Satisfied through active treatment.

TABLE 6-1 (Continued)

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
SHORT-TERM EFFECTIVENESS					
• Community Protection	Potential risks to the community will not be increased.	Potential risks to the community will not be significantly increased.	Potential risks to the community will be increased during system construction and O&M activities.	Potential risks to the community will be increased during system construction and O&M activities.	Potential risks to the community will be increased during system construction and O&M activities.
• Worker Protection	No risks to workers.	No significant risks to workers.	Potential risks to workers will be increased during system construction and O&M activities.	Potential risks to workers will be increased during system construction and O&M activities.	Potential risks to workers will be increased during system construction and O&M activities.
• Environmental Impact	No additional environmental impacts.	No additional environmental impacts.	Potential environmental impacts resulting from aquifer drawdown can be minimized or eliminated.	Potential environmental impacts resulting from vapor build up can be minimized or eliminated.	Potential environmental impacts resulting from vapor build up can be minimized or eliminated.
• Time Until Action is Complete	Not applicable.	Thirty years.	Thirty years.	Ten years of system O&M and 30 years of monitoring.	Thirty years.

TABLE 6-1 (Continued)

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
IMPLEMENTABILITY					
• Ability to Construct and Operate	No construction or operation activities.	Monitoring well installation has been easily implemented in the past.	Pavement removal, underground utilities, and current site operations may complicate construction. Disposal of treatment residuals (i.e., sludge) and inorganics precipitation on well screens may complicate system O&M.	Pavement removal, underground utilities, and current site operations may complicate construction. Inorganics precipitation on well screens may complicate system O&M.	Pavement removal, underground utilities, and current site operations may complicate construction. Disposal of treatment residuals (i.e., sludge) and inorganics precipitation on well screens may complicate system O&M.
• Reliability of Technology	Not applicable.	Not applicable.	Inorganics may precipitate on the well screens creating the need for well replacement. If contaminants migrate into inaccessible regions, the pump and treat system will be less effective at collecting them.	Inorganics may precipitate on the injection well screens creating the need for well replacement. Since air sparging/SVE is relatively new and innovative, the reliability of this technology has not been well-demonstrated.	Inorganics may precipitate on the well screens creating the need for well replacement. If contaminants migrate into inaccessible regions, the pump and treat system will be less effective at collecting them.
• 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 remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.
• Ability to Monitor Effectiveness	No monitoring plan for measuring effectiveness.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.
• Availability of Services and Capacities; Equipment	No services or equipment required.	Services and equipment should be readily available.	Services and equipment should be readily available.	Services and equipment should be readily available.	Services and equipment should be readily available.

TABLE 6-1 (Continued)

DETAILED ANALYSIS OF THE SURFICIAL AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1S: No Action	RAA 2S: Natural Attenuation	RAA 3S: Groundwater Extraction and Treatment	RAA 4S: Air Sparging and Soil Vapor Extraction	RAA 5S: Groundwater Extraction and Treatment - Expanded System
IMPLEMENTABILITY (Continued)					
• Requirements for Agency Coordination	None required.	No significant requirements.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.
COST (Net Present Worth)	**$0**	**$2,068,000**	**$3,725,000**	**$3,678,000**	**$3,927,000**

7.0 DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES

This section contains a detailed analysis of the deep aquifer RAAs that were developed in Section 5.0. The detailed analysis has been conducted using the nine USEPA evaluation criteria defined in Section 6.1. These criteria include:

- 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 RAB has reviewed the FS and the PRAP. The RAB includes participants from the NC DEHNR, USEPA Region IV, and the public.

The 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 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). (An initial screening of alternatives was not conducted.)

Section 7.1 presents an individual analysis of each alternative, with respect to the evaluation criteria, and Section 7.2 presents a comparative analysis of all the alternatives. (Please note that the detailed analysis of surficial aquifer RAAs was presented in Section 6.0.)

7.1 Individual Analysis of Alternatives

The following subsections present the detailed analysis of the deep aquifer 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 7-1 summarizes the individual, detailed analysis of alternatives.

7.1.1 RAA 1D: No Action

Description

Under the no action alternative, contaminated groundwater in the deep aquifer will remain as it currently is. No active remedial actions will be implemented.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 1D, contaminants in the deep aquifer will remain untreated and will continue to discharge into Courthouse Bay. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- According to the human health and ecological RAs, the fuel and chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- The groundwater contamination that is migrating into Courthouse Bay appears to be discharging at levels that will not adversely affect potential receptors. The North Carolina Framework Groundwater-Surface Water Model (located in Appendix B) was used to determine the maximum groundwater concentrations that can discharge into Courthouse Bay before unsafe surface water conditions develop. The contaminant concentrations that are currently discharging into the bay are far below the acceptable discharge limits that were developed using the model. In addition, the maximum contaminant concentrations detected in the deep aquifer are far below the acceptable discharge limits.

- According to the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeyer, 1996) and the Technical Protocol for Implementing Intrinsic Remediation With Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater (Wiedemeyer, 1995) fuel and chlorinated solvent contaminants are capable of naturally attenuating provided the appropriate conditions are present at the site. The contamination at Site 73 appears to be naturally attenuating because TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected. The arrangement of the TCE, cis-1,2-DCE, and vinyl chloride plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation. Thus, the contamination in the deep aquifer, if left untreated, is expected to naturally attenuate over time.

Based on this information, no action is a justifiable solution for the deep aquifer. RAA 1D, however, fails to provide a means (such as a monitoring program or aquifer-use restrictions) for ensuring the protection of human health and the environment over time. The alternative also does not achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"). Based on this information, RAA 1D will not provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 1D, no active effort will be made to reduce contaminant levels to below chemical-specific ARARs. Natural attenuation processes, however, are expected to eventually achieve these ARARs. Thus, RAA 1D has the potential to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over an extended period of time. A waiver of the chemical-specific ARARs may be required before this alternative can be implemented. No action-specific or location-specific ARARs apply to this no action alternative.

Long-Term Effectiveness and Permanence: No action is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant both now and in the future; 2) the North Carolina Framework Groundwater-Surface Water Model indicates that the groundwater contamination is not adversely impacting Courthouse Bay; and 3) the fuel and chlorinated solvent contamination appears to be naturally attenuating. However, RAA 1D does not ensure the safety of potential receptors over time. The no action alternative provides no means for monitoring contaminant concentrations, prohibiting future potable use of the deep aquifer, or proving that natural attenuation is indeed occurring. As a result, the safety of potential receptors will be uncertain and RAA 1D will not provide long-term effectiveness and permanence.

Under RAA 1D, 5-year reviews by the lead agency will be required. However, these reviews alone will not be sufficient for ensuring the safety of potential receptors.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The no action alternative does not provide a treatment process; there will be no toxicity, mobility, or volume reduction through treatment. There may, however, be some toxicity, mobility, and volume reduction through passive treatment (i.e., natural attenuation). Thus, RAA 1D does not satisfy the statutory preference for treatment.

Short-Term Effectiveness: There are no remedial action activities associated with RAA 1D. As a result, short-term potential risks to the community and workers will not be increased, and there will be no additional environmental impacts.

Implementability: The no action alternative is implementable since no additional construction or operation activities will be conducted. In terms of administrative feasibility, RAA 1D should not require additional coordination with other agencies. The availability of services, materials, and/or technologies is not applicable to this alternative.

If groundwater quality appears to be deteriorating, additional remedial actions could easily be implemented under RAA 1D.

Cost: There are no capital costs or O&M costs associated with this alternative. The NPW is $0.

7.1.2 RAA 2D: Natural Attenuation

Description

Under RAA 2D, no active remedial actions will be implemented for the deep aquifer contamination. Instead, passive treatment via natural attenuation processes will be relied upon to reduce contaminant levels. The main component of RAA 2D is a long-term groundwater and surface water monitoring program. Groundwater samples will be analyzed for TCL VOCs and natural attenuation parameters. These parameters will indicate the type of natural biodegradation that is occurring in the aquifer, and the amount of contaminant reduction that can be expected. Surface water samples will be analyzed for TCL VOCs. RAA 2D will also include aquifer-use restrictions that will prohibit future use of the surficial and Castle Hayne aquifers, within a 1,500-foot radius of Site 73, as potable water sources. To further support the occurrence of natural attenuation, RAA 2D may include two optional components: a contaminant fate and transport model and a laboratory microcosm study.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 2D, contaminants in the deep aquifer will remain untreated and will continue to discharge into Courthouse Bay. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- According to the human health and ecological RAs, the fuel and chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- The groundwater contamination that is migrating into Courthouse Bay appears to be discharging at levels that will not adversely affect potential receptors. The North Carolina Framework Groundwater-Surface Water Model (located in Appendix B) was used to determine the maximum groundwater concentrations that can discharge into Courthouse Bay before unsafe surface water conditions develop. The contaminant concentrations that are currently discharging into the bay are far below the acceptable discharge limits that were developed using the model. In addition, the maximum contaminant concentrations detected in the deep aquifer are far below the acceptable discharge limits.

- Technical literature (see Section 8.0) indicates that fuel and chlorinated solvent contaminants are capable of naturally attenuating provided the appropriate conditions are present at the site. The contamination at Site 73 appears to be naturally attenuating because TCE and the daughter products of TCE degradation (cis-1,2-DCE and vinyl chloride) have been detected. The arrangement of the TCE, cis-1,2-DCE, and vinyl chloride plumes suggests that the 1,2-DCE and vinyl chloride are a direct result of TCE degradation. Thus, the contamination in the deep aquifer, if left untreated, is expected to naturally attenuate over time.

Based on this information, no active groundwater treatment is a justifiable solution for the deep aquifer. RAA 2D ensures the protection of human health and the environment over time through natural attenuation, monitoring, and aquifer-use restrictions. Thus, RAA 2D will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"), and the alternative will provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 2D, no active effort will be made to reduce groundwater contaminant levels below federal MCLs or NC WQSs (groundwater). However, a Natural Attenuation Evaluation Study (NAES) will be conducted at Site 73 to assess natural attenuative processes that are occurring in the deep aquifer. It is anticipated that the results of this study will provide evidence that natural attenuative processes are reducing contaminant levels.

A review of the action-specific ARARs indicated that this alternative must comply with the requirements outlined in 15A NCAC 2L .0106 , section (l) and discussed in 15A NCAC 2L Implementation Guidance (Implementation Guidance). In order to comply with 15A NCAC 2L the ten following conditions (enumerated items) must be demonstrated. Following each of these items is an explanation of how each condition will be met.

- " (1) that all sources of contamination and free product have been removed or controlled;"

  No soil contamination associated with dissolved- phase groundwater contamination or free product was detected during either phase of the RI. The results of surface and subsurface soils analysis collected under the RI will be included in the Corrective Action Plan (CAP).

- " (2) that the contaminant has the capacity to degrade or attenuate under the site-specific conditions;"

  As a part of the NAES, the appropriate geochemical and contaminant data will be gathereand d and an assessment of the aquifer's ability to degrade and attenuate the COCs will be performed The data and results of the NAES will be used in the development of the Corrective Action Plan (CAP).

  The sample strategy plan that will support the NAES will be developed using the following documents 15A NCAC 2L Implementation Guidance; Technical Protocol For Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1996); Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation (Wiedemeier, 1995); and OSWER Directive 9200.4-17, Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, Underground Storage Tank Sites.

- " (3) that the time and direction of contaminant travel can be predicted with reasonable certainty;"

  A three dimensional groundwater model has been developed for this site and can be used to estimate the time and direction of contaminant travel. Multiple rounds of static water levels were collected during the RI that supported the development of this model. However, simple analytical calculations or a simple one-dimensional model may also be used to estimate travel time as recommended in the Implementation Guidance.

  The technical basis for determining the values of aquifer parameters used in any calculations or models will be discussed in the CAP.

- " (4) that contaminant migration will not result in any violation of applicable groundwater standards at any existing or foreseeable receptor;"

  The Implementation Guidance generally defines receptors as utility lines, basements, elevator shafts, surface waters, domestic supply wells and regions of groundwater that have been identified for development. The only known receptor of contamination located in the deep aquifer is Courthouse Bay. Currently, no foreseeable (future) receptors have been identified. Currently there are no formal plans to develop the shallow groundwater resources in the vicinity of site 73.

  The extent of the groundwater contamination in the Castle Hayne aquifer has not clearly been delineated horizontally and vertically. In addition, contaminant levels

in the Castle Hayne aquifer at the Courthouse Bay shoreline have not been clearly determined. However, multiple surface water and sediment samples were obtained from Courthouse Bay during the RI. No site related volatile organic compounds were detected in these samples. Under the NAES additional monitoring wells will be installed to clearly delineate the horizontal and vertical extent of contamination in the Castle Hayne aquifer. In addition, contaminant data from wells located at the Courthouse Bay shoreline will be used to determine if groundwater at the Courthouse Bay is in violation of MCls or NC WQS (groundwater).

Currently, there are no formal plans to develop the Castle Hayne aquifer at Site 73 as a source of drinking water. However, to identify foreseeable receptors Planning and Public Works departments at MCB Camp Lejeune will be contacted to determine if formal plans exist for the development of the Castle Hayne aquifer in the vicinity of Site 73 as a water resource.

Courthouse Bay will be shown on a base figure that will be included in the CAP.

- " (5) that contaminants have not and will not migrate onto adjacent properties, or that: (A) such properties are served by an existing public water system dependant on surface waters or hydraulically isolated groundwater, or (B) the owners of such properties have consented in writing to the request;"

  The limits of the Site 73 shallow contaminant plume are well inside the boundaries of MCB Camp Lejeune and are not immediately adjacent to other private or other government owned parcels of land. Therefore, off-site migration of shallow groundwater contamination is not an issue. A figure will be provided in the CAP that shows the relationship between Site 73 and the nearest private property.

  Additionally, the existing data indicates that this plume is in a state of equilibrium. As a part of the NAES additional monitoring wells will be installed and sampled to more clearly define the extent of the contaminant plume and determine if the plume is migrating or shrinking. Contaminant data that will be gathered during the NAES will be compared to existing data in the CAP to further assess the status of the plume. The nearest supply well is located approximately 4,225 feet from Site 73. A figure will be included that shows the relationship of the closest supply wells to the contaminant plume.

- " (6) that, if the contaminant plume is expected to intercept surface waters, the groundwater will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 2B .0200;"

  No site-related volatile organic compounds were detected in surface water or sediment samples collected during the RI. The analytical results of the sediment and surface water sampling will be included in the CAP.

- " (7) that the person making the request will put in place a groundwater monitoring program sufficient to track degradation and attenuation of contaminants and contaminant by-products within and down gradient of the plume and to detect contaminants and contaminant by-products prior to their reaching any existing or

foreseeable receptor at least one year's travel time upgradient of the receptors and no greater than the distance the groundwater at the contaminated site is predicted to travel in five years;"

Based on the results of the NAES a groundwater monitoring program will be developed and implemented that will meet the intent of Item (7). The monitoring program will be developed using the following documents 15A NCAC 2L Implementation Guidance; Technical Protocol For Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1996); Technical Protocol for Implementing Intrinsic Remediation with Long Term Monitoring for Natural Attenuation (Wiedemeier, 1995); and

Wells that will monitor the down gradient edge of the contaminant plume will be located at least one year's travel time up gradient of Courthouse Bay and no further down gradient of the leading edge of the plume than five years travel

- " (8) that all necessary access agreements needed to monitor groundwater quality have been or can be obtained"

  Site 73 and the surrounding area are part of MCB Camp Lejeune. No access agreements will be required in order to implement the groundwater monitoring program.

- " (9) that public notice of this request has been provided in accordance with Rule .0114 (b) of this Section;"

  Public notification and review of the selected remedy at Site 73 is required under CERCLA. Prior to the signing of the Record of Decision (ROD) a public notice will be placed in a local newspaper and a public meeting held. It is assumed that public notification under CERCLA meets the requirement of Item (9) and Rule .0114.

- " (10) that the proposed corrective action plan would be consistent with all other environmental laws."

  A review of ARARS will be performed to assure the corrective action plan is consistent with all environmental laws.

Long-Term Effectiveness and Permanence: Leaving the groundwater untreated is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant both now and in the future; 2) the North Carolina Framework Groundwater-Surface Water Model indicates that the groundwater contamination is not adversely impacting Courthouse Bay; and 3) the fuel and chlorinated solvent contamination appears to be naturally attenuating. Through monitoring and aquifer-use restrictions, RAA 2D provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the surficial aquifer, and proving that natural attenuation is indeed occurring. As a result, RAA 2D will ensure the safety of potential receptors and will provide long-term effectiveness and permanence.

Under RAA 2D, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 2D does not provide an active treatment process; there will be no toxicity, mobility, or volume reduction through active treatment. There may, however, be some reduction in toxicity, mobility, and volume through passive treatment (i.e., natural attenuation). Thus, RAA 2D satisfies the statutory preference for treatment.

Short-Term Effectiveness: Under RAA 2D, the only activities that may increase risks to the community and to workers are monitoring well installation and periodic groundwater and surface water sampling. However, proper materials handling procedures and PPE should sufficiently protect against these risks. RAA 2D will not create any additional environmental impacts. The time required for the action to be complete cannot be estimated, but 30 years was assumed for cost estimating purposes.

Implementability: RAA 2D is a technically implementable alternative since monitoring well installation, groundwater and surface water monitoring, and ordinance procurement have been easily implemented in the past. If water quality appears to be deteriorating over time, additional remedial actions could easily be implemented under RAA 2D.

In terms of administrative feasibility, this alternative will not require additional coordination with other agencies. However, semiannual reports must be submitted to document sampling procedures. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 2D is $231,000. The projected annual O&M costs are approximately $123,000 for quarterly sampling in years 1-5, and $64,000 for semiannual sampling in years 6-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $1,470,000. Table D-2 (Appendix D) presents a cost estimate for RAA 2D.

7.1.3 RAA 3D: Groundwater Extraction and Treatment

Description

RAA 3D is a conventional pump and treat alternative which incorporates groundwater extraction wells and ex situ treatment at an on-site treatment facility. Under RAA 3D, one extraction well will be positioned to collect the hot portions of the contaminated plumes, and one extraction well will be positioned to collect the contamination that is trapped underneath the concrete structure near 73-MW09. Portions of the plumes that do not receive active treatment are assumed will experience contaminant reduction through natural attenuation. The extracted groundwater will be conveyed to an on-site treatment facility where it will receive suspended solids/metals pretreatment and air stripping for VOC removal. Once treated, the groundwater will be discharged to Courthouse Bay. In addition to a pump and treat system, RAA 3D includes a groundwater and surface water monitoring program and aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 3D, the hot areas of contamination will receive active treatment in the form of a pump and treat system. The remaining contamination will experience passive remediation through natural attenuation processes. To ensure

the safety of potential receptors over time, monitoring and aquifer use restrictions are included under RAA 3D. Thus, the alternative will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The pump and treat system and natural attenuation processes associated with RAA 3D are expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 3D is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAA 3D can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 3D incorporates an active groundwater treatment system and natural attenuation processes to reduces contaminant levels in the deep aquifer. Through monitoring and aquifer use restrictions, RAA 3D provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the surficial aquifer, and proving that natural attenuation is indeed occurring. As a result, RAA 3D will ensure the safety of potential receptors and will provide long-term effectiveness and permanence.

Pump and treat systems, however, are only effective to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into pore spaces and fissures where they become difficult to extract. The potential for inorganics precipitation to clog well screens also limits the reliability of the extraction well technology.

Under RAA 3D, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The active treatment processes associated with RAA 3D include air stripping and liquid-phase carbon adsorption for VOC removal, and neutralization, precipitation, flocculation, sedimentation, and filtration for suspended solids/metals removal. RAA 3D also includes natural attenuation as a passive treatment process. These treatment processes will reduce the toxicity and volume of contaminants. The time frame in which these reductions will occur is assumed to be 30 years.

RAA 3D satisfies the statutory preference for treatment. Residuals remaining after treatment may include sludge, spent carbon, and treated groundwater.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the pump and treat system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 3D may cause aquifer drawdown during groundwater extraction. Excessive drawdown could result in foundation settlement. However, through the proper placement of extraction wells and system operation the effects of aquifer drawdown can be minimized.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 30 years of system operation and monitoring have been assumed.

Implementability: RAA 3D is a technically implementable alternative. All of the associated technologies are conventional and well-demonstrated to be implementable. However, extraction well and piping installation will be difficult due to the pavement removal that will be required and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system will be energy-intensive and frequent maintenance and equipment replacement may be required. Dissolved metals will most likely precipitate out of solution and clog the extraction well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 3D.

In terms of administrative feasibility, RAA 3D will require extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of water discharge permits will have to be met. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 3D is $1,064,000. The projected annual O&M costs are $123,000 for quarterly sampling in years 1-5, $64,000 for semiannual sampling in years 6-30, and $46,000 for treatment system O&M in years 1-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $3,010,000. Table D-3 (Appendix D) presents the cost estimate for RAA 3D.

7.1.4 RAA 4D: In-Well Aeration

Description

Under RAA 4D, in-well aeration wells will be installed in the upper portion of the Castle Hayne aquifer. The wells will be positioned to treat the hot portions of the contaminated plumes and the contamination that is trapped underneath the concrete structure near 73-MW09. Portions of the plumes that do not receive active treatment will experience contaminant reduction through natural attenuation. A separate treatment unit (containing a vapor-phase carbon adsorption unit, a vapor-water separation unit, a blower, and a vacuum pump) will be located at each aeration well. In addition to in-well aeration, RAA 4D includes a groundwater and surface water monitoring program and aquifer-use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 4D, the hot areas of contamination will receive active treatment in the form of an in-well aeration system. The remaining contamination will experience passive remediation through natural attenuation processes. To ensure the safety of potential receptors over time, monitoring and aquifer use restrictions are included under RAA 4D. Thus, RAA 4D will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The in-well aeration system and natural attenuation processes associated with RAA 4D are expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 4D is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over

time. RAA 4D can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 4D incorporates an active groundwater treatment system and natural attenuation processes to reduce contaminant levels in the deep aquifer. Through monitoring and aquifer use restrictions, RAA 4D provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the deep aquifer, and proving that natural attenuation is indeed occurring. As a result, RAA 4D will ensure the safety of potential receptors and will provide long-term effectiveness and permanence.

Under RAA 4D, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The active treatment processes associated with RAA 4D include in-well air stripping and vapor-phase carbon adsorption. RAA 4D also includes natural attenuation as a passive treatment process. These treatment processes will reduce the toxicity, mobility, and volume of the contaminants that are within the wells' radii of influence. The time frame in which these reductions will occur is assumed to be 10 years based on technical literature referenced in Section 8.0.

RAA 4D satisfies the statutory preference for treatment. Residuals remaining after treatment may include spent carbon and separated water from the vapor-water separation unit.

Short-Term Effectiveness: Dust production during the underground piping and aeration well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the in-well aeration system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 4D may result in vapor build up underneath foundations and paved areas. However, through adequate monitoring, vapor build up can be detected and the system modified.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 10 years of system (based on technical literature referenced in Section 8.0) operation and 30 years of groundwater and surface water monitoring have been assumed.

Implementability: Although in-well aeration is a relatively new and innovative technology, RAA 4D appears to be a technically implementable alternative. However, aeration well and piping installation will be difficult due to the pavement removal that will be required, and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system may require frequent maintenance and equipment replacement. Dissolved metals will most likely precipitate out of solution and clog the aeration well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 4D.

In terms of administrative feasibility, RAA 4D will require extensive coordination with the Base Public Works/Planning Department. However, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 4D is $1,079,000. The projected annual O&M costs are $123,000 for quarterly sampling in years 1-5, $64,000 for semiannual sampling in years 6-30, and $43,000 for treatment system O&M in years 1-10. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $2,979,000. Table D-4 (Appendix D) presents the cost estimate for RAA 4D.

7.1.5 RAA 5D: In-Well Aeration - Expanded System

Description

RAA 5D expands upon the in-well aeration system presented in RAA 4D by attempting to treat all of the contamination that exceeds remediation levels, as opposed to only the most highly contaminated (i.e., hot) areas. Thus, eleven aeration wells will be positioned to span the entire contaminated area. A separate treatment unit (containing a vapor-phase carbon adsorption unit, a vapor-water separation unit, a blower, and a vacuum pump) will be located at each aeration well. In addition to in-well aeration, RAA 4D includes a groundwater and surface water monitoring program and aquifer use restrictions.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 5D, an in-well aeration system will attempt to treat all of the contaminated groundwater in the deep aquifer. To ensure the safety of potential receptors over time, monitoring and aquifer use restrictions are included under RAA 5D. Thus, RAA 5D will provide overall protection of human health and the environment. Moreover, the alternative will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater").

Compliance With ARARs: The in-well aeration system associated with RAA 5D is expected to eventually achieve the chemical-specific ARARs. Therefore, RAA 5D is expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAA 5D can be designed to meet the location-specific and action-specific ARARs that apply to it (see Section 3.0).

Long-Term Effectiveness and Permanence: RAA 5D incorporates an active groundwater treatment system to reduce contaminant levels in the deep aquifer. Through monitoring and aquifer use restrictions, RAA 5D provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the deep aquifer, and proving that natural attenuation is indeed occurring. As a result, RAA 5D will ensure the safety of potential receptors and will provide long-term effectiveness and permanence.

Because RAA 5D involves separate treatment units at each aeration well, the current operations at Site 73 may be complicated by this alternative. Several treatment units will be located aboveground in the Building A47 fenced area. These units will be obstacles that vehicles will have to avoid when traveling in the fenced area. Thus, the long-term effectiveness and permanence of RAA 5D may be limited.

Under RAA 5D, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 5D include in-well air stripping and vapor-phase carbon adsorption. These treatment processes will reduce the toxicity, mobility, and volume of the contaminants that are within the wells' radii of influence. The time frame in which these reductions will occur is assumed to be 10 years based on technical literature referenced in Section 8.0.

RAA 5D satisfies the statutory preference for treatment. Residuals remaining after treatment may include spent carbon and separated water from the vapor-water separation unit.

Short-Term Effectiveness: Dust production during the underground piping and aeration well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the in-well aeration system. The following measures will be taken to provide community and worker protection: proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. In terms of environmental impacts, RAA 5D may cause vapor build up underneath foundations and paved areas. However, through adequate monitoring, vapor build up can be detected and the system modified.

The exact amount of time required to complete the remedial action is unknown. For costing purposes, 10 years of system (based on technical literature referenced in Section 8.0) operation and 30 years of groundwater and surface water monitoring have been assumed.

Implementability: Although in-well aeration is a relatively new and innovative technology, RAA 5D appears to be a technically implementable alternative. However, aeration well and piping installation will be difficult due to the pavement removal that will be required, and the underground utilities that may be encountered. In addition, Site 73 is actively used as an amphibious vehicle maintenance facility so current operations at the site will complicate construction efforts. Operation of the system may require frequent maintenance and equipment replacement. Dissolved metals will most likely precipitate out of solution and clog the aeration well screens.

If the long-term monitoring program indicates that water quality is deteriorating, additional remedial actions could easily be implemented under RAA 5D.

In terms of administrative feasibility, RAA 5D will require extensive coordination with the Base Public Works/Planning Department. However, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 5D is $1,602,000. The projected annual O&M costs are $71,000 for quarterly sampling in years 1-5, $38,000 for semiannual sampling in years 6-30, and $104,000 for treatment system O&M in years 1-10. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $3,928,000. Table D-5 (Appendix D) presents the cost estimate for RAA 5D.

7.2 Comparative Analysis

This section presents a comparative analysis of the deep aquifer alternatives. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA.

7.2.1 Overall Protection of Human Health and the Environment

With the exception of RAA 1D, all of the deep aquifer alternatives will provide overall protection of human health and the environment. By monitoring natural attenuation parameters at the site, monitoring contaminant concentrations over time, and prohibiting future potable use of the deep aquifer, RAAs 2D, 3D, 4D, and 5D will ensure the safety of potential receptors over time. RAA 1D provides no means for ensuring their safety. In addition, RAAs 3D, 4D, and 5D include active groundwater treatment systems which will provide additional protection to human health and the environment. Thus, RAAs 2D, 3D, 4D, and 5D will achieve RAO #1 ("mitigate the potential for direct exposure via ingestion, dermal contact, and inhalation, to contaminated groundwater"), while RAA 1D will not.

Although RAAs 3D, 4D, and 5D provide additional protection by actively treating the contaminated groundwater, active groundwater treatment may not be necessary in order to provide adequate protection. Passive treatment via natural attenuation processes (i.e., RAA 2D) is expected to sufficiently protect human health and the environment. This is because the potential human health and ecological risks were insignificant, groundwater contamination is not adversely impacting Courthouse Bay, and the fuel and chlorinated solvent contamination appears to be naturally attenuating. As a result, it appears as though the groundwater may be left untreated without endangering potential receptors.

7.2.2 Compliance with ARARs

All five alternatives are expected to eventually achieve the chemical-specific ARARs through either passive or active treatment systems. All five alternatives are also expected to achieve RAO #2 ("remediate groundwater to the specified remediation levels") over time. RAAs 1D and 2D will attempt to achieve it passively through natural attenuation processes, whereas RAAs 3D, 4D, and 5D will attempt to achieve it through a combination of natural attenuation and active groundwater treatment systems.

No location- or action specific ARARs are applicable to RAA 1D. In addition, a waiver of chemical-specific ARARs will be required if this alternative is implemented.

Considering the available data it is anticipated that treatment and/or monitoring programs described in RAAs 2D, 3D, 4D and 5D can be designed to meet location- and action-specific ARARs. Because the natural attenuation process option is included under RAAs 2D, 3D, and 4D 15A NCAC 2L .0106, section (l) and the Implementation Guidance are applicable ARARs. Under these RAAs sufficient data will gathered to meet the requirements of these ARARs.

7.2.3 Long-Term Effectiveness and Permanence

With the exception of RAA 1D, all of the deep aquifer alternatives will be designed to provide long-term effectiveness and permanence. The common elements that RAAs 2D, 3D, 4D, and 5D share are a groundwater and surface water monitoring program and aquifer use restrictions. These controls will be effective provided they are enforced over time. RAAs 2D, 3D, and 4D also share natural attenuation as a common passive treatment component. Based on current information, it appears as though natural attenuation can be an effective and permanent solution for the deep aquifer. RAAs 3D, 4D, and 5D include active groundwater treatment systems in addition to or in lieu of natural attenuation.

All five alternatives will require 5-year reviews by the lead agency. Once contaminant concentrations reach the specified remediation levels, these reviews will no longer be required.

7.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

RAAs 3D, 4D, and 5D will reduce the toxicity, mobility, and volume of contaminated groundwater through active treatment. Although RAAs 1D and 2D do not involve active treatment systems, the contamination may experience toxicity, mobility, and volume reduction through passive treatment (i.e., natural attenuation).

Unlike RAAs 1D and 2D, RAAs 3D, 4D, and 5D will create treatment residuals. The residuals associated with RAA 3D (sludge, spent carbon, and treated groundwater) will be voluminous and must be properly treated and/or disposed. The residuals associated with RAAs 4D and 5D (spent carbon, a small amount of separated liquid, and treated vapor) will be more easily treated and/or disposed. Compared to RAA 4D, RAA 5D will create a larger volume of treatment residuals.

RAAs 2D, 3D, 4D, and 5D satisfy the statutory preference for treatment; RAA 1D does not.

7.2.5 Short-Term Effectiveness

Implementation of RAAs 1D and 2D does not pose substantial risks to the community or to workers. Implementation of RAAs 3D, 4D, and 5D does pose risks because these alternatives require extensive construction activities. In addition, RAA 3D involves long-term operation and maintenance of an extraction well system and on-site treatment facility. For all of the alternatives, potential risks will be reduced through the use of proper materials handling procedures, PPE, construction safety fencing, and dust minimization procedures. The treatment facilities will generate residual waste streams that must be properly treated and/or disposed. Potential environmental impacts that may be caused by excessive aquifer drawdown (RAAs 3D) and vapor build up (RAA 4D and 5D) can be eliminated during design or through system modification.

Under all five RAAs, the time for the action to be complete is unknown. Thirty years of monitoring was assumed for RAAs 2D, 3D, 4D, and 5D. Thirty years of treatment system O&M was assumed for RAA 3D, and 10 years of treatment system O&M was assumed for RAAs 4D and 5D.

7.2.6 Implementability

RAA 1D is the easiest alternative to implement, if not the most effective. RAA 2D is the next most implementable alternative followed by RAAs 3D, 4D, and 5D. RAAs 3D, 4D, and 5D have similar difficulties associated with their implementation. Pavement removal, underground utilities, and current site operations will complicate the construction of piping, extraction wells, and in-well aeration wells. Construction of RAA 5D will be more difficult than construction of RAAs 3D and 4D because RAA 5D involves a much larger treatment system.

RAA 1D requires no operation or maintenance. RAA 2D requires minimal operation and maintenance (groundwater and surface water samples will be collected periodically). RAA 3D requires extensive operation and maintenance. RAAs 4D and 5D also requires extensive operation and maintenance, but for a shorter period of time than RAA 3D (10 years as opposed to 30 years). In addition, RAAs 4D and 5D involve the extraction of air rather than groundwater so they will be

a less energy-intensive alternatives compared to RAA 3D. Under all five RAAs, additional remedial actions could easily be implemented.

RAAs 2D, 3D, 4D, and 5D involve conventional equipment and services that should be readily available. Compared to RAA 2D, RAAs 3D, 4D, and 5D will require more extensive coordination with the Base Public Works/Planning department. Unlike RAA 1D, RAAs 2D, 3D, 4D, and 5D will require semiannual submission of reports that document sampling results.

Under RAAs 1D and 2D no substantial reduction of contamination will occur immediately upon implementation. Contaminants are being gradually degraded into nonhazardous nontoxic by-products via natural attenuative processes. Although contaminant levels may be above the Remediation limits for a period time it is anticipated that in the long-term, Remediation levels will be achieved under these RAAs.

Although RAAs 3D and 4D are removal systems they are primarily barriers against the movement contamination into Courthouse Bay. It is anticipated that groundwater contaminant levels in the immediate vicinity of air sparging or extraction system will meet remediation levels in the short term. However, up gradient of the treatment systems contamination may remain above Remediation levels until transported into the treatment systems' zone of influence.

Under RAAs 3D and 4D contamination that does not threaten Courthouse Bay will be allowed to degraded via natural attenuation. In these areas contaminant levels may be above the Remediation limits for a period time. However, it is anticipated that in the long-term, Remediation levels will be achieved under these RAAs.

Under RAA 5D the area of influence of the extraction system overlays the contaminant plumes. It is anticipated that groundwater contaminant levels in the immediate vicinity of the extraction system will meet remediation levels in the short term.

7.2.7 Cost

In terms of NPW, the no action alternative (RAA 1D) will be the least expensive RAA to implement, followed by RAA 2D, RAA 4D, RAA 5D, and RAA 3D. The estimated NPW values in increasing order are $0 (RAA 1D), $1,470,000 (RAA 2D), $2,979,000 (RAA 4D), $3,010,000 (RAA 3D), and $3,928,000 (RAA 5D).

SECTION 7.0 TABLES

TABLE 7-1

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
OVERALL PROTECTIVENESS					
• Human Health	Does not provide overall protection of human health.	Provides overall protection of human health through natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through a pump and treat system, natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through an in-well aeration system, natural attenuation, monitoring, and aquifer use restrictions.	Provides overall protection of human health through a pump and treat system, monitoring, and aquifer use restrictions.
• Environmental Protection	Does not provide overall protection of the environment.	Provides overall protection of the environment through natural attenuation and monitoring.	Provides overall protection of the environment through a pump and treat system, natural attenuation, and monitoring.	Provides overall protection of the environment through an in-well aeration system, natural attenuation, and monitoring.	Provides overall protection of the environment through a pump and treat system, monitoring, and aquifer use restrictions.
COMPLIANCE WITH ARARs					
• Chemical-Specific ARARs/TBCs	Eventually, natural attenuation is expected to achieve the ARARs over an extended period of time.	Eventually, natural attenuation is expected to achieve the ARARs over an extended period of time.	Eventually, natural attenuation and pump and treat are expected to achieve ARARs.	Eventually, in-well aeration and natural attenuation is expected to achieve ARARs.	Eventually, in-well aeration is expected to achieve ARARs.
• Location-Specific ARARs	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	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 7-1 (Continued)

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	Minimal.	Minimal.	Minimal.	Minimal.	Minimal.
• Adequacy and Reliability of Controls	Not applicable - no controls.	Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the pump and treat system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the in-well aeration system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.	Once designed in accordance with site-specific characteristics, the in-well aeration system should be adequate and reliable. Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination.
• 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.

TABLE 7-1 (Continued)

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	No active treatment process. Natural attenuation is a passive treatment process.	No active treatment process. Natural attenuation is a passive treatment process.	Extraction wells, air stripping, liquid-phase carbon adsorption treatment, metals pretreatment, and natural attenuation.	In-well aeration vapor-phase carbon adsorption, and natural attenuation.	In-well aeration and vapor-phase carbon adsorption.
• Amount Destroyed or Treated	Expected to treat and/or destroy the majority of the contamination through natural attenuation.	Expected to treat and/or destroy the majority of the contamination through natural attenuation.	Expected to treat and/or destroy the majority of the contamination.	Expected to treat and/or destroy the majority of the contamination.	Expected to treat and/or destroy the majority of the contamination.
• Reduction of Toxicity, Mobility, or Volume Through Treatment	Some reduction in toxicity, mobility, and volume through natural attenuation.	Some reduction in toxicity, mobility, and volume through natural attenuation.	Some reduction in toxicity, mobility, and volume.	Some reduction in toxicity, mobility, and volume.	Some reduction in toxicity, mobility, and volume.
• Residuals Remaining After Treatment	Not applicable - no treatment.	Not applicable - no active treatment.	Treatment residuals will include sludge, spent carbon, and treated groundwater.	Treatment residuals will include spent carbon, separated water, and treated vapor.	Treatment residuals will include spent carbon, separated water, and treated vapor.
• Statutory Preference for Treatment	Not satisfied.	Satisfied through passive treatment.	Satisfied through active treatment.	Satisfied through active treatment.	Satisfied through active treatment.

TABLE 7-1 (Continued)

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
SHORT-TERM EFFECTIVENESS					
• Community Protection	Potential risks to the community will not be increased.	Potential risks to the community will not be significantly increased.	Potential risks to the community will be increased during system construction and O&M activities.	Potential risks to the community will be increased during system construction and O&M activities.	Potential risks to the community will be increased during system construction and O&M activities.
• Worker Protection	No risks to workers.	No significant risks to workers.	Potential risks to workers will be increased during system construction and O&M activities.	Potential risks to workers will be increased during system construction and O&M activities.	Potential risks to workers will be increased during system construction and O&M activities.
• Environmental Impact	No additional environmental impacts.	No additional environmental impacts.	Potential environmental impacts resulting from aquifer drawdown can be minimized or eliminated.	Potential environmental impacts resulting from vapor build up can be minimized or eliminated.	Potential environmental impacts resulting from aquifer drawdown can be minimized or eliminated.
• Time Until Action is Complete	Not applicable.	Thirty years.	Thirty years.	Ten years of system O&M and 30 years of monitoring.	Ten years of system O&M and 30 years of monitoring.

TABLE 7-1 (Continued)

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
IMPLEMENTABILITY					
• Ability to Construct and Operate	No construction or operation activities.	Monitoring well installation has been easily implemented in the past.	Pavement removal, underground utilities, and current site operations may complicate construction. Disposal of treatment residuals (i.e., sludge) and inorganics precipitation on well screens may complicate system O&M.	Pavement removal, underground utilities, and current site operations may complicate construction. Inorganics precipitation on well screens may complicate system O&M.	Pavement removal, underground utilities, and current site operations may complicate construction. Inorganics precipitation on well screens may complicate system O&M.
• Reliability of Technology	Not applicable.	Not applicable.	Inorganics may precipitate on the well screens creating the need for well replacement. If contaminants migrate into inaccessible regions, the pump and treat system will be less effective at collecting them.	Inorganics may precipitate on the injection well screens creating the need for well replacement. Since in-well aeration is relatively new and innovative, the reliability of this technology has not been well-demonstrated.	Inorganics may precipitate on the injection well screens creating the need for well replacement. Since in-well aeration is relatively new and innovative, the reliability of this technology has not been well-demonstrated.
• 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 remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.
• Ability to Monitor Effectiveness	No monitoring plan for measuring effectiveness.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.	Monitoring plan will detect contaminants before significant exposure can occur.
• Availability of Services and Capacities; Equipment	No services or equipment required.	Services and equipment should be readily available.	Services and equipment should be readily available.	Services and equipment should be readily available.	Services and equipment should be readily available.

TABLE 7-1 (Continued)

DETAILED ANALYSIS OF THE DEEP AQUIFER ALTERNATIVES - SUMMARY TABLE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1D: No Action	RAA 2D: Natural Attenuation	RAA 3D: Groundwater Extraction and Treatment	RAA 4D: In-Well Aeration	RAA 5D: In-Well Aeration-Expanded system
IMPLEMENTABILITY (Continued)					
• Requirements for Agency Coordination	None required.	No significant requirements.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.	Coordination with the Base Public Works/Planning Department and the Department of Transportation.
COST (Net Present Worth)	**$0**	**$1,470,000**	**$3,010,000**	**$2,979,000**	**$3,928,000**

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APPENDIX A
RISK-BASED RGO CALCULATIONS

GROUNDWATER EXPOSURE ASSESSMENT-REMEDIATION GOAL OPTIONS (RGOs)
INGESTION, DERMAL, AND INHALATION ROUTES OF EXPOSURE
CTO 0312, SITE 73
MCB, CAMP LEJEUNE, NORTH CAROLINA
FUTURE ADULT RESIDENT

RGO concentrations from groundwater ingestion, dermal contact, and volatile inhalation are calculated as follows:

Cc (mg/L) = (TR * BW * ATc) / [(EF * ED)((IR-1 * CSFo) + (PC * SA * ET * CF * CSFd) + (IR-2 * ET * k * CSFi))]

Cnc (mg/L) = (THI * BW * ATnc) / [(EF * ED)((IR-1 * 1/RfDo) + (PC * SA * ET * CF * 1/RfDd) + (IR-2 * ET * k * 1/RfDi))]

Where:	INPUTS
TR = total lifetime cancer risk (unitless)	1.0E-06
THI = total hazard index (unitless)	1
Cc = carcinogenic contaminant concentration in water (mg/L)	calculated
Cnc = noncarcinogenic contaminant concentration in water (mg/L)	calculated
BW = body weight (kg)	70
ATc = averaging time for carcinogen (days)	25550
ATnc = averaging time for noncarcinogen (days)	10950
CF = conversion factor (L/1000 cm3)	0.001
CSFo = oral cancer slope factor (mg/kg-day)-1	specific
CSFd = dermal cancer slope factor (mg/kg-day)-1	specific
CSFi = inhalation cancer slope factor (mg/kg-day)-1	
RfDo = oral reference dose (mg/kg-day)	specific
RfDd = dermal reference dose (mg/kg-day)	specific
RfDi = inhalation reference dose (mg/kg-day)	
PC = permeability constant (cm/hr)	specific
EF = exposure frequency (days/year)	350
ED = exposure duration (years)	30
ET = exposure time (hours/day)	0.25
IR-1 = daily water ingestion rate (L/day)	2
SA = surface area (cm2)	23000
IR-2 = inhalation rate (m3/hr)	0.6
k = volatilization factor (L/m3)	specific

Note: Inputs are scenario and site specific

Contaminant	TR	THI	Permeability Constant (cm/hour)	Oral Slope Factor (mg/kg-day)-1	Dermally Adj. Slope Factor (mg/kg-day)-1	Inhalation Slope Factor (mg/kg-day)-1	Oral Reference Dose (mg/kg-day)	Dermally Adj. Ref. Dose (mg/kg-day)	Inhalation Ref. Dose (mg/kg-day)	k (L/m3)	RGO Noncarc (mg/L)	RGO Carc (mg/L)
1,2-Dichloroethane	1.0E-06	1	0.0053	9.10E-02	1.14E-01	9.10E-02	0.00E+00	0.00E+00	2.86E-03	0.5	0.00	8.9E-04
1,2-Dichloroethene (total)	1.0E-06	1	0.0100	0.00E+00	0.00E+00	0.00E+00	9.00E-03	7.20E-03	0.00E+00	0.5	0.32	NA
Cis-1,2-Dichloroethene	1.0E-06	1	0.0100	0.00E+00	0.00E+00	0.00E+00	1.00E-02	8.00E-03	0.00E+00	0.5	0.35	NA
Benzene	1.0E-06	1	0.0210	2.90E-02	3.63E-02	2.91E-02	0.00E+00	0.00E+00	1.70E-03	0.5	1.65	2.6E-03
Vinyl Chloride	1.0E-06	1	0.0073	1.90E+00	2.37E+00	3.00E-01	0.00E+00	0.00E+00	0.00E+00	0.5	NA	4.3E-05
Trichloroethene	1.0E-06	1	0.0160	1.10E-02	1.38E-02	6.00E-03	6.00E-03	4.80E-03	0.00E+00	0.5	0.21	7.2E-03
Aluminum	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	1.00E+00	2.00E-01	0.00E+00	--	35.98	NA
Barium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	7.00E-02	1.40E-02	1.43E-04	--	2.52	NA
Chromium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	4.20E+01	5.00E-03	1.00E-03	0.00E+00	--	0.18	NA
Cobalt	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	6.00E-02	1.20E-02	0.00E+00	--	2.16	NA
Copper	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	4.00E-02	8.00E-03	0.00E+00	--	1.44	NA
Iron	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	3.00E-01	6.00E-02	0.00E+00	--	10.79	NA
Manganese	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	2.30E-02	4.60E-03	1.43E-05	--	0.83	NA
Vanadium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	0.00E+00	7.00E-03	1.40E-03	0.00E+00	--	0.25	NA

NA = not applicable due to lack of toxicity criteria

GROUNDWATER EXPOSURE ASSESSMENT-REMEDIATION GOAL OPTIONS (RGOs)
INGESTION AND DERMAL ROUTES OF EXPOSURE
CTO 0312, SITE 73
MCB, CAMP LEJEUNE, NORTH CAROLINA
FUTURE CHILD RESIDENT

RGO concentrations from groundwater ingestion and dermal contact are calculated as follows:

Cc (mg/L) = (TR * BW * ATc) / [(EF * ED) ((IR * CSFo) + (PC * CF * SA * ET * CSFd))]

Cnc (mg/L) = (THI * BW * ATnc) / [(EF * ED) ((IR * 1/RfDo) + (PC * CF * SA * ET * 1/RfDd))]

Where:	INPUTS
TR = total lifetime cancer risk (unitless)	1.0E-06
THI = total hazard index (unitless)	1
Cc = carcinogenic contaminant concentration in water (mg/L)	calculated
Cnc = noncarcinogenic contaminant concentration in water (mg/L)	calculated
BW = body weight (kg)	15
ATc = averaging time for carcinogen (days)	25550
ATnc = averaging time for noncarcinogen (days)	2190
CF = conversion factor (L/1000 cm3)	0.001
CSFo = oral cancer slope factor (mg/kg-day)-1	specific
CSFd = dermal cancer slope factor (mg/kg-day)-1	specific
RfDo = oral reference dose (mg/kg-day)	specific
RfDd = dermal reference dose (mg/kg-day)	specific
PC = permeability constant (cm/hr)	specific
EF = exposure frequency (days/year)	350
ED = exposure duration (years)	6
ET = exposure time (hours/day)	0.25
IR = daily water ingestion rate (L/day)	1
SA = surface area (cm2)	10000

Note: Inputs are scenario and site specific

Contaminant	TR	THI	Permeability Constant (cm/hour)	Oral Slope Factor (mg/kg-day)-1	Dermally Adj. Slope Factor (mg/kg-day)-1	Oral Reference Dose (mg/kg-day)	Dermally Adj. Ref. Dose (mg/kg-day)	RGO Noncarc (mg/L)	RGO Carc (mg/L)
1,2-Dichloroethane	1.0E-06	1	0.0053	9.10E-02	1.14E-01	0.00E+00	0.00E+00	NA	0.0015
1,2-Dichloroethene (total)	1.0E-06	1	0.0100	0.00E+00	0.00E+00	9.00E-03	7.20E-03	0.14	NA
Cis-1,2-Dichloroethene	1.0E-06	1	0.0100	0.00E+00	0.00E+00	1.00E-02	8.00E-03	0.16	NA
Benzene	1.0E-06	1	0.0210	2.90E-02	3.63E-02	0.00E+00	0.00E+00	NA	0.0057
Vinyl Chloride	1.0E-06	1	0.0073	1.90E+00	2.37E+00	0.00E+00	0.00E+00	NA	1.1E-05
Trichloroethene	1.0E-06	1	0.0160	1.10E-02	1.38E-02	6.00E-03	4.80E-03	0.09	0.0159
Aluminum	1.0E-06	1	0.0010	0.00E+00	0.00E+00	1.00E+00	2.00E-01	15.64	NA
Barium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	7.00E-02	1.40E-02	1.10	NA
Chromium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	5.00E-03	1.00E-03	0.08	NA
Cobalt	1.0E-06	1	0.0010	0.00E+00	0.00E+00	6.00E-02	1.20E-02	0.94	NA
Copper	1.0E-06	1	0.0010	0.00E+00	0.00E+00	4.00E-02	8.00E-03	0.63	NA
Iron	1.0E-06	1	0.0010	0.00E+00	0.00E+00	3.00E-01	6.00E-02	4.69	NA
Manganese	1.0E-06	1	0.0010	0.00E+00	0.00E+00	2.30E-02	4.60E-03	0.36	NA
Vanadium	1.0E-06	1	0.0010	0.00E+00	0.00E+00	7.00E-03	1.40E-03	0.11	NA

NA = not applicable due to lack of toxicity criteria

APPENDIX B
NORTH CAROLINA FRAMEWORK GROUNDWATER-SURFACE WATER MODEL

TABLE A1.1. WORK TABLE FOR DETERMINING GROUNDWATER TARGET CONCENTRATIONS.

See Worksheet A1.1 For Instructions On Completing This Work Table.

DATE: March 17, 1998
SITE: Site 73, MCB Camp Lejeune
COUNTY: Onslow
MAILING ADDRESS:

INCIDENT NUMBER: _____
RESPONSIBLE PARTY: _____
PHONE NUMBER: _____

All concentrations are in mg/L.

I	II	III	IV	V	VI	VII
Contaminants Found in Groundwater	Maximum Groundwater Concentration at Site	Target Concentrations by Groundwater Category			Required Groundwater Target Concentration*	Groundwater Category and Method
		G-1	G-2	G-3		
TCE (surficial)	46 ug/L			818	818 ug/L	G-3 II
DCE (surficial)	72 ug/L			16,200	16,200 ug/L	G-3 II
VC (surficial)	43 ug/L			15	15 ug/L	G-3 II
TCE (deep)	320 ug/L			994	994 ug/L	G-3 II
DCE (deep)	120 ug/L			5.53e+6	5.53e+6 ug/L	G-3 II
VC (deep)	4 ug/L			15	15 ug/L	G-3 II

* Lowest of the three target concentrations in Columns III through V unless none of the categories applied. If none of the categories apply, then enter the concentration for CCL where: CCL = the lower of 1000 times Groundwater quality standard (or interim groundwater quality standard) and 50% of the aqueous solubility of the contaminant.

DATAFILE NAME: TCE-MW27.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		Trichloroethene
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.0924
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	660
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.01
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	66
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	300
THICKNESS OF SURFICIAL AQUIFER	(Feet)	15
WIDTH OF CONTAMINANT PLUME	(Feet)	300
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.002
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.8674E+01 years
with Groundwater Concentration C/Csource = 0.2576E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.8178E+00 mg/l
for the chemical Trichloroethene

DATAFILE NAME: TCE-DW03.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		Trichloroethene
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.0924
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	380
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.001
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	38
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	300
THICKNESS OF SURFICIAL AQUIFER	(Feet)	60
WIDTH OF CONTAMINANT PLUME	(Feet)	300
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.001
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.5618E+02 years
with Groundwater Concentration C/Csource = 0.2418E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.9937E+00 mg/l
for the chemical Trichloroethene

DATAFILE NAME: DCE-MW09.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		cis-1,2-DCE
SURFACE WATER CHEMICAL STANDARD	(mg/l)	7.0
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	50
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.032
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	5
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	125
THICKNESS OF SURFICIAL AQUIFER	(Feet)	15
WIDTH OF CONTAMINANT PLUME	(Feet)	100
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.002
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.7757E+00 years
with Groundwater Concentration C/Csource = 0.9524E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.1617E+02 mg/l
for the chemical cis-1,2-DCE

DATAFILE NAME: DCE-A3-8.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		cis-1,2-DCE
SURFACE WATER CHEMICAL STANDARD	(mg/l)	7.0
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	290
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.01
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	29
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	200
THICKNESS OF SURFICIAL AQUIFER	(Feet)	15
WIDTH OF CONTAMINANT PLUME	(Feet)	200
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.002
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.4817E+01 years
with Groundwater Concentration C/Csource = 0.3703E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.5520E+02 mg/l
for the chemical cis-1,2-DCE

DATAFILE NAME: DCE-DW03.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		cis-1,2-DCE
SURFACE WATER CHEMICAL STANDARD	(mg/l)	7.0
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	500
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.001
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	50
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	300
THICKNESS OF SURFICIAL AQUIFER	(Feet)	60
WIDTH OF CONTAMINANT PLUME	(Feet)	300
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	1.0
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.5658E+02 years
with Groundwater Concentration C/Csource = 0.2025E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.5535E+05 mg/l
for the chemical cis-1,2-DCE

DATAFILE NAME: VC-A3-8.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		Vinyl Chloride
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.525
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	290
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.01
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	29
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	200
THICKNESS OF SURFICIAL AQUIFER	(Feet)	15
WIDTH OF CONTAMINANT PLUME	(Feet)	200
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.002
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.4817E+01 years
with Groundwater Concentration C/Csource = 0.3703E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.4140E+01 mg/l
for the chemical Vinyl Chloride

DATAFILE NAME: VC-MW09.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		Vinyl Chloride
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.525
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	50
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.032
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	5
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	125
THICKNESS OF SURFICIAL AQUIFER	(Feet)	15
WIDTH OF CONTAMINANT PLUME	(Feet)	100
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.002
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.7757E+00 years
with Groundwater Concentration C/Csource = 0.9524E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.1213E+01 mg/l
for the chemical Vinyl Chloride

DATAFILE NAME: VC-DW03.DAT
North Caroline Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME		Vinyl Chloride
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.525
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (P.L.E. = PLUME LEADING EDGE)	(Feet)	500
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	3
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.001
AQUIFER EFFECTIVE POROSITY	(unitless)	0.2
AQUIFER DISPERSION COEFFICIENT	(Feet^2/Day)	50
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0.0
LENGTH OF CONTAMINANT PLUME	(Feet)	300
THICKNESS OF SURFICIAL AQUIFER	(Feet)	60
WIDTH OF CONTAMINANT PLUME	(Feet)	300
7Q10 OF RIVER OR STREAM	(Feet^3/Second)	0.001
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:
Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.5658E+02 years
with Groundwater Concentration C/Csource = 0.2025E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.6741E+01 mg/l
for the chemical Vinyl Chloride

APPENDIX C
COST ESTIMATES - SURFICIAL AQUIFER ALTERNATIVES

TABLE C-1

COST ESTIMATE SUMMARY TABLE
SURFICIAL AQUIFER ALTERNATIVES
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

ALTERNATIVE	ANNUAL O & M COSTS	CAPITAL COSTS	PRESENT WORTH
RAA 1S - No Action	$0	$0	$0
RAA 2S - Natural Attenuation (Table C-2)	$185,000 (Years 1-5) $94,000 (Years 6-30)	$275,00	$2,068,000
RAA 3S - Groundwater Extraction and Treatment (C-3)	$185,000 (Years 1-5) $94,000 (Years 6-30) $45,000 (Years 1-30)	$1,194,000	$3,725,000
RAA 4S - Air Sparging and Soil Vapor Extraction (Table C-4)	$185,000 (Years 1-5) $94,000 (Years 1-6) $49,000 (Years 1-30)	$1,086,000	$3,678,000
RAA 5S - Groundwater Extraction and Treatment - Expanded System (Table C-5)	$142,000 (Years 1-5) $73,000 (Years 6-30) $65,000 (Years 1-30)	$1,507,000	$3,927,000

TABLE C-2

RAA 2S: NATURAL ATTENUATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$10,886	$10,886		Install 2 shallow wells and 5 soil borings	Engineering Estimates - Table C-2A
TOTAL					$56,654		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$32,708	$32,708		Initial groundwater & soil sampling for natural attenuation parameters	Engineering Estimates - Table C-2B
Laboratory Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$182,708		
TOTAL DIRECT CAPITAL COSTS					**$239,362**		
INDIRECT CAPITAL COSTS:							
Contingency Allowance	LS	1	$35,904	$35,904		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$35,904**		

TABLE C-2

RAA 2S: NATURAL ATTENUATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	264	$40	$10,560		10 days/event, 10 hrs/day/person, 3 people (23 wells)	Engineering Estimate - Table C-2C
Travel	Sample Event	1	$2,620	$2,620		Includes minivan rental and airfare for 3 people	Engineering Estimate - Table C-2C
Per Diem	Sample Event	1	$1,752	$1,752		Includes lodging and meals for 3 people	Engineering Estimate - Table C-2C
Laboratory Analysis & Data Validation:							
Groundwater Samples	Sample (per event)	23	$657	$15,112		23 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table C-2D
Surface Water Samples	Sample (per event)	3	$170	$510		Surface water to be analyzed for VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table C-2C
Shipping	Sample Event	1	$1,328	$1,328		2 coolers per day for 8 days; $83/cooler	Engineering Estimate - Table C-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Replacement and Redevelopment	Year	1	$2,980	$2,980		Replace 23 wells @ year 15 Redevelop 23 wells @ years 5, 10, 20 & 25.	Engineering Estimates - Table C-2E
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					$185,029	Quarterly sampling for years 1 - 5. No well redevelopment or replacement.	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					$94,005	Semiannual sampling, and well redevelopment and replacement	Engineering Estimate
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					$275,000		
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS)					$185,000		
TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)					$94,000		
NET PRESENT WORTH					$2,068,000	Based on a discount rate of 5%	

TABLE C-2A
COST ESTIMATE ASSUMPTIONS FOR ADDITIONAL MONITORING WELLS AND SOIL BORINGS

5 shallow soil borings (each 12-ft deep)
2 shallow monitoring wells (each 12-ft deep)
1 day mob, 1 day soil borings, 1 day monitoring well installation, 1 day pads /cleanup

Item	Units	Unit Cost	No. of Units	Total
Mobilization(rig and backhoe)	Each	$1,000	1	$1,000
Backhoe rental with operator	Day	$200	4	$800
Soil Boring (3-1/4 in HSA)	LF	$15	84	$1,260
Split spoon (4 per well/boring)	Each	$15	8	$120
Type II Well installation	LF	$15	24	$360
2" PVC sch. 40 riser (flush)	LF	$1.25	4	$5
2" PVC sch. 40 screen (10' screen)	LF	$11	20	$220
Protective cover (flush/stickup)	Each	$400	2	$800
Drums	Each	$42	10	$420
Well development	Hour	$65	2	$130
Temp. decon. pad	Each	$200	1	$200
Storage /disposal liquid IDW/solid	Each	$1,000	1	$1,000
Misc. expenses	Each	$1,000	1	$1,000
Contractor per diem	Day	$150	4	$600
Geologist labor	Hour	$40	40	$1,600
Geologist travel	Each	$1,079	1	$1,079
Geologist per diem	Day	$73	4	$292
Well Installation Costs				$10,886

TABLE C-2B
ESTIMATED COSTS FOR INITIAL FIELD EFFORT

23 natural attenuation monitoring points.
Baker crew of 2 for 8 days.

Item	Units	Unit Cost	Quantity	Subtotal	Remarks
Equipment	LS	$3,130.34	1	$3,130.34	Table C-2D
Water Analysis	Each	$657.05	23	$15,112.15	Table C-2D, full NA
Surface Water (VOAs)	Each	$170	3	$510	Engineering Estimate
Soil Analysis	Each	$200	5	$1,000	Engineering Estimate
IDW Analysis	LS	$1,500	1	$1,500	Engineering Estimate
Labor	Hour	$40	176	$7,040	Engineering Estimate
Travel	Hour	$700	2	$1,400	Engineering Estimate
Shipping	Each	$83	16	$1,328	
Truck/Van Rental	Day	$65	8	$520	Engineering Estimate
Per Diem (2 Baker)	Day	$73	16	$1,168	Engineering Estimate
			Total	$32,708.00	

TABLE C-2C
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

A total of 23 wells will be sampled

LABOR	264	hours/event
No. of people:	3	
Days required:	8	
Hours per day:	10	
Travel Time/person	8	
LABOR COST	$10,560	/event
TRAVEL	$2,620	/event
No. of people:	3	
Days required:	8	
Airfare (roundtrip PIT-OAJ, full fare)	$700.00	
Mini-van rental	$65.00	
PER DIEM	$1,752.00	/event
No. of people:	3	
Days required:	8	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

ITEM	UNIT RATE	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
Peristaltic Pump	$6.62 /Day	20	$132.40
P.E. Tubing	$21.25 /100 feet	10	$212.50
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:	$3,130.34

TABLE C-2D
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
Duplicates/QC/QC	$22.16	$3.10	$25.26
	TOTAL		$657.05

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, xylenes, or perchloroethene, trichloroethene, and dichloroethene (cis & trans)

TABLE C-2E
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REPLACEMENT/DEVELOPMENT

21 shallow monitoring wells (12-ft deep) will be replaced at year 15,
2 intermediate-shallow monitoring wells (45-ft deep) will be replaced at year 15

Item	Units	Unit Cost	No. of Units	Total	Comment
Mobilization	Each	$500	2	$1,000	rig and backhoe
Backhoe with operator	Day	$200	14	$2,800	
Well abandonment (overdrill & pull)	LF	$15	342	$5,130	shallow only
Type II Well installation	LF	$16.50	252	$4,158	shallow
2" PVC sch. 40 riser	LF	$1.25	200	$250	
2" PVC sch. 40 screen	LF	$11	230	$2,530	
8" mud rotary drilling< 50' bgs	LF	$15	36	$540	to 18 feet bgs
6" mud rotary drilling< 50 bgs	LF	$13	54	$702	18 -45 feet bgs
6" Steel Casing Installation	LF	$30	36	$1,080	
Type III Well installation	LF	$16.50	90	$1,485	intermediate-shallow
Protective cover/flush mount	LF	$400	23	$9,200	
Drums	Each	$42	10	$420	
Well development	Each	$65	70	$4,550	3 hour per well
Temp. decon. pad	Each	$200	1	$200	
Contractor per diem	Day	$150	14	$2,100	3 man crew
Storage /disposal liquid IDW	Each	$2,000	1	$2,000	
Storage /disposal solid IDW	Each	$1,000	1	$1,000	
IDW Analysis	Each	$1,500	1	$1,500	
Geologist labor	Hour	$40	140	$5,600	
Geologist travel	Each	$700	1	$700	
Geologist per diem	Each	$73	14	$1,022	
Van/truck rental	Day	$65	14	$910	
Cost of well replacement @ year 15 (F)				$48,877	
Present Worth Cost (P/F)				$23,510	
Annualized Cost over 30 years (A/P)				$1,530	

TABLE C-2E (continued)
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REPLACEMENT/DEVELOPMENT

23 wells redeveloped years 5, 10, 20 and 25, 4 events.
2 person crew for 5 days

Item Well Development and inspection	Units	Unit Cost	No. of Units	Total	Comments
Materials	LS	$500	1	$500	
Equipment (pumps, hose, etc.)	LS	$300	1	$300	
Storage /disposal liquid IDW	LS	$2,000	1	$2,000	2 months storage, 1 tanker, and removal.
IDW Analysis	LS	$1,500	1	$1,500	
Geologist labor	Hour	$40	100	$4,000	2 people
Geologist travel	Each	$700	2	$1,400	
Geologist per diem	Day	$73	10	$730	
Van/truck rental	Day	$65	5	$325	
Cost of a well development event (events to occur in years 5, 10, 20 & 25)				$10,755	
Present Worth Cost of well redevlopment and replacement (P/F) (F=5, F=10, F=20, F=25)				$22,259	
Annualized Cost of Present Worth Cost over 30 years (A/P)				$1,449	
ANNUALIZED COST REPLACEMENT AND DEVELOPMENT				$2,980	

TABLE C-3

RAA 3S: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
DRILLING COSTS							
Additional Well & Soil Boring Installation	LS	1	$10,886	$10,886		Install 2 shallow wells and 5 soil borings	Engineering Estimates - Table C-2A
Extraction Well Installation	LS	1	$40,746	$40,746			
TOTAL					$51,632		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$32,708	$32,708		Initial groundwater & soil sampling for natural attenuation parameters	Engineering Estimates - Table C-2B
Laboratory Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$182,708		
GENERAL COSTS FOR THE EXTRACTION/TREATMENT SYSTEM							
Preconstruction Submittals	LS	1	$20,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans, QC Plans, Shop Drawings	Engineering Estimate
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$20,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc progress reports	Engineering Estimate
TOTAL					$90,000		
SITE WORK							
Concrete Saw	LF	3100	$2.08	$6,448			Means Site 1997, 020-728-0420
Demolished Rod Reinforced Concrete	CY	185	$93.26	$17,253			Means Echos, 1996
Load and Transport concrete	CY	185	$5.77	$1,067			Means Echos, 1996
Trenching for Collection Line	LF	1500	$7.32	$10,980		Includes excavation, backfill, and tamping	Means Site 1997, A12.3-110 & -310
Trenching for Discharge Line	LF	150	$6.63	$995			Means Site 1997, A12.3-110
Hay Bales	Ton	1	$375.00	$375		Place where construction is near bulkherad	Means Site 1997, 022-704-1200
Silt Fence	LF	750	$1.14	$855			
Chan Link Fence Removal	LF	200	$2.42	$484			
Fence Replacement	LF	200	$33.35	$6,670			
Gate Replacement	Each	1	$300	$300			
Jack and Bore under utilities	LF	300	$15	$4,500			
Jacking Pits and Mob/Denmob per bore	Each	6	$3,150	$18,900			
Sanitary Sewer Connection	LS	1	$1,750	$1,750			
Water Connection - Treatment Plant	LS	1	$1,750	$1,750		Includes trenching, meter, piping, and tamping	Means Site 1997
Overhead Electrical to Treatment Plant	LF	150	$95	$14,250		Includes overhead routing and poles	Engineering Estimate; Previous Projects
Erosion Protection at Discharge	SY	55	$50	$2,750		Rip-rap protection at discharge	Engineering Estimate; Previous Projects
Headwall for Discharge	Each	1	$1,500	$1,500		Includes precast headwall and placement	Engineering Estimate; Previous Projects
Topsoil Spreading	CY	240	$50	$12,000		Includes off-site topsoil and 6" placement	Engineering Estimate; Previous Projects
Fine Grading and Seeding	SY	1500	$4.38	$6,570			Means Site 1997, 022-286-0900
Pavement Rehabilitation Over Trench	SY	275	$28	$7,700		8" concrete thickness	Engineering Estimate; Previous Projects
Manhole Installation	Each	5	$1,495	$7,475			
TOTAL					$124,572		

TABLE C-3

RAA 3S: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
EXTRACTION WELLS							
2 HP Goundwater Pumps with controls	Each	3	$7,657	$22,971		Each well has its own control box. Electric Pumps.	Means Echos 1996 Unit Cost Book 33 23 0605
Miscellaneous Fittings	Each	3	$1,000	$3,000			Previous Engineering; Previous Projects
TOTAL					$25,971		
PIPING SYSTEMS							
1" PVC Recovery and Discharge Lines	LF	3000	$3.95	$11,850			Means Site 1997, 026-678
Electrical service line and ground	CLF	30	$424.00	$12,720			Means Site 1997, 025-854
3" PVC Containment Line	LF	3000	$6.65	$19,950			Means Site 1997, 026-678
Miscellaneous Fittings	LS	1	$8,904	$8,904		Assumes 20% of piping costs	Engineering Estimate; Previous Projects
TOTAL					$53,424		
TREATMENT PLANT EQUIPMENT							
Enclosure							
Low Profile Air Stripper	LS	1	$30,000	$30,000		Includes blower, exhaust port, horizontal transfer pump, etc	Vendor Quote
Flowmeter	LS	1	$10,000	$10,000			Engineering Estimate; Previous Projects
Metals Pretreatment System	LS	1	$100,000	$100,000		Includes 4,200 gallon surge tank, clarifier, filter press, etc.	Engineering Estimate; Previous Projects
Instrument/Control Panel	LS	1	$10,000	$10,000		Includes pump controls, 3/60/230 volt panel, etc.	Engineering Estimate; Previous Projects
Installation of Equipment	LS	1	$112,500	$112,500		Assume 75% of equipment costs incl. enclosure & electrical hook-up.	Engineering Estimate; Previous Projects
TOTAL					$262,500		
TOTAL DIRECT CAPITAL COSTS					**$790,807**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$47,448	$47,448		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$118,621	$118,621		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$118,621	$118,621		15% of Total Direct Capital Costs	Engineering Estimate
Start-up Costs	LS	1	$118,621	$118,621		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$403,312**		

TABLE C-3

RAA 3S: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	264	$40	$10,560		10 days/event, 10 hrs/day/person, 3 people (23 wells)	Engineering Estimate - Table C-2C
Travel	Sample Event	1	$2,620	$2,620		Includes minivan rental and airfare for 3 people	Engineering Estimate - Table C-2C
Per Diem	Sample Event	1	$1,752	$1,752		Includes lodging and meals for 3 people	Engineering Estimate - Table C-2C
Laboratory Analysis & Data Validation							
Groundwater Samples	Sample (per event)	23	$657	$15,111		23 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table C-2D
Surface Water Samples	Sample (per event)	3	$170	$510		Surface water to be analyzed for VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table C-2C
Shipping	Sample Event	1	$1,328	$1,328		2 coolers per day for 8 days; $83/cooler	Engineering Estimate - Table C-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Replacement & Redevelopment	Year	1	$2,980	$2,980		Replace 23 wells @ year 15. Redevelop 23 wells @ years 5, 10, 20 & 25.	Engineering Estimates - Table C-2E
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$185,024**	Quarterly sampling years 1 - 5. No well development or replacement.	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$94,002**	Semiannual sampling years 6-30. Well development and replacement.	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 30 years of system operation)							
Extraction Well Replacement	Year	1	$1,887	$1,887		Extraction well replacement @ year 15.	See Table C-3A
Labor for Plant O&M	Week	52	$240	$12,480		Assumed 8 hrs/week for 52 weeks/year at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$400	$4,800		Assumed 8 hrs/month, 12 months/year at $50/hr	Engineering Estimate
Chemicals	LS	1	$2,000	$2,000		Assumed one sample/month	Engineering Estimate
Air Sampling - Analysis	Sample	12	$300	$3,600		Assumed one sample/month	Engineering Estimate
Effluent Sampling and Analysis	Sample	12	$400	$4,800		One sample per well per month; Includes materials and labor	Engineering Estimate
Sludge Disposal	Month	12	$450	$5,400		3 drums/month at $150/drum for disposal	Engineering Estimate
Electricity	KWH	65323	$0.07	$4,573		24 hours/day for 365 days/year operation, 10 HP required	Engineering Estimate; Previous Projects
Administration and Records	Hours	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-30)					**$44,539**		
OTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,194,000**		
TOTAL ANNUAL O&M COSTS (1-5 YEARS)					**$185,000**		
TOTAL ANNUAL O&M COSTS (6-30 YEARS)					**$94,000**		
TOTAL ANNUAL O&M COSTS (1-30 YEARS)					**$45,000**		
ET PRESENT WORTH					**$3,725,000**	Based on a discount rate of 5%	

TABLE C-3A
COST ESTIMATE ASSUMPTIONS FOR RAA 3S
SHALLOW EXTRACTION WELL

Based on discussion with PM and drillers, use 6" PVC
Cost is for 3 extraction wells, includes all costs associated with well installation, wellhead protection, and pumping equipment.

Item	Units	Unit Cost	No. of Units	Total	Comment
Mobilization	Each	$500.00	2	$1,000.00	rig and backho
Backhoe with operator	Day	$200.00	5	$1,000.00	Vendor BOA
Type II Well installation	LF	$16.50	36	$594.00	Vendor BOA
6" PVC sch. 40 riser	LF	$8.50	10	$85.00	Vendor BOA
6" PVC sch. 40 screen (10 ft section)	LF	$460.00	3	$1,380.00	Vendor BOA
8" mud rotary drilling< 50' bgs	LF	$22.00	36	$792.00	Echos
Split spoon (5 per well boring)	Each	$15.00	15	$225.00	Vendor BOA
Traffic load well protection	Each	$3,106.00	3	$9,318.00	Echos
Pump and level control	Each	$5,716.44	3	$17,149.32	Echos
Guardposts	Each	$49.86	15	$747.90	Echos
Drums	Each	$42.00	10	$420.00	Vendor BOA
Well development	Each	$65.00	9	$585.00	3 hour per well
Temp. decon. pad	Each	$200.00	1	$200.00	Vendor BOA
Contractor per diem	Day	$150.00	5	$750.00	3 man crew
Storage /disposal liquid IDW	Each	$2,000.00	1	$2,000.00	Previous job
Storage /disposal solid IDW	Each	$1,000.00	1	$1,000.00	Previous job
IDW Analysis	Each	$1,500.00	1	$1,500.00	Previous job
Geologist labor	Hour	$ 40.00	50	$ 2,000.00	Previous job
Well Installation Costs Per Event				$40,746	
Present Worth Cost of Replacement (replacement @ year 15)				$19,599	
Annualized costs for well replacment years 1-15				$1,887	

TABLE C-4

RAA 4S: AIR SPARGING AND SOIL VAPOR EXTRACTION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$10,886	$10,886		Install 2 shallow wells and 5 soil borings	Engineering Estimates - Table C-2A
IAS System Monitoring Well Installation	LS	1	$26,586	$26,586		Install 8 wells, to monitor efficiency of IAS/SVE systems	Engineering Estimates - Table C - 4A
TOTAL					$37,472		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$32,708	$32,708		Initial groundwater & soil sampling for natural attenuation parameters	Engineering Estimates - Table C-2B
Laboratory Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$182,708		
GENERAL COSTS FOR THE EXTRACTION/TREATMENT SYSTEM							
Preconstruction Submittals	LS	1	$20,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans, QC Plans, Shop Drawings	Engineering Estimate
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$20,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc. progress reports	Engineering Estimate
TOTAL					$90,000		
SITE WORK						Includes site prep items and items common to/shared by IAS and SVE	
Saw Cut Cement	LF	600	$2.08	$1,248		Saw-cut 2 sides of 5 trenches.	Means Site 1997 - Table C-4B
Demolish Rod Reinforced Concrete, 7"- 24" thick	CY	25	$93.26	$2,332		Trenches are minimum of 36" in width. Reinforced concrete 12" thick.	Means Echos 1996 - Table C-4B
Load and Transport Concrete	CY	70	$5.77	$404		Remove excavated concrete offsite	Means Echos 1996 - Table C-4B
Silt Fence	LF	750	$1.14	$855			
Hay Bales	Ton	1	$375.00	$375			
Trenching (for manifold piping blowers to BP trench including backfill and compaction not BP trench)	CY	227	$3.17	$720		Includes trenching and IAS piping	Means Echos 1996 - Table C-4B
Stainless Steel Manifold in Trench (not BP Trench)	LF	400	$20.76	$8,304			
Jacking and Boring for Utility Clearance	LF	150	$15.00	$2,250		For SVE collection system. From sparge trench to trailer.	Means Echos 1996 - Table C-4B
Jacking Pits	Each	6	$3,130.00	$18,780			
Overhead Electrical to Treatment Trailer	Event	3	$3,000	$9,000		Each of 3 trailers will require hook-up.	Eng. Estimate; Previous Projects - Table C-4B
Trailer	Each	3	$772.96	$2,319		3 sites will need 3 trailers	Means Echos 1996 - Table C-4B
Grading And Seeding	SY	10,750	$4.38	$47,085		Majority of area is currently minimally maintained.	Eng. Estimate; Previous Projects - Table C-4B
Reinforced Concrete Replace Over All Trenches	SF	2,325	$6.79	$15,787		12" thick reinforced	Eng. Estimate; Previous Projects - Table C-4B
TOTAL					$109,458		

TABLE C-4

RAA 4S: AIR SPARGING AND SOIL VAPOR EXTRACTION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
IN SITU AIR SPARGE (IAS) INJECTION, SOIL VAPOR EXTRACTION COLLECTION SYSTEM (SVE)							
IAS/SVE installation via biopolymer trenching	SF	13,500	$10.00	$135,000		IAS/SVE piping installed, doesn't include packing or concrete work	Means Echos 1996 - Table C-4C
Gravel	CY	1,500	$20.16	$30,240		Materials only. Gravel to serve as packing in trench.	Means Echos 1996 - Table C-4C
Deliver And Dump Gravel	CY	1,500	$6.70	$10,050		Load , transport, and install gravel packing	Means Echos 1996 - Table C-4C
TOTAL					$175,290		
IN SITU AIR SPARGING EQUIPMENT							
Blower , 3.2 HP	EA	3	$4,359.00	$13,077		Cost of blower installation is included in the cost.	Means Echos 1996 - Table C-4C
Check Valve	EA	6	$200.00	$1,200			Means Echos 1996 - Table C-4C
Pressure Gauge	EA	6	$136.73	$820			Means Echos 1996 - Table C-4C
Misc. Fittings	LS	3	$934.35	$2,803		20% of IAS total equipment cost	Eng. Estimate; Previous Projects - Table C-4C
Equipment Installation	EA	3	$953.31	$2,860		Installation of fittings, gauges, and valves. 75% of cost for these items.	Eng. Estimate; Previous Projects - Table C-4C
TOTAL					$20,760		
VAPOR COLLECTION SYSTEM							
Blower, 5 HP	EA	3	$5,258.00	$15,774		Cost includes installation.	Means Echos 1996 - Table C-4C
Carbon Treatment Unit (Air)	EA	3	$2,912.00	$8,736		Cost includes installation.	Means Echos 1996 - Table C-4C
Monitoring Port w/gas Monitor	EA	8	$14.61	$117			Means Echos 1996 - Table C-4C
Continuous Monitoring Flow Meter	EA	3	$11,416.00	$34,248			Means Echos 1996 - Table C-4C
Knock-out Unit and drums	EA	3	$51.00	$153			Vendor Quote
Check Valve	EA	3	$800.00	$2,400			Means Echos 1996 - Table C-4C
Pressure Gauge	EA	6	$136.00	$816			Means Echos 1996 - Table C-4C
Miscellaneous Fittings and Piping	LS	3	$2,483.52	$7,451		20% of meters, valves, ports, and gauges costs.	Eng. Estimate; Previous Projects - Table C-4C
Carbon for Carbon Treatment Unit	LB	300	$.83	$249		3 units 400 lbs. each	Means Echos 1996 - Table C-4C
Above Ground System Installation	EA	3	$11,175.85	$33,528		Installation of fittings, gauges, meters & valves. 75% of cost for these.	Eng. Estimate; Previous Projects - Table C-4C
TOTAL					$103,471		
TOTAL DIRECT CAPITAL COSTS					**$719,159**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$43,150	$43,150		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$107,874	$107,874		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$107,874	$107,874		15% of Total Direct Capital Costs	Engineering Estimate
Start-Up Costs	LS	1	$107,874	$107,874		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$366,771**		

TABLE C-4

RAA 4S: AIR SPARGING AND SOIL VAPOR EXTRACTION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	264	$40	$10,560		10 days/event, 10 hrs/day/person, 3 people (23 wells)	Engineering Estimate - Table C-2C
Travel	Sample Event	1	$2,620	$2,620		Includes minivan rental and airfare for 3 people	Engineering Estimate - Table C-2C
Per Diem	Sample Event	1	$1,752	$1,752		Includes lodging and meals for 3 people	Engineering Estimate - Table C-2C
Laboratory Analysis & Data Validation:							
Groundwater Samples	Sample (per event)	23	$657	$15,111		23 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table C-2D
Surface Water Samples	Sample (per event)	3	$170	$510		Surface water to be analyzed for VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table C-2C
Shipping	Sample Event	1	$1,328	$1,328		2 coolers per day for 8 days; $83/cooler	Engineering Estimate - Table C-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Replacement and Redevelopment	Year	1	$2,980	$2,980		Replace 23 wells @ year 15 and Redevelop 23 wells @ years 5, 10, 20 & 25.	Engineering Estimates - Table C-2E
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$185,024**	Quarterly sampling for years 1 - 5. No well redevelopment or replacement.	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$94,002**	Semiannual sampling, and well redevelopment and replacement	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 30 years of system operation)							
IAS Well Replacement	Year	1	$1,231	$1,231			
Labor for Plant O&M	Week	52	$240	$12,480		Assumed 8 hrs/week for 52 weeks/year at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$400	$4,800		Assumed 8 hrs/month, 12 months/yr. at $50/hr	Engineering Estimate
Remove/Reinstall Carbon Units	LS	3	$166	$499		Done once a year as part of carbon regeneration.	Means Echos 1996 -Table C-4C
Regenerate Carbon	LB	300	$.83	$249		Carbon regeneration performed yearly.	Means Echos 1996 -Table C-4C
Air Sampling - Analysis	Sample	36	$300	$10,800		Assumed one sample/month for each of 3 systems	Engineering Estimate
Electricity	kWh	195,970	$.07	$13,718		24 hours/day for 365 days/year operation, 3 IAS & 3 SVE blowers	Means Echos 1996 -Table C-4C
Administration and Records	Hours	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-30)					**$48,777**		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,086,000**		
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS)					**$185,000**		
TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)					**$94,000**		
TOTAL ANNUAL O&M COSTS (1-30 YEARS)					**$49,000**		
NET PRESENT WORTH					**$3,678,000**	Based on a discount rate of 5%	

TABLE C-4A
COST ESTIMATE ASSUMPTIONS FOR RAA 4S
IN SITU AIR SPARGING SYSTEM MONITORING WELLS
INSTALLATION AND REPLACEMENT

Install 8 monitoring wells to monitor IAS performance.
lls at north system and 2 at each bayside systems.
Wells are needed upgradient and down gradient to assess efficiency

Mobilization(rig and backhoe)	Each	$1,000	2	$2,000
Backhoe rental with operator	Week	$3,000	1	$3,000
Soil Boring (6-1/4 in HSA)	LF	$15	96	$1,440
Split spoon (4 per well/boring)	Each	$15	32	$480
Type II Well installation	LF	$15	96	$1,440
2" PVC sch. 40 riser (flush)	LF	$1.25	16	$20
2" PVC sch. 40 screen (10' screen)	LF	$11	80	$880
Protective cover (flush/stickup)	Each	$400	8	$3,200
Drums	Each	$42	10	$420
Well development	Hour	$65	24	$1,560
Temp. decon. pad	Each	$200	1	$200
IDW Analytical	LS	$1,500	1	$1,500
Storage /disposal liquid IDW/solid	Each	$5,000	1	$5,000
Misc. expenses	Each	$1,000	1	$1,000
Contractor per diem	Day	$150	5	$750
Geologist labor	Hour	$40	50	$2,000
Geologist travel	Each	$1,079	1	$1,079
Geologist per diem	Day	$73	4	$292
Vehicle	Day	$65	5	$325
IAS Well Installation Costs Per Event				$26,586
Present Worth Cost of Replacement (P/F)				$12,788
Annualized Costs for IAS Well Replacment years 1-15				$1,231

TABLE C-4B
COST ESTIMATE OF SITE WORK BY AREA

	Item	Units	Unit Cost	PLANT 1 No. of Units	PLANT 2 No. of Units	PLANT 3 No. of Units	Total No. of Units	Site Total	Source
1.	Saw Cut Cement (fror trenching)	LF	$2.08	1000	0	600	1600	$3,328.00	Means Site 1997
2.	Demolish Rod Reinforced Concrete, 7"- 24" thick	CY	$93.26	40	0	25	65	$6,061.90	Means 1996, Echos
3.	Disposal Charges (Load and Transport, conc & spoil)	CY	$5.77	220	0	70	290	$1,673.30	Means 1996, Echos
4.	Trenching for manifold piping (blowers to BP trench) including backfill and compaction not BP trench	CY	$3.17	180	0	45	225	$713.25	Means 1996, Echos
5.	Overhead Electrical to Treatment Trailer	Event	$3,000.00	1	1	1	3	$9,000.00	Means 1996, Echos
6.	Stainless steel SVE piping (blowers to BP trench)	LF	$20.76	325	0	75	400	$8,304.00	Means 1996, Echos
7.	Trailer	Each	$772.96	1	1	1	3	$2,318.88	Means 1996, Echos
8.	Fine grading and seeding	SY	$4.38	0	9000	1750	10750	$47,085.00	Means 1996, Echos
9.	Reinforced Concrete Replace Over All Trenches	SF	$6.79	1425	0	900	2325	$15,786.75	Means 1996, Echos
	Total							$94,271.08	

Plant No. 1 is near Building A-47.
Plant No. 2 is near Washdown Area.
Plant No. 3 is near Building A-1.
See attached calculation sheet for assumptions.

TABLE C-4C
COST ESTIMATE ASSUMPTIONS FOR RAA 4S
IN SITU AIR SPARGING AND SOIL VAPOR EXTRACTION SYSTEMS

Item	Units	Unit Cost	PLANT 1 No. of Units	PLANT 2 No. of Units	PLANT 3 No. of Units	Total No. of Units	Site Total	Source
IAS Trench/SVE System								
Air Sparging System								
Trench (biopoymer trench install with AS/SVE piping)	SF	$10.00	2,250	7,875	3,375	13,500	$135,000.00	Vendor
Air Sparge Trench Gravel Packing								
Gravel	CY	$20.16	250	875	375	1,500	$30,240.00	Echos 17 03 0419
Deliver and dump gravel	CY	$6.70	250	875	375	1,500	$10,050.00	Echos 17 03 0420
Load and transport BP trench spoil	CY	$5.77	250	875	375	1,500	$8,655.00	Means 1996, Echos
Total Injection/Collection System							$175,290.00	Means Echos 1996
In Situ Air Sparging System								
Blower 3.2 HP	EA	$4,335	1	1	1	3	$13,005.00	Means Echos 1996
Check valve	EA	$200	4	1	1	6	$1,200.00	Means Echos 1996
Pressure Gauge	EA	$136.73	4	1	1	6	$820.38	Means Echos 1996
Miscellaneous fittings	LS	$934	1	1	1	3	$2,803.04	Means Echos 1996
Above ground system installation	EA	$953	1	1	1	3	$2,859.92	Means Echos 1996
Total Air Sparging System							$20,688.34	
Vapor Collection System								
Blower, 5 HP , 90 SCFM	EA	$5,258.00	1	1	1	3	$15,774.00	Means Echos 1996
Carbon treatment unit (air)	EA	$2,912.00	1	1	1	3	$8,736.00	Means Echos 1996
Monitoring port w/gas monitor	EA	$14.61	4	2	2	8	$116.88	Means Echos 1996
Continuous monitoring flow	EA	$11,416.00	1	1	1	3	$34,248.00	Means Echos 1996
Knock-out Unit and drums	EA	$51.00	1	1	1	3	$153.00	Means Echos 1996
Checkvalve	EA	$800.00	1	1	1	3	$2,400.00	Means Echos 1996
Pressure Gauge	EA	$136.00	4	1	1	6	$816.00	Means Echos 1996
Miscellaneous fittings and piping	LS	$2,483.52	1	1	1	3	$7,450.57	Engineering Estimate
Above ground system installation	EA	$11,175.85	1	1	1	3	$33,527.55	Engineering Estimate
Total Vapor Collection System							$103,221.99	
Annual Maintenance IAS								
Electrical usage (10 hp total requirement)	KWH	$.07	65,323	65,323	65,323	195,970	$13,717.90	Means Echos 1996
Annual Maintenance SVE Collection System								
Remove/reinstall carbon unit	EA	$166.48	1	1	1	3	$499.44	Means Echos 1996
Regenerate Carbon	LB	$.83	100	100	100	300	$249.00	Means Echos 1996
Electrical usage	KWH	$.07	8,760	8,760	8,760	26,280	$1,839.60	Means Echos 1996
Total Maintenance							$16,305.94	

See attached calculation sheet for assumptions on biopolymer trench.

TABLE C-5

RAA 5S: GROUNDWATER EXTRACTION AND TREATMENT - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
Drilling Costs							
Extraction Well Installation	LS	1	$77,782	$77,782		Install 7 extraction wells.	Engineering Estimates - Table C-5A
TOTAL					$77,782		
GENERAL COSTS FOR THE EXTRACTION/TREATMENT SYSTEM							
Preconstruction Submittals	LS	1	$50,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans, QC Plans, Shop Drawings	Engineering Estimate
Mobilization/Demobilization	LS	1	$35,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$30,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc. progress reports	Engineering Estimate
TOTAL					$90,000		
SITE WORK							
Concrete Saw	LF	5000	$2.08	$10,400			Means Site 1997, 020-728-0420
Demolish Rod Reinforced Concrete 7"- 24"	CY	250	$93.26	$23,315			Means Echos1996
Load and transport concrete	CY	250	$5.77	$1,443			Means Echos1996
Trenching for Collection Line	LF	5000	$7.32	$36,600		Includes excavation, backfill, and tamping. Installation on page 2	Means Site 1997, A12.3-110 & -310
Trenching for Discharge Line	LF	150	$6.63	$995		Includes excavation, backfill, and tamping. Installation on page 2.	Means Site 1997, A12.3-110
Clear and Grub	ACRE	1	$3,819	$3,819		Includes clear and grub of medium brush and trees and haul 2 miles.	Means Echos 1996, 17 01 0107
Silt Fence	LF	750	$1.14	$855			Means Echos 1996, 18 05 0206
Chain Link Fence Removal	LF	250	$2.42	$605			Means Site 1998, 020 550 0700
Fence Replacement	LF	250	$33.35	$8,338		10' Security fenc wire with barbed strands	Means Echos 1996, 18 04 02101
Gate Installation	Each	1	$300	$300			Engineering Estimate; Previous Projects
Jack and Bore Under Utilities	LF	400	$15	$6,000		Assume 8 utility lines that will require bore	Means Site 1997, 022 270 1000
Jacking Pits and Mob/Denmob per bore	Each	8	$3,150	$25,200			Means Site 1997, 022 270 1100
Water Connection - Treatment Plant	LS	1	$1,750	$1,750		Includes trenching, meter, piping, and tamping	Means Site 1997
Sanitary Sewer Connection- Treatment Plant	LS	1	$2,000	$2,000			Engineering Estimate; Previous Projects
Overhead Electrical to Treatment Plant	LF	150	$95	$14,250		Includes overhead routing and poles	Engineering Estimate; Previous Projects
Erosion Protection at Discharge	SY	55	$50	$2,750		Rip-rap protection at discharge	Engineering Estimate; Previous Projects
Headwall for Discharge	Each	1	$1,500	$1,500		Includes precast headwall and placement	Engineering Estimate; Previous Projects
Topsoil Spreading	CY	788	$50	$39,400		Includes off-site topsoil and 6" placement	Engineering Estimate; Previous Projects
Fine Grading and Seeding	SY	3570	$4.38	$15,637			Means Site 1997, 022-286-0900
Pavement Rehabilitation Over Trench	SY	1710	$28	$47,880		8" concrete thickness	Engineering Estimate; Previous Projects
Manhole Installations	Each	14	$1,495	$20,930		Install where extraction well, every 500 ft , and where bend.	Means 1998, A12.3-710
TOTAL					$263,965		

TABLE C-5

RAA 5S: GROUNDWATER EXTRACTION AND TREATMENT - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
EXTRACTION WELLS							
2 HP Goundwater Pumps with controls	Each	4	$7,657	$30,628		Each well has its own control box. Electric Pumps.	Means Echos 1996 Unit Cost Book 33 23 0605
1 HP Goundwater Pumps with controls	Each	3	$6,577	$19,731		Each well has its own control box. Electric pumps.	Means Echos 1996 Unit Cost Book 33 23 0605
Miscellaneous fittings, valves and gauges	Each	7	$1,000	$7,000		Cost is per well	Engineering Estimate
TOTAL					$57,359		
PIPING SYSTEMS							
1" PVC Recovery and Discharge Lines	LF	5,000	$3.95	$19,750			Means Site 1997, 026-678
Electrical sevice line and ground	CLF	50	$424.00	$21,200			Means Site 1997, 025-854
3" PVC Containment Line	LF	5,000	$6.65	$33,250			Means Site 1997, 026-678
Miscellaneous Fittings	LS	1	$14,840	$14,840		Assumes 20% of piping costs	Engineering Estimate; Previous Projects
TOTAL					$89,040		
TREATMENT PLANT EQUIPMENT							
Low Profile Air Stripper	LS	1	$50,000	$50,000		Includes blower, exhaust port, horizontal transfer pump, etc.	Vendor Quote
Flowmeter	LS	1	$20,000	$20,000			Engineering Estimate; Previous Projects
Metals Pretreatment System	LS	1	$150,000	$150,000		Includes 4,200 gallon tank, clarifier, filter press, etc.	Engineering Estimate; Previous Projects
Instrument/Control Panel	LS	1	$20,000	$20,000		Includes pump controls, 3/60/230 volt panel, etc.	Engineering Estimate; Previous Projects
Installation of Equipment	LS	1	$180,000	$180,000		Assume 75% of equipment costs incl. enclosure & electrical hook-up.	Engineering Estimate; Previous Projects
TOTAL					$420,000		
TOTAL DIRECT CAPITAL COSTS					**$998,146**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$59,889	$59,889		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$149,722	$149,722		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$149,722	$149,722		15% of Total Direct Capital Costs	Engineering Estimate
Start-up Costs	LS	1	$149,722	$149,722		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$509,055**		

TABLE C-5

RAA 5S: GROUNDWATER EXTRACTION AND TREATMENT - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	264	$40	$10,560		10 days/event, 10 hrs/day/person, 3 people (23 wells)	Engineering Estimate - Table C-2C
Travel	Sample Event	1	$2,620	$2,620		Includes minivan rental and airfare for 3 people	Engineering Estimate - Table C-2C
Per Diem	Sample Event	1	$1,752	$1,752		Includes lodging and meals for 3 people	Engineering Estimate - Table C-2C
Laboratory Analysis & Data Validation							
Groundwater Samples	Sample (per event)	23	$194	$4,462		23 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table C-2D
Surface Water Samples	Sample (per event)	3	$170	$510		Surface water to be analyzed for VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table C-2C
Shipping	Sample Event	1	$1,328	$1,328		2 coolers per day for 8 days; $83/cooler	Engineering Estimate - Table C-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Development and Replacement	Year	1	$2,980	$2,980		Replace 23 wells @ year 15. Redevelop 23 wells @ years 5, 10, 20 & 25.	Engineering Estimates - Table C-2E
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$142,428**	Quarterly sampling for years 1 - 5. No well redevelopment or replacement.	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$72,704**	Semiannual sampling, and well redevelopment and replacement	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 30 years of system operation)							
Extraction Well Replacement	Year	1	$3,601	$3,601			
Labor for Plant O&M	Week	52	$360	$18,720		Assumed 12 hrs/week for 52 weeks/year at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$400	$4,800		Assumed 8 hrs/month, 12 months/year at $50/hr	Engineering Estimate
Chemicals	LS	1	$5,000	$5,000		Assumed one sample/month	Engineering Estimate
Air Sampling - Analysis	Sample	12	$300	$3,600		Assumed one sample/month	Engineering Estimate
Effluent Sampling and Analysis	Sample	12	$400	$4,800		One sample per well per month; Includes materials and labor	Engineering Estimate
Sludge Disposal	Month	12	$900	$10,800		6 drums/month at $150/drum for disposal	Engineering Estimate
Electricity	KWH	130647	$0.07	$9,145		24 hours/day for 365 days/year operation, 20 hp required	Engineering Estimate; Previous Projects
Administration and Records	Hours	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-30)					**$65,467**		
OTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,507,201**		
TOTAL ANNUAL O&M COSTS (1-5 YEARS)					**$142,000**		
TOTAL ANNUAL O&M COSTS (6-30 YEARS)					**$73,000**		
TOTAL ANNUAL O&M COSTS (1-30 YEARS)					**$65,000**		
ET PRESENT WORTH					**$3,927,000**	Based on a discount rate of 5%	

TABLE C-5A
COST ESTIMATE ASSUMPTIONS FOR RAA 5S
SHALLOW EXTRACTION WELL INSTALLATION AND REPLACEMENT

Based on discussion with PM and drillers, use 6" PVC
Cost is for 7 extraction wells, includes all costs associated with well installation, wellhead protection, and pumping equipment. Wells to be initially installed and replaced at year 15.

Item	Units	Unit Cost	No. of Units	Total	Comment
Mobilization	Each	$500.00	2	$1,000.00	rig and backhoe
Backhoe with operator	Day	$200.00	5	$1,000.00	Vendor BOA
Type II Well installation	LF	$16.50	84	$1,386.00	Vendor BOA
6" PVC sch. 40 riser	LF	$8.50	14	$119.00	Vendor BOA
6" PVC sch. 40 screen (10 ft section)	LF	$460.00	7	$3,220.00	Vendor BOA
8" mud rotary drilling< 50' bgs	LF	$22.00	84	$1,848.00	Echos
Split spoon (5 per well boring)	Each	$15.00	35	$525.00	Vendor BOA
Traffic load well protection	Each	$3,106.00	3	$9,318.00	Echos
Flush mount	Each	$1,000.00	4	$4,000.00	Vendor
Pump and level control	Each	$5,716.44	7	$40,015.08	Echos
Guardposts	Each	$49.86	28	$1,396.08	Echos
Drums	Each	$42.00	10	$420.00	Vendor BOA
Well development	Each	$65.00	9	$585.00	3 hour per well
Temp. decon. pad	Each	$200.00	1	$200.00	Vendor BOA
Contractor per diem	Day	$150.00	15	$2,250.00	3 man crew
Storage /disposal liquid IDW	Each	$2,000.00	1	$2,000.00	Previous job
Storage /disposal solid IDW	Each	$1,000.00	1	$1,000.00	Previous job
IDW Analysis	Each	$1,500.00	1	$1,500.00	Previous job
Geologist labor	Hour	$ 40.00	150	$ 6,000.00	Previous job
Well Installation Costs Per Event				$77,782	
Present Worth Cost of Replacement (replacement @ year 15)				$37,413	
Annualized costs for well replacment years 1-15				$3,601	

APPENDIX D
COST ESTIMATES - DEEP AQUIFER ALTERNATIVES

TABLE D-1

COST ESTIMATE SUMMARY TABLE
SURFICIAL AQUIFER ALTERNATIVES
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

ALTERNATIVE	ANNUAL O & M COSTS	CAPITAL COSTS	PRESENT WORTH
RAA 1D - No Action	$0	$0	$0
RAA 2D - Natural Attenuation (Table D-2)	$123,000 (Years 1-5) $64,000 (Years 6-30)	$231,000	$1,470,000
RAA 3D - Groundwater Extraction and Treatment (D-3)	$123,000 (Years 1-5) $64,000 (Years 6-30) $46,000 (Years 1-30)	$1,064,000	$3,010,000
RAA 4D - Air Sparging and Soil Vapor Extraction (Table D-4)	$123,000 (Years 1-5) $64,000 (Years 1-6) $43,000 (Years 1-30)	$1,079,000	$2,979,000
RAA 5D - Groundwater Extraction and Treatment - Expanded System (Table D-5)	$71,000 (Years 1-5) $38,000 (Years 6-30) $104,000 (Years 1-30)	$1,602,000	$3,928,000

TABLE D-2

RAA 2D: NATURAL ATTENUATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$29,204	$29,204		Install 3 deep wells to 70' bgs	Engineering Estimates - Table D-2A
TOTAL					$29,204		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$21,267	$21,267		Initial groundwater & soil sampling for natural attenuation parameter	Engineering Estimates - Table D-2B
Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort.	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$171,267		
TOTAL DIRECT CAPITAL COSTS					**$200,471**		
INDIRECT CAPITAL COSTS							
Contingency Allowance	LS	1	$30,071	$30,071		Assume 15% of Total Direct Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$30,071**		

TABLE D-2

RAA 2D: NATURAL ATTENUATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	116	$40	$4,640		5 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Table D-2C
Travel	Sample Event	1	$1,725	$1,725		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table D-2C
Per Diem	Sample Event	1	$730	$730		Includes lodging and meals for 2 people	Engineering Estimate - Table D-2C
Laboratory Analysis & Data Validation:							
Groundwater Samples	Sample (per event)	12	$657	$7,885		12 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table D-2D
Surface Water Samples	Sample (per event)	2	$170	$340		2 samples, VOAs	Basic Ordering Agreement
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table D-2C
Shipping	Sample Event	1	$830	$830		2 coolers per day for 5 days; $83/cooler	Engineering Estimate - Table D-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Well Replacement and Development	Year	1	$4,114	$4,114			
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					$123,234	Quarterly sampling will be performed for the first five years.	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					$63,674	Semiannual sampling years 6-30.	Engineering Estimate
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					$231,000		
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS)					$123,000		
TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)					$64,000		
NET PRESENT WORTH					$1,470,000	Based on a discount rate of 5%	

TABLE D-2A
COST ESTIMATE ASSUMPTIONS FOR ADDITIONAL MONITORING WELLS AND SOIL BORINGS

3 deep monitoring wells (each 70-ft deep).
Soil samples collected from well borings
Installation will require 7 days

Item	Units	Unit Cost	No. of Units	Total	Comments
Mobilization(rig and backhoe)	Each	$1,000	1	$1,000	
Backhoe rental with operator	Day	$200	7	$1,400	
Split spoon (5 per well/boring)	Each	$15	15	$225	
10" mud rotary < 50'	LF	$17	54	$918	to 18'
8" casing installation	LF	$40	54	$2,160	to 18'
8" mud rotary < 50'	LF	$15	81	$1,215	18' - 45'
6" casing installation	LF	$30	81	$2,430	18' - 45'
6" mud rotary < 50'	LF	$13	15	$195	45' - 50'
6" mud rotary > 50'	LF	$25	60	$1,500	50' - 70'
Type III Well installation	LF	$16.50	210	$3,465	0 - 70'
2" PVC sch. 40 riser	LF	$1.25	180	$225	
2" PVC sch. 40 screen (10' screen)	LF	$11	30	$330	
Protective cover (flush or stick-up)	Each	$400	3	$1,200	
Drums	Each	$42	10	$420	
Well development	Hour	$65	9	$585	3 hours per well
Temp. decon. pad	Each	$200	1	$200	
Storage /disposal liquid IDW	Each	$2,000	1	$2,000	
Storage /disposal solid IDW	Each	$1,000	1	$1,000	
IDW Analysis	LS	$1,500	1	$1,500	
Misc. expenses	Each	$1,000	1	$1,000	
Contractor per diem	Day	$150	7	$1,050	3 person crew
Geologist labor	Hour	$40	88	$3,520	
Geologist travel	Each	$700	1	$700	
Geologist per diem	Day	$73	7	$511	
Vehicle Rental	Day	$65	7	$455	
Total Well Installation Costs				$29,204	

TABLE D-2B
ESTIMATED COSTS FOR INITIAL FIELD EFFORT

12 natural attenuation monitoring points.
Baker crew of 2 for 5 days.

Item	Units	Unit Cost	Quantity	Subtotal	Remarks
Equipment	LS	$3,130.34	1	$3,130.34	Table D-2D
Water Analysis	LS	$657.05	13	$8,541.65	Table D-2D, full NA
Soil Analysis	Each	$200	5	$1,000	Engineering Estimate
IDW Analysis	LS	$1,500	1	$1,500	Engineering Estimate
Labor	Hour	$40	116	$4,640	Engineering Estimate
Travel	Hour	$700	2	$1,400	Engineering Estimate
Vehicle Rental	Day	$65	5	$325	Engineering Estimate
Per Deim (2 Baker)	Day	$73	10	$730	Engineering Estimate
			Total	$21,267	

TABLE D-2C
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

Groundwater will be sampled semiannually for years 5-30
A total of 13 deep wells will be sampled

LABOR	116	hours/event
No. of people:	2	
Days required:	5	
Hours per day:	10	
Travel Time/person	8	
LABOR COST	$4,640	/event
TRAVEL	$1,725	/event
No. of people:	2	
Days required:	5	
Airfare (roundtrip	$700.00	
PIT-OAJ, full fare)		
Mini-van rental	$65.00	
PER DIEM	$730.00	/event
No. of people:	2	
Days required:	5	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

ITEM	UNIT RATE	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	10	$212.50
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:	$3,130.34

TABLE D-2D
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
Duplicates/QC/QC (4)	$22.16	$3.10	$25.26
	TOTAL		$657.05

NOTES
(1) Costs based on laboratory quotes and LANTDIV bidding prices.
(2) The cost for field analysis is included in equipment and labor costs
(3) Specific parameters include benzene, toluene, ethylbenzene, xlyenes, or perchloroethene, trichloroethene, and dichloroethene (cis & trans)
(4) Duplicates assumed to be 15% of VOA costs

TABLE D-2E
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REDEVELOPMENT AND REPLACEMENT

12 deep monitoring wells (each 70-ft deep) willl be replaced at year 15. Installation, 10 days.

Item	Units	Unit Cost	No. of Units	Total	Comments
Well Installation					
Mobilization	Each	$500	1	$500	
Backhoe with operator	Day	$200	24	$4,800	
Split spoon (5 per well/boring)	Each	$15	60	$900	
10" mud rotary < 50'	LF	$17	216	$3,672	to 18'
8" casing installation	LF	$40	216	$8,640	to 18'
8" mud rotary < 50'	LF	$15	324	$4,860	18' - 45'
6" casing installation	LF	$30	324	$9,720	18' - 45'
6" mud rotary < 50'	LF	$13	60	$780	45' - 50'
6" mud rotary > 50'	LF	$25	240	$6,000	50' - 70'
Type III Well installation	LF	$16.50	840	$13,860	0 - 70'
2" PVC sch. 40 riser	LF	$1.25	720	$900	
2" PVC sch. 40 screen (10' screen)	LF	$11	120	$1,320	
Protective cover/flush mount	Each	$400	12	$4,800	
Drums	Each	$42	10	$420	
Well development	Hour	$65	36	$2,340	3 hours per well
Temp. decon. pad	Each	$200	1	$200	
Storage /disposal liquid IDW	Each	$2,000	1	$2,000	2 months storage, 2 tankers,and removal.
Storage /disposal solid IDW	Each	$1,000	1	$1,000	2 months storage, 2 roll-offs, and removal.
IDW Analysis	LS	$1,500	1	$1,500	
Misc. expenses	Each	$1,000	1	$1,000	
Contractor per diem	Day	$150	24	$3,600	3 person crew
Geologist labor	Hour	$40	240	$9,600	
Geologist travel	Each	$700	1	$700	
Geologist per diem	Day	$73	24	$1,752	
Van/truck rental	Day	$65	24	$1,560	
Well Installation Costs per Event				$86,424	

Present Worth Costs (P/F)	$41,570
Annualized Costs Over 30 Years (A/P)	$2,706

TABLE D-2E (Continued)
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REDEVELOPMENT AND REPLACEMENT

12 wells redeveloped years 5, 10, 20, and 25. 4 events.
Redevelopment will require 6 days and a 2 person crew

Item	Units	Unit Cost	No. of Units	Total	Comments
Well Development and inspection					
Materials	LS	$500	1	$500	
Equipment (pumps, hose, etc.)	LS	$150	1	$150	
Data Logger	Day	$70	1	$70	
Storage /disposal liquid IDW	LS	$2,000	1	$2,000	2 months storage, 2 tankers,and removal.
IDW Analysis	LS	$700	1	$700	
Geologist labor	Hour	$40	120	$4,800	
Geologist travel	Each	$700	2	$1,400	
Geologist per diem	Day	$73	6	$438	
Van rental	Day	$65	6	$390	

Well development per event(events at years 5, 10, 20, and 25))	$10,448
Present Worth Costs (P/F)	$21,623
F=5, F=10, F=20 & F=25	
Annualized Costs Over 30 Years (A/P)	$1,408
ANNUALIZED COST REPLACEMENT AND DEVELOPMENT	$4,114

TABLE D-3

RAA 3D: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$29,204	$29,204		Install 3 deep wells to 70' bgs	Engineering Estimates - Table D-2A
Extraction Well Installation	LS	1	$62,655	$62,655		Well redevelopment and replacement over 30 years	Engineering Estimates - Table D-2E
TOTAL					$91,859		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$21,267	$21,267		Initial groundwater & soil sampling for natural attenuation parameters	Engineering Estimates - Table D-2B
Laboratory Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$171,267		
GENERAL COSTS FOR THE EXTRACTION/TREATMENT SYSTEM							
Preconstruction Submittals	LS	1	$20,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans, QC Plans, Shop Drawings	Engineering Estimate
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$20,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc. progress reports	Engineering Estimate
TOTAL					$90,000		
SITE WORK							
Trenching for Collection Line	LF	975	$7.32	$7,137		Includes excavation, backfill, and tamping	Means Site 1997, A12.3-110 & -310
Trenching for Discharge Line	LF	150	$6.63	$995		Includes excavation, backfill, and tamping	Means Site 1997, A12.3-110
Concrete Saw	LF	575	$2.08	$1,196			Means Site 1997, 020-728-0420
Water Connection - Treatment Plant	LS	1	$1,750	$1,750		Includes trenching, meter, piping, and tamping	Means Site 1997
Overhead Electrical to Treatment Plant	LF	150	$95	$14,250		Includes overhead routing and poles	Engineering Estimate; Previous Projects
Erosion Protection at Discharge	SY	55	$50	$2,750		Rip-rap protection at discharge	Engineering Estimate; Previous Projects
Headwall for Discharge	Each	1	$1,500	$1,500		Includes precast headwall and placement	Engineering Estimate; Previous Projects
Topsoil Spreading	CY	85	$50	$4,250		Includes off-site topsoil and 6" placement	Engineering Estimate; Previous Projects
Fine Grading and Seeding	SY	510	$4.38	$2,234			Means Site 1997, 022-286-0900
Pavement Rehabilitation Over Trench	SY	640	$28	$17,920		8" concrete thickness	Engineering Estimate; Previous Projects
TOTAL					$53,981		

TABLE D-3

RAA 3D: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
EXTRACTION WELLS							
Pulse Air Groundwater Pump & Controls	Each	2	$6,000	$12,000			Previous Estimate
Miscellaneous Fittings	LS	1	$1,000	$1,000			
TOTAL					$13,000		
PIPING SYSTEMS							
Manhole	Each	2	$1,315	$2,630		Includes pre-cast manhole and cover	Means Site 1997, 027-152-08000 & 027-152-2100
1" PVC Recovery and Discharge Lines	LF	1,950	$3.95	$7,703			Means Site 1997, 026-678
1/2" PVC Air Supply Line	LF	975	$2.29	$2,233			Means Site 1997, 025-854
3" PVC Containment Line	LF	975	$6.65	$6,484			Means Site 1997, 026-678
Miscellaneous Fittings	LS	1	$2,722	$2,722		Assumes 20% of piping costs	Engineering Estimate; Previous Projects
TOTAL					$21,771		
TREATMENT PLANT EQUIPMENT							
Low Profile Air Stripper	LS	1	$30,000	$30,000		Includes blower, exhaust port, horizontal transfer pump, etc.	Vendor Quote
Flowmeter	LS	1	$10,000	$10,000			Engineering Estimate; Previous Projects
Metals Pretreatment System	LS	1	$100,000	$100,000		Includes 4,200 gallon surge tank, clarifier, filter press, etc.	Engineering Estimate; Previous Projects
Instrument/Control Panel	LS	1	$10,000	$10,000		Includes pump controls, 3/60/230 volt panel, etc.	Engineering Estimate; Previous Projects
Installation of Equipment	LS	1	$112,500	$112,500		Assume 75% of equipment costs including enclosure	Engineering Estimate; Previous Projects
TOTAL					$262,500		
TOTAL DIRECT CAPITAL COSTS					**$704,379**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$42,263	$42,263		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$105,657	$105,657		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$105,657	$105,657		15% of Total Direct Capital Costs	Engineering Estimate
Start-up Costs	LS	1	$105,657	$105,657		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$359,233**		

TABLE D-3

RAA 3D: GROUNDWATER EXTRACTION AND TREATMENT
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	116	$40	$4,640		5 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Table D-2C
Travel	Sample Event	1	$1,725	$1,725		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table D-2C
Per Diem	Sample Event	1	$730	$730		Includes lodging and meals for 2 people	Engineering Estimate - Table D-2C
Laboratory Analysis & Data Validation							
Groundwater Samples	Sample (per event)	12	$657	$7,884		12 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table D-2D
Surface Water Samples	Sample (per event)	2	$170	$340		2 samples, VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table D-2C
Shipping	Sample Event	1	$830	$830		2 coolers per day for 5 days; $83/cooler	Engineering Estimate - Table D-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Replacement and Development	Year	1	$4,114	$4,114			
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$123,230**	Quarterly sampling will be performed for the first 5 years	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$63,672**	Semiannual sampling years 6-30.	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 30 years of system operation)							
Extraction Well Replacement	Year	1	$2,901	$2,901		See Table D-3A	Engineering Estimate
Labor for Plant O&M	Week	52	$240	$12,480		Assumed 8 hrs/week for 52 weeks/year at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$400	$4,800		Assumed 8 hrs/month, 12 months/year at $50/hr	Engineering Estimate
Chemicals	LS	1	$2,000	$2,000		Assumed one sample/month	Engineering Estimate
Air Sampling - Analysis	Sample	12	$300	$3,600		Assumed one sample/month	Engineering Estimate
Effluent Sampling and Analysis	Sample	12	$400	$4,800		One sample per well per month; Includes materials and labor	Engineering Estimate
Sludge Disposal	Month	12	$450	$5,400		3 drums/month at $150/drum for disposal	Engineering Estimate
Electricity	KWH	65323	$0.07	$4,573		24 hours/day for 365 days/year operation. 10 hp required.	Engineering Estimate; Previous Projects
Administration and Records	Hours	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-30)					**$45,554**		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,064,000**		
TOTAL ANNUAL O&M COSTS (1-5 YEARS)					**$123,000**		
TOTAL ANNUAL O&M COSTS (6-30 YEARS)					**$64,000**		
TOTAL ANNUAL O&M COSTS (1-30 YEARS)					**$46,000**		
ET PRESENT WORTH					**$3,010,000**	Based on a discount rate of 5%	

TABLE D-3A
COST ESTIMATE ASSUMPTIONS FOR RAA 3D
DEEP EXTRACTION WELL INSTALLATION

Based on discussion with PM and drillers, use 6" PVC.
Cost includes all work associated with well installation, wellhead protection, and pumping equipment
Cost is for 3 deep wells, assume site supervision for these tasks is addressed in another cost unit

Item	Units	Unit Cost	No. of Units	Total	Comments
Well Installation					
Mobilization	Each	$500.00	2	$1,000.00	Rig and back hoe
Backhoe with operator	Day	$200.00	10	$2,000.00	Vendor BOA
Split spoon (5 per well/boring)	Each	$15.00	15	$225.00	Vendor BOA
12" mud rotary < 50'	LF	$35.00	60	$2,100.00	to 20', Vendor BOA
10" casing installation	LF	$70.00	60	$4,200.00	to 20', Vendor BOA
10" mud rotary < 50'	LF	$25.00	75	$1,875.00	20'-45' Vendor BOA
8" casing installation	LF	$40.00	75	$3,000.00	20'-45' Vendor BOA
8" mud rotary < 50'	LF	$22.00	15	$330.00	45' - 50' Echos
8" mud rotary > 50'	LF	$22.00	60	$1,320.00	50' - 70' Echos
Type III Well installation	LF	$17.50	210	$3,675.00	0 - 70' Vendor BOA
6" PVC sch. 40 riser	LF	$8.50	120	$1,020.00	Vendor BOA
6" PVC sch. 40 screen (10' screen)	Each	$460.00	9	$4,140.00	30' interval to screen
Traffic Load well protection	Each	$3,106.00	3	$9,318.00	Echos, 33 23 2205,
Guardposts	Each	$49.86	15	$747.90	Echos, 33 23 2301
Pump and level control	Each	$5,716.44	3	$17,149.32	Echos, 33 23 0601
Drums	Each	$42.00	10	$420.00	Vendor BOA
Well development	Hour	$65.00	9	$585.00	3 hours per well
Temp. decon. pad	Each	$200.00	1	$200.00	Vendor BOA
Storage /disposal liquid IDW	Each	$2,000.00	1	$2,000.00	Previous jobs
Storage /disposal solid IDW	Each	$1,000.00	1	$1,000.00	Previous jobs
IDW Analysis	LS	$ 1,500.00	1	$ 1,500.00	Previous jobs
Misc. expenses	Each	$1,000.00	1	$1,000.00	Previous jobs
Contractor per diem	Day	$150.00	7	$1,050.00	3 person crew
Geologist labor	Hour	$40.00	70	$2,800.00	Installation only

Well Installation Costs per Event	$62,655
Present Worth Cost of Replacement (replacement @ year 15)	$30,137
Annualized costs for well replacment years 1-15	$2,901

Note: Costs for well installation less pumping equipment can be used for In-well aeration

TABLE D-4

RAA 4D: IN-WELL AERATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$29,204	$29,204		Install 3 deep wells to 70' bgs	Engineering Estimates - Table D-2A
TOTAL					$29,204		
GENERAL NATURAL ATTENUATION COSTS							
Initial Sampling Effort	LS	1	$21,267	$21,267		Initial groundwater & soil sampling for natural attenuation parameters	Engineering Estimates - Table D-2B
Laboratory Microcosm Study	LS	1	$50,000	$50,000		Study to determine biodegradation rate	Engineering Estimates - Previous Projects
Model Development	LS	1	$60,000	$60,000		Fate and transport model development	Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$20,000	$20,000		Work plans to support the long-term monitoring field effort	Engineering Estimates - Previous Projects
Natural Attenuation Report	LS	1	$20,000	$20,000		Presents results of initial sampling, microcosm study, and model	Engineering Estimates - Previous Projects
TOTAL					$171,267		
GENERAL COSTS FOR THE IN-WELL AERATION SYSTEM							
Preconstruction Submittals	LS	1	$20,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans	Engineering Estimate
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$20,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc. progress reports	Engineering Estimate
Pilot-Scale Treatability Study	LS	1	$150,000	$150,000			Engineering Estimate; Vendor Quote
TOTAL					$240,000		
SITE WORK							
Electrical Service Installation	LF	1100	$50	$55,000		Underground Lines	Engineering Estimates - Previous Projects
TOTAL					$55,000		

TABLE D-4

RAA 4D: IN-WELL AERATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
IN-WELL AERATION SYSTEM							
Well Installation	LF	210	$225	$47,250		Borings, castings, pack, benotonite pellets, grout; 3@70' deep each	Engineering Estimate; Previous Projects
Well Development	EA	3	$260	$780			Engineering Estimate; Previous Projects
UVB Equipment	EA	3	$40,000	$120,000			Engineering Estimate; Vendor Quote
UVB Equipment Installation	EA	3	$10,000	$30,000			Engineering Estimate; Vendor Quote
Air Blowers	EA	3	$2,000	$6,000			Engineering Estimate
Vapor-Liquid Separation Units	EA	3	$1,000	$3,000			Engineering Estimate
Carbon Units	EA	3	$1,000	$3,000			Engineering Estimate
Aboveground Equipment Installation	LS	1	$9,000	$9,000		Assumes 75% of air blower, vapor-liquid separation, and carbon costs	
TOTAL					$219,030		
TOTAL DIRECT CAPITAL COSTS					**$714,501**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$42,870	$42,870		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$107,175	$107,175		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$107,175	$107,175		15% of Total Direct Capital Costs	Engineering Estimate
Start-up Costs	LS	1	$107,175	$107,175		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$364,396		

TABLE D-4

RAA 4D: IN-WELL AERATION
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	116	$40	$4,640		5 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Table D-2C
Travel	Sample Event	1	$1,725	$1,725		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table D-2C
Per Diem	Sample Event	1	$730	$730		Includes lodging and meals for 2 people	Engineering Estimate - Table D-2C
Laboratory Analysis & Data Validation							
Groundwater Samples	Sample (per event)	12	$657	$7,884		12 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement - Table D-2D
Surface Water Samples	Sample (per event)	2	$170	$340		2 samples, VOAs.	
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table D-2C
Shipping	Sample Event	1	$830	$830		2 coolers per day for 5 days; $83/cooler	Engineering Estimate - Table D-2C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Model Updates & Reporting	Update (per event)	1	$7,500	$7,500		Quarterly updates for years 1-5 only	Engineering Estimate
Monitoring Well Replacement and Development	Year	1	$4,114	$4,114			
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$123,230**	Quarterly sampling will be performed for the first 5 years	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$63,672**	Semiannual sampling years 6-30.	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 10 years of system operation)							
Aeration Equipment O&M	EA	4	$3,000	$12,000		Three days per quarter; Includes labor and travel costs	Engineering Estimate; Vendor Quote
Carbon Replacement	EA	1	$5,000	$5,000		One carbon unit replacement per year; Includes material and labor for a new unit and disposal costs for the old unit	Engineering Estimate; Previous Projects
Electricity	KWH	65323	$0.07	$4,573		24 hours/day for 365 days/year operation, 10 HP required	Engineering Estimate; Previous Projects
Disposal of Water	LS	1	$2,000	$2,000			Engineering Estimate
Air Sampling and Analysis	EA	36	$400	$14,400		One sample per well per month; Includes materials and labor	Engineering Estimate
Administration and Records	Hours	100	$50	$5,000		25 hours/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-10)					**$42,973**		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,078,897**		
TOTAL ANNUAL O&M COSTS (1-5 YEARS)					**$123,000**		
TOTAL ANNUAL O&M COSTS (6-30 YEARS)					**$64,000**		
TOTAL ANNUAL O&M COSTS (1-10 YEARS)					**$43,000**		
ET PRESENT WORTH					**$2,979,000**	Based on a discount rate of 5%	

TABLE D-5

RAA 5D: IN-WELL AERATION - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
MONITORING WELLS & SOIL BORINGS							
Additional Well & Soil Boring Installation	LS	1	$29,204	$29,204		Install 3 deep wells to 70' bgs	Engineering Estimates - Table D-2A
TOTAL					$29,204		
GENERAL COSTS FOR THE IN-WELL AERATION SYSTEM							
Preconstruction Submittals	LS	1	$20,000	$20,000		Work Plan, E&S/NPDES Plans, H&S Plans	Engineering Estimate
Mobilization/Demobilization	LS	1	$30,000	$30,000		Includes mobilization for all subcontractors	Engineering Estimate
Contract Administration	LS	1	$20,000	$20,000		Invoicing, shop drawings, etc.	Engineering Estimate
Post-Construction Submittals	LS	1	$20,000	$20,000		Includes misc. progress reports	Engineering Estimate
Pilot-Scale Treatability Study	LS	1	$150,000	$150,000			Engineering Estimate; Vendor Quote
TOTAL					$240,000		
SITE WORK							
Electrical Service Installation	LF	3000	$50	$150,000		Underground Lines	Engineering Estimates - Previous Projects
TOTAL					$150,000		

TABLE D-5

RAA 5D: IN-WELL AERATION - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
IN-WELL AERATION SYSTEM							
Well Installation	LF	770	$225	$173,250		Borings, castings, pack, benotonite pellets, grout; 11@70' deep each	Engineering Estimate; Previous Projects
Well Development	EA	11	$260	$2,860			Engineering Estimate; Previous Projects
UVB Equipment	EA	11	$30,000	$330,000			Engineering Estimate; Vendor Quote
UVB Equipment Installation	EA	11	$7,500	$82,500			Engineering Estimate; Vendor Quote
Air Blowers	EA	11	$2,000	$22,000			Engineering Estimate
Vapor-Liquid Separation Units	EA	11	$1,000	$11,000			Engineering Estimate
Carbon Units	EA	11	$1,000	$11,000			Engineering Estimate
Aboveground Equipment Installation	LS	1	$9,000	$9,000		Assumes 75% of air blower, vapor-liquid separation, and carbon costs	
TOTAL					$641,610		
TOTAL DIRECT CAPITAL COSTS					**$1,060,814**		
INDIRECT CAPITAL COSTS							
Engineering and Design	LS	1	$63,649	$63,649		6% of Total Direct Capital Costs	Engineering Estimate
Construction Administration	LS	1	$159,122	$159,122		15% of Total Direct Capital Costs	Engineering Estimate
Contingency Allowance	LS	1	$159,122	$159,122		15% of Total Direct Capital Costs	Engineering Estimate
Start-up Costs	LS	1	$159,122	$159,122		15% of Total Direct Capital Costs	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					**$541,015**		

TABLE D-5

RAA 5D: IN-WELL AERATION - EXPANDED SYSTEM
COST ESTIMATE
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
FEASIBILITY STUDY, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
ANNUAL O&M COSTS:							
GROUNDWATER AND SURFACE WATER MONITORING - O&M PER EVENT							
Labor	Hours (per event)	116	$40	$4,640		5 days/event, 10 hrs/day/person, 2 people	Engineering Estimate
Travel	Sample Event	1	$1,725	$1,725		Includes minivan rental and airfare for 2 people	Engineering Estimate
Per Diem	Sample Event	1	$730	$730		Includes lodging and meals for 2 people	Engineering Estimate
Laboratory Analysis & Data Validation							
Groundwater Samples (TCL VOCs only)	Sample (per event)	12	$194	$2,328		12 samples and 15% additional to cover duplicates/QA/QC	Basic Ordering Agreement
Surface Water Samples	Sample (per event)	2	$170	$340		2 samples, VOAs.	Basic Ordering Agreement
Equipment & Supplies	Sample Event	1	$3,130	$3,130		Ice, DI water, expendables, pump, etc.	Engineering Estimate
Shipping	Sample Event	1	$830	$830		2 coolers per day for 5 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Monitoring Well Development and Replacemrnt	Year	1	$4,114	$4,114			
TOTAL ANNUAL MONITORING O&M (YEARS 1-5: QUARTERLY SAMPLING EVENTS)					**$71,006**	Quarterly sampling will be performed for the first 5 years	Engineering Estimate
TOTAL ANNUAL MONITORING O&M (YEARS 6-30: SEMIANNUAL SAMPLING EVENTS)					**$37,560**	Semiannual sampling years 6-30	Engineering Estimate
TREATMENT SYSTEM - ANNUAL O&M (Based on 10 years of system operation)							
Aeration Equipment O&M	EA	4	$5,000	$20,000		Five days per quarter; Includes labor and travel costs	Engineering Estimate; Vendor Quote
Carbon Replacement	EA	1	$10,000	$10,000		Two carbon unit replacement per year; Includes material and labor for a new unit and disposal costs for the old unit	Engineering Estimate; Previous Projects
Electricity	KWH	163308	$0.07	$11,432		24 hours/day for 365 days/year operation, 25 HP required	Engineering Estimate; Previous Projects
Disposal of Water	LS	1	$5,000	$5,000			Engineering Estimate
Air Sampling and Analysis	EA	132	$400	$52,800		One sample per well per month; Includes materials and labor	Engineering Estimate
Administration and Records	Hours	100	$50	$5,000		25 hours/quarter at $50/hr	Engineering Estimate
TOTAL ANNUAL TREATMENT SYSTEM O&M (YEARS 1-10)					**$104,232**		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					**$1,601,829**		
TOTAL ANNUAL O&M COSTS (1-5 YEARS)					**$71,000**		
TOTAL ANNUAL O&M COSTS (6-30 YEARS)					**$38,000**		
TOTAL ANNUAL O&M COSTS (1-10 YEARS)					**$104,000**		
ET PRESENT WORTH					**$3,928,000**	Based on a discount rate of 5%	