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FINAL

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 1
(SITES 21, 24 and 78)

MARINE CORPS BASE,
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0177

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	area of concern
APEG	alkaline polyethylene glycol
ARARs	applicable or relevant and appropriate requirements
AT	averaging time
AWQC	Federal Ambient Water Quality Criteria
Baker	Baker Environmental, Inc.
BTEX	benzene, toluene, ethylbenzene, xylenes
BOD	biological oxygen demand
CC	Cogdel Creek
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	contaminant of concern
CSF	cancer slope factor
CWA	Clean Water Act
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
1,1-DCA	1,1-dichloroethane
DON	Department of the Navy
DOT	Department of Transportation
EF	exposure frequency
ED	exposure duration
EPIC	Environmental Photographic Interpretation Center
ERA	ecological risk assessment
ER-L	effects range - low
ER-M	effects range-median
ESE	Environmental Science and Engineering, Inc.
FFA	Federal Facilities Agreement
gpm	gallons per minute
GW	groundwater well
HA	health advisory
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HP	Hadnot Point
HPIA	Hadnot Point Industrial Area
IAS	initial assessment study
ICR	incremental cancer risk
IR	ingestion rate
IRA	interim remedial action

IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
KPEG	potassium polyethylene glycol
KOH	potassium hydroxide
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
MCL	maximum contaminant level
mg/kg	milligram per kilogram
ml	milliliter
NACIP	Navy Assessment and Control of Installation Pollutants Program
NCAC	North Carolina Administrative Code
NC DEHNR	North Carolina Department of Environment, Health and Natural Resources
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCWQS	North Carolina Water Quality Standards
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NPW	net present worth
OLM	Organic Leaching Model
OU	operable unit
O&M	operations and maintenance
PACT	powered activated carton treatment
PAH	polynuclear aromatic hydrocarbon
PA/SI	preliminary assessment/site investigation
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PRAP	proposed remedial action plan
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAA	remedial action alternatives
RA	risk assessment
RBCs	rotating biological contractors
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RGO	remediation goal option
RI/FS	remedial investigation/feasibility study
RL	remediation level
RME	reasonable maximum exposure
ROD	record of decision
SA	skin surface area
SARA	Superfund Amendments and Reauthorization Act

SB	soil boring
SD	sediment
SDWA	Safe Drinking Water Act
SSVs	sediment screening values
STP	sewage treatment plant
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SW	surface water
T-1,2-DCE	trans-1,2-dichloroethene
TAL	Target Analyte List
TCE	trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substances Control Act
µg/L	micrograms per Liter
µg/kg	micrograms per kilogram
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOCs	volatile organic compounds
WAR	Water and Air Research, Inc.

EXECUTIVE SUMMARY

INTRODUCTION

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 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 was to ensure that environmental impacts associated with past and present activities at the MCB, Camp Lejeune were thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives were developed and implemented as necessary to protect public health and the environment.

The Fiscal Year 1994 Site Management Plan for MCB, Camp Lejeune, a primary document identified in the FFA, identifies 27 sites requiring Remedial Investigation/Feasibility Study (RI/FS) activities. This report documents the FS completed for three of these sites: Site 21, Site 24, and Site 78. Collectively these sites comprise Operable Unit (OU) No. 1 at MCB, Camp Lejeune. The purpose of this FS is to select a remedy for OU No. 1 that is protective of human health and the environment, attains Federal and State requirements, and is cost effective.

This 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]. The USEPA's document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988a) has been used as guidance for preparing this document. This FS has been based on data collected during the RI conducted at Sites 21, 24 and 78 (Baker, 1994). This FS also is based on an interim remedial action (IRA) that has been designed to contain the migration of contaminated groundwater known to exist within the shallow aquifer at Site 78 (Baker 1992a, Baker 1992b).

SITE DESCRIPTION AND HISTORY

The study area for this FS is OU No. 1, which consists of Sites 21, 24, and 78. Site 21 is known as the Transformer Storage Lot 140; Site 24 is referred to as the Industrial Fly Ash Dump; and Site 78 is commonly referred to as the Hadnot Point Industrial Area or HPIA.

OU No. 1 is located approximately one mile east of the New River and two miles south of State Route 24 within the main section of MCB, Camp Lejeune. The operable unit is bordered by Holcomb Boulevard to the northwest, Sneads Ferry Road to the northeast, Main Service Road to the southwest, and Cogdels Creek to the southeast. The Camp Lejeune Railroad operates rail lines parallel to Holcomb Boulevard extending into OU No. 1. The entire operable unit covers approximately 690 acres.

The site descriptions and histories for each of the sites investigated under OU No. 1 are presented below.

Site 21: Transformer Storage Lot 140

Site 21 is located within the northwest section of Site 78. The site is bordered by Ash Street to the southwest, Center Road to the southeast, and a wooded area to the northwest. The southern and central portions of the site (approximately 220 feet by 1,200 feet) include several fenced-in areas, while the northern section (approximately 500 feet long) is an open area. A water tower is located in the fenced portion of the site. The ground surface of the majority of the site is covered by gravel and concrete. Portions of the site, primarily the northern "open area," are unpaved and vegetated. Site 21 (Lot 140) has had a history of pesticide usage and reported transformer oil disposal. There are two areas of concern within Site 21: the Former Transformer Oil Disposal Pit and the Former Pesticide Mixing/Disposal Area.

The Former Transformer Oil Disposal Pit was located in the northeastern portion of the site. The pit was reportedly used as a disposal area for transformer oil during a one year period between 1950 and 1951. The pit reportedly measured 25 to 30 feet long by 6 feet wide by 8 feet deep. Sand was occasionally placed in the pit when oil was found standing in the bottom of the pit. The total quantity of oil disposed in this pit is unknown. A small area, slightly depressed in elevation, which may be the former oil pit, is evident in the northern portion of Site 21.

The Former Pesticide Mixing/Disposal Area was reported to be located in the southeast corner of the lot (the exact location is not documented). Based on the RI data, the area appears to be throughout the southern portion of the site. This part of the site was used as a pesticide mixing area and as a cleaning area for pesticide application equipment from 1958 to 1977. Chemicals reportedly stored at this site included diazinon, chlordane, lindane, DDT, malathion (46% solution), mirex, 2,4-D, silvex, dalapon and dursban. Small spills, discharge of washout fluids, and indiscriminate disposal are believed to have occurred in this area. In 1977, before these mixing/cleaning activities were moved to a different location, overland discharge of washout fluids was estimated to be approximately 350 gallons per week. It is not clear for how long this discharge of washout fluids occurred (ESE, 1990).

The southern portion of the site is periodically utilized for storage by Marine Corps Reserve units. Currently this portion of the site is being used for storage of military vehicles.

Site 24 - Industrial Fly Ash Dump

Site 24 is located adjacent to the southeast portion of Site 78. Specifically, the site is located south and east of the intersection of Birch and Duncan Streets and extends south toward Cogdels Creek. The site is primarily a wooded area, approximately 100 acres in size, that is somewhat overgrown. The site is hilly and is unpaved with site drainage towards Cogdels Creek. Dirt roads are interspersed throughout and lead to suspected disposal areas. The roads are periodically utilized for military vehicle maneuvers. Several areas indicating past disposal activities are evident throughout the site (i.e., surficial deposits of fly ash and mounding).

Site 24 was used for the disposal of fly ash, cinders, solvents, used paint stripping compounds, sewage sludge, and/or water treatment spiractor sludge from the late 1940s to 1980 (ESE, 1990). Spiractor sludge from the wastewater treatment plant and sewage sludge from the sewage treatment plant were reportedly disposed at this site since the late 1940s. Construction debris was reportedly disposed at the site in the 1960s. During 1972 to 1979, fly ash and cinders were dumped on the ground surface, and solvents used to clean out boilers were poured onto these piles. Furniture stripping wastes were also reported to be disposed of at this area. Due to these past waste disposal activities, there are five primary areas of concern within Site 24: the Spiractor Sludge Disposal Area; the Fly Ash Disposal Area; the Borrow and Debris Disposal Area; and two Buried Metal Areas. Site 24 is not currently used for the disposal of wastes.

Site 78 - HPIA

Site 78 is located adjacent to the northwest portion of Site 24 and houses the industrial area of MCB, Camp Lejeune. This area is comprised of maintenance shops, warehouses, painting shops, printing shops, auto body shops, and other similar industrial facilities. In general, Site 78 is defined as the area bounded by Holcomb Boulevard to the northwest, Sneads Ferry Road to the northeast, Duncan Street to the southeast, and Main Service Road to the southwest. Site 78 covers approximately 590 acres. The majority of the site area is paved (e.g., roadways, parking lots, loading dock areas, and storage lots), however, there are many small lawn areas associated with individual buildings within the site and along lengthy stretches of roadways. In addition, there are several acres of woods in the southern portion of the site. Recreational ballfields and a parade ground are located in the southwest corner of the site.

The land within Site 78 is relatively flat. Natural drainage has generally been altered by the installation of drainage ditches, storm sewers, and extensive paving. Surface runoff not intercepted by a manmade structures from the southern portions of the site may drain to Cogdels Creek. Surface runoff from some areas in the northwestern portions of the site may drain to Beaver Dam Creek via stormwater sewers.

The HPIA, constructed in the late 1930s, was the first developed area at MCB, Camp Lejeune. It was comprised of approximately 75 buildings and facilities including: maintenance shops, gas stations, administrative offices, commissaries, snack bars, warehouses, and storage yards.

There is presently no known uncontrolled disposal of wastes related to the various industrial activities at the site. Due to the industrial nature of the site, many spills and leaks have occurred over the years. Most of these spills and leaks have consisted of petroleum-related products and solvents from underground storage tanks (USTs), drums, and uncontained waste storage areas. It appears that several general building areas within Site 78 may be potential source areas of contamination.

INVESTIGATION AND STUDY HISTORY

Investigations at OU No. 1 date back to 1983. The studies/investigations that have been conducted with respect to at least one of the three sites within OU No. 1 include:

- Initial Assessment Study of MCB, Camp Lejeune, 1983.
- Confirmation Studies for Sites 21, 24, and 78; 1984-1987.
- Groundwater Study at the Hadnot Point Fuel Farm; 1990.
- Supplemental Characterization Step for Site 78; 1990-1991.
- Remedial Investigation for the Shallow Soils and Castle Hayne Aquifer at Site 78; 1992.
- Interim Remedial Action Remedial Investigation and Feasibility Study for the Shallow Aquifer at Site 78; 1992.
- Pre-Investigation Study for the Remedial Investigation/Feasibility Study; 1992.
- Remedial Investigation for OU No. 1; 1993-1994.

NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination within OU No. 1 based on the analytical results from the Remedial Investigation (RI) are addressed below with respect to each site and the nearby surface water bodies.

Site 21 - Transformer Storage Lot 140

Soils

- Pesticides and polychlorinated biphenyls (PCBs) were the dominant contaminants present in soils at Site 21. The majority of the pesticides were detected in surface soils collected in the vicinity of the Former Pesticide Mixing/Disposal Area (the pesticides were detected in an area covering approximately 150,000 square feet). The maximum detected pesticide concentration was 34,000 µg/kg (4,4'-DDD). PCBs, specifically PCB-1260, were present primarily in surface soils in the vicinity of the Former PCB Transformer Disposal Area (approximately 20,000 square feet). PCBs were also detected in two other areas of the site. The maximum detected PCB concentration was 4,600 µg/kg (PCB-1260).

- Volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) were not extensively found in Site 21 soils.

Groundwater

- Metals were the most prevalent contaminants in groundwater at Site 21. The metals that were detected at concentrations above Federal drinking water standards and/or State groundwater standards included: arsenic, cadmium, chromium, beryllium, lead, nickel, and manganese. Note that metals were also present extensively in groundwater throughout OU No. 1 (all three sites) and, therefore, the metals detected in groundwater at Site 21 are most likely the result of a regional (entire MCB, Camp Lejeune) problem rather than a site-specific problem.

- VOCs in the groundwater were primarily limited to the northeastern portion of the site. Trichloroethene (TCE), benzene, toluene, ethylbenzene, and xylenes (BTEX) were detected in this area at concentrations above the Federal and/or State standards. This groundwater contamination is most likely related to Site 78, specifically the edge of a contaminated groundwater plume located near Buildings 901, 902, and 903. Pesticides and PCBs, which were found in site soils, were not detected in the groundwater at Site 21.

Surface Water and Sediments

- Surface water present at the site (only in the northern section of the site) did not appear to be contaminated.

- Pesticides and PCBs were the dominant contaminants present in sediments collected from the drainage ditch surrounding Site 21. The highest pesticide concentrations were detected at locations downgradient of the suspected pesticide mixing area, along the southwestern corner of the site (along approximately 600 feet of the drainage ditch). PCBs were detected near the Former PCB Transformer Disposal Area. Pesticide and PCB concentrations exceeded sediment screening values.

Based on the analytical results, the human health risk assessment estimated an incremental cancer risk (ICR) below the USEPA's target range of 1E-04 and a hazard index (HI) less than than 1.0 for all exposure scenarios. The potential risks were driven by the presence of PCBs in the Site 21 soils.

The ecological risk assessment indicated that the detected levels of pesticides, lead and chromium at Site 21 may decrease the viability of terrestrial invertebrate and flora species.

Site 24 - Industrial Area Fly Ash Dump

Soils

- Analytical results indicated that pesticides and metals were the predominant contaminants impacting soils at Site 24. Pesticide concentrations were not as elevated as other areas within MCB, Camp Lejeune; the highest detected concentration was 350 µg/kg. The relatively low pesticide levels appear to be the result of historical pest control spraying activities rather than direct disposal due to their relatively low concentrations, widespread detections throughout the Base, and absence of any record of pesticide disposal and handling activities at the site.

- The highest concentrations of metals, in both surface and subsurface soils, were detected within the Fly Ash Disposal Area and the Buried Metal Areas (an area covering approximately 180,000 square feet). Detected concentrations of several metals including arsenic, beryllium, copper, chromium, lead, and manganese were above base-specific background levels. Some of these metals concentrations were comparable to those detected at Sites 21 and 78.

- Test pit samples, which were collected in the vicinity of the Buried Metal Areas and the Fly Ash Disposal Area, were tested for leachability via RCRA Toxicity Characteristics Leaching Procedure (TCLP). The samples tested were below TCLP regulatory levels indicating that the soils are not characteristically hazardous. Additionally, the soils classified as nonhazardous under RCRA for ignitability, corrosivity, and reactivity. Low levels of TCE, 4,4'-DDD, 4,4'-DDT, and several metals were detected in some of the test pit samples.

Groundwater

- Metals were the predominant contaminants impacting Site 24 shallow groundwater. No trends or source areas were identified. The metals that were detected above the Federal drinking water standards and/or State groundwater standards included: arsenic, chromium, lead, manganese, cadmium, mercury, and nickel. The metals concentrations detected in the shallow groundwater at Site 24 were similar to the metals concentrations detected at Site 21 and Site 78.

- The pesticide, heptachlor epoxide, was detected in the groundwater at Site 24 near the Spiractor Sludge Disposal Area and south of the Fly Ash Disposal Area. Although the concentrations appeared to be low, they exceeded the State groundwater standard. It is relevant to note that low levels of heptachlor (5.0J µg/kg)epoxide was only detected in one soil sample collected at the site.

The human health risk assessment conducted for Site 24 estimated that the ICRs and HIs with respect to a future residents scenario were above the USEPA's acceptable (target) risk ranges. Note that the risks evaluated with respect to groundwater were based on the data from all OU No. 1 wells. Over 95 percent of the total site risk was associated with the ingestion and dermal contact of groundwater within the entire operable unit. The risk was driven by vinyl chloride (detected at Site 78), arsenic, beryllium, vanadium, and chromium.

The ecological risk assessment indicated that the detected levels of lead, chromium, beryllium, copper, mercury, and zinc at Site 24 may decrease the viability of terrestrial invertebrates and floral species.

Site 78 - HPIA

Soils

SVOCs, pesticides, and metals were the predominant contaminants impacting Site 78 soils. The concentrations of the detected pesticides were generally below 500 µg/kg, with the exception of a few samples exhibiting levels above 1,000 µg/kg at Buildings 1103 and 1502.

The higher pesticide concentrations were detected in surface soil samples. These pesticide levels are higher than typical levels, but disposal is not documented.

SVOCs were present in soils in the vicinity of Buildings 903, 1103, 1502, 1601, and 1608. In general, higher SVOC concentrations and more frequent detections occurred in surface soils. A few detections of SVOCs, however, were also noted in subsurface soils near Building 1601. The most frequently detected SVOCs were PAHs, which included phenanthrene, anthracene, fluoranthene, pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and benzo(g,h,i)perylene. These compounds are found in petroleum fuels such as fuel oil No. 2, diesel, and kerosene which are used for heating purposes, emergency generators, or refueling base vehicles. Storage of these fuels in aboveground tanks or USTs is common at a number of buildings throughout Site 78. It is possible that the source of the SVOCs is surface (i.e., spills) or subsurface releases (i.e., leaking tanks) of fuels.

Barium, lead, and zinc were the three most common metals detected at an order of magnitude or more above base-specific background levels. These metals were found predominantly in surface soils collected from Buildings 1103, 1502, and 1608. The specific sources of these metals are unknown since there is no history of disposal at these buildings that would relate to these three contaminants.

Analytical data indicated that VOCs and PCBs are not significantly impacting soils at the five building areas investigated within Site 78. Low levels of toluene and total xylenes were detected at Building 1103 (surface); somewhat higher levels of ethylbenzene and total xylenes were detected in subsurface soils (6 to 7 feet) at Building 1601. The source of the ethylbenzene and xylenes at Building 1601 may be related to releases of fuel from the suspected UST at the building. It is important to note that TCE and 1,2-DCE were detected in the subsurface soil samples collected during the installation of well 78GW09-1. PCBs were detected in a single surface sample collected at Building 1300.

Groundwater

- The analytical findings indicated that shallow groundwater at Site 78 was impacted by organics and metals. The primary organic contaminants were VOCs including: BTEX, tetrachloroethene (PCE), TCE, vinyl chloride, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (T-1,2-DCE), and 1,2-dichloropropane. The highest concentrations of these compounds were detected in wells located near the northeastern portion of Site 78 in the vicinity of the 901 through 903 buildings and in the southwestern portion of the site near Buildings 1601 and 1709. There was no particular area which exhibited excessive metals contamination since the entire site (as with Sites 21 and 24) appeared to be impacted.

- Contamination levels in the shallow groundwater appear to have decreased over time. Several wells which exhibited elevated VOCs in 1987 and/or 1991 either had nondetectable or significantly lower concentrations in 1993. Three of the shallow wells showed either increased contaminant levels or compounds not previously detected. These three wells are situated near the northeastern portion of Site 78 where multiple sources of contamination are known to exist (e.g., Hadnot Point Fuel Farm, numerous maintenance shops). These sources are presumed to be continually impacting the groundwater in the area.

- The intermediate wells sampled at Site 78 exhibited low levels of VOCs and only a few metals which exceeded Federal and/or State standards. Benzene, TCE, 1,2-DCE, vinyl chloride, and dichloromethane were the most prevalent VOCs detected. The highest VOC concentrations were found in the northeastern and southern portions of the site. Several SVOCs, including naphthalene, acenaphthene, and carbazole, were detected in one well in the northern portion of Site 78. Beryllium, cadmium, lead, manganese, and nickel concentrations in the northeastern portion of the site exceeded the Federal and/or State groundwater standards.

- Benzene, cis-1,2-DCE, T-1,2-DCE, and TCE were the only organics detected in the deep wells sampled at Site 78. Benzene was detected near Buildings 903, 1301, and 1709. The other volatiles were detected near Building 903, in between Buildings 1103 and 1301, and near Building 1709.

- Several of the deep wells have exhibited increased levels of VOCs over time. Wells 78GW04-3, 78GW09-3, 78GW24-3, and 78GW32-3, which all indicated nondetectable levels of VOCs in 1991, had positive detections of benzene, TCE, 1,2-dichloroethane, cis-1,2-DCE, and/or T-1,2-DCE in 1993. These wells are situated along a linear direction from southwest to northeast across Site 78. Only one of the deep wells, 78GW31-3, revealed lower concentrations in 1993 compared to 1991. The suggests that the contaminants may be migrating into the deeper water-bearing zone at Site 78. Additional rounds of sampling, however, may be required to support this conclusion.

The human health risk assessment conducted for the groundwater throughout OU No. 1 estimated an ICR above 1E-04 and an HI greater than 1.0 with respect to a potential future residential scenario. The potential risks were driven by vinyl chloride, arsenic, vanadium, and chromium.

Cogdels Creek and New River

- Inorganics were the only compounds found in Cogdels Creek and the New River surface water samples which exceeded surface water standards and/or screening values. Copper, lead, and zinc were detected throughout the creek and river at concentrations above Federal and/or State surface water standards. No trends were detected. The highest concentrations were detected near the Hadnot Point Sewage Treatment Plant (along the southern end of Site 78).

- The most prevalent contaminants found in Cogdels Creek and New River sediments were polynuclear aromatic hydrocarbon (PAH) compounds, pesticides (particularly 4,4'-DDD), and several inorganics (e.g., lead and zinc). No trends or source areas were identified. The locations with the highest detected concentrations were south of the Borrow and Debris Disposal Area at Site 24 and downgradient of OU No. 1 in the New River.

The human health risk assessment estimated an ICR and HI below the USEPA target ranges for the surface water and sediments within Cogdels Creek and the New River with respect to all exposure scenarios evaluated.

The ecological risk assessment indicated that the detected levels of chromium, copper, lead, silver, zinc, several PAHs, and pesticides may decrease the viability of aquatic life within Cogdels Creek and/or the New River.

Beaver Dam Creek

- The only contaminants that were present in Beaver Dam Creek surface water were inorganics. Copper, lead, and zinc were detected at levels exceeding Federal and/or State surface water standards. No trends or source areas could be identified. The location exhibiting the highest levels of detections was east of the northern portion of Site 78. The source of this contamination is probably not operable unit related.

- The most prevalent contaminants found in Beaver Dam Creek sediments were PAHs, pesticides, and inorganics (lead was the only inorganic to exceed sediment screening values). Storage of petroleum fuels (which can contain PAHs and lead) is common practice throughout Site 78. It is likely that the source of PAHs and possibly lead is related to surface or subsurface releases of fuels. A second potential source of PAHs may be from stormwater runoff from roads. The presence of pesticides may be from spraying activities rather than disposal practicies or spills.

The human health risk assessment estimated an ICR and HI below the USEPA target ranges for the surface water and sediments within Beaver Dam Creek with respect to all exposure scenarios evaluated.

The ecological risk assessment indicated that the detected levels of pesticides may decrease the viability of aquatic life within Beaver Dam Creek.

DEVELOPMENT OF REMEDIATION LEVELS AND COCs

The results of the human health and ecological risk assessments conducted for OU No. 1 determined that groundwater and soil are the media of concern. Remediation levels (RLs) were identified for the contaminants of concern (COCs). This list was based on a comparison of contaminant-specific applicable or relevant and appropriate requirements (ARARs) and the site-specific risk-based remediation goal options (RGOs). If a COC had an ARAR, the most limiting (or conservative) ARAR was selected as the remediation goal for that contaminant. If a COC did not have an ARAR, the most conservative risk-based RGO was selected.

The contaminants which exceeded at least one of the RLs were retained as final COCs. The contaminants that did not exceed any RL will no longer be considered as COCs in the FS. The set of COCs that exceeded the associated RLs are presented on Table ES-1.

TABLE ES-1

COCs THAT EXCEEDED THE REMEDIATION LEVELS DEVELOPED FOR OU NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	RL(1)
Groundwater		
	Benzene	1.0
	Trichloroethene	2.8
	Tetrachloroethene	0.7
	Vinyl Chloride	0.015
	1,2-Dichloroethene (total)	70
	Toluene	1,000
	Ethylbenzene	29
	Xylenes (total)	400
	Arsenic	50
	Barium	1,000
	Beryllium	4
	Chromium	50
	Manganese	50
	Vanadium	110
Soil(3)		
	PCBs (total)	370
	4,4'-DDD	12,000
	4,4'-DDT	8,400
	Chlordane (total)	2,200

(1) RL = Remediation Level
(2) Groundwater RLs expressed as µg/L (ppb)
(3) Soil RLs expressed as µg/kg (ppb)

REMEDIAL ACTION ALTERNATIVE DEVELOPMENT AND EVALUATION

The Remedial Action Alternatives (RAAs) were developed to address contaminated media at various areas of concern (AOCs) within OU No. 1, including the following eight Groundwater AOCs and seven Soil AOCs:

Groundwater AOCs

- A VOC-contaminated plume located near the 901/903-Series Building area within Site 78 (referred to as Groundwater AOC1).
- Three small areas of groundwater contamination (PCE only) located throughout Site 78 (Groundwater AOCs 2, 4, and 8).
- A fuel-contaminated plume located near the Hadnot Point Fuel Farm (Groundwater AOC3).
- A VOC-contaminated plume located near the 1600 and 1700 Series Building area of Site 78 (Groundwater AOC5).
- Two areas of groundwater contamination located within Site 24 (heptachlor epoxide only) (Groundwater AOCs 6 and 7).

Soil AOCs

- The northeastern portion of Site 21 with elevated levels of PCBs in surface soil (Soil AOC1).
- Southwest portion of Site 21 with elevated PCB concentrations in surface soil (Soil AOC2).
- Southwest portion of Site 21 with elevated pesticide concentrations in surface soil (Soil AOC3).
- Northeastern edge of Building 1502 within Site 78 with elevated levels of pesticides in surface soil (Soil AOC4).

Based on the AOCs identified above, five groundwater RAAs and four soil RAAs were developed and evaluated in the FS. A brief overview of each of the RAAs per media is included below.

Groundwater RAAs

The following groundwater RAAs were developed and evaluated for OU No. 1:

- RAA No. 1 No Action
- RAA No. 2 Limited Action
- RAA No. 3 Source Control (Interim Action Treatment System Extension)
- RAA No. 4 Source Control (Air Sparging)
- RAA No. 5 Source Control and Vertical Containment

Common Elements - All of the Groundwater RAAs will have a few common components. Specifically, the components of the interim remedial action (IRA) to be implemented at Site 78 will be included under all of the Groundwater RAAs. RAA Nos. 2 through 5 have several common remedial elements between them including aquifer-use restrictions, deed restrictions, and long-term monitoring of existing monitoring wells and water supply wells. Each of the common elements will be briefly discussed below.

An IRA is under construction within Site 78. The IRA includes the installation of two groundwater pump and treat systems within Site 78, a long-term groundwater monitoring program, and institutional controls. The primary objective of the IRA is to contain the migration of two shallow groundwater plumes located within Site 78. In terms of the FS for the entire operable unit, the IRA will contain the shallow groundwater contamination from Groundwater AOCs 1 and 5.

The IRA groundwater treatment systems will include air stripping, carbon adsorption, oil/water separation, and metals removal. One treatment system is to be located within the northeast contaminated plume. Four extraction wells will be initially installed near the downgradient edge of this plume. The second treatment system is to be located within the southwest contaminated plume. Five extraction wells will be initially installed along the downgradient edge of this second plume. Approximately 3 to 5 gallons of groundwater per minute are anticipated to be extracted from each well. Each of the treatment units will be designed to handle a maximum influent of 80 gallons per minute (gpm).

In addition to the pump and treat systems, the IRA will include a long-term groundwater monitoring program. Under this program, 20 existing monitoring wells will be sampled for the contaminants of concern (i.e., VOCs and inorganics) on a quarterly basis. The wells to be monitored include 16 shallow monitoring wells, two intermediate wells, and two deep wells.

The institutional controls under the IRA include placing aquifer-use restrictions on the shallow aquifer; and keeping the closed water supply wells out of service.

Under Groundwater RAA Nos. 2 through 5, aquifer-use restrictions will be retained on the closed water supply wells. Deed restrictions, restricting the placement of additional water supply wells within the entire OU No. 1, will also be included under these four RAAs.

In addition to the twenty wells included under the long-term monitoring program for the IRA for Site 78, an additional five shallow monitoring wells and the nearby water supply wells will also be included under a long-term monitoring program for the Groundwater RAA Nos. 2, 3, 4, and 5. Several of these wells are associated with the newly identified Groundwater AOCs. Both active and inactive water supply wells will be monitored. Additional wells may be added to the monitoring program, if necessary.

Samples will be collected on a semiannual basis for five years and analyzed for Target Compound List (TCL) VOCs. As required, after five years the operable unit will be re-evaluated to determine the effectiveness of the implemented remedial action. Based on the the semiannual groundwater data and the data from the IRA, a less frequent sampling program may be implemented (such as annually), or it may be determined that sampling is no longer required at certain areas. In time, the results of the monitoring program may indicate that one or more of the currently inactive water supply wells can be considered for use.

The Groundwater RAAs will only include remediation of the groundwater from Groundwater AOCs 1 and 5. No additional remedial actions, other than the long-term monitoring, will be performed for Groundwater AOCs 2, 3, 4, 6, 7, and 8 under any of the Groundwater RAAs. This decision for most of the AOCs was based on the contaminant concentrations and since no apparent source(s) were identified. If the monitoring indicates that the groundwater at these areas is deteriorating, additional measures will be taken. This will be evaluated every five years. Once the remediation levels have been obtained for these areas, monitoring will no longer be necessary. Since these areas will potentially exceed the chemical-specific ARARs, a waiver will be required for this monitoring action.

No additional actions will be implemented at Groundwater AOC 3 since this is the area of the Hadnot Point Fuel Farm (Site 22). A fuel recovery system/groundwater treatment is currently operating at this area. Investigations/remediations related to the Fuel Farm are being handled under the UST Program, not CERCLA. Therefore, only monitoring will be conducted near this area for purposes of this FS.

A description of the remaining remedial actions associated with each alternative as well as the estimated cost and timeframe to implement the alternative follows:

- **RAA No. 1: No Action**

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

  The No Action RAA is required under CERCLA to establish a baseline for comparison. Under this RAA, no further action at the operable unit will be implemented (note that an IRA to contain the migration of the plumes and prevent exposure to groundwater contamination will be implemented).

- **RAA No. 2: Institutional Controls**

  Capital Cost: $0
  Annual O&M Costs: $26,000 for Years 1 through 5, $13,000 for Years 6 through 30
  NPW: $260,000
  Months to Implement: 3-6

  Under RAA No. 2, no additional remedial actions will be performed to reduce the toxicity, mobility, or volume of the wastes at OU No. 1. This RAA will include only the common institutional controls of monitoring, ordinances, or directives preventing the operation of nearby supply wells, and deed restrictions for prohibiting construction of potable supply wells.

- **RAA No. 3: Source Control (Interim Remedial Action Treatment System Extension)**

  Capital Cost: $180,000
  Annual O&M Costs: $30,000 for Years 1 through 5, $15,000 for Years 6 through 30
  NPW: $460,000
  Months to Implement: 10

  In general, RAA No. 3 is a source control alternative with the primary objective to remediate the source(s) of shallow groundwater contamination. Under this alternative three additional shallow extraction wells will be installed at areas exhibiting the highest VOC contamination. The contaminated groundwater will be pumped to the interim action groundwater treatment system. The extraction wells will be designed the same as for the interim action wells.

  No extraction wells will be placed in the deeper portions of the aquifer under this alternative. It is believed that once the source of deep groundwater contamination (i.e., the shallow aquifer) is removed and treated, the contaminant levels in the deeper portions of the aquifer will be reduced in time. Deeper extraction wells could actually draw the existing shallow contamination down into the deeper portions of the aquifer, and thereby increase the vertical extent of the contaminant plume.

- **RAA No. 4: Source Control (Air Sparging)**

  Capital Cost: $230,000
  Annual O&M Costs: $110,000 for Years 1 through 5
  NPW: $690,000
  Months to Implement: 12

  In general, RAA No. 4 is a source control alternative with the primary objective to remediate highly contaminated shallow aquifer, which is the source of deep groundwater contamination. Under this alternative, two in situ air sparging/soil venting treatment systems will be installed at areas of the highest VOC contamination.

  The treatment systems will be designed to primarily treat the shallow (source) contamination. It is believed that once the source of contamination (the shallow aquifer) is remediated, the contaminant levels in the deeper portions of the aquifer will be reduced in time.

- **RAA No. 5: Source Control and Vertical Containment**

  Capital Cost: $310,000
  Annual O&M Costs: $32,000 for Years 1 through 5, $16,000 for Years 6 through 30
  NPW: $615,000
  Months to Implement: 15

  In general, RAA No. 5 is a source control and vertical containment alternative with the primary objectives to remediate the source(s) of groundwater contamination and to mitigate the vertical migration of the contamination. The source control component of this alternative is the same as with RAA No. 3. In such, three additional shallow extraction wells will be installed at areas of the highest VOC contamination and connected to the interim action groundwater treatment system. The extraction wells will be designed the same as for the interim action wells.

  The vertical containment component of this alternative includes the installation of two extraction wells at the areas of the highest VOC contamination in the deeper portions of the aquifer at OU No. 1.

  The remedial alternatives for addressing groundwater were evaluated against nine evaluation criteria. These criteria included overall protection of public health and the environment; compliance with ARARs; long-term effectiveness of permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; cost; USEPA and NC DEHNR acceptance; and community acceptance.

A comparison of these alternatives with respect to these evaluation criteria is provided on Table ES-2.

Soil RAAs

The following Soil RAAs were developed and evaluated for OU No. 1:

- RAA No. 1 No Action
- RAA No. 2 Capping
- RAA No. 3 On-Site Treatment
- RAA No. 4 Off-Site Treatment/Disposal

TABLE ES-2

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
OVERALL PROTECTIVENESS					
• Human Health Protection	Potential risks associated with groundwater exposure are mitigated due to the interim remedial action and long-term monitoring program.	Potential risks associated with groundwater exposure are mitigated due to the interim remedial action and long-term monitoring program.	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).
• Environmental Protection	Migration of contamination is reduced via the interim remedial action.	Migration of contamination is reduced via the interim remedial action.	Migration of contaminated groundwater is reduced by pump and treat.	Migration of contaminated groundwater is reduced by in situ treatment.	Migration of contaminated groundwater is reduced by pump and treat.
COMPLIANCE WITH ARARS					
• Chemical-Specific ARARs	Will exceed Federal and/or NC groundwater quality ARARs.	Will exceed Federal and/or NC groundwater quality ARARs.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.
• Location-Specific ARARs	Not applicable.	Not applicable.	Will meet location-specific ARARs.	Will meet location-specific ARARs.	Will meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Not applicable.	Will meet action-specific ARARs.	Will meet action-specific ARARs.	Will meet action-specific ARARs.

TABLE ES-2(Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	Risk reduced via the interim remedial action.	Risk reduced via the interim remedial action.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.
• Adequacy and Reliability of Controls	Not applicable - no additional controls.	Additional monitoring is adequate to determine effectiveness of alternative.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.
• Need for 5-year Review	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review not needed once remediation levels are met.	Review not needed once remediation levels are met.	Review not needed once remediation levels are met.

TABLE ES-2(Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	No additional treatment other than the IRA treatment system. The IRA treatment train consisting of air striping, activated carbon, and metals removal.	No additional treatment other than the IRA treatment system. The IRA treatment train consisting of air striping, activated carbon, and metals removal.	Treatment train for metals removal, air stripping, and activated carbon.	In addition to IRA treatment train, includes air sparging and soil vapor extraction.	Treatment train for metals removal, air stripping, and activated carbon.
• Amount Destroyed or Treated	Contaminants in groundwater at the outer edges of two plumes.	Contaminants in groundwater at the outer edges of two plumes.	Majority of contaminants in groundwater plumes.	Majority of contaminants in groundwater.	Majority of contaminant in groundwater plumes.
• Reduction of Toxicity, Mobility or Volume	Reduced volume and toxicity of contaminated groundwater via the IRA.	Reduced volume and toxicity of contaminated groundwater via the IRA.	Reduced volume and toxicity of contaminated groundwater.	Reduced volume and toxicity of contaminated groundwater.	The mobility of the VOC contamination in the shallow aquifer may be increased due to operating extraction wells in the deeper zones.
• Residuals Remaining After Treatment	Source areas will be a continuing source of contamination.	Source areas will be a continuing source of contamination.	Potentially minimal residuals after goals are met.	Potentially minimal residuals after goals are met.	Potentially minimal residuals after goals are met.
• Statutory Preference for Treatment	Satisfied via the IRA.	Satisfied via the IRA.	Satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS					
• Community Protection	Risks to community not increased by remedy implementation.	Risks to community not increased by remedy implementation.	Minimal, if any, risks during extraction and treatment.	Possible migration of toxic vapors, should be controlled with the soil vapor extraction systems.	Minimal, if any, risks during extraction and treatment.
• Worker Protection	No significant risk to workers.	No significant risk to workers.	Protection required during treatment.	Protection required during treatment.	Protection required during treatment.
• Environmental Impacts	Continued impacts from existing conditions.	Continued impacts from existing conditions.	Aquifer drawdown during extraction. This is not expected to be an environmental concern.	Possible migration of toxic vapors, should be controlled with the soil vapor extraction systems.	Aquifer drawdown during extraction. This is not expected to be an environmental concern. Potential vertical migration of contaminants may occur via remediation of the Castle Hayne aquifer.
• Time Until Action is Complete	Estimated 30 years.	Estimated 30 years.	Estimated 30 years.	Estimated 5 years.	Estimated 30 years.

TABLE ES-2(Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
IMPLEMENTABILITY					
• Ability to Construct and Operate; Reliability	No construction or operation activities.	No construction or operation activities.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.
• Ability to Monitor Effectiveness	No monitoring. Failure to detect contamination will result in potential ingestion of contaminated groundwater.	Proposed monitoring will give notice of failure before significant exposure occurs.	Adequate system monitoring.	Adequate system monitoring.	Adequate system monitoring.
• Availability of Services and Capacities; Equipment	None required.	None required.	Services and materials are available.	Services and materials are available.	Services and materials are available.
COSTS NPW	$0	$260,000	$460,000	$690,000	$615,000

A description of each alternative as well as the estimated cost and timeframe to implement the alternative follows:

- **RAA No. 1: No Action**

  Capital Cost: $0
  Annual O&M Costs: $0
  NPW: $0
  Months to Implement: None

  The No Action RAA is required under CERCLA to establish a baseline for comparison. Under this RAA, no further action at the operable unit will be implemented to prevent exposure to contaminated soil.

- **RAA No. 2: Capping**

  Capital Cost: $260,000
  Annual O&M Costs: $60,000 for 30 years
  NPW: $1.2 million
  Months to Implement: 6

  In general, Soil RAA No. 2 includes the installation of an asphalt or concrete cap over the contaminated soil areas. The thickness of the cap will be approximately four to eight inches in the capped area. To ensure the integrity of the capping system, periodic maintenance (e.g., applying a sealant over asphalt) will be required. In order to monitor the effectiveness of the cap (i.e., the migration of the COCs), groundwater sampling will be conducted semiannually. Groundwater samples will be collected from six monitoring wells. The capped areas will be fenced to restrict access to the capped areas and reduce damage to the caps. New fencing may not be required for Soil AOC3. The existing fence at Soil AOC1 will be adequate. Routine maintenance and repairs of the fence, as necessary, are also included under this RAA. In addition to the fence, deed restrictions restricting the use of the area in and around the capped areas will be implemented. Any soil excavated during potential future construction activities will require appropriate disposal in accordance with applicable Federal and State regulations.

  The objectives of this RAA are to prevent the potential for direct contact with the soils, and to prevent the potential for the horizontal or vertical migration of contaminants via storm water infiltration.

- **RAA No. 3: On-Site Treatment**

  Capital Cost: $650,000 (incineration); $1.4 million (dechlorination)
  Annual O&M Costs: $0
  NPW: $650,000 (incineration); $1.4 million (dechlorination)
  Months to Implement: 8-12

  RAA No. 3 includes the excavation of up to 1,050 cubic yards of contaminated soil from soil AOCs 1 through 4 and treatment on site via either chemical dechlorination, or incineration. Following treatment, any residual soils will be removed from the treatment unit, analyzed, and if permitted (due to treated levels which exceed the remediation levels), used as backfill at the site. If not permitted, the treated soils will be properly disposed off site. The excavated areas will be graded to conform to the surrounding terrain. Clean fill may be added to the excavated areas as necessary to bring the areas up to grade. The excavated areas will be revegetated.

- **RAA No. 4: Off-Site Treatment/Disposal**

  Capital Cost: $480,000 (disposal); $1.3 million (treatment)
  Annual O&M Costs: $0
  NPW: $480,000 (disposal); $1.3 million (treatment)
  Months to Implement: 8-12

  Soil RAA No. 4 includes the excavation of soil from all of the Soil AOCs (1,050 cubic yards) and off-site treatment and/or disposal. The treatment/disposal facility will have to be permitted to accept low levels [i.e., less than 50 parts per million (ppm)] of PCBs, and pesticides.

The remedial alternatives for addressing soil were evaluated against the nine evaluation criteria previously identified. A comparison of these soil remediation alternatives with respect to these nine criteria is provided on Table ES-3.

TABLE ES-3

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
OVERALL PROTECTIVENESS				
• Human Health Protection	No reduction in risk.	Would reduce potential for human exposure.	Reduces overall risk to human health.	Reduces overall risk to human health.
• Environmental Protection	No reduction in risk to ecological receptors.	Would reduce potential for exposure and migration.	Reduces overall risk to ecological receptors.	Reduces overall risk to ecological receptors.
COMPLIANCE WITH ARARs				
• Chemical-Specific ARARs	Will exceed ARARs.	Will exceed ARARs.	Will meet contaminant-specific ARARs.	Will meet ARARs.
• Location-Specific ARARs	Not applicable.	Will meet location-specific ARARs.	Will meet location-specific ARARs.	Will meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Will meet action-specific ARARs.	Will meet action-specific ARARs.	Will meet action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE				
• Magnitude of Residual Risk	Source has not been removed. Potential risks not reduced.	Contaminated soils are not removed from the site, but potential risk due to exposure to COCs are reduced as long as the cap is maintained.	Soil AOCs will be remediated. Remaining contaminants do not present an unacceptable human health or environmental risk.	Contaminated soil is removed from the site. No residual wastes will remain onsite.
• Adequacy and Reliability of Controls	Not applicable - no controls.	Multilayered cap controls contaminated soil - can be a reliable option if maintained properly.	Soil will be treated to meet risk-based action levels. Treated soil will be analyzed to ensure that remediation levels are met.	No residual wastes will remain onsite. Wastes will be treated offsite and disposed of in a suitable landfill.
• Need for 5-year Review	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review not needed since contaminated soil treated.	Review not needed since contaminated soil removed.

TABLE ES-3 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT				
• Treatment Process Used	None.	None.	Chemical dechlorination, or incineration.	Off-site treatment.
• Amount Destroyed or Treated	None.	None.	Majority of soil COCs.	Majority of soil COCs.
• Reduction of Toxicity, Mobility or Volume	None.	No reduction in toxicity or volume. However; capping will mitigate contaminant migration.	Reduction in toxicity, mobility and volume of contaminated soil.	Reduction in toxicity, mobility and volume of contaminated soil.
• Residuals Remaining After Treatment	Not applicable - no treatment.	Residuals are capped.	Residuals remaining onsite will be below remediation goals.	No residuals will remain onsite.
• Statutory Preference for Treatment	Not satisfied.	Not satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS				
• Community Protection	Risks to community not increased by remedy implementation.	Temporary potential risks during soil grading and cap installation activities.	Limited potential risks during soil excavation and treatment activities.	Limited potential risks during soil excavation and transport activities.
• Worker Protection	No significant risks to workers.	Temporary potential risks during soil grading and cap installation activities.	Potential risks during soil excavation and treatment activities.	Potential risks during excavation and transportation activities.
• Environmental Impacts	Continued impacts from existing conditions.	No additional environmental impacts.	Air quality and odors - but treatment system will be designed to meet standards.	No additional environmental impacts.
• Time Until Action is Complete	Not applicable.	Less than one year. Monitor for 30 years.	Less than one year.	Less than one year.

TABLE ES-3 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
IMPLEMENTABILITY				
• Ability to Construct and Operate	No construction or operation activities.	Simple to construct and maintain. Requires materials handling procedures.	Requires soil excavation activities. Requires assembly of treatment systems.	Requires soil excavation activities. No other on-site operations.
• Ability to Monitor Effectiveness	No monitoring included.	Cap maintenance and groundwater monitoring will adequately monitor effectiveness.	Adequate system monitoring.	No monitoring other than confirmation soil sampling.
• Availability of Services and Capacities; Equipment	None required.	No special services or equipment required. Cap materials should be readily available.	Qualified vendors available to perform on-site treatment.	Off-site treatment and disposal facilities should have adequate capacity.
COSTS				
NPW	$0	$1.2 million	$650,000 (incineration) $1.4 million (dechlorination)	$480,000 (disposal) $1.3 million (treatment)

1.0 INTRODUCTION

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 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 was to ensure that environmental impacts associated with past and present activities at the MCB, Camp Lejeune were thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives were developed and implemented as necessary to protect public health and the environment (FFA, 1989).

The Fiscal Year 1994 Site Management Plan for MCB, Camp Lejeune, a primary document identified in the FFA, identifies 27 sites requiring Remedial Investigation/Feasibility Study (RI/FS) activities. This report documents the FS completed for three of these sites: Site 21, Site 24, and Site 78. Collectively, these sites comprise Operable Unit (OU) No. 1 at MCB, Camp Lejeune. The purpose of this FS is to select a remedy for OU No. 1 that is protective of human health and the environment, attains Federal and State requirements, and is cost effective.

This FS has been prepared by Baker Environmental, Inc. (Baker) under the DON Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program for Contract Task Order 0177 (RI/FS for Sites 21, 24 and 78). This FS has been conducted in accordance with the requirements delineated in the National 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. The USEPA's document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988a) has been used as guidance for preparing this document.

This FS has been based on data collected during the RI conducted at Sites 21, 24 and 78 (Baker, 1994). Field investigations at these three sites began in April 1993 and continued through December 1993. Results of the field investigations are summarized in the RI Report under separate cover. This FS also is based on an interim remedial action (IRA) that has been designed to contain the migration of contaminated groundwater known to exist within the shallow aquifer at Site 78. The IRA is planned to be implemented in 1994. Details of this IRA are presented throughout this FS and can also be found in the IRA FS prepared by Baker in 1992 (Baker, 1992a).

1.1 Purpose and Organization of the Report

1.1.1 Purpose of the Feasibility Study

The purpose of the FS for OU No. 1 is to select a remedial alternative that is protective of human health and the environment, attains Federal and State requirements that are applicable or relevant and appropriate, and is 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:

- Development and screening of remedial action alternatives, and
- Detailed analysis of remedial action alternatives.

The first phase includes the following major activities: (1) developing remedial action objectives and remediation levels; (2) developing general response actions; (3) identifying volumes or areas of affected media; (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 to alternatives involving 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 comparison analysis of the evaluated alternatives.

1.1.2 Report Organization

This FS Report is organized in six sections. The Introduction (Section 1.0) presents the purpose of the report, a brief discussion of the FS process, and pertinent site background information including a summary of the nature and extent of contamination at OU No. 1. Section 2.0 contains the remedial action objectives and remediation levels that have been established for the operable unit. Section 3.0 contains the identification of general response actions, and the identification and preliminary screening of the remedial action technologies and process options. Section 4.0 contains the development and preliminary screening of remedial action alternatives. Section 5.0 presents the results of the detailed analysis of the remedial alternatives (both individual analysis and comparative analysis). The detailed analysis is based on a set of nine criteria including short- and long-term effectiveness, implementability, cost, state and local acceptance, compliance with applicable regulations, and overall protection of human health and the environment. The references are listed in Section 6.0.

1.2 Site Background Information

Background information pertaining to OU No. 1 is presented below. Additional details pertaining to the operable unit can be found in the RI Report (Baker, 1994).

1.2.1 Site Description

MCB, Camp Lejeune is a training base for the United States Marine Corps (USMC), located in Onslow County, North Carolina. The base covers approximately 236 square miles and is bounded to the southeast by the Atlantic Ocean, to the northeast by State Route 24, and to the west by U.S. 17. The town of Jacksonville, North Carolina is north of the Base. A map of MCB, Camp Lejeune with the location of OU No. 1 identified is presented on Figure 1-1.

The study area for this FS is OU No. 1, which consists of Sites 21, 24, and 78. Site 21 is the Transformer Storage Lot 140. Site 24 is referred to as the Industrial Fly Ash Dump Site. Site 78 is commonly referred to as the Hadnot Point Industrial Area or HPIA.

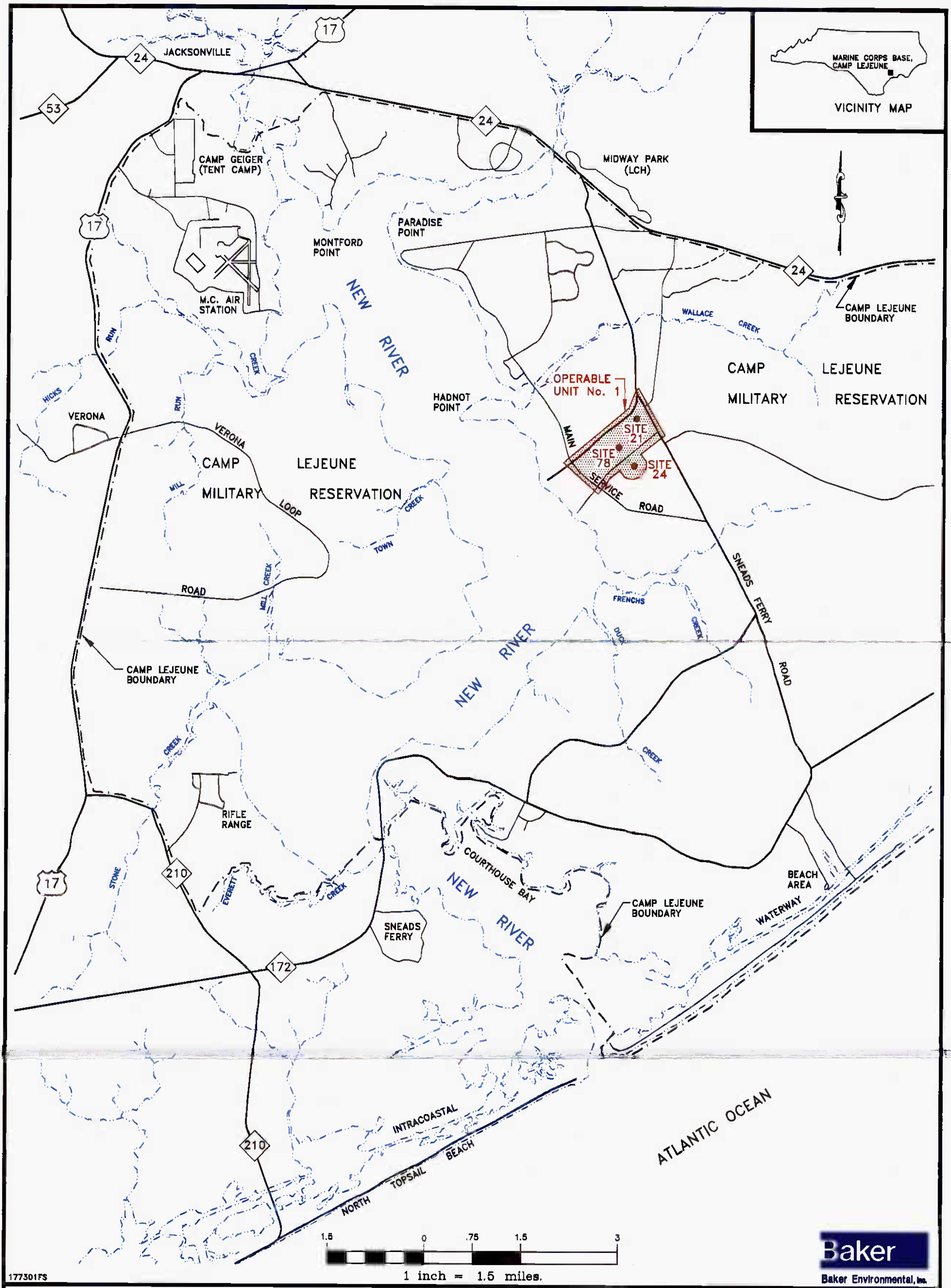

FIGURE 1-1
LOCATION MAP-OPERABLE UNIT No. 1
SITES 21, 24 AND 78
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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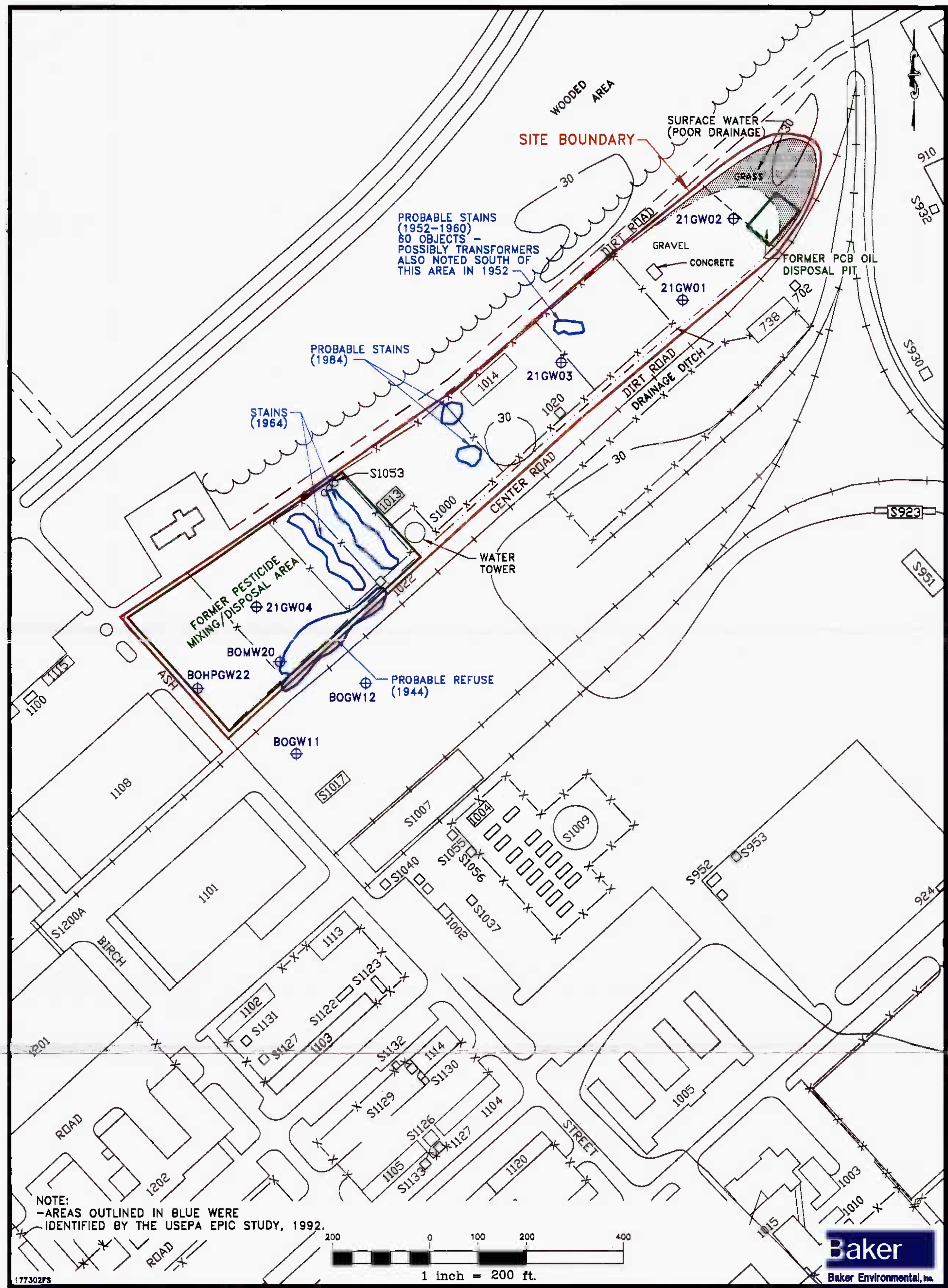
OU No. 1 is located approximately one mile east of the New River and two miles south of State Route 24 within the main section of MCB, Camp Lejeune. The operable unit is bordered by Holcomb Boulevard to the northwest, Sneads Ferry Road to the northeast, Main Service Road to the southwest, and woodlands and Cogdels Creek to the southeast. Camp Lejeune Railroad operates rail lines parallel to Holcomb Boulevard extending into OU No. 1. The entire operable unit covers approximately 690 acres. The site descriptions for each of the sites investigated under OU No. 1 are presented below.

1.2.1.1 Site 21: Transformer Storage Lot 140

Site 21 is located within the northwest section of Site 78. The site is bordered by Ash Street to the southwest, Center Road to the southeast, and a wooded area to the northwest. Figure 1-2 presents a site plan of Site 21. A dirt road surrounds most of the site along with surface drainage ditches. The southern and central portions of the site (approximately 220 feet by 900 feet) has several fenced-in areas, while the northern section (approximately 500 feet long) is an open area. A water tower is located in the fenced portion of the site. Surface cover within the site primarily consists of gravel, sandy soil, and concrete, with a few vegetated areas. In the northern portion of the site, a small area, slightly depressed in elevation, is evident. This may have been the reported former transformer oil disposal pit.

The land within Site 21 is relatively flat and unpaved. A drainage ditch which surrounds the site collects surface runoff from the site and adjacent roadways. The direction of flow from the drainage ditch is unclear. During the RI field activities, observations of the drainage ditch revealed that it was parched of water, with the exception of the northern end. Therefore, it can be assumed that water only occupies the drainage ditch during periods of heavy precipitation. The southern portion of the site is periodically utilized for storage by Marine Corps Reserve units. Currently this portion of the site is being used for storage of military vehicles.

A few potential areas of concern within Site 21 were identified by a USEPA Environmental Photographic Interpretation Center (EPIC) Study, as shown on Figure 1-2. The two primary areas of concern, which were the focus of the RI, are the Former Pesticide Mixing/Disposal Area and the Former PCB Transformer Disposal Area. As shown on Figure 1-2, the Former Pesticide Mixing/Disposal Area is located near the southwestern portion of the site, and the Former PCB Transformer Disposal Area is located near the northeastern portion of the site. With the exception of a low depression area at the northern portion of the site, there are no visual signs of waste disposal throughout the site.



NOTE:
-AREAS OUTLINED IN BLUE WERE IDENTIFIED BY THE USEPA EPIC STUDY, 1992.

200 0 100 200 400
1 inch = 200 ft.

Baker
Baker Environmental, Inc.

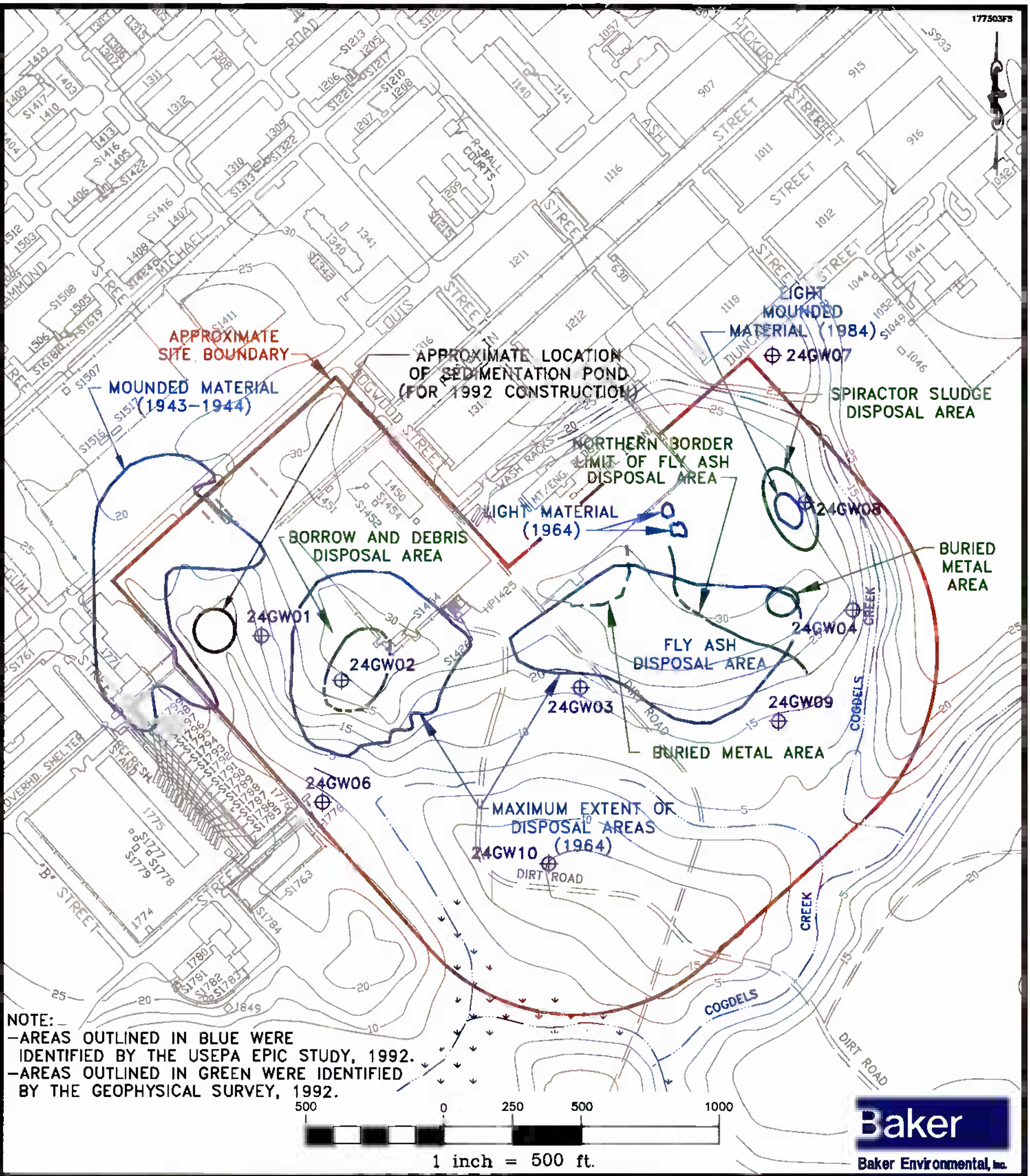
LEGEND

21GW01 ⊕ SHALLOW MONITORING WELL

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 1–2
SITE MAP
SITE 21: TRANSFORMER STORAGE LOT 140
FEASIBILITY STUDY CTO–0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- AREAS OUTLINED IN BLUE WERE IDENTIFIED BY THE USEPA EPIC STUDY, 1992.
- AREAS OUTLINED IN GREEN WERE IDENTIFIED BY THE GEOPHYSICAL SURVEY, 1992.

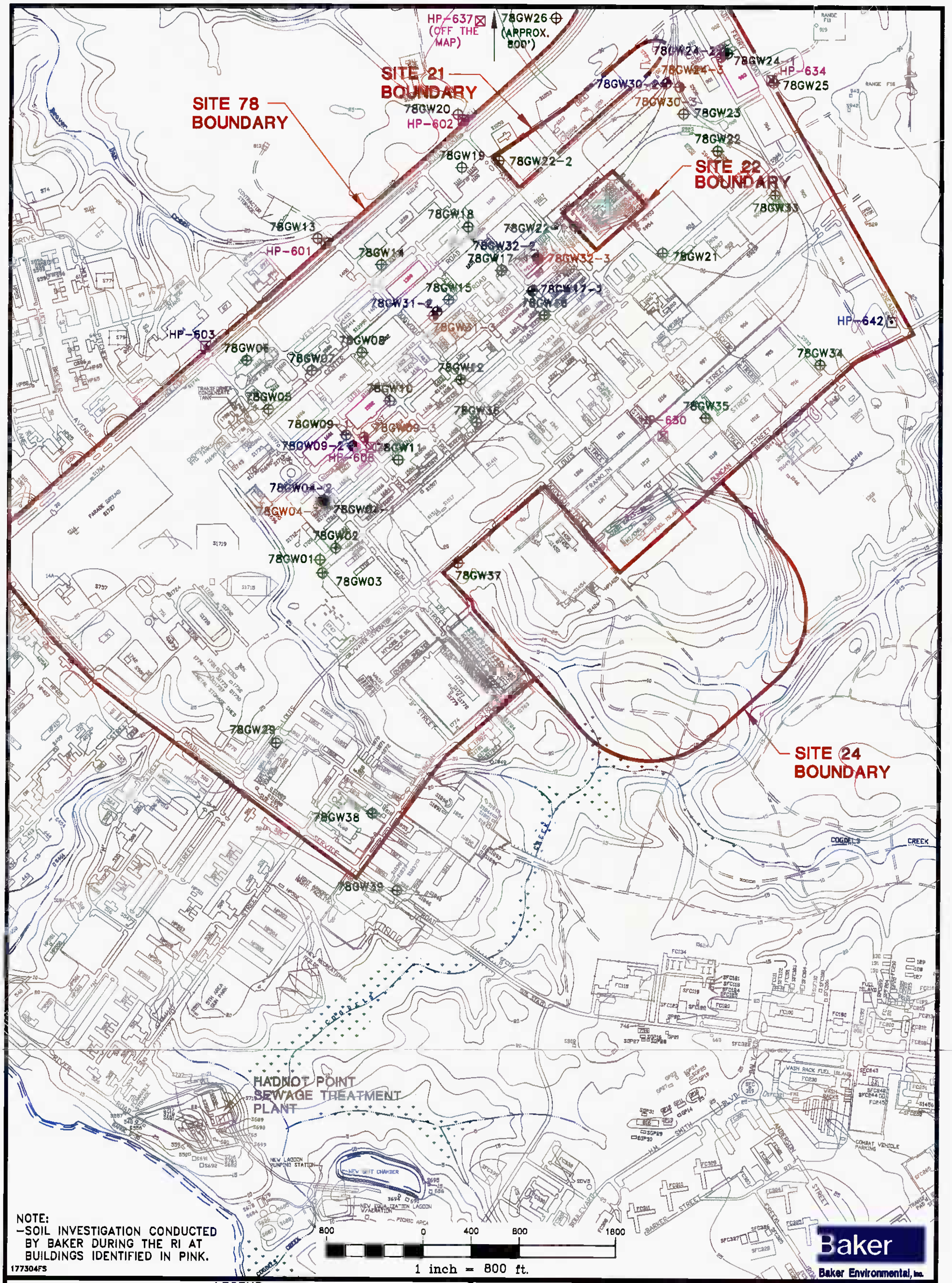
LEGEND

24GW01 ⊕	SHALLOW MONITORING WELL

SOURCE: LANTDIV, FEB. 1992

FIGURE 1-3
SITE MAP
SITE 24: INDUSTRIAL FLY ASH DUMP
FEASIBILITY STUDY CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
-SOIL INVESTIGATION CONDUCTED
BY BAKER DURING THE RI AT
BUILDINGS IDENTIFIED IN PINK.

177304FS

LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL	HP-603 ⊡	WATER SUPPLY WELL (ACTIVE)
78GW04-2 ⊕	INTERMEDIATE MONITORING WELL	HP-601 ☒	WATER SUPPLY WELL (INACTIVE)
78GW04-3 ⊕	DEEP MONITORING WELL		

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 1-4
SITE MAP
SITE 78: HPIA
FEASIBILITY STUDY CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

1.2.1.2 Site 24 - Industrial Fly Ash Dump

Site 24 is located adjacent to the southeast portion of Site 78. Specifically, the site is located south and east of the intersection of Birch and Duncan Streets and extends south towards Cogdels Creek. Figure 1-3 presents a site plan of Site 24, with suspected areas of former disposal shown (based on the USEPA EPIC Study). The site is primarily a wooded area, approximately 100 acres in size, that is somewhat overgrown. The site is hilly and is unpaved with site drainage towards Cogdels Creek. Dirt roads are interspersed throughout, which lead to the suspected disposal areas. The roads are periodically utilized for military vehicle maneuvers. Several areas indicating past disposal activities are evident throughout the site (i.e., surficial deposits of fly ash and mounding). Site 24 is not currently used for the disposal of wastes.

1.2.1.3 Site 78 - HPIA

Site 78 is located adjacent to the northwest portion of Site 24 and houses the industrial area of MCB, Camp Lejeune. This area is comprised of maintenance shops, warehouses, painting shops, printing shops, auto body shops, and other similar industrial facilities. In general, Site 78 is defined as the area bounded by Holcomb Boulevard to the northwest, Sneads Ferry Road to the northeast, Duncan Street to the southeast, and Main Service Road to the southwest. Figure 1-4 presents a plan view of Site 78 and the approximate site boundary. The site boundaries for Sites 21 and 24 are also shown on this figure. In addition, the location of Site 22, the Hadnot Point Fuel Farm is shown on Figure 1-4. Additional information related to Site 22 is presented in Section 1.3.3 of the RI Report for OU No. 1 (Baker, 1994). Site 78 covers approximately 590 acres. The majority of the site area is paved (e.g., roadways, parking lots, loading dock areas, and storage lots), however, there are many small lawn areas associated with individual buildings within the site and along lengthy stretches of roadways. In addition, there are several acres of woods in the southern portion of the site. Recreational ballfields and a parade ground are located in the southwest corner of the site.

The land within Site 78 is relatively flat with surface elevations ranging between 22 to 32 feet above mean sea (msl). Natural drainage has been altered by the installation of drainage ditches, storm sewers, buildings, and extensive paving. Surface runoff not intercepted by a manmade structure from southern portions of the site may drain directly to Cogdels Creek.

Surface runoff from some areas in the northwestern portions of the site appears to drain into Beaver Dam Creek.

Eight potable water supply wells are in the vicinity of Site 78. The depths of these wells range from 160 feet to 225 feet, and their screened intervals range from 45 feet to 225 feet. All of the wells utilize the Castle Hayne aquifer which serves as the principal water supply aquifer for MCB, Camp Lejeune (Harned, et al., 1989). According to Base personnel, six of the eight wells in the vicinity of Site 78 are no longer in service. The reason these wells were put out of service is that contaminants (volatiles) were identified in groundwater samples collected from them. Additional information regarding these supply wells is presented in Section 3.9 of the RI Report for OU No. 1 (Baker, 1994).

1.2.2 Site History

The documented history with respect to waste storage and disposal activities for each of the sites within OU No. 1 is presented below.

1.2.2.1 Site 21 - Transformer Storage Lot 140

Site 21 has had a history of pesticide usage/storage and reported transformer oil disposal. Portions of the site were used as a pesticide mixing area and as a cleaning area for pesticide application equipment from 1958 to 1977. This area was reported to be located in the southeast corner of the lot (the exact location is not documented). Based on the RI data, the area appears to be throughout the southern portion of the site. Chemicals reportedly stored at this site included diazinon, chlordane dust, lindane, DDT dust, malathion (46% solution), mirex, 2,4-D, silvex, dalapon and dursban. Small spills, discharge of washout fluids, and indiscriminate disposal are believed to have occurred in this area. In 1977, before these mixing/cleaning activities were moved to a different location, overland discharge of washout fluids was estimated to be approximately 350 gallons per week. It is not clear for how long this discharge of washout fluids occurred (ESE, 1990).

Aerial photographs from 1944, 1964, and 1984 revealed several areas which appear as ground stains possibly from the pesticide mixing. The approximate locations of these stained areas are shown on Figure 1-2. The stains identified on the aerial photographs appear as long narrow dark patches which are adjacent to the suspected pesticide mixing area.

A former transformer oil disposal pit was reportedly located in the northeastern portion of the site. The pit was reportedly used as a disposal area for transformer oil during a one year period between 1950 and 1951. The pit reportedly measured 25 to 30 feet long by 6 feet wide by 8 feet deep. Sand was occasionally placed in the pit when oil was found standing in the bottom of the pit. The total quantity of oil disposed in this pit is unknown (ESE, 1990).

Review of the aerial photographs from 1952 through 1960 revealed an area of visibly stained soil south of the former disposal pit. This area is identified (in blue) on Figure 1-2. It is unknown whether this stained area is related to the disposal activities. In addition, approximately 60 objects suspected of being transformers were identified south of the stained area in the 1952 photograph.

1.2.2.2 Site 24 - Industrial Fly Ash Dump

Site 24 was used for the disposal of fly ash, cinders, solvents, used paint stripping compounds, sewage sludge, and/or water treatment spiractor sludge from the late 1940s to 1980 (ESE, 1990). Spiractor sludge from the wastewater treatment plant and sewage sludge from the sewage treatment plant were reportedly disposed at this site since the late 1940s. Construction debris was reportedly disposed at the site in the 1960s. During 1972 to 1979, fly ash and cinders were dumped on the ground surface, and solvents used to clean out boilers were poured onto these piles. Furniture stripping wastes were also reported to be disposed of at this area (ESE, 1990).

Previous reports identified four separate disposal areas within the site. A recent geophysical survey investigation conducted at the site (as part of the RI), confirmed the general location of three of these disposal areas in addition to locating two buried metal areas. One of the borrow and debris areas could not be identified. Based on a review of the USEPA EPIC Study (USEPA, 1992a) aerial photographs of the site, the second borrow and debris area may have only been a mound of material that was present at the site during 1943-1944. No other activities were noted in this area, so it is probable that this area might not have been a disposal area. Therefore, based on the RI data, five primary areas of concern have been identified within Site 24: the Spiractor Sludge Disposal Area; the Fly Ash Disposal Area; the Borrow and Debris Disposal Area; and two Buried Metal Areas (Figure 1-3).

1.2.2.3 Site 78 - HPIA

The HPIA, constructed in the late 1930s, was the first developed area at MCB, Camp Lejeune. It was comprised of approximately 75 buildings and facilities including: maintenance shops, gas stations, administrative offices, commissaries, snack bars, warehouses, and storage yards. Table 1-1 provides a summary of some of the buildings within Site 78, their usage, and activities which may have contributed to potential contamination. The information presented on this table is from a previous records search conducted in 1988 (see Section 1.2.3.2 of this report).

There is presently no known uncontrolled disposal of wastes related to the various industrial activities at the site. Due to the industrial nature of the site, many spills and leaks have occurred over the years. Most of these spills and leaks have consisted of petroleum-related products and solvents from underground storage tanks (USTs), drums, and uncontained waste storage areas.

1.2.3 Investigation and Study History

In response to the passage of the CERCLA Act of 1980, the DON initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify, investigate, and clean up past hazardous waste disposal sites at Navy installations. The NACIP investigations conducted by the DON consisted of Initial Assessment Studies (IAS), similar to the USEPA's Preliminary Assessments/Site Investigations (PA/SI) and Confirmation Studies, similar to the USEPA's RI/FS. When SARA was passed in 1986, the DON aborted the NACIP program in favor of the Installation Restoration Program (IRP), which adopted the USEPA Superfund procedures.

The following sections provide a brief summary of the previous investigations performed at OU No. 1. A more detailed discussion of the previous investigations is provided in the RI Report for OU No. 1 (Baker, 1994).

1.2.3.1 Initial Assessment Study

An IAS was conducted by Water and Air Research, Inc. in 1983. The IAS identified a number of sites at MCB, Camp Lejeune as potential sources of contamination, including two of the three sites discussed in this FS (Site 78 was added later). The IAS included a review of

TABLE 1-1

POTENTIAL AREAS OF CONCERN WITHIN SITE 78 IDENTIFIED DURING A 1988 RECORD SEARCH
FEASIBILITY STUDY CTO-0177
MCB, CAMP LEJEUNE, NORTH CAROLINA

Building No.	Building Type	Comments and Concerns
901	Tank Rebuild Facility	History of degreaser; organic solvent usage; POL area
902	Engineering Shop and Armory	Sump and POL area; armory uses organics for weapon cleaning.
903	Warehouse	Identified UST
907	Warehouse	Potential active UST (hydraulic oil)
908	Paint Storage	Storage of large amounts of paint and painting chemicals
909	Equipment Shop	Wastes, solvents, oils; stressed vegetation; degreasers used
910	Welding Shop	Abandoned wash rack
913	Vehicle Maintenance	Battery acid, contaminated soil in bags stored on pallets; used oil drums
915	Warehouse	Solvent drain from wash line; stressed vegetation
916	Warehouse	Drum storage outside of building (kerosene, oil, gasoline)
926	Admin/Warehouse	Past - Kerosene tank leaked; contaminated soil removed
927	Admin/Warehouse	Past - Kerosene tank leaked; contaminated soil removed
928	Auto Maintenance/ Warehouse	Past - Kerosene tank leaked; contaminated soil removed
1011	Warehouse	No chemicals used or stored; oil tank with soil contamination
1012	Warehouse	Leaking kerosene tank; soil contamination
1014	Paint Locker	Paint supply area; solvent storage
1100	Printing Shop	Former service station
1101	Warehouse/Data Processing Office	Solvent usage and outside storage
1103	Paint Storage Facility	Old grease rack; adjacent waste area; solvents
1104	Telephone Shop	Past use of wash pad without oil/water separator
1105	Equipment Storage and Office	Vehicle washing area; sump; oil/water separator
1106	Wood Shop	Potential Active UST (used oil); aerial photography study indicates this as a potential area of concern
1114	Warehouse	Solvent usage; used oil; tanks for used oil, kerosene, diesel fuel, gasoline

Source: ESE, 1988b

TABLE 1-1 (Continued)

POTENTIAL AREAS OF CONCERN WITHIN SITE 78 IDENTIFIED DURING A 1988 RECORD SEARCH
FEASIBILITY STUDY CTO-0177
MCB, CAMP LEJEUNE, NORTH CAROLINA

Building No.	Building Type	Comments and Concerns
1116	AC/S Logistics	Engineers area stores caustics and other organic detergents
1117	Warehouse/Armory	Armory; solvent usage
1202	Maintenance Building	TCE and other solvent usage; suspected waste UST
1203	Maintenance	Vehicle washing; fuel oil tank; anti-freeze spill
1204	Base Telephone Storehouse	Past use of wash pad
1205	Vehicle Service	potential inactive UST (used oil); solvent usage; waste oil; aerial photography study indicates this as a potential area of concern
1206	Vehicle Service	Service area; solvent usage; waste oil; aerial photography study indicates this as a potential area of concern
1300	Cold/Frozen Storage	Refrigeration maintenance shop; solvent storage/usage
1308	Not Specified	Partially buried kerosene storage tank
1310	Auto Maint./Equip. Storage	potential inactive USTs; visible oil in ditch; aerial photography study indicates this as a potential area of concern
1406	Not Specified	Wash/grease rack used since 1942
1407	MT Offices/Whse.	Past spills in wash pit; aerial photography study indicates this as a potential area of concern
1408	Whse./Equip. Storage	Past spills in wash pit; aerial photography study indicates this as a potential area of concern
1450	Vehicle Service	Potential active UST (diesel, used oil); solvent usage; POL areas
1502	Base Maint. Motor Repair	Potential inactive USTs (No. 2 fuel/gasoline/ used oil/diesel); solvents/oils use
1505	Auto Shop	Potential inactive USTs; aerial photography study indicates this as a potential area of concern
1601	Maintenance	Potential inactive UST (used oil); use of chemicals highly suspected
1602 and 1603	Former Maintenance Buildings	Former motor wash and service area
1604	Auto Shop	Potential inactive USTs; aerial photography study indicates this as a potential area of concern
1607	Body Shop	Solvent usage

Source: ESE, 1988b

TABLE 1-1 (Continued)

POTENTIAL AREAS OF CONCERN WITHIN SITE 78 IDENTIFIED DURING A 1988 RECORD SEARCH
FEASIBILITY STUDY CTO-0177
MCB, CAMP LEJEUNE, NORTH CAROLINA

Building No.	Building Type	Comments and Concerns
1700	Steam Generator/Machine Repair Shop	Solvent and waste solvent usage and storage (waste tank)
1709	Not Specified	POL areas
1710 and 1711	Vehicle and Armory Maintenance	Solvent usage; wash area; POL area
1750	Heavy Equipment Maint.	Potential inactive UST (used oil); past and present solvent usage
1755	Heavy Equipment Maint.	Potential inactive UST (used oil); past and present use of solvents
1765	Maintenance	Potential active UST (No. 2 fuel oil)
1775	Heavy Equipment Maint.	Potential active USTs (gasoline/used oil/diesel); past/present solvent usage
1780	Heavy Equipment Maint.	Potential active USTs (used oil); past/present solvent usage; waste area
1804	Storage/Maintenance	Potential active USTs (used oil); past vehicle repair; solvent usage now minimal
1808	Storage Building	Past vehicle repair - solvent use; present - no signs of chemical usage
1810	Admin Office	Former vehicle maint. shop - past solvent use likely
1812	Not Identified	Potential inactive UST (No. 2 fuel oil)
1815	Auto Shop	Empty building; potential inactive UST (diesel fuel)
1817	Auto Shop	Previous washing area; contaminated soils
1826	Auto Shop	Old grease rack with drain to ditch; waste oil tank at grease rack
1828	Auto Shop	Waste oil tank contaminated surrounding soils
1841	Heavy Equipment Maint.	Potential inactive USTs (gasoline/used oil/diesel); wide use of solvents
1854	Multipurpose Facility	Potential active USTs (used oil, diesel); past and present solvent usage
1855	Armory	Solvent usage; little waste
1860	Maintenance	Potential active UST (used oil); solvent usage in garage and shop areas
1880	Heavy Equipment Maint.	Potential active USTs (used oil/diesel); large amounts of chemicals used.

Source: ESE, 1988b

historical records and aerial photographs, as well as inspections and personnel interviews to evaluate potential hazards at the various sites on MCB, Camp Lejeune. The IAS recommended performing Confirmation Studies at all three sites to further evaluate environmental impacts to the sites.

1.2.3.2 Confirmation Study

Confirmation Studies for Sites 21, 24 and 78 were conducted by Environmental Science and Engineering, Inc. (ESE) during the period 1984 through 1987. These studies focused on investigating the potential source areas identified in the IAS. The Confirmation Studies were divided into two separate phases: a Verification Step which was conducted in 1984, and a Confirmation Step which was conducted in 1986 through 1987. As part of the Confirmation Study conducted by ESE, samples of soils (Sites 21 and 78), groundwater (all three sites), and surface water/sediment (Site 24 only) were collected and analyzed. A soil gas survey and an aquifer pump test were also conducted at Site 78.

The results of the Confirmation Study conducted for Site 21 indicated that the soil within the site was contaminated with pesticides and possibly PCBs. The soil samples were analyzed for pesticides, herbicides, and PCBs. Groundwater samples collected from a single well at Site 21 did not exhibit any significant levels of organic contamination.

The results of the Confirmation Study conducted for Site 24 indicated that several metals including arsenic, chromium, copper, lead, nickel, selenium, and zinc were present in the groundwater. Only chromium and lead were detected at concentrations exceeding Federal drinking water standard and/or State groundwater standards. Metals were also detected in the surface water and sediment samples collected from Cogdels Creek.

The Confirmation Study results for Site 78 indicated that the shallow groundwater near the Hadnot Point Fuel Farm (Site 22) was contaminated with fuel-related volatile organic compounds (VOCs) such as benzene and toluene. These results were from the two shallow monitoring wells installed during this study. In addition, VOCs such as trichloroethene (TCE), benzene, trans-1,2-dichloroethene (T-1,2-DCE),and tetrachloroethene (PCE) were detected in nearby water supply wells. As a result, four supply wells (HP-601, HP-602, HP-608, and HP-634) were immediately shut down by Camp Lejeune utilities staff.

The groundwater results from Site 78 triggered the conductance of the Characterization Step of the Confirmation Study. The Characterization Step consisted of: a records search; a soil gas survey, installation of 33 additional monitoring wells, additional groundwater sampling; and an aquifer test. The results from these additional investigations indicated that there were several primary potential source areas for waste solvent and fuel-related material throughout Site 78. Groundwater samples indicated that three primary zones of contamination were present in the shallow portion of the aquifer, centered in the vicinity of Building 902, Site 22, and Building 1601.

1.2.3.3 Groundwater Study at the Hadnot Point Fuel Farm

O'Brien and Gere Engineers, Inc. conducted a groundwater study at the Hadnot Point Fuel Farm (Site 22) as part of the MCB, Camp Lejeune UST Program. Although this study was conducted for Site 22 and not Site 78, the results are applicable to Site 78 given the proximity of the sites (Figure 1-4).

The fuel farm, constructed around 1941, consisted of 14 USTs and one above ground storage tank. These tanks contained either diesel fuel, leaded gasoline, unleaded gasoline, or kerosene. The purpose of this study was to provide follow-up hydrogeologic services to investigate hydrogeology and evaluate the extent of fuel leakage from the USTs and associated transfer lines. The study included the installation of 20 groundwater monitoring wells in the vicinity of the fuel farm, measurement of groundwater elevation and floating product thickness, and sampling and analysis of groundwater for VOCs. The study concluded that fuel losses of gasoline have likely occurred predominantly through leaks in the transfer lines or valves. Laboratory analyses indicate that the floating product has contributed significant levels of dissolved petroleum compounds including BTEX into the groundwater. Trace levels of non-petroleum VOCs including TCE and PCE were also detected within the fuel farm.

Based on these results, O'Brien and Gere designed a product recovery system and contaminated groundwater treatment system for the fuel farm. The system consists of four recovery wells, a product recovery tank, an oil/water separator, an air stripper, and activated carbon canisters. The entire system began operation in the latter part of 1991. It is important to note that the recovery/treatment system implemented at the fuel farm is addressing a different yet complimentary phase of the groundwater problem at Site 78 (i.e., this system is addressing the recovery of free phase product). Since the fuel farm area is a UST problem, it is not included as part of the CERCLA RI/FS process, but is being handled as a separate study under the UST Program.

1.2.3.4 Supplemental Characterization Step

A Supplemental Characterization Step, performed by ESE at Site 78 from 1990 through 1991, was designed to further evaluate the extent of contamination in the Castle Hayne aquifer and to characterize the contamination within the shallow soils at suspected source locations. This study consisted of 30 soil borings at three suspected source locations identified above (Buildings 902, 1202, and 1601) for the characterization of shallow soil contamination, installation of additional intermediate (73 to 78 feet deep) and deep (148 to 153 feet deep) monitoring wells, and the collection of samples from all new and existing Site 78 monitoring wells and several nearby water supply wells (ESE, 1992).

The soil sample results from this study detected VOCs (TCE and 1,2-DCE) and a few semivolatile organic compounds (SVOCs) near Building 902. Fuel-related VOCs (ethylbenzene and xylenes) were detected near Building 1202. Pesticides were detected near Buildings 1103 and 1601. PCBs and pesticides were identified near Building 1300.

The results of the shallow groundwater sampling yielded similar results as with the previous studies. The results from the intermediate and deep monitoring wells indicated that BTEX constituents were detected downgradient of the fuel farm and at other areas of the site.

1.2.3.5 Remedial Investigation for the Shallow Soils and Castle Hayne Aquifer at Site 78

ESE conducted an RI in 1991 to investigate shallow soils and the upper portion of the Castle Hayne aquifer at Site 78. The purpose of this investigation was to delineate the horizontal and vertical extent of contamination within the shallow and deeper water-bearing zones. In addition, soil contamination within the shallow soils at suspected source locations was characterized as to its nature and extent. This RI did not involve any additional field investigations. The RI report used data from the previous ESE investigations: Confirmation Study (Verification Step and Characterization Step) and the Supplemental Characterization Step (ESE, 1992).

The RI report concluded that while TCE and other VOCs were the primary concern during the soil gas survey, these compounds were detected in only a few of the soil samples collected. The only TCE detection in soils appeared to be associated with an UST at Building 902, which reportedly was used to store spent solvents.

The detected SVOCs appeared to be related to fuel releases from Building 1202 which is used for vehicle repairs and maintenance. Pesticide contamination was also detected in five samples collected from three boreholes. Many of the metals detected were found in all samples analyzed and therefore, may be indicative of the naturally occurring soil matrix and associated clays (ESE, 1992).

1.2.3.6 Interim Remedial Action Remedial Investigation for the Shallow Aquifer at Site 78

Baker conducted an Interim Remedial Action (IRA) RI for the shallow aquifer at Site 78, the results of which are provided in the IRA RI Report (Baker, 1992b). The objectives of this investigation were:

- To determine the nature and extent of shallow groundwater contamination in the shallow aquifer at two areas of concern within Site 78;
- To qualitatively assess human health risks associated with future potential use of the shallow aquifer; and
- To document and evaluate existing information pertaining to the shallow aquifer to support the selection of an IRA alternative.

This RI report used the data from previous investigations only; no additional field studies were conducted. The IRA RI report concluded that three contaminant plumes were identified within the shallow groundwater at Site 78. Two of the plumes contained BTEX and TCE. One of the plumes contained BTEX compounds only. The BTEX only plume is associated with the Hadnot Point Fuel Farm (Site 22) which is being remediated under a separate investigative program. One of the BTEX/TCE plumes is located east of Cedar Street and extends from the vicinity of the 900 Building area to the tank farm. The plume exhibits solvent contamination and low levels of fuel-related contamination. The other BTEX/TCE plume is believed to originate in the vicinity of Buildings 1502, 1601, and 1602. This plume is contaminated with the same constituents as the plume located east of Cedar Street, with the exception of lead.

Lead is a contaminant of concern at the site since it is above naturally occurring levels (Baker, 1992b).

As part of this IRA RI, a qualitative risk assessment was performed to identify receptors and exposure pathways, quantify exposure levels, and evaluate human and/or environmental risk. The contaminants of concern for the site were identified as solvents (TCE and 1,2-DCE), BTEX, SVOCs (naphthalene and 2-methylnaphthalene), and inorganics (antimony, arsenic, beryllium, chromium, lead, manganese, mercury, nickel, and iron). The qualitative risk assessment concluded that benzene and TCE may impact human health if shallow groundwater migrates into the deep aquifer (potable water), or if the shallow aquifer is utilized in the future as a potable water source (Baker, 1992b).

1.2.3.7 Interim Remedial Action Feasibility Study for the Shallow Aquifer at Site 78

Based on the results of the IRA RI for the shallow aquifer, Baker prepared an IRA FS Report (Baker 1992a). The IRA FS developed and evaluated several IRA alternatives for the impacted shallow groundwater. The preferred alternative involved two on-site pump and treat systems which would be implemented to contain the two fuel/solvent-contaminated plumes at the site. Following extraction, the groundwater would be treated on site via air stripping, carbon adsorption, and metals removal, then discharged to the Hadnot Point Sewage Treatment Plant (STP). This IRA alternative was accepted by the USEPA, the NC DEHNR, and the public. The extraction/treatment systems have been designed and construction will be initiated in 1994.

1.2.3.8 Pre-Investigation Study for the RI/FS

Pre-investigation activities were conducted by Baker at Sites 24 and 78 in 1992 to assist in the scope for the RI field program and to confirm the presence or absence of several suspected USTs within Site 78. As part of the pre-investigation activities, groundwater samples were collected from the existing Site 24 monitoring wells, and selected existing monitoring wells (i.e., deep wells at Site 78 which were located near areas where the shallow aquifer was known to be contaminated) and potable water supply wells in the area of Site 78. Further, a geophysical survey was also conducted at these sites by employing surface investigative techniques. The geophysical investigation was conducted at Site 24 to delineate the boundaries of suspected buried metal disposal areas, and the investigation was conducted at Site 78 to confirm the presence or absence of several suspected USTs. The results of the geophysical survey indicated that USTs were potentially present at Buildings 903, 1502, and 1601. No USTs were identified at Buildings 1202 or 1709. BTEX and several metals were detected in the wells sampled. Additional details of these investigations are described in detail in the Final RI Report for OU No. 1 (Baker, 1994).

1.2.3.9 Remedial Investigation Conducted by Baker, 1993

The RI field program conducted at OU No. 1 was initiated by Baker to further characterize potential environmental and ecological impacts, and to evaluate threats to human health resulting from previous storage, operation, and disposal activities. The field investigations commenced in April 1993 and continued through December 1993. The field program initiated at OU No. 1 consisted of a soil gas survey (Site 78 only); a preliminary site survey; a soil investigation which included drilling and sampling; a groundwater investigation which included well installation and sampling; test pit sampling (Site 24 only); and a surface water/sediment investigation (Sites 21 and 78 only). The results of the RI are summarized in the next sections with respect to nature and extent of contamination, and the baseline risk assessments. A summary of the data collected from OU No. 1 is presented in Appendix A.

1.2.4 Nature and Extent of Contamination

The following provides a summary of the nature and extent of contamination at each of the three sites in addition to Cogdels Creek and Beaver Dam Creek. The discussions are based on the results from the RI for OU No. 1.

1.2.4.1 Site 21: Transformer Storage Lot 140

Soils

Pesticides and PCBs were the dominant contaminants present in soils at Site 21. The most significant pesticide levels were found in surface soils collected in the vicinity of the Former Pesticide Mixing/Disposal Area. These concentrations (ranging from 4.6 to 34,000 J µg/kg) are believed to be related to the previous handling practices which were reported by Base personnel. The pesticides were detected in an area covering approximately 150,000 square feet.

PCBs (PCB-1260) were present primarily in surface soils in the vicinity of the Former PCB Transformer Disposal Area (approximately 20,000 square feet). PCBs were also detected in two other areas of the site.

VOCs and SVOCs were not extensively found in Site 21 soils. In general, the VOCs and SVOCs appear to be limited to the surface soils. The detected VOCs and their maximum concentrations included toluene (37 J µg/kg), ethylbenzene (570 µg/kg), and total xylenes (3,400 µg/kg). Furthermore, several of the more prevalent detected SVOCs and their maximum concentrations included naphthalene (3,200 J µg/kg), fluorene (1,300 µg/kg), pyrene (520 µg/kg), benzo(b & k)fluoranthene (560 µg/kg), and chrysene (450 µg/kg). Because these constituents are petroleum based, they may be associated with the pesticide mixing/disposal since petroleum products are used for a base-medium.

Groundwater

Metals were the most prevalent contaminants in groundwater at Site 21. Concentrations of arsenic, manganese, cadmium, beryllium, chromium, lead, and/or nickel were found above Federal drinking water standards or North Carolina groundwater standards in seven of the eight shallow wells sampled. The highest concentrations were detected in wells located near the southwestern portion of the site. Note that metals were also present extensively in groundwater throughout OU No. 1, and therefore, the metals may be a result of a regional (entire MCB, Camp Lejeune) problem rather than a site-specific problem.

VOCs in the groundwater were primarily limited to the northeastern portion of the site. TCE and BTEX were detected in this area at concentrations which exceeded Federal and State standards. Note that this groundwater contamination is most likely related to Site 78, specifically the 901/903 series buildings, since the same contaminants were found in this area. Note that pesticides and PCBs, which were found extensively in site soils, were not detected in the groundwater at Site 21.

Surface Water

Surface water present at the site (only in the northern section of Site 21) did not appear to be contaminated.

Sediments

Pesticides and PCBs were the dominant contaminants present in sediments collected from the drainage ditch surrounding Site 21. Pesticides were detected a total of 66 times in the Site 21 sediment samples, all of which exceeded USEPA Region IV sediment screening values. The highest pesticide levels were found in sediment samples collected from locations downgradient from the suspected pesticide mixing area, along the southwestern portion of the site (along approximately 600 feet of the drainage ditch). PCBs were detected near the Former PCB Transformer Disposal Area. The PCB concentration exceeded the USEPA screening value.

1.2.4.2 Site 24: Industrial Area Fly Ash Dump

Soils

Analytical results indicated that pesticides and metals were the predominant contaminants impacting soils at Site 24. Pesticide concentrations (highest concentration at 350 µg/kg), were not elevated (as compared to other areas within MCB, Camp Lejeune); however, pesticides were present in surface soils throughout the site. The presence of the pesticides appeared to be the result of spraying activities rather than direct disposal due to the relatively low concentrations, widespread detections, and absence of any record of pesticide disposal or pesticide mixing activities at the site.

Detections of metals in surface and subsurface soils were an order of magnitude or higher above base-specific background levels. The presence of metals is most likely attributed to the disposal of fly ash material and various metal debris. The metals that exceeded base-specific background levels (surface and/or subsurface soils) included: aluminum, calcium, barium, copper, chromium, iron, lead, manganese, nickel, and selenium. Samples collected from the Fly Ash Disposal Area and Buried Metal Areas exhibited the highest overall concentration of these metals (an area covering approximately 180,000 square feet). A few of these elevated metals were detected to depths of 12 feet.

Test pit samples, which were collected in the vicinity of the Buried Metal and the Fly Ash Disposal Area, were tested for leachability via RCRA toxicity characteristics leaching procedure (TCLP). The samples tested were below TCLP regulator levels indicating that the soils are not characteristically hazardous. Additionally, the soils classify as nonhazardous under RCRA for ignitability, corrosivity, and reactivity. TCE, 4,4'-DDD, 4,4'-DDT, and several metals were detected in the samples collected from the test pits.

Groundwater

Metals are the predominant contaminants impacting Site 24 groundwater. The most elevated concentrations above Federal or State standards occurred near the suspected Buried Metals Area and the Fly Ash Disposal Area. The metals that were detected above the Federal drinking water standards and/or State groundwater standards included: arsenic, chromium, lead, manganese, cadmium, mercury, and nickel. The metals concentrations detected in the groundwater at Site 24 were similar to the metals concentrations detected at Site 21.

Low levels of the pesticide, heptachlor epoxide, were detected in three wells near the Spiractor Sludge Disposal Area and south of the Fly Ash Disposal Area. The concentrations were slightly above the State groundwater standard. The source of the heptachlor epoxide appeared to be related to pesticide spraying (rather than disposal or mixing) activities, since the overall concentrations were relatively low in both the groundwater and soil. Heptachlor epoxide was only detected in one soil sample collected at the site.

1.2.4.3 Site 78: HPIA

Soils

SVOCs, pesticides, and metals were the predominant contaminants impacting Site 78 soils. The concentrations of these pesticides were generally below 500 µg/kg, with the exception of a few samples exhibiting levels above 1,000 µg/kg at Buildings 1103 and 1502. The higher pesticide concentrations were detected in surface soil samples. The data suggests that the pesticide-impacted soils at Site 78 are the result of routine spraying activities since: 1) disposal of pesticides (e.g., buried drums, pesticide mixing) has not been documented at these building locations; and 2) overall concentrations are relatively low and comparable to other surface soils within OU No. 1.

SVOCs were present in soils in the vicinity of Buildings 903, 1103, 1502, 1601, and 1608. In general, higher SVOC concentrations and more frequent detections occurred in surface soils. A few detections of SVOCs, however, were also noted in subsurface soils near Building 1601. The most frequently detected SVOCs were PAHs, which included phenanthrene, anthracene, fluoranthene, pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and benzo(ghi)perylene. These compounds are found in petroleum fuels such as fuel oil No.2, diesel, and kerosene which are used for heating purposes, emergency generators, or refueling base vehicles. Storage of these fuels in aboveground tanks or USTs is common at a number of buildings throughout Site 78. It is possible that the source of the SVOCs is surface (i.e., spills) or subsurface releases (i.e., leaking tanks) of fuels.

Barium, lead, and zinc were the three most common metals detected at an order of magnitude or more above base-specific background levels. These metals were found predominantly in surface soils collected from Buildings 1103, 1502, and 1608. The specific sources of these metals are unknown since there is no history of disposal at these buildings that would relate to these three contaminants.

Analytical data indicated that VOCs and PCBs are not significantly impacting soils at the five buildings investigated within Site 78. Low levels of toluene and total xylenes were detected at Building 1103 (surface); somewhat higher levels of ethylbenzene and total xylenes were detected in subsurface soils (6 to 7 feet) at Building 1601. The source of the ethylbenzene and xylenes at Building 1601 may be related to releases of fuel from the suspected UST at the building. It is important to note that TCE and 1,2-DCE were detected in the subsurface soil samples collected from well/boring 78GW09-1. PCBs were detected in a single surface sample collected at Building 1300.

Groundwater - Shallow

Shallow groundwater at Site 78 has been impacted by organics and metals. The primary organic contaminants were VOCs, namely BTEX, PCE, TCE, vinyl chloride, 1,1-DCE, cis-1,2-DCE, T-1,2-DCE, and 1,2-dichloropropane. The highest overall concentrations of these compounds were detected near the northeastern portion of Site 78 in the vicinity of the 901/903 series buildings and in the southwestern portion of the site near Buildings 1601 and 1709. A number of these buildings, reportedly stored/handled petroleum fuels and/or solvents.

Metals were detected throughout the site at concentrations above the Federal and/or State standards. Thee was no particular area which exhibited excessive metals contamination since the entire site (as with Sites 21 and 24) appeared to be impacted. The metals most frequently detected at concentrations exceeding Federal or State groundwater standards were beryllium, chromium, lead, and manganese. Manganese is commonly found at elevated concentrations in soil and groundwater throughout MCB, Camp Lejeune, and is, therefore, thought to be naturally occurring. The elevated lead concentrations may be related to releases of leaded fuels which may have been stored at the Base at one time. The specific sources for beryllium and chromium are unknown, but they are most likely related to industrial processes or buried metal debris.

Contamination levels in shallow groundwater appears to have decreased over time. Several wells which exhibited elevated VOCs in 1987 and/or 1991 either had nondetectable or significantly lower concentrations in 1993. These wells included 78GW01, 78GW02, 78GW03, 78GW09-1, 78GW10, 78GW11, 78GW17-1, and 78GW19. Several possible explanations may account for the decrease in contaminant levels, including:

- The contaminants may have migrated vertically from the shallow aquifer into the underlying aquifer (contaminants were detected in the deep wells sampled in 1993), or horizontally to other portions of the site.

- The contaminant concentrations may have dissipated over time through natural processes.

Since the validity of the previous data in unknown, it is difficult to conclude which one of these possible explanations above is the most valid.

Three of the shallow wells (78GW22-1, 78GW23, and 78GW24-1) showed either increased contaminant levels or compounds not previously detected. These three wells are situated near the northeastern portion of Site 78 where multiple sources of contamination are known to exist (e.g., Hadnot Point Fuel Farm, numerous maintenance shops). These sources are presumed to be continually impacting the groundwater in the area.

Groundwater - Intermediate

The intermediate wells sampled at Site 78 exhibited low levels of VOCs and a few metals which exceeded Federal and/or State standards. Benzene, TCE, 1,2-DCE, vinyl chloride, and dichloromethane were the most prevalent VOCs detected. The highest VOC concentrations were found in the northeastern and southern portions of the site. The concentrations of the detected VOCs were less than those found in the shallow wells. Several SVOCs, including naphthalene, acenaphthene, and carbazole, were detected in one well in the northern portion of Site 78. Beryllium, cadmium, lead, manganese, and nickel concentrations in the northeastern portion of the site exceeded the Federal and/or State groundwater standards.

Groundwater - Deep

The analytical data indicated that organic compounds, namely VOCs, were the predominant contaminants in the deep wells. The detected VOCs included benzene, cis-1,2-DCE, T-1,2-DCE, and TCE. Wells located in the northeastern and southwestern portions of the site exhibited the overall highest concentrations of VOCs. Further, one well located in the southwestern portion of the site exhibited elevated alpha chlordane (pesticide) levels above the State groundwater standards.

Several of the deep wells have exhibited increased levels of VOCs over time. Wells 78GW04-3, 78GW09-3, 78GW24-3, and 78GW32-3, which all indicated nondetectable levels of VOCs in 1991, had positive detections of benzene, TCE, 1,2-dichloroethane, cis-1,-2, DCE, and/or T-1,2-DCE in 1993. These wells are situated along a linear direction from southwest to northeast across Site 78. Only one of the deep wells, 78GW31-3, revealed lower concentrations in 1993 compared to 1991. The suggests that the contaminants may be migrating into the deeper water-bearing zone at Site 78.

1.2.4.4 Cogdels Creek and the New River

Surface Water

The surface water within Cogdels Creek and the New River did not appear to be impacted with the exception of a few VOCs and a few metals. TCE was present in the surface water samples collected in the upper reaches (approximately 800 feet) of Cogdels Creek (east of the Buried Metal Area and Fly Ash Disposal Area at Site 24). Copper and lead were detected throughout the water bodies at concentrations above Federal and/or State surface water standards. No trends were detected. The highest concentrations were detected near the Hadnot Point STP (along the southern end of Site 78).

Sediments

The most prevalent contaminants found in Cogdels Creek and New River sediments were PAH compounds, pesticides (particularly 4,4'-DDD), and several inorganics. A number of inorganics were detected at every sediment sample location. Lead and zinc were most often in exceedence of sediment screening values. No trends or source areas were identified. Locations with the highest concentrations were south of the Borrow and Debris Disposal Area at Site 24 and in the New River, downgradient of the Operable Unit.

PAH compounds can be found in petroleum fuels such as No. 2 oil, diesel, and kerosene, which are used for heating purposes, emergency generators, or refueling base vehicles. Storage of these fuels in aboveground or USTs is a common practice throughout Site 78. It is likely, therefore that the source of SVOCs, and possibly lead, is related to surface or subsurface releases of fuels.

Pesticides were detected throughout Site 78 sediments, but in concentrations that were relatively low. This suggests that the presence of pesticides throughout Cogdels Creek and New River sediments are the result of spraying activities rather than disposal practices or spill incidents, since pesticide detections are not exceptionally high or concentrated in any specific area.

1.2.4.5 Beaver Dam Creek

Surface Water

The only contaminants were present in Beaver Creek surface water were inorganics. Copper, lead, and zinc were detected at levels exceeding Federal and/or State surface water standards. No trends or source areas were identified. The location exhibiting the highest levels of detection was east of the northern portion of Site 78. The source of this contamination is probably not operable unit related.

Sediments

The most prevalent contaminants found in Beaver Dam Creek sediments were PAHs, pesticides, and inorganics (lead was the only inorganic to exceed sediment screening values). As discussed earlier, storage of petroleum fuels (which can contain PAH and lead compounds) in aboveground or USTs is a common practice throughout Site 78. It is likely, therefore that the source of PAHs, and possibly lead, is related to surface or subsurface releases of fuels. Additionally, a second source of the PAHs may be from stormwater runoff from roads. Pesticides were detected throughout Beaver Dam Creek sediments, but in concentrations that were relatively low. As is the case with Cogdels Creek and New River sediments, this data suggests that the presence of pesticides in Beaver Dam Creek may be the result of spraying activities rather than disposal practices or spill incidents, since pesticides detections are not exceptionally high or concentrated in any specific area.

1.2.5 Baseline Risk Assessments

Baseline Human Health and Ecological Risk Assessments (RAs) were conducted as part of the RI for OU No. 1. The results of these RAs are discussed below.

1.2.5.1 Baseline Human Health Risk Assessment

The human health risk assessment conducted for OU No. 1 was based on several scenarios. Site 21 was evaluated with respect to exposure to current military personnel (soil); future residents (Beaver Dam Creek surface water and sediments); and future construction worker (soil). Site 24 was evaluated with respect to exposure to current military personnel (soil); future residents (groundwater and Cogdels Creek surface water and sediments). Site 78 was evaluated with respect to Operable Unit groundwater only. The soil data was focused on a limited number of potential source areas within Site 78. Due to the size of Site 78 (approximately 590 acres), this limited amount of soil data was not evaluated in the risk assessment because the results would be too biased.

The human health BRA highlighted the media of interest from the human health standpoint at OU No. 1 by identifying areas with elevated ICR and HI values. Overall, the RA indicated that areas of groundwater throughout OU No. 1 may pose potential risks. The following paragraphs summarize the results of the human health assessment performed for OU No. 1.

The estimated site risks for Site 21 fell within the USEPA's acceptable risk range (i.e., ICR < 1E-04 and HI ≤ 1.0). Therefore, the contaminants detected at Site 21 do not appear to present an unacceptable risk to human health and the derivation of remediation levels for protection of human health will not be necessary.

Future potential residential exposure (i.e., children and adults) to surface water and sediments (Beaver Dam Creek and Cogdels Creek) did not produce ICRs in excess of the target risk range or HIs exceeding unity. Therefore, derivation of remediation levels for protection of human health for either of these water bodies will not be necessary.

With respect to Site 24, the majority of the total site risk (greater than 95 percent) was associated with the ingestion and dermal contact of Operable Unit groundwater by future residents. With the exception of the total site risk associated with groundwater exposure to future adult and child residents, all total site risks fall within the USEPA's acceptable risk range. The ICR and HI for future potential adult residents were 2E-03 and 13, respectively. The ICR and HI for future potential child residents were 7E-04 and 29, respectively. The risk was driven by vinyl chloride, arsenic, vanadium, and chromium. Therefore, OU No. 1 groundwater must be considered a medium of interest for which remediation levels for protection of human health will be needed.

It is important to note that although lead could not be quantitatively evaluated in the Human Health RA, lead was mainly detected in the shallow groundwater and not the deeper portions of the aquifer. Therefore, exposure is unlikely since the water supply wells withdraw potable water from the deeper Castle Hayne Aquifer.

1.2.5.2 Ecological Risk Assessment

Aquatic Environment

The aquatic environment was assessed in the Ecological RA. Based on the potential habitat and other physical characteristics, the most significant populations of aquatic organisms at OU No. 1 were in Cogdels Creek and Beaver Dam Creek since the surface water in the drainage ditch at Site 21 was either shallow or nonexistent, and intermittent in flow.

Chromium, copper, lead, and zinc were the only contaminants of potential concern (COPCs) detected in the surface water in Cogdels Creek at concentrations that exceeded any of the water quality standards. These same four constituents, in addition to silver, several PAHs and pesticides, were detected in sediments at concentrations that potentially may decrease the viability of aquatic life.

Copper and zinc were the only COPCs detected in surface water at Beaver Dam Creek that exceeded any of the water quality standards. Lead, several PAHs and several pesticides were detected in sediment samples from Beaver Dam Creek.

The pesticides noted above appear to be the most significant site-related COPCs that have the potential for decreasing the viability of aquatic organisms at OU No. 1. There is aquatic life inhabiting both Cogdels Creek and Beaver Dam Creek, including fish, tadpoles, and benthic macroinvertebrates. In addition, some terrestrial invertebrates probably inhabit the undeveloped areas within OU No.1. Pesticides are not only potentially toxic to aquatic life through a direct exposure pathway, but as indicated by their high bioconcentration factor value, they have a high potential to bioconcentrate pesticides in organisms. Therefore, other fauna that feed on these organisms will be exposed to pesticides via this indirect exposure pathway.

Terrestrial Environment

No wetlands were identified at OU No. 1 from available wetland maps, nor are there any known spawning and nursery areas for resident fish species within Cogdels Creek or Beaver Dam Creek. Therefore, the Ecological RA for the terrestrial environment concentrated on plants and terrestrial invertebrates. Based on the soil toxicity data for plants and terrestrial invertebrates (earthworms), the following conclusions can be drawn: 1) lead and chromium were detected in concentrations that may decrease the viability of terrestrial invertebrates and floral species at Site 21; 2) lead and chromium, along with beryllium, copper, mercury, and vanadium were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species at Site 24; and 3) lead and chromium, along with beryllium and zinc, were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species at Site 78. Other terrestrial organisms (e.g., rabbits, birds, deer) may be exposed to contaminants in the surface soils and surface water by ingestion. Overall, pesticides appear to be the most significant site-related COPCs that have the potential for decreasing the viability of terrestrial organisms at OU No. 1. Potential adverse impacts to these threatened or endangered species from contaminants at OU No. 1 appear to be low.

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

This section presents the development of remediation goal options (RGOs), remediation levels (RLs), and remedial action objectives for OU No. 1. RGOs are chemical-specific concentration goals established for specific medium and land use combinations for the protection of human health and the environment. There are two general sources of chemical-specific RGOs: (1) concentrations based on applicable or relevant and appropriate requirements (ARARs) and, (2) risk-based concentrations for the protection of public health and the environment. The selection of RGOs includes: identifying the media(s) of concern, selection of contaminants of concern (COCs), evaluation of ARARs, and identification of site-specific information for the exposure pathway information (i.e., exposure frequency, duration, or intake rate data). The development of RGOs for OU No. 1 via these criteria is detailed in Sections 2.1 through 2.6. The resulting RLs, areas that require remediation, and the remedial action objectives are presented in Sections 2.7, 2.8, and 2.9, respectively.

2.1 Media(s) of Concern

The results of the baseline human health RA presented in the RI Report (Baker, 1994) indicated that groundwater was the media of concern, with respect to carcinogenic and noncarcinogenic risks. The other media (soil, sediment, surface water, and air) had ICRs less than 1.0E-04 and HIs less than 1.0. Therefore, the primary focus of this FS is on groundwater remediation. Soil was added as a media of concern for this FS due to a limited number of areas exhibiting levels of pesticides and PCBs (i.e, "hot spots"). This was partly due to the results of the ecological RA.

Surface water, sediments, and air are not medias of concern, based on the conclusions drawn by the human health RA. However, potential ecological risk may be of concern from contaminants detected in the surface water and sediment. Although contaminants were present in both media, neither media will be directly remediated since the resultant action may create a greater risk to the environment.

2.2 Contaminants of Concern

COCs initially selected and evaluated in the RAs were selected on the basis of frequency of detection, toxicity, and comparison to established criteria or standards. The COCs identified for groundwater, soil, surface water, and sediment for both the human health and ecological RAs are listed in Table 2-1. COCs that do not exceed a regulatory or a risk-based RGO will be

TABLE 2-1

PRELIMINARY CONTAMINANTS OF CONCERN
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern Evaluated in the Risk Assessment	Human Health		Ecological Health		
	Ground-water	Soil	Surface Water	Sediment	Soil
Volatiles					
Benzene	X				
Ethylbenzene	X				
Trichloroethene	X		X		
Tetrachloroethene	X				
Toluene	X				
1,2-Dichloroethene (total)	X				
Vinyl Chloride	X				
Xylenes (total)	X				
Semivolatile					
Benzo(a)anthracene		X		X	X
Benzo(b)fluoranthene		X		X	X
Benzo(k)fluoranthene		X		X	X
Benzo(a)pyrene		X		X	X
Benzo(g,h,i)perylene				X	X
Chrysene		X		X	X
Fluoranthene		X		X	X
Indeno(1,2,3-cd)pyrene		X		X	X
Phenanthrene		X		X	X
Phenol	X				
Pyrene		X		X	X
Anthracene					X
Carbazole					X
Pesticides and PCBs					
4,4'-DDD		X		X	X
4,4'-DDE		X		X	X
4,4'-DDT		X		X	X
Dieldrin		X			X
Heptachlor Epoxide	X				
Chlordane (total)		X		X	X
PCBs (total)		X			X

TABLE 2-1 (Continued)

PRELIMINARY CONTAMINANTS OF CONCERN
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern Evaluated in the Risk Assessment	Human Health		Ecological Health		
	Groundwater	Soil	Surface Water	Sediment	Soil
Inorganics					
Aluminum			X	X	X
Arsenic	X	X	X	X	X
Barium	X			X	X
Beryllium	X	X	X	X	X
Cadmium			X	X	X
Chromium	X	X	X	X	X
Cobalt					X
Copper	X		X	X	X
Iron			X	X	X
Lead	X		X	X	X
Manganese	X	X	X	X	X
Mercury	X		X		X
Nickel	X				X
Selenium		X	X	X	X
Silver				X	
Vanadium	X	X	X	X	X
Zinc	X	X	X	X	X

eliminated from further consideration as a COC. In addition, an evaluation will be conducted on the remaining set of contaminants to determine areas and media of concern for the operable unit. A final set of COCs will be identified which then will be the basis for a set of remedial action objectives applicable to OU No. 1.

2.3 Remediation Goal Options

RGOs are based on Federal and State criteria or risk-based concentrations. Federal and State criteria will be identified and evaluated in Section 2.3.1. Site specific risk-based RGOs for the COCs at OU No. 1 will be developed in Section 2.3.2. The results from both of these sections will be used to develop the initial set of RGOs for the operable unit.

2.3.1 Applicable or Relevant and Appropriate Federal and State 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. CERCLA's definition of "Applicable Requirements" is:

> ...cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant or 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.

CERCLA's 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. The first type, chemical-specific ARARs, are requirements which set health or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants. Federal Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act (SDWA) are examples of chemical-specific ARARs.

The second type of ARARs, location-specific, set restrictions on activities based upon the characteristics of the site and/or the nearby suburbs. Examples of this type of ARAR 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 the 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 Federal and State substantive requirements that qualify as ARARs be complied with by remedies. Federal, State, or local permits do not need to be obtained for removal or remedial actions implemented on site but their substantive requirement must be obtained. "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, specific site characteristics, and particular remedial actions proposed for the site. ARARs identified for OU No. 1 are presented in the following section.

2.3.1.1 Chemical-Specific ARARs

The following criteria were used in the selection of chemical-specific ARARs: the North Carolina Water Quality Standards (NCWQSs) applicable to groundwaters, the Federal MCLs and secondary MCLs, Federal risk-based Health Advisories (HAs), the PCB Spill Cleanup Policy under the Toxic Substances Control Act (TSCA), NCWQSs applicable to surface waters and the Region IV Surface Water/Sediment Screening Values (SSVs) and USEPA Region III Risk-Based Soil Screening Concentrations (RBCs). A brief description of each these standards/guidance is presented below.

North Carolina Water Quality Standards (Groundwater) - Under the North Carolina Administrative Code (NCAC), Title 15A, Subchapter 2L, Section .0200, (15A NCAC 2L.0200) the DNC 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 groundwaters (15A NCAC 2L.0201 and 2L.0300).

The water quality standards for the groundwaters 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 NCWQSs 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 1.0E-6
- Taste threshold limit value
- Odor threshold limit value

- Federal MCL
- National Secondary Drinking Water Standard (or secondary MCL)

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

The Class GA groundwater NCWQSs for the groundwater COCs for OU No. 1 are listed on Table 2-2. As shown on the table, the majority of the State standards are the same or more stringent than the Federal MCLs.

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.

Secondary MCLs are nonenforceable guidelines established under the SDWA. The secondary MCLs are set to control contaminants in drinking water that primarily affect the aesthetic qualities relating to public acceptance of drinking water.

Table 2-2 presents a comparison of groundwater COCs to MCLs. For manganese and zinc, the secondary MCL has been listed.

Federal Health Advisories (HAs) - Federal HAs are guidelines developed by the USEPA Office of Drinking Water for nonregulated constituents in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (assumed body weight 10 kg) who consume 1 liter of water per day or in adults (assumed body weight 70 kg) who consume 2 liters of water per day. HAs are generally available for acute (1 day), subchronic (10 days), and chronic (longer-term) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, are not used to set acceptable levels of potential human carcinogens. Long-term HAs for the groundwater COCs listed in Table 2-2 are included for both a child (10 kg) and an adult (70 kg).

Revised July 22, 1994

TABLE 2-2

CONTAMINANT-SPECIFIC GROUNDWATER CRITERIA
FEASIBILITY STUDY CTO-0177
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Groundwater Criteria(1)			
			Federal Health Advisories	
Preliminary Groundwater Contaminant of Concern	NCWQS(2)	MCL(3)	For a 10 kg Child	For a 70 kg Adult
Benzene	1.0	5	NE(4)	NE
Ethylbenzene	29	700	1,000	3,000
Trichloroethene	2.8	5	NE	NE
Tetrachloroethene	0.7	5	1,000	5,000
Toluene	1,000	1,000	2,000	7,000
1,2-Dichloroethene (total)	70(5)	70(5)	3,000(5)	11,000(5)
Vinyl Chloride	0.015	2	10	50
Xylenes (total)	400	10,000	40,000	100,000
Phenol	NE	NE	6,000	20,000
Heptachlor Epoxide	0.038	0.2	0.1	0.1
Arsenic	50	50	NE	NE
Barium	1,000	2,000	NE	NE
Beryllium	NE	4	4,000	20,000
Chromium	50	100	200	800
Copper	1,000	1,300	NE	NE
Lead	15	15	NE	NE
Manganese	50	50(6)	NE	NE
Mercury	1.1	2.0	NE	2.0
Nickel	100	100	500	1,700
Vanadium	NE	NE	NE	NE
Zinc	2,100	5,000(6)	3,000	12,000

(1) Concentrations expressed in µg/L (ppb)
(2) NCWQS = North Carolina Water Quality Standards for Class GA groundwaters
(3) MCL = Safe Drinking Water Act Maximum Contaminant Level
(4) NE = Long-term advisory not established for this contaminant
(5) Values are for cis-1,2-dichloroethene
(6) Value represents a secondary MCL

Toxic Substances Control Act - The PCB Spill Cleanup Policy (40 CFR 761.120 through 761.139) describes the level of cleanup required for PCB spills occurring after May 4, 1987. Because this policy is not a regulation and applies only to recent spills, the Spill Policy is not an ARAR for CERCLA response actions. However, as a codified policy representing substantial scientific and technical evaluation, it has been considered in developing the guidance cleanup levels for PCB contamination at CERCLA sites (USEPA, 1990a). A summary of the policy with respect to soil contamination follows.

For spills of low concentration PCBs [50 parts per million (ppm) to 500 ppm] involving less than one pound of PCBs, all soils within the spill areas plus a one-foot lateral boundary must be excavated. The excavation must be backfilled with clean (less than 1 ppm PCB) soil. No confirmation sampling is required (USEPA, 1990a).

For spills of 500 ppm or greater PCBs and spills of low concentration PCBs or more than one pound PCBs by weight in nonrestricted access areas, soil must be cleaned up to 10 ppm PCBs. In addition, a cap of at least 10 inches of clean material must be placed on top of the excavation. Confirmation sampling is required (USEPA, 1990a).

For spills of 500 ppm or greater PCBs and spills of low concentration PCBs of more than one pound in industrial and other restricted access areas, cleanup of soil to 25 ppm is required. Confirmation sampling is required (USEPA, 1990a).

Ambient Water Quality Criteria (AWQC) - AWQC are nonenforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. They may also be used for identifying the potential for human health risks. AWQCs consider acute and chronic effects in both freshwater and saltwater aquatic life, and potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), or from ingestion of water alone (2 liters/day). The AWQCs for the protection of human health for potential carcinogenic substances are based on the USEPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 (i.e. the 10E-7 to 10E-5 range). The AWQCs for the surface water COCs for OU No. 1 are listed on Table 2-3.

North Carolina Water Quality Standards (Surface Water) - The NCWQSs for surface water are the standard concentrations, that either alone or in combination with other wastes, in surface waters that will not render waters injurious to aquatic life or wildlife, recreational

TABLE 2-3

CONTAMINANT-SPECIFIC SURFACE WATER CRITERIA
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Preliminary Surface Water Contaminant of Concern	Surface Water Criteria(1)				
	Region IV Surface Water Screening Values		NCWQS(2)	AWQC(3)	
	Acute	Chronic		Acute	Chronic
Trichloroethene	NE(4)	NE	92.4	45,000	21,900
Aluminum	NE	NE	NE	NE	NE
Arsenic	69	36	50	NE	NE
Beryllium	NE	NE	NE	130	5.3
Cadmium	1.79	0.66	2.0	3.9	1.1
Chromium (III)	1,030	103	20	1,700	210
Copper	2.9	2.9	3	18	12
Iron	NE	NE	NE	NE	1,000
Lead	140	5.6	25	83	3.2
Manganese	NE	NE	NE	NE	NE
Mercury	2.4	0.012	0.012	2.4	0.012
Selenium	20	5	5	20	5.0
Silver	1.2	NE	0.06	4.1	0.12
Vanadium	NE	NE	NE	NE	NE
Zinc	86	95	86	120	110

(1) Concentrations expressed in µg/L (ppb)
(2) NCWQS = North Carolina Water Quality Standard for Surface Water
(3) AWQC = Ambient Water Quality Criteria (Freshwater Criteria for Aquatic Species)
(4) NE = Not Established

activities, public health, or impair the waters for any designated use. The NCWQS for the surface water COCs for OU No. 1 are listed on Table 2-3.

USEPA Region IV Surface Water Screening Values - The USEPA Region IV Surface Water Screening Values for hazardous waste sites are intended to serve as preliminary screening tools for the review of chemical data associated with hazardous waste sites. These screening values are considered dynamic in that they will be updated by the USEPA as more information and other sources become available with the addition of media, parameters, screening levels, or changes in the screening levels. Exceedences of the screening levels indicates a need for more investigation, such as site-specific toxicity tests, literature reviews, etc. Table 2-3 presents the surface water criteria with respect to these Region IV screening values for the surface water COCs at OU No. 1.

USEPA Region IV Sediment Screening Values - In the absence of promulgated sediment quality criteria, USEPA Region IV uses the Sediment Screening Values (SSVs) compiled by the National Oceanic and Atmospheric Administration (NOAA) for evaluating the potential for chemical constituents in sediments to cause adverse biological effects (USEPA, 1992b). The low ten percentile [Effects Range - Low (ER-L)] and the median percentile [Effects Range - Median (ER-M)] of biological effects have been developed for several of the chemicals identified during the sediment investigations at OU No. 1. If sediment contaminant concentrations are between the ER-L and ER-M, adverse effects on the biota are considered possible, and USEPA recommends conducting toxicity tests or other evaluations as a follow up. If contaminant concentrations are below the ER-L, adverse effects on the biota are considered unlikely (USEPA, 1992b). The SSVs (ER-L and ER-M) for the sediment COCs for OU No. 1 are listed on Table 2-4.

Risk-Based Concentrations (RBCs) - the RBCs were developed by the USEPA, Region III as benchmark screening concentrations for evaluating site investigation data. RBCs are not intended as stand alone decision making tools, but can be used in conjunction with other information to help in the selection of COCs. RBCs as a screening tool is accomplished by the comparison of the maximum concentration of each chemical detected in each medium to it's corresponding RBC. Industrial and residential RBCs for soil have been developed. The RBCs were developed using protective default exposure scenarios suggested by the USEPA, and the latest available toxicity indices for carcinogenic and systemic chemicals. The RBCs utilized correspond to a Hazard Quotient of 0.1 and a lifetime cancer risk of 1E-6. The RBCs represent protective environmental concentrations at which the USEPA would not typically take action

TABLE 2-4

CONTAMINANT-SPECIFIC SEDIMENT CRITERIA
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Primary Sediment Contaminant of Concern	Region IV Sediment Screening Value(1)		Preliminary Sediment Contaminant of Concern	Region IV Sediment Screening Value(1)	
	ER-L(2)	ER-M(3)		ER-L(2)	ER-M(3)
Benzo(a)anthracene	230	1,600	Aluminum	NE(4)	NE
Benzo(b)fluoranthene	NE	NE	Arsenic	33	85
Benzo(k)fluoranthene	NE	NE	Barium	NE	NE
Benzo(a)pyrene	400	2,500	Beryllium	NE	NE
Benzo(g,h,i)perylene	NE	NE	Cadmium	5	9
Chrysene	400	2,800	Chromium	80	145
Fluoranthene	600	3,600	Copper	70	390
Indeno(1,2,3-cd)pyrene	NE	NE	Iron	NE	NE
Phenanthrene	225	1,380	Lead	35	110
Pyrene	350	2,200	Manganese	NE	NE
4,4'-DDD	2	20	Selenium	NE	NE
4,4'-DDE	2	15	Silver	1	2.2
4,4'-DDT	1	7	Vanadium	NE	NE
Chlordane (total)	0.5	6	Zinc	120	270

(1) Organic Concentrations expressed in µg/kg (ppb)
Inorganic concentrations expressed in mg/kg (ppm)
(2) ER-L - Effective Range-Low
(3) ER-M - Effective Range - Medium
(4) NE - Not Established

(USEPA, Region III, 1993). The RBCs were utilized as to be considered (TBC) chemical-specific values for the soil evaluation.

2.3.1.2 Location-Specific ARARs

Potential location-specific ARARs identified for OU No. 1 are listed on Table 2-5. An evaluation determining the applicability of these location-specific ARARs with respect to OU No. 1 is also presented and summarized on Table 2-5. Based on this evaluation, specific sections of the following location-specific ARARs may be applicable to OU No. 1:

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

Please note that the citations listed on Table 2-5 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.

2.3.1.3 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 and not evaluated for OU No. 1. A set of potential action-specific ARARs are listed on Table 2-6. These ARARs are based on RCRA, CWA, SDWA, and Department of Transportation (DOT) requirements. Note that the citations listed on Table 2-6 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 OU No. 1. Additional action-specific ARARs may also be identified and evaluated at that time.

TABLE 2-5

LOCATION-SPECIFIC ARARs EVALUATED
FOR OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
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. 1, therefore, this act will not be considered as an ARAR
Archeological and Historic Preservation Act - establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain.	16 USC 469, and 40 CFR 6.301(c)	No known historical or archeological data is known to be present at the sites, therefore, this act will not be considered as 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. 1, 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	Cogdels Creek and Beaver Dam Creek are located near and/or within the operable unit boundaries. If remedial actions are implemented that modify these creeks, 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 as an ARAR.

TABLE 2-5 (Continued)

LOCATION-SPECIFIC ARARs EVALUATED
FOR OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
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 as 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 as 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, Cogdels Creek has areas of wetlands. Therefore, this will be an applicable ARAR.
Executive Order 11988 on Floodplain Management - establishes special requirements for Federal agencies to evaluate the adverse impacts associated with direct and indirect development of a floodplain.	Executive Order Number 11988, and 40 CFR 6	Based on the Federal Emergency Management Agency's Flood Insurance Rate Map for Onslow County, OU No. 1 is primarily within a minimal flooding zone (outside the 500-year floodplain). The immediate areas around Cogdels Creek and Beaver Dam Creek are within the 100-year floodplain (FEMA, 1987). Therefore, this may be an ARAR for the operable unit.
Wilderness Act - requires that federally owned wilderness area are not impacted. Establishes nondegradation, maximum restoration, and protection of wilderness areas as primary management principles.	16 USC 1131, and 50 CFR 35.1	No known federally owned wilderness areas near the operable unit, therefore, this act will not be considered as an ARAR.

TABLE 2-5 (Continued)

LOCATION-SPECIFIC ARARs EVALUATED
FOR OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
National Wildlife Refuge System - restricts activities within a National Wildlife Refuge.	16 USC 668, and 50 CFR 27	No known National Wildlife Refuge areas near the operable unit, therefore, this will not be considered as 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 near the operable unit, therefore, this act will not be considered as 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 will affect land or water uses in a coastal zone, therefore, this act will not be considered as 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 as 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 includes the on-site storage, treatment, or disposal of RCRA hazardous waste. Therefore, these requirements may be an applicable ARAR for the operable unit.

TABLE 2-6

POTENTIAL ACTION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Standard (1)	Action	General Citation
RCRA	Capping	40 CFR 264
	Closure	40 CFR 264, 244
	Container Storage	40 CFR 264, 268
	New Landfill	40 CFR 264
	New Surface Impoundment	40 CFR 264
	Dike Stabilization	40 CFR 264
	Excavation, Groundwater Diversion	40 CFR 264, 268
	Incineration	40 CFR 264, 761
	Land Treatment	40 CFR 264
	Land Disposal	40 CFR 264, 268
	Slurry Wall	40 CFR 264, 268
	Tank Storage	40 CFR 264, 268
	Treatment	40 CFR 264, 265, 268; 42 USC 6924; 51 FR 40641; 52 FR 25760
	Waste Pile	40 CFR 264, 268
CWA	Discharge to Water of United States	40 CFR 122, 125, 136
	Direct Discharge to Ocean	40 CFR 125
	Discharge to POTW	40 CFR 403, 270
	Dredge/Fill	40 CFR 264; 33 CFR 320-330; 33 USC 403
SDWA	Underground Injection Control	40 CFR 144, 146, 147, 268
TSCA	PCB Regulations	40 CFR 761
DOT	DOT Rules for Transportation	49 CFR 107

(1) RCRA = Resource Conservation Recovery Act
CWA = Clean Water Act
SDWA = Safe Drinking Water Act
TSCA = Toxic Substance Control Act
DOT = Department of Transportation

2.3.2 Risk-Based Remediation Goal Options

In conjunction with the RGOs based on Federal and State ARARs (Section 2.3.1), risk-based RGOs were developed for the groundwater and soil COCs. The methodology used for the derived RGOs was in accordance with USEPA risk assessment guidance (USEPA, 1989a) (USEPA, 1991a). For noncarcinogenic effects, an action level was calculated that corresponds to a HI of 1.0, or unity, which is the level of exposure to a contaminant from all significant exposure pathways in a given medium below which it is unlikely for even sensitive populations to experience health effects. For carcinogenic effects, an action level was calculated that corresponds to 1.0E-04 (one in ten thousand) ICR over a lifetime as a result of exposure to the potential carcinogen from all significant exposure pathways for a given medium. A 1.0E-04 risk level was used as an end point for determining action levels 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 1.0E-04 and 1.0E-06. The action levels for OU No. 1 are representative of acceptable incremental risks based on current and probable future use of the area.

Three steps were involved in estimating the risk-based RGOs for OU No. 1 COCs. These steps are generally conducted for a medium and land-use combination and involved identifying: (1) the most significant exposure pathways and routes, (2) the most significant 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.

The development of the site-specific risk-based RGOs for OU No. 1 were determined from a risk evaluation assessment and from a soil/water partitioning approach as presented in the sections that follow. In addition, EPA Region III RBCs were considered as TBC values.

2.3.2.1 Derivation of Risk Equations

The determination of chemical-specific RGOs was performed in accordance with USEPA guidance (USEPA, 1989a). Reference doses (RfDs) were used to evaluate noncarcinogenic contaminants, while cancer slope factors (CSFs) were used to evaluate carcinogenic contaminants.

Potential exposure pathways and receptors used to determine RGOs are site-specific and consider the current and future land use of a site. The following exposure scenarios were used in the determination of RGOs for OU No. 1:

- Dermal contact with soil (current military personnel and future resident)
- Ingestion of groundwater (future resident)

The potential risk estimated in the human health risk assessment indicated that the majority of the site-specific risk is likely to occur from exposure to groundwater. Soil does not appear to pose an appreciable risk with respect to both dermal contact and incidental ingestion. For this FS, though, the most plausible soil exposure pathway (i.e., dermal contact) was used in the development of remediation levels. The RGOs for current (military personnel) receptors were calculated for dermal contact with soil, and future (adult and children) receptors for two exposure pathways (i.e., groundwater ingestion and dermal contact with soil), were calculated in order to provide site-specific remediation level concentrations from which remedial alternatives could be generated.

Consistent with USEPA guidance, noncarcinogenic health effects were estimated using the concept of an average annual exposure. The action level incorporated the exposure time and/or frequency that represented the number of days per year and number of years that 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 represented the exposure duration (years) over the course of a potentially exposed individual's lifetime (70 years).

The estimation methods and models used in this section were consistent with current USEPA risk assessment guidance (USEPA, 1989a) (USEPA, 1991a). Exposure estimates associated with each exposure route are presented below. For current military personnel the RGO was estimated using a 4 year 350 day/yr exposure duration. For the future residential land use action levels (i.e., dermal contact with soil), the carcinogenic RGO considered 6 years as a child (weighing 15 kg on average) and 24 years as an adult (weighing 70 kg on average), for a total exposure of 30 years (the 90th percentile at one residence). RGOs were developed, with site-specific inputs, for all soil and groundwater COCs presented in the human health risk assessment. However, in order to determine if a medium at a site requires remediation, estimated RGOs were compared to site-specific contaminant levels. This assessment was conducted to assure that media and contamination at each site would be addressed on a site-specific basis. The following sections present the equations and inputs used in the estimation of action levels developed for OU No. 1.

Dermal Contact with Soil

Physical contact with contaminated soils can result in the dermal absorption of chemicals. RGOs for this route are estimated as follows (USEPA, 1989a):

$$Cs = \frac{TR \text{ or } THI * BW * AT_c \text{ or } AT_{nc} * DY}{CSF \text{ or } 1/RfD * SA * AF * ABS * EF * ED * CF}$$

Where:
Cs = contaminant concentration in soil (mg/kg)
TR = total lifetime risk
THI = total hazard index
BW = body weight (kg)
ATc = averaging time carcinogens (yr)
ATnc = averaging time noncarcinogens (yr)
DY = days per year (day/year)
CSF = cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD = reference dose (mg/kg-day)
SA = surface area of skin available for contact (cm^2)
AF = soil to skin adherence factor (mg/cm^2)
ABS = absorption factor
EF = exposure frequency (day/year)
ED = exposure duration (yr)
CF = conversion factor $(10^{-6}$ kg/mg)

Military Personnel

During daily activities, there is a potential for base personnel to absorb COCs by dermal contact. It was assumed that military personnel have approximately 5,800 cm^2 (USEPA, 1992a) of skin surface area (SA) available for dermal exposure with COCs. Exposed body parts are the hands, head, forearms and lower legs are 25 percent of the total body surface area (23,000 cm^2). Thus, applying 25 percent to the upper-bound total body surface area results in a default of 5,800 cm^2 for military personnel.

Future On-Site Residents

Future on-site residents could also be potentially exposed to COCs in on-site soil through dermal contact experienced during activities near their home.

SAs used in the on-site resident exposure scenario were developed for a reasonable worst case scenario for an individual wearing a short sleeve shirt, shorts, and shoes. The exposed skin surface area was limited to the head, hands, forearms, and lower legs. Thus, applying 25 percent of the total body surface area results in a default of 5,800 cm^2 for adults and 2,300 cm^2 for children. The child SA was calculated using information presented in Dermal Exposure Assessment: Principles and Applications (USEPA, 1992d).

Data on soil adherence (AF) are limited. A value of 1.0 mg/cm^2 (USEPA, 1992d) was used in this assessment. A summary of the soil input parameters for dermal contact is presented in Table 2-7.

Ingestion of Groundwater

Currently there are no receptors who are exposed to groundwater contamination in this area since groundwater is obtained from "noncontaminated" supply wells, pumped to water treatment plants, and distributed via a potable water system. However, it is assumed for the purposes of calculating remediation goals, that potable wells would pump groundwater from the site area for public consumption. Groundwater ingestion RGOs are characterized using the following equation:

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

Where:

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

TABLE 2-7

SURFACE SOIL - DERMAL CONTACT
RGO PARAMETERS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Dermal Contact with Surface Soil Input Parameters			
Input Parameter	Description	Value	Rationale
C_s	Exposure Concentration	Calculated	USEPA, 1989a
TR	Total Lifetime Risk	1.0E-04	USEPA, 1991a
THI	Total Hazard Index	1.0	USEPA, 1991a
BW	Body Weight	Child 15 kg Adult 70 kg	USEPA, 1989a
ATc	Averaging Time Carcinogen	All 70 yr	USEPA, 1989a
ATnc	Averaging Time Noncarcinogen	Child 6 yr Adult 30 yr Military Personnel 4 yr	USEPA, 1989a
DY	Days Per Year	365 days/yr	USEPA, 1989a
CSF	Carcinogenic Slope Factor	Chemical Specific	IRIS, HEAST, USEPA
RfD	Reference Dose	Chemical Specific	IRIS, HEAST, USEPA
SA	Exposed Surface Area of Skin Available for Contact	Child 2,300 cm^2 Adult 3,800 cm^2 Military Personnel 5,800 cm^2	USEPA, 1992d
AF	Soil-to-Skin Adherence Factor	1.0 mg/cm^2	USEPA, 1992b
ABS	Absorption Factor (dimensionless)	Organics 1.0 Inorganics 0.1	USEPA, 1992b
EF	Exposure Frequency	Child 350 days/yr Adult 350 days/yr Military Personnel 350days/yr	USEPA, 1989a
ED	Exposure Duration	Child 6 yr Adult 24 yr Military Personnel 4 yr	USEPA, 1989a USEPA, 1991b

Future On-Site Residents

Exposure to COCs via ingestion of groundwater was retained as a potential future exposure pathway for both children and adults.

An ingestion rate (IR) of 1.0 liter/day was used for the amount of water consumed by a 1 to 6 year old child weighing 15 kg. This ingestion rate provides a health conservative exposure estimate (for systemic, noncarcinogenic toxicants) designed to protect young children who could potentially be more affected than adolescents, or adults. This value assumes that children obtain all the tap water they drink from the same source for 350 days/year [which represents the exposure frequency (EF)]. An averaging time (AT) of 2,190 days (6 years x 265 days/year) is used for noncarcinogenic compound exposure.

The IR for adults was 2 liters/day (USEPA, 1989a). The exposure duration (ED) used for the estimation of adult CDIs was 30 years (USEPA, 1989a), which represents the national upper-bound (90th percentile) time at one residence. The averaging time for noncarcinogens was 10,950 days. An AT of 25,550 days (70 years x 365 days/year) was used to evaluate exposure for both children and adults to potential carcinogenic compounds.

Table 2-8 presents a summary of the input parameters for the ingestion of groundwater scenarios.

2.3.2.2 Soil/Water Partitioning

COCs detected in the site soil samples could act as a potential source of contamination to underlying groundwater. To evaluate this potential contaminant migration pathway, a soil/water partitioning approach was used. The Organic Leaching Model (OLM) was used to determine the potential leachate concentrations of COCs leaching from the affected soils. This approach is described below.

The OLM Approach (USEPA, 1986) was used to estimate the potential concentration of contaminants in the groundwater due to leaching from soil. The OLM is an empirical equation which was developed through application of modeling techniques. The maximum detected organic soil concentrations were used in this estimation to determine a maximum concentration in groundwater. Contaminant specific solubilities were obtained from literature. Leachate concentrations were estimated using the following equation:

TABLE 2-8

INGESTION OF GROUNDWATER
RGO PARAMETERS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Ingestion of Groundwater Input Parameters			
Input Parameter	Description	Value	Rationale
C_w	Exposure Concentration	Calculated	USEPA, 1989a
TR	Total Lifetime Risk	1.0E-04	USEPA, 1991a
THI	Total Hazard Index	1.0	USEPA, 1991a
BW	Body Weight	Child 15 kg Adult 70 kg	USEPA, 1989a
ATc	Averaging Time Carcinogen	All 70 yr	USEPA, 1989a
ATnc	Averaging Time Noncarcinogen	Child 6 yr Adult 30 yr	USEPA, 1989a
DY	Days Per Year	365 days/yr	USEPA, 1989a
CSF	Carcinogenic Slope Factor	Chemical Specific	IRIS, HEAST, USEPA
RfD	Reference Dose	Chemical Specific	IRIS, HEAST, USEPA
EF	Exposure Frequency	Child 350 days/yr Adult 350 days/yr	USEPA, 1989a
ED	Exposure Duration	Child 6 yr Adult 30 yr	USEPA, 1991b
IR	Ingestion Rate	Child 1 L/day Adult 2 L/day	USEPA, 1989a

TABLE 2-9

CONTAMINANT MIGRATION FROM SOIL TO GROUNDWATER ACTION LEVEL PARAMETERS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Description	Value	Rationale
C_1	Constituent Concentration in Leachate (mg/L)	Calculated	OLM - Model
K	Constant	0.00211	Federal Register Vol. 51, No. 145
Cw	Constituent Concentration in Waste (mg/kg)	Contaminant Specific	Obtained from Maximum Concentration Detected in Site Soils
S	Constituent Solubility (mg/L)	Contaminant Specific	USEPA Aquatic Fate Process Data for Organic Priority Pollutants, 1982

$$C_1 = 0.00211 * (Cw)^{0.0678} * (S)^{0.373}$$

Where:

C_1 = contaminant concentration in (leachate) groundwater (mg/L)
C_w = contaminant concentration in (waste) soil (mg/kg)
S = contaminant solubility (mg/L)

These estimated concentrations will be compared to the Federal and State groundwater ARARs to determine if the contaminants in the soil could potentially produce a groundwater concern. Table 2-9 summarizes the input parameters used for this model.

The OLM Approach was also used to estimate soil action levels that are protective of groundwater. This approach is considered conservative because it does not account for the vertical dilution of a contaminant through the unsaturated zone. Using the State or Federal Groundwater ARARs as target concentrations, the following method was used to estimate the soil action levels:

$$Cs = \left[\frac{C_1}{0.00211 \text{ x } S^{0.373}} \right] 1.4749$$

Where:

Cs = contaminant concentration in soil (mg/kg)
C_1 = State or Federal groundwater criteria concentration (mg/L)
S = contaminant solubility (mg/L)

These estimated concentrations were compared to the maximum soil concentrations to determine if the soil could potentially produce a groundwater concern.

2.3.2.3 Summary of Site-Specific Risk-Based Remediation Goal Options

Site-specific risk-based RGOs were calculated from the risk evaluation assessment, from the OLM Approach, and USEPA Region III RBCs. (Note that the ARAR-based RGOs were discussed in Section 2.3.1.) These action levels represent the risk-based RGOs for the cleanup of a specific medium, and are used in the FS to identify areas of concern. COCs were chosen based on available toxicity data and frequency of detection and available ARARs. RGOs were generated for contaminants with available toxicity data. A summary of the risk-based RGOs calculated for the exposure scenarios is presented below. Separate RGOs for base personnel, adult residents, and children have been calculated. In addition, both carcinogenic and noncarcinogenic RGOs have been calculated. Calculations are provided in Appendix B of this report.

Dermal Contact with Soil

RGOs for exposure via dermal contact with surface soil were estimated for current and future populations (i.e., military personnel, adult residents, and child residents). COCs were selected based on frequency of detection in the surface soil and available toxicity data. RGOs for the carcinogenic and noncarcinogenic chemicals are presented in Tables 2-10 and 2-11, respectively. Note that since many of the calculated RGOs are large numbers, the values presented on the tables are 1/1000th of the concentration (i.e., 50,345 presented on the table is actually 50,345,000).

Ingestion of Groundwater

The groundwater ingestion RGOs were estimated for the groundwater within the entire operable unit. Currently, there are no known receptors who are exposed to contaminated groundwater. Base personnel receive potable water via a base water distribution. However, a hypothetical future ingestion RGO was estimated for the COCs. In order to estimate conservative RGOs for subpopulations (i.e., adult resident and child resident), specific input variables were developed for each subpopulation. Tables 2-12 and 2-13 present the RGOs calculated for the carcinogenic and noncarcinogenic COCs in the groundwater, respectively.

OLM Approach

The soil/water partitioning approach was used to estimate the concentration of contaminants in the aqueous phase due to leaching or partitioning from the solid phase. Model inputs, solubility, and partitioning coefficients limited the estimating to organic contaminants. The concentrations estimated from this model are discussed below.

Estimating exposure concentrations in groundwater using models such as the OLM Approach can be very complex because of the many physical and chemical processes that may affect transport and transformation in groundwater. Among the important mechanisms that should

TABLE 2-10

DERMAL CONTACT CARCINOGENIC RGOs (SOIL)
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Carcinogenic RGO		
	Military Personnel	Adult Resident	Child Resident
Benzo(a)anthracene	3,017	503	5,072
Chrysene	30,172	5,029	50,725
Benzo(b)fluoranthene	3,017	503	5,072
Benzo(k)fluoranthene	3,017	503	5,072
Benzo(a)pyrene	302	50	507
Indeno (1,2,3-cd) pyrene	3,017	503	5,072
4,4'-DDE	6,478	1,080	10,891
4,4'-DDD	9,177	1,530	15,429
4,4'-DDT	6,478	1,080	10,891
Total Chlordane	1,694	282	2,848
Total PCBs	286	48	481
Arsenic	12,956	2,159	21,782
Beryllium	5,122	854	8,611

Notes: RGO = Remedial Goal Options
Remediation Goal Options concentrations expressed as µg/kg.
Remediation Goal Options based on risk of 1.0E-04.
Remediation Goal Options are 1/1000th of the actual concentrations.

TABLE 2-11

DERMAL CONTACT NONCARCINOGENIC RGOs (SOIL)
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Noncarcinogenic RGO		
	Military Personnel	Adult Resident	Child Resident
Fluoranthene	50,345	50,345	126,957
Pyrene	37,759	37,759	95,217
4,4'-DDT	629	629	1,587
Total Chlordane	76	76	190
Total PCBs	88	88	222
Arsenic	3,776	3,776	9,522
Barium	881,034	881,034	2,221,739
Beryllium	62,931	62,931	158,696
Chromium	62,931	62,931	158,696
Manganese	62,931	62,931	158,696
Vanadium	88,103	88,103	222,174
Zinc	3,775,862	3,775,862	9,521,739

Notes: RGO = Remedial Goal Options
Remediation Goal Options concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a HI of 1.0.
Remediation Goal Options are 1/1000th of the actual concentration.

TABLE 2-12

INGESTION OF GROUNDWATER CARCINOGENIC RGOs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Carcinogenic RGO	
	Adult Resident	Child Resident
Benzene	294	629
Trichloroethene	774	1,659
Tetrachloroethene	164	351
Vinyl Chloride	4	10
Arsenic	5	11
Beryllium	2	4

Notes: RGO = Remedial Goal Options
Remediation Goal Options concentrations expressed in µg/L (ppb).
Remediation Goal Options based on a risk of 1.0E-04.

TABLE 2-13

INGESTION OF GROUNDWATER NONCARCINOGENIC RGOs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Noncarcinogenic RGO	
	Adult Resident	Child Resident
Total 1,2-Dichloroethene	730	313
Toluene	7,300	3,129
Ethylbenzene	3,650	1,564
Total Xylenes	73,000	31,286
Tetrachloroethene	365	156
Phenol	21,900	9,386
Arsenic	11	5
Barium	2,555	1,095
Beryllium	183	78
Chromium	183	78
Manganese	183	78
Nickel	730	313
Vanadium	256	110
Zinc	10,950	4,693

Notes: RGO = Remedial Goal Options
Remediation Goal Options concentrations expressed in µg/L (ppb).
Remediation Goal Options based on a HI of 1.0.

be considered when estimating exposure concentrations in groundwater are: leaching from the surface, advection, dispersion, sorption, and transformation.

The OLM, used to estimate a groundwater concentration, is a conservative model that estimates the amount of organic contaminants that will leach into the groundwater from a source (soil contamination). It does not account for physical or chemical processes that may impact the migration of contamination from soil to water.

In order to calculate a conservative concentration, maximum concentration of contaminants detected in the soil at OU No. 1 were used. The groundwater concentrations estimated using the OLM are presented in Table 2-14. For chemicals where Federal and State groundwater ARARs are not established, the estimated concentrations can be compared to toxicity values to assist in determining long-range remediation levels for surface soils.

The OLM Approach was also used to estimate soil action levels that are protective of groundwater. The soil action levels that were calculated are presented on Table 2-14. Soil contaminants, benzo(a)anthracene, benzo(b)fluoranthene, and total PCBs may potentially have an adverse impact on groundwater. Concentrations detected in soil for these compounds may not be protective of human health and the environment.

2.4 Comparison of Risk-Based Remediation Goal Options to Maximum Contaminant Concentrations in Soils

Generally, RGOs are not required for any contaminants in a medium with a cumulative cancer risk of less than 1.0E-04, where an HI is less than or equal to 1.0, or where the RGOs are clearly defined by ARARs. However, a medium or contaminant may meet the protectiveness criterion but contribute 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 the estimation of the reasonable maximum exposure (RME), which is the maximum exposure that is reasonably expected to occur at the site, the maximum concentration of a contaminant in a media can be compared to the estimated action

TABLE 2-14

ESTIMATED SOIL RGOs FOR THE PROTECTION OF GROUNDWATER AND ESTIMATED GROUNDWATER CONCENTRATIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Maximum Concentration in Soil	Soil Remediation Goal Option	Estimated Concentration in Groundwater	Federal MCL	NCWQS
Benzo(a)anthracene	**510**	191	**0.2**	0.1	--
Chrysene	450	1,000	0.1	0.2	--
Benzo(b)fluoranthene	**540**	324	**0.3**	0.2	--
Benzo(k)fluoranthene	320	620	0.1	0.2	--
Benzo(a)pyrene	310	664	0.1	0.2	--
Indeno(1,2,3-cd)pyrene	240	5,456	0.01	0.4	--
Fluoranthene	560	--	0.9	--	--
Pyrene	870	--	0.9	--	--
4,4'-DDD	3,400	--	9.0	--	--
4,4'-DDE	350	--	0.3	--	--
4,4'-DDT	4,100	--	0.8	--	--
Total Chlordane	4,000	4,500	1.8	2.0	0.027
Total PCBs	**4,600**	3,000	**0.7**	0.5	--

Notes: Bolded/Highlighted concentrations indicate potential exceedences.
Soil concentrations and RGOs expressed in µg/kg.
Groundwater concentrations, MCLs, and NCWQSs expressed in µg/L.

level. Assessment of hot spot contaminants is performed as a conservative approach in place of using the concentration term (i.e., the 95th percent upper confidence limit) which is used in estimating the RME. This value is usually compared to the estimated risk-based action level because in most situations, assuming long-term contact with the maximum contaminant concentration is not reasonable.

Conclusions of the human health RA for cumulative current and future baseline cancer risks for soil are within the USEPA's acceptable risk range of 1.0E-04 and 1.0E-06. Due to specific "hot spots" identified in the soils, a comparison between the risk-based action levels previously estimated to the maximum concentrations of soil COCs has been conducted. Risk-based action levels for contaminants which may not have been COCs in the baseline RA, due to prevalence, have been estimated for inhalation of particulates, incidental ingestion of soil, and dermal contact with soil.

The carcinogenic and noncarcinogenic risk-based RGOs for dermal contact with respect to a current military personnel scenario are compared to maximum soil contaminant concentrations in Tables 2-15 and 2-16, respectively. As shown on the tables, all of the maximum contaminant levels detected at Site 21 and Site 24 were below the RGOs estimated for dermal contact with soil for current military personnel. The carcinogenic and noncarcinogenic risk-based RGOs for dermal contact with respect to a future residents scenario (Site 24 only) are compared to maximum soil contaminant levels on Tables 2-17 and 2-18, respectively. As shown on these tables, all of the maximum contaminant levels detected in the soil at Site 24 were below the risk-based RGOs.

Identification of remedial alternatives should not solely be placed on the estimation of risk-based RGOs, especially in the event of the maximum hot spot contamination. Comparison of maximum contaminant concentration to risk-based RGOs was performed to provide a upper-bound conservative estimation, and aid in the screening and identification of remedial alternatives. They are not to be used in making final remedial decisions.

2.5 Uncertainty Associated with Risk-Based RGOs

The uncertainties associated with calculating risk-based RGOs are summarized below. The RGO estimations presented in this section are quantitative in nature, and their results are highly dependent upon the accuracy of the input. The accuracy with which input values can

TABLE 2-15

COMPARISON OF DERMAL CARCINOGENIC RISK-BASED RGOs TO MAXIMUM SOIL CONTAMINANT LEVELS
(CURRENT MILITARY PERSONNEL SCENARIO)
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	RGO	Maximum Soil Contaminant Concentration	
	Military Personnel	Site 21	Site 24
Benzo(a)anthracene	3,017,000	510	330
Chrysene	30,172,000	450	260
Benzo(b)fluoranthene	3,017,000	560	350
Benzo(k)fluoranthene	3,017,000	320	140
Benzo(a)pyrene	302,000	310	240
Indeno(1,2,3-cd)pyrene	3,017,000	180	240
4,4'-DDE	6,478,000	160	350
4,4'-DDD	9,177,000	34,000	130
4,4'-DDT	6,478,000	4,100	320
Total Chlordane	1,694,000	4,000	50
Total PCBs	286,000	4,600	215
Arsenic	12,956,000	3,900	35,200
Beryllium	5,122,000	220	4,000

Notes: RGO = Remedial Goal Options
Concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a risk of 1.0E-04.

TABLE 2-15

COMPARISON OF DERMAL CARCINOGENIC RISK-BASED RGOs TO MAXIMUM SOIL CONTAMINANT LEVELS (CURRENT MILITARY PERSONNEL SCENARIO) FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	RGO	Maximum Soil Contaminant Concentration		
	Military Personnel	Site 21	Site 24	Site 78
Benzo(a)anthracene	3,017,000	510	330	2,900
Chrysene	30,172,000	450	260	2,300
Benzo(b)fluoranthene	3,017,000	560	350	2,700
Benzo(k)fluoranthene	3,017,000	320	140	1.400
Benzo(a)pyrene	302,000	310	240	2,000
Indeno(1,2,3-cd)pyrene	3,017,000	180	240	400
4,4'-DDE	6,478,000	160	350	1,400
4,4'-DDD	9,177,000	34,000	130	2,900
4,4'-DDT	6,478,000	4,100	320	16,000
Total Chlordane	1,694,000	4,000	50	1,900
Total PCBs	286,000	4,600	215	100
Arsenic	12,956,000	3,900	35,200	6,200
Beryllium	5,122,000	220	4,000	260

Notes: RGO = Remedial Goal Options
Concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a risk of 1.0E-04.

TABLE 2-16

COMPARISON OF DERMAL NONCARCINOGENIC RISK-BASED RGOs TO MAXIMUM SOIL CONTAMINANT LEVELS (CURRENT MILITARY PERSONNEL SCENARIO) FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	RGO	Maximum Soil Contaminant Concentration		
	Military Personnel	Site 21	Site 24	Site 78
Fluoranthene	50,345,000	560	520	8,800
Pyrene	37,759,000	520	870	7,600
4,4'-DDT	629,000	4,100	320	16,000
Total Chlordane	76,000	4,000	50	1,900
Total PCBs	88,000	4,600	215	100
Arsenic	3,776,000	3,900	35,200	6,200
Barium	881,034,000	31,600	502,000	13,000
Beryllium	62,931,000	220	4,000	260
Chromium	62,931,000	19,900	23,000	18,500
Manganese	62,931,000	70,000	93,000	9,200
Vanadium	88,103,000	17,400	634,000	19,200
Zinc	3,775,862,000	67,700	94,000	7,900

Notes: RGO = Remedial Goal Options
Concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a HI of 1.0.

TABLE 2-17

COMPARISON OF DERMAL CARCINOGENIC RISK-BASED RGOs TO MAXIMUM SOIL CONTAMINANT LEVELS (FUTURE RESIDENTS SCENARIO) FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	RGO		Maximum Soil Contaminant Concentration
	Future Adult Resident	Future Child Resident	Site 24
Benzo(a)anthracene	503,000	50,700	330
Chrysene	5,029,000	507,000	260
Benzo(b)fluoranthene	503,000	50,700	350
Benzo(k)fluoranthene	503,000	50,700	140
Benzo(a)pyrene	50,000	5,070	240
Indeno(1,2,3-cd)pyrene	503,000	50,700	240
4,4'-DDE	1,080,000	109,000	350
4,4'-DDD	1,530,000	154,300	130
4,4'-DDT	1,080,000	109,000	320
Total Chlordane	282,000	28,500	50
Total PCBs	48,000	4,800	215
Arsenic	2,159,000	217,800	35,200
Beryllium	854,000	86,000	4,000

Notes: RGO = Remedial Goal Options
Concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a risk of 1.0E-04.

TABLE 2-18

COMPARISON OF DERMAL NONCARCINOGENIC RISK-BASED RGOs TO MAXIMUM SOIL CONTAMINANT LEVELS
(FUTURE RESIDENTS SCENARIO)
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	RGO		Maximum Contaminant Concentration
	Future Potential Adult Resident	Future Potential Child Resident	Site 24
Fluoranthene	50,345,000	1,270,000	520
Pyrene	37,759,000	952,000	870
4,4'-DDT	629,000	15,900	320
Total Chlordane	76,000	1,900	50
Total PCBs	88,000	2,200	215
Arsenic	3,776,000	95,200	35,200
Barium	881,034,000	22,000,000	502,000
Beryllium	62,931,000	1,600,000	4,000
Chromium	62,931,000	1,600,000	23,000
Manganese	62,931,000	1,600,000	93,000
Vanadium	88,103,000	2,200,000	634,000
Zinc	3,775,862,000	95,000,000	94,000

Notes: RGO = Remedial Goal Options
Concentrations expressed in µg/kg (ppb).
Remediation Goal Options based on a HI of 1.0.

be quantified is critical to the degree of confidence that the decision maker has in the action levels.

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

The toxicity factors, 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 the potential effects on humans. However, because human data exists for very few chemicals, risks are based on these values. In addition, the exposure assumption (e.g., 10 events per year, etc.) also have uncertainties associated with them.

Although RGOs are believed to be fully protective for the RME individual(s), the existence of the same contaminants in multiple media or of multiple chemicals affecting the same population(s), may lead to a situation where, even after attainment of all RGOs, protectiveness is not freely achieved (i.e., cumulative risk may fall outside the risk range).

2.6 Remediation Levels

This section presents the remediation levels (RLs) chosen for OU No. 1. RLs are chosen by the risk manager for the COCs and are included in the FS and the ROD. These numbers derived from the RGOs are no longer goals and should be considered required levels for the remedial actions to achieve.

The RLs associated with OU No. 1 are presented on Table 2-19. This list was based on a comparison of contaminant-specific ARARs (or ARAR-based RGOs) and the site-specific risk-based RGOs. If a COC had an ARAR, the most limiting (or conservative) ARAR was selected as the RL for that contaminant. If a COC did not have an ARAR, the most conservative risk-based RGO was selected for the RL.

TABLE 2-19

REMEDIATION LEVELS FOR POTENTIAL COCs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	RL(1)	Basis of Goal	Corresponding Risk
Groundwater	Benzene	1.0	NCWQS(2)	
	Ethylbenzene	29	NCWQS	
	Trichloroethene	2.8	NCWQS	
	Tetrachloroethene	0.7	NCWQS	
	Toluene	1,000	NCWQS/MCL	
	1,2-Dichloroethene (total)	70	NCWQS/MCL	
	Vinyl Chloride	0.015	NCWQS	
	Total Xylenes	400	NCWQS	
	Phenol	9,386	Risk-Ingestion	HI(3) =1
	Arsenic	50	NCWQS	
	Barium	1,000	NCWQS	
	Beryllium	4	MCL(4)	
	Chromium	50	NCWQS	
	Copper	1,000	NCWQS	
	Lead	15	NCWQS/MCL	
	Manganese	50	NCWQS/MCL	
	Mercury	1.1	NCWQS	
	Nickel	100	NCWQS/MCL	
	Vanadium	110	Risk-Ingestion	HI = 1
	Zinc	2,100	NCWQS	
Soil	Benzo(a)anthracene	3,900	USEPA Region III RBC	
	Chrysene	5,029,000	Risk - Dermal Contact	ICR(5) = 1.0E-04
	Benzo(b)fluoranthene	3,900	USEPA Region III RBC	
	Benzo(k)fluoranthene	503,000	Risk - Dermal Contact	ICR = 1.0E-04
	Benzo(a)pyrene	50,000	Risk - Dermal Contact	ICR = 1.0E-04
	Indeno (1,2,3-cd)pyrene	503,000	Risk - Dermal Contact	ICR = 1.0E-04
	Fluoranthene	50,345,000	Risk - Dermal Contact	ICR = 1.0E-04
	Pyrene	37,759,000	Risk - Dermal Contact	ICR = 1.0E-04

TABLE 2-19 (Continued)

REMEDIATION LEVELS FOR POTENTIAL COCs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	RL(1)	Basis of Goal	Corresponding Risk
Soil	4,4'-DDD	12,000	USEPA Region III RBC	
	4,4'-DDE	8,400	USEPA Region III RBC	
	4,4'-DDT	8,400	USEPA Region III RBC	
	Total Chlordane	2,200	USEPA Region III RBC	
	Total PCBs	370	USEPA Region III RBC	
	Arsenic	2,159,000	Risk - Dermal Contact	HI = 1
	Barium	881,034,000	Risk - Dermal Contact	HI = 1
	Beryllium	854,000	Risk - Dermal Contact	ICR = 1.0E-04
	Chromium	62,931,000	Risk - Dermal Contact	HI = 1
	Manganese	62,931,000	Risk - Dermal Contact	HI = 1
	Vanadium	88,103,000	Risk - Dermal Contact	HI = 1
	Zinc	3,775,862,000	Risk - Dermal Contact	HI = 1

Notes: (1) RL = Remediation Level
Groundwater RLs expressed as µg/L
Soil RLs expressed as µg/kg
(2) NCWQS = North Carolina Water Quality Standard
(3) HI = Hazard Index
(4) MCL = Maximum Contaminant Level
(5) ICR = Incremental Cancer Risk

In order to determine the final COCs for OU No. 1, the contaminant concentrations detected at each site were compared to the RLs presented on Table 2-19. The contaminants which exceeded at least one of the RLs have been retained as final COCs. The contaminants that did not exceed any of the RLs are no longer considered as COCs with respect to this FS. The final COCs and their associated RLs are presented on Table 2-20.

2.7 Areas of Concern Requiring Remediation

The results of the human health and ecological risk assessments and an evaluation of the COCs concentrations exceeding the RLs were used to determine the areas of concern (AOCs) at OU No. 1 requiring remediation. Groundwater and soil were determined as the media of concern. This determination is presented below.

2.7.1 Groundwater AOCs

Based on the human health risk evaluation presented in the RI Report, groundwater was the only media at the OU No. 1 which presented a carcinogenic risk greater than 1.0E-04 and/or a noncarcinogenic HI > 1.0. The carcinogenic risk from the other media was generally 1.0E-5 or less. The HIs for other media were significantly less than 1.0. In addition, based on a comparison of the detected concentrations of the COCs in the groundwater to the RLs, several RLs were exceeded (Table 4-20). The organic COCs were exceeded primarily in the monitoring wells located within Site 78. The inorganic COCs exceeding the RLs were detected in monitoring wells throughout the operable unit. Based on the prevalence of inorganic analytes, the AOC requiring remediation (with respect to contaminated groundwater) will focus on the organic contamination.

The shallow groundwater AOCs are presented on Figure 2-1. The main AOCs are:

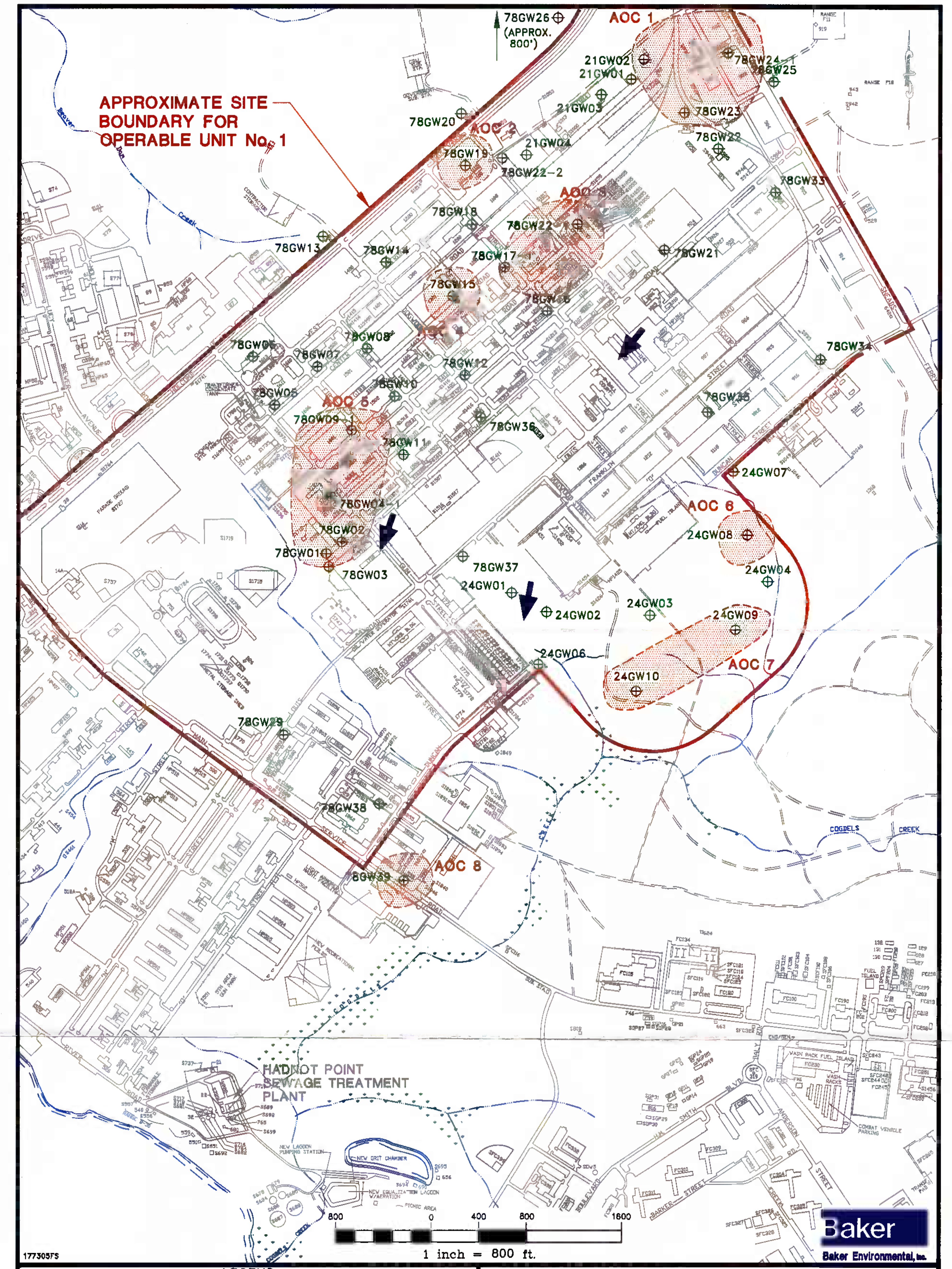
- AOC1 - (21GW02, 78GW23, and 78GW24-1) due to the presence of TCE, vinyl chloride, and BTEX
- AOC3 - (78GW22-1) due to BTEX
- AOC5 - (78GW01, 78GW04-1, and 78GW09-1) due to the presence of TCE and 1,2-DCE

TABLE 2-20

COCs THAT EXCEED THE REMEDIATION LEVELS AT OU NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	RL(1)
Groundwater(2)		
	Benzene	1.0
	Trichloroethene	2.8
	Tetrachloroethene	0.7
	Vinyl Chloride	0.015
	1,2-Dichloroethene (total)	70
	Toluene	1,000
	Ethylbenzene	29
	Xylenes (total)	400
	Arsenic	50
	Barium	1,000
	Beryllium	4
	Chromium	50
	Lead	15
	Manganese	50
	Mercury	1.1
	Nickel	100
	Vanadium	110
Soil(3)		
	PCBs (total)	370
	4,4'-DDD	12,000
	4,4'-DDT	8,400
	Chlordane (total)	2,200

(1) RL = Remediation Level
(2) Groundwater RLs expressed as µg/L (ppb)
(3) Soil RLs expressed as µg/kg (ppb)



LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL
➡	ESTIMATED DIRECTION OF GROUNDWATER FLOW
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION GOALS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 2-1
GROUNDWATER AREAS OF CONCERN WITHIN THE UPPER PORTION OF THE SURFICIAL AQUIFER (SHALLOW WELLS) AT OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

Five additional groundwater AOCs (AOC2, AOC4, AOC6, AOC7, AOC8) are shown on Figure 2-1. These AOCs have been identified due to the presence of PCE (78GW15, 78GW19 and 78GW39) and heptachlor epoxide (24GW08, 24GW09 and 24GW10).

The intermediate groundwater AOCs are shown on Figure 2-2. Three AOCs (AOC1, AOC4, and AOC5) within Site 78 were identified due to the presence of benzene in well 78GW04-2; TCE in well 78GW09-2; TCE in well 78GW31-2; and benzene, toluene, xylenes, 1,2-DCE, and vinyl chloride in well 78GW30-2.

Deep groundwater AOCs (AOC1, AOC3, AOC4 and AOC5), shown on Figure 2-3, were identified due to the presence of benzene in wells 78GW04-3, 78GW24-3, and 78GW31-3; and due to the presence of TCE and/or 1,2-DCE in wells 78GW04-3, 78GW24-3, 78GW31-3, and 78GW32-3.

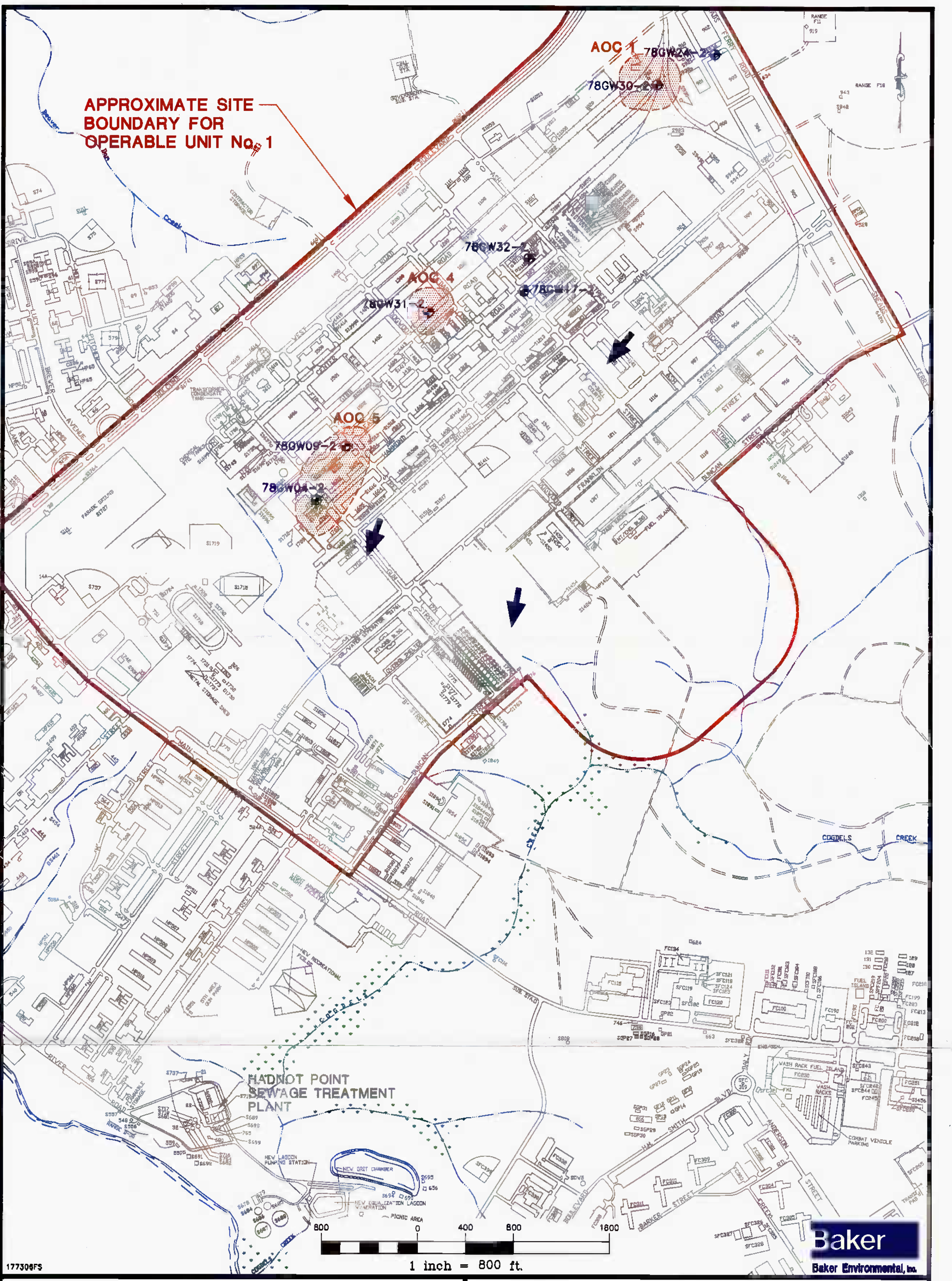
2.7.2 Soil AOCs

Four soil AOCs were identified at OU No. 1. The rationale for the identification of these areas was based on the RLs developed for soils in addition to evaluation of the ecological RA conclusions. Note that the results of the human health risk assessment did not indicate soil as a media of concern. The soil AOCs are shown on Figure 2-4. The justification for each of these AOCs is presented below:

- Soil AOC 1 is located in the northern portion of Site 21 near the Former Transformer Disposal Pit. This area was determined to be an AOC due to PCB concentrations in surface soil exceeding the RL of 370 µg/kg. This RL was based on the USEPA Region III RBC. AOC 1 is estimated to cover approximately 3,200 square feet.

- Soil AOC 2 is located within Site 21 north of the suspected Former Pesticide Mixing/Disposal Area. This area was identified as an AOC due to PCB concentrations in surface soil exceeding the RL of 370 µg/kg. AOC 2 is estimated to cover approximately 800 square feet.

- Soil AOC 3 is located within Site 21 near the suspected Former Pesticide Mixing/Disposal Area. This area was identified as an AOC due to high levels of pesticides detected in surface soils such as 4,4'-DDD (34,000 µg/kg), 4,4'-DDT (4,100

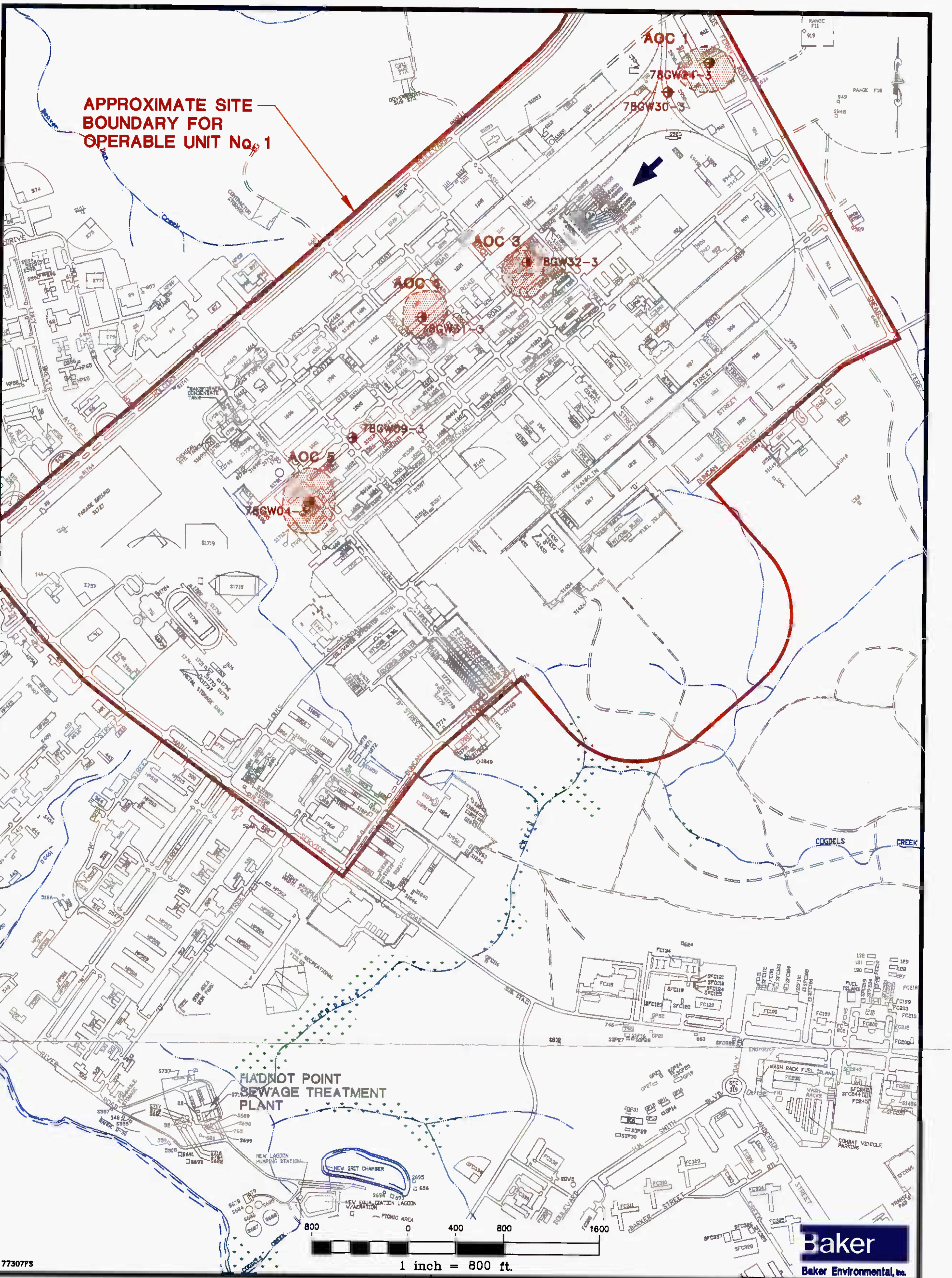


LEGEND

78GW04-2 ⊕	INTERMEDIATE MONITORING WELL
➔	ESTIMATED DIRECTION OF GROUNDWATER FLOW
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING THE REMEDIATION LEVELS FOR ORGANICS (INTERMEDIATE MONITORING WELLS)
AOC 4	AREA OF CONCERN

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 2-2
GROUNDWATER AREAS OF CONCERN WITHIN THE LOWER PORTION OF THE SURFICIAL AQUIFER (INTERMEDIATE WELLS) AT OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

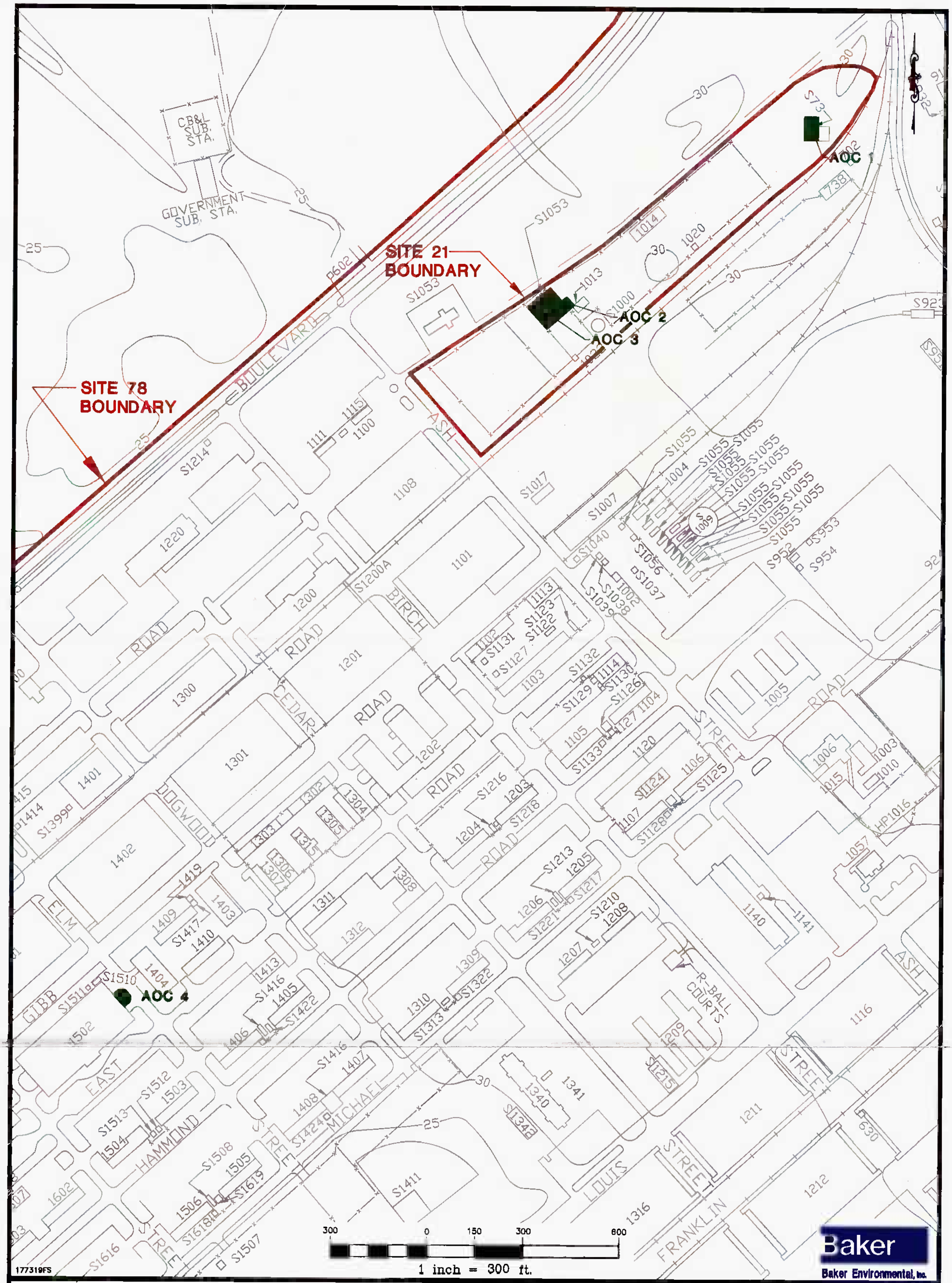


LEGEND

78GW04-3 ⊕	DEEP MONITORING WELL
→	ESTIMATED DIRECTION OF GROUNDWATER FLOW
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING THE REMEDIATION GOALS FOR ORGANICS (DEEP MONITORING WELLS)
AOC 1	AREA OF CONCERN

SOURCE: LANTDIV. FEBRUARY 1992

FIGURE 2-3
GROUNDWATER AREAS OF CONCERN WITHIN THE CASTLE HAYNE AQUIFER (DEEP WELLS) AT OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

LEGEND

AOC 1 ● APPROXIMATE LOCATION OF SOIL EXCEEDING REMEDIATION LEVELS.

SOURCE: LANTDIV, OCT. 1991

FIGURE 2-4
APPROXIMATE LOCATION OF SOIL AREAS OF CONCERN
OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

µg/kg), and gamma-chlordane (2,200 µg/kg). These levels meet or exceed the RLs which were based on the USEPA Region III RBCs. In addition, the results of the ecological RA indicated that pesticides appear to be the most significant site-related contaminants that have the potential for decreasing the viability of aquatic organisms at OU No.1. AOC 3 is estimated to cover approximately 8,100 square feet.

- Soil AOC 4 is located within Site 78 near the northeastern edge of Building 1502. This area was identified as an AOC for the same reasons as mentioned for AOC 3. The pesticides, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were detected in the surface soil in this area at concentrations of 1,300 µg/kg, 2,900 µg/kg, and 16,000 µg/kg, respectively. AOC5 is estimated to cover approximately 2,000 square feet.

2.8 Remedial Action Objectives

Remedial action objectives developed for OU No. 1 (groundwater and soil) at MCB Camp Lejeune are summarized on Table 2-21. As identified on Table 2-21, the primary objectives are to prevent ingestion of contaminated groundwater and to prevent contact with contaminated soils.

TABLE 2-21

REMEDIAL ACTION OBJECTIVES APPLICABLE TO OU NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	Area of Concern	Remedial Action Objective
Groundwater	Surficial aquifer and Castle Hayne aquifer (1)	• Prevent ingestion of water with groundwater COCs exceeding the remediation levels. • Prevent the horizontal and vertical migration of contaminated groundwater in the aquifers. • Restore the groundwater aquifer to meet the remediation levels set for the groundwater COCs.
Soil	AOC1(2) and AOC2	• Remediate the soil to meet the remediation level set for PCBs in soil.
	AOC3 and AOC4	• Mitigate the potential ecological risks due to elevated pesticide-contaminated surface soil. • Remediate the soil to meet the remediation level set for pesticides in soil.

(1) There is no confining layer between the Surficial and Castle Hayne aquifers at this operable unit. Therefore, both aquifers act as one water-bearing zone.

(2) AOC = Area of Concern.

3.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL TECHNOLOGIES

This section includes the identification and preliminary screening of a set of remedial action technologies that may be applicable for the remediation of the groundwater and soils at OU No. 1. Section 3.1 identifies a set of general response actions that may be applicable to the site. Section 3.2 includes the identification of a set of remedial technologies applicable to groundwater remediation and a set applicable to soil remediation. Section 3.3 presents the preliminary screening of the set of identified remedial technologies and process options. Section 3.4 presents a summary of the preliminary screening, and Section 3.5 presents the process option evaluation. A brief description of each of the technologies/process options that passed both of the preliminary screenings is presented in Section 3.6.

3.1 General Response Actions

General response actions are broad-based medium-specific categories of actions that can be identified to satisfy the remedial action objectives of an FS. The general response actions that will satisfy the remedial action objectives identified for OU No. 1 are listed on Table 3-1. As shown on Table 3-1, four general response actions have been identified for the groundwater objectives: no action, institutional controls, containment actions, and collection/treatment actions. Four response actions have also been identified for the soil objectives: no action, institutional controls, containment actions, and excavation/treatment actions. A brief description of each of the above-mentioned general response actions follows.

3.1.1 No Action

The NCP requires the evaluation of the no action response action as part of the FS process. A no action response provides the baseline assessment for the comparison with other remedial alternatives that have a greater level of response. A no action alternative may be considered appropriate when an alternative response action may cause a greater environmental or health danger than the no action alternative itself.

TABLE 3-1

GENERAL RESPONSE ACTIONS FOR OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	Area of Concern	Remedial Action Objective	General Response Action
Groundwater	Surficial and Castle Hayne aquifers(1)	• Prevent ingestion of water with groundwater COCs exceeding the remediation levels. • Prevent the horizontal and vertical migration of contaminated groundwater in the Surficial and Castle Hayne aquifers. • Restore the groundwater aquifer to meet the remediation levels set for the groundwater COCs.	• No Action • Institutional Controls • Containment Actions • Collection/Treatment Actions
Soil	AOC1(2) AOC2 AOC3 AOC4	• Remediate the PCB-contaminated soil to meet the PCB remediation level for soil. • Mitigate the potential ecological risks due to elevated pesticide contaminated surface soil. • Remediate the pesticide-contaminated soil to meet the pesticide remediation levels for soil.	• No Action • Institutional Controls • Containment Actions • Excavation /Treatment Actions

(1) There is no confining layer between the Surficial and Castle Hayne aquifers at this operable unit. Therefore, both aquifers act as one water bearing zone.

(2) AOC = Area of Concern.

3.1.2 Institutional Controls

Institutional controls are various "institutional" actions that can be implemented at a site as part of a complete remedial alternative to minimize exposure to potential hazards at the site. With respect to groundwater, institutional controls may include monitoring programs, ordinances, and access restrictions. With respect to soil, institutional controls may include monitoring and access restrictions.

3.1.3 Containment Actions

Containment actions include various technologies which contain and/or isolate the contaminants of concern at a site. The actions provide isolation and prevent direct exposure with or migration of the contaminated media without disturbing or removing the waste from the site. Containment actions generally consists of measures which cover, seal, chemically stabilize, or provide an effective barrier against specific areas of contamination. These actions can be applicable to both medias of concern at OU No. 1.

3.1.4 Collection/Treatment Actions

Collection/treatment actions are typically associated with groundwater or surface water. For this FS, only groundwater collection/treatment actions will be addressed. Collection of contaminated groundwater may be achieved via withdrawal techniques such as pumping or interceptor trenches. There are many methods for treating contaminated groundwater including chemical, biological, thermal, or physical removal systems, or in situ treatment systems.

General collection/treatment actions may include: (1) collecting the contaminated groundwater, treating it on site, and then discharging it; (2) collecting the groundwater and discharging it; (3) collecting the groundwater and then treating it off site; and (4) treating the groundwater in situ.

3.1.5 Excavation/Treatment Actions

Excavation/treatment actions are typically associated with soil, sediment, or solid wastes. For this FS, only soil excavation/treatment actions will be addressed. General excavation/treatment actions may include one of the following options: (1) excavating contaminated soil, treating it on site, and then disposing of treated residuals; (2) excavating the soil and then treating (or disposing) it off site; and (3) treating the soil in situ.

3.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable technology types and process options will be identified for each of the general response actions identified for both medias of concern at OU No. 1. The term "technology type" refers to general categories of technologies such as physical/chemical treatment, thermal treatment, biological treatment, and in situ treatment. The term "technology process option" refers to specific processes within each technology type, for example air stripping, steam stripping, carbon adsorption, and reverse osmosis are process options of physical/chemical treatment. Several technology types may be identified for each general response action, and numerous technology process options may exist within each technology type.

Remedial action technologies potentially applicable to OU No. 1 are listed on Table 3-2 with respect to their corresponding general response action. Also identified on the table are applicable process options associated with each of the listed technologies.

3.3 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 reduced (or screened) by evaluating the technologies with respect to technical implementability and site-specific factors. This screening step is site-specific and 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, 1988a). In general, all technologies/options which appear to be applicable to the site contaminants and to the site conditions will be retained for further evaluation. The preliminary screening is presented on Tables 3-3 and 3-4 with respect to groundwater and soil, respectively. Each of the process options remaining, following the preliminary screening, will be evaluated in Section 3.4.

As shown on Tables 3-3 and 3-4, several technologies and/or process options were eliminated from further evaluation since they were determined to be inappropriate for the site-specific

TABLE 3-2

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS IDENTIFIED FOR OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	No Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
			Fencing
	Containment Actions	Capping	Clay/Soil Cap
			Asphalt /Concrete Cap
			Soil Cover
			Multilayered Cap
		Vertical Barriers	Grout Curtain
			Slurry Wall
			Sheet Piling
			Rock Grouting
		Horizontal Barriers	Grout Injection
			Block Displacement
		Extraction	Extraction Wells
		Subsurface Drains	Interceptor Trenches
		Discharge	Reinjection ● Injection Wells ● Infiltration Galleries
	Collection/Treatment Actions	Extraction	Extraction Wells
		Subsurface Drains	Interceptor Trenches
		Biological Treatment	Aerobic ● Aerated Lagoon ● Activated Sludge ● Powered Activated Carbon Treatment ● Trickling Filter ● Rotating Biological Contactor
			Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			Reverse Osmosis
			Ion Exchange
			Chemical Reduction
			Chemical Oxidation
			Neutralization
			Precipitation
			Oil/Water Separator
			Filtration
			Flocculation
			Sedimentation
			Chemical Dechlorination

TABLE 3-2 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS IDENTIFIED FOR OPERABLE UNIT NO. 1 FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater (Cont)	Collection/Treatment Actions (Cont)	Thermal Treatment	Incineration • Liquid Injection • Rotary Kiln • Fluidized Bed • Multiple Hearth
			Molten Salt
			Plasma Arc Torch
			Pyrolysis
			Wet Air Oxidation
		Off-Site Treatment	POTW
			RCRA Facility
			Sewage Treatment Plant
		In Situ Treatment	Biodegradation
			Air Sparging
		On-Site Discharge	Surface Water
			Reinjection • Injection Wells • Infiltration Galleries
		Off-Site Discharge	POTW
			Pipeline to River
			Sewage Treatment Plant
			Deep Well Injection
Soil	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Monitoring
		Access Restriction	Deed Restrictions
			Fencing
	Containment Actions	Capping	Clay/Soil Cap
			Asphalt/Concrete Cap
			Soil Cover
			Multilayered Cap
		Surface Controls	Grading
			Revegetation
	Excavation/Treatment Actions	Excavation	Soils Excavation
		Biological Treatment	Land Treatment
			Composting (Bio Piling)
		Physical/ Chemical Treatment	Solidification/Stabilization • Cement-Based Processes • Polymer-Based Processes • Silicate-Based Processes • Thermoplastic Techniques • Surface Microencapsulation • Vitrification
			Soil Washing (Solvent Washing/ Extraction)
			Chemical Dechlorination (KPEG)

TABLE 3-2 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS IDENTIFIED FOR OPERABLE UNIT NO. 1 FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Soil (Cont)	Excavation/Treatment Actions (Cont)	Thermal Treatment	Incineration ● Rotary Kiln ● Fluidized Bed
			Low Temperature Thermal Stripper
			Molten Salt
			Plasma Arc Torch
			Infrared Incineration
			Pyrolysis
			Wet Air Oxidation
		In Situ Treatment	Biodegradation
			Volatilization (Vapor Extraction)
			Soil Flushing
			Chemical Immobilization ● Polymerization ● Precipitation
			Chemical Detoxification ● Oxidation ● Reduction ● Neutralization ● Hydrolysis
			Vitrification
			Heating
			Artificial Ground Freezing
		Off-Site Treatment/Disposal	RCRA Facility
			Landfill ● Hazardous ● Nonhazardous

TABLE 3-3

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No action - contaminated groundwater remains as is.	Potentially applicable to any site; required by the NCP.	Retained
Institutional Controls	Monitoring	Groundwater Monitoring	Ongoing monitoring of existing wells.	Potentially applicable.	Retained
	Ordinances	Aquifer-Use Restrictions	Prohibit the use of the contaminated aquifer as a drinking water source.	Potentially applicable.	Retained
	Access Restrictions	Deed Restrictions	Limit the future use of land including placement of wells.	Potentially applicable.	Retained
		Fencing	Limit access by installing a fence around contaminated area.	Potentially applicable; some fencing already exists.	Retained
Containment Actions	Capping	Clay/Soil Cap Asphalt/Concrete Cap Soil Cover Multilayered Cap	Capping material placed over areas of contamination.	Does not appear to be applicable for contaminated groundwater based on the current use and physical development at Site 78.	Eliminated
	Vertical Barriers	Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes to contain contamination.	The heterogeneity of the fill material at the Operable Unit may prevent a "gap-free" curtain. No continuous confining layer under the sites for the wall to adjoin to.	Eliminated
		Slurry Wall	Trench around areas of contamination. The trench is filled with a soil bentonite slurry to limit migration of contaminants.	The heterogeneity of the fill material at the Operable Unit may prevent a "gap-free" curtain. No continuous confining layer under the sites for the wall to adjoin to.	Eliminated
		Sheet Piling	Interlocking sheet pilings installed via drop hammer around areas of contamination.	No continuous confining layer under the sites for the wall to adjoin to.	Eliminated
		Rock Grouting	Specialty operation for sealing fractures, fissures, solution cavities, or other voids in rock to control flow of groundwater.	No bedrock underlies the sites.	Eliminated
	Horizontal Barriers	Grout Injection	Pressure injection of grout to form a bottom seal across a site at a specific depth.	Technique is in the experimental stage. Does not appear to be applicable for OU No. 1 due to the physical development at Site 78.	Eliminated
		Block Displacement	Continued pumping of grout into specially notched holes causing displacement of a block of contaminated earth.	Does not appear to be applicable for OU No. 1 due to the physical development at Site 78. Technique is in the experimental stage.	Eliminated

TABLE 3-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Containment Actions (cont)	Extraction	Extraction Wells	Series of wells used to extract contaminated 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.	Installation of subsurface drain system would be extremely difficult at OU No. 1 due to the excavation required as well a the numerous physical barriers on site.	Eliminated
	Discharge	Reinjection: • Injection Wells • Infiltration Galleries	The extracted groundwater can be reinjected back into the aquifer (following some type of treatment) to enhance the collection of contaminated groundwater via extraction wells.	Based on the physical characteristics of the shallow aquifer at OU No. 1 (low permeability), as a containment option deep aquifer injection wells or infiltration galleries may not be effective as a containment option.	Eliminated
Collection/Treatment Actions	Extraction	Extraction Wells	Series of wells used to extract contaminated groundwater.	Potentially applicable	Retained
		Extraction/Injection Wells	Injection wells inject uncontaminated groundwater to enhance collection of contaminated groundwater via the extraction wells. Injection wells can also inject material into an aquifer to remediate groundwater.	Based on the physical characteristics of the shallow aquifer at OU No. 1 (low permeability) deep aquifer injection wells may not be effective.	Eliminated
	Subsurface Drains	Interceptor Trenches	Perforated pipe installed in trenches backfilled with porous media to collect contaminated groundwater. Generally limited to shallow depths.	Installation of subsurface drain system would be extremely difficult at OU No. 1 due to the excavation required as well as the numerous physical barriers on site.	Eliminated
	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powered Activated Carbon Treatment • Trickling Filter • Rotating Biological Contractor	Degradation of organics using microorganisms in an aerobic environment.	Potentially applicable to organic contaminants of concern.	Retained
		Anaerobic	Degradation of organics using microorganisms in an anaerobic environment	Potentially applicable to some of the groundwater contaminants of concern (multichlorinated compounds with three or more chlorines). Possible use as pretreatment for aerobic treatment.	Retained

TABLE 3-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Collection/Treatment Actions (cont)	Physical/Chemical Treatment	Air Stripping	Mixing large volumes of air with water in a packed column to promote transfer of VOCs to air. Applicable to VOCs and some SVOCs.	Potentially applicable	Retained
		Steam Stripping	Mixing large volumes of steam with water in a packed column to promote transfer of VOCs to air. Applicable to a wide range of organics.	Potentially applicable	Retained
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column. Applicable to wide range of organics.	Potentially applicable	Retained
		Reverse Osmosis	Using high pressure to force water through a membrane leaving contaminants behind. Applicable to dissolved solids (organic and inorganic).	Not applicable for most of the constituents of concern.	Eliminated
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Applicable for inorganics, not organics.	Potentially applicable	Retained
		Chemical Reduction	Addition of a reducing agent to lower the oxidation state of a substance to reduce toxicity/solubility. Applicable to chromium, mercury and lead.	Potentially applicable	Retained
		Chemical Oxidation	Addition of an oxidizing agent to raise the oxidation state of a substance. Applicable to cyanide, organics, and some inorganics.	Potentially applicable	Retained
		Neutralization	Addition of an acid or base to a waste in order to adjust its pH. Applicable to acidic or basic waste streams.	Although pH is not a concern at the operable unit, neutralization may be applicable in a treatment train with precipitation.	Retained
		Precipitation	Materials in solution are transferred into a solid phase for removal. Applicable to particulates and metals.	Potentially applicable for inorganics.	Retained
		Oil/Water Separation	Materials in solution are transferred into a separate phase for removal. Applicable to petroleum hydrocarbons.	Potentially applicable if free phase product (Site 22) is detected and extracted.	Retained

TABLE 3-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Collection/Treatment Actions (cont)	Physical/Chemical Treatment (cont)	Filtration	Removal of suspended solids from solution by forcing the liquid through a porous medium. Applicable to suspended solids.	Potentially applicable	Retained
		Flocculation	Small, unsettleable particles suspended in a liquid medium are made to agglomerate into larger particles by the addition of flocculating agents. Applicable to particulates and inorganics.	Potentially applicable	Retained
		Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation. Applicable to suspended solids.	Potentially applicable	Retained
		Chemical Dechlorination (KPEG)	Process which uses specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them to form other less harmful compounds. Applicable to PCBs, chlorinated hydrocarbons and dioxins.	Not applicable to the groundwater contaminants of concern.	Eliminated
	Thermal Treatment	Incineration ● Liquid Injection ● Rotary Kiln ● Fluidized Bed ● Multiple Hearth	Combustion of waste at high temperatures. Different incinerator types can be applicable to pumpable organic wastes, combustible liquids, soils, slurries, or sludges.	Potentially applicable	Retained
		Molten Salt	Advanced incineration; waste contacts hot molten salt to undergo catalytic destruction. Applicable for hazardous liquids, low ash, high chlorine wastes.	Potentially applicable	Retained
		Plasma Arc Torch	Advanced incineration; pyrolyzing wastes into combustible gases in contact with a gas which has been energized to its plasma state by an electrical discharge. Applicable for liquid organic waste.	Lack of operational experience	Eliminated

TABLE 3-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Collection/Treatment Actions (cont)	Thermal Treatment	Pyrolysis	Advanced incineration; thermal conversion of organic material into solid, liquid, and gaseous components; takes place in an oxygen-deficient atmosphere. Applicable for organics and inorganics.	Typically used for compounds not conductive to conventional incineration; Operable Unit No. 1 compounds are suitable to other incineration methods.	Eliminated
		Wet Air Oxidation	Advanced incineration; aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures. Applicable for organics with high COD, high strength wastes, and for oxidizable inorganics.	Not recommended for aromatic halogenated organics and several inorganics.	Eliminated
	Off-site Treatment	POTW	Extracted groundwater discharged to Jacksonville POTW for treatment.	Potentially applicable	Retained
		RCRA Facility	Extracted groundwater transported to licensed RCRA facility for treatment and/or disposal.	Potentially applicable	Retained
		Sewage Treatment Plant	Extracted groundwater discharged to Hadnot Point STP for treatment.	Potentially applicable	Retained
	In Situ Treatment	Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Applicable to a wide range of organic compounds.	Potentially applicable to shallow aquifer. Soil contamination at OU No. 1 is not directly related to the contaminated groundwater, therefore, soil in the unsaturated zone would not require treatment.	Eliminated
		Air Sparging	"In Situ Air Stripping". Used in combination with treatment of soils in the unsaturated zone. Applicable to organics.	Potentially applicable as a shallow aquifer technology.	Retained
	On-Site Discharge	Surface Water	Treated water discharged to stream on the site (i.e., Cogdels Creek).	Limited flow capacity of Cogdels Creek.	Eliminated
		Reinjection • Injection Wells • Infiltration Galleries	Treated water reinjection into the site aquifer via use of shallow infiltration galleries (trenches) or via deep injection wells.	Deep injection wells potentially applicable for discharge. Site geology and low water table may prohibit the use of infiltration galleries.	Retained
	Off-Site Discharge	POTW	Treated water discharged to Jacksonville POTW.	Potentially applicable	Retained

TABLE 3-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Collection/Treatment Actions (cont)	Off-Site Discharge (continued)	Pipeline to River	Treated water discharged to river off site (i.e., New River).	Potentially applicable	Retained
		Sewage Treatment Plant	Treated water discharged to Hadnot Point STP	Potentially applicable	Retained
		Deep Well Injection	Treated water is reinjected into the brine aquifer located under the Castle Hayne aquifer.	Potentially applicable	Retained

TABLE 3-4

PRELIMINARY SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No Action - contaminated soil remains untreated.	Potentially applicable to any site; required by NCP.	Retained
Institutional Controls	Monitoring	Monitoring	Periodic sampling and analyses.	Potentially applicable	Retained
	Access Restrictions	Deed Restrictions	Limit future land use in areas with soil contamination.	Potentially applicable	Retained
		Fencing	Limit access by installing fencing around contaminated areas.	Potentially applicable; some fencing already exists	Retained
Containment Actions	Capping	Clay/Soil Cap	Compacted impermeable clay layer covered with soil installed over contaminated area.	Potentially applicable	Retained
		Asphalt/Concrete Cap	Spray a layer of asphalt over contaminated areas or seal the area with concrete.	Potentially applicable	Retained
		Soil Cover	Soil layer placed on existing ground surface to seal off contamination from aboveground surface.	Potentially applicable	Retained
		Multilayered Cap	Clay and synthetic membrane placed over contaminated area. Areas then covered with soil and revegetated.	Potentially applicable	Retained
	Surface Controls	Grading	Modifying the natural topography and run-off characteristics on and around contaminated areas to control infiltration and erosion due to surface water.	Potentially applicable - could be used in conjunction with a capping option. Alone, does not address soil contamination.	Retained
		Revegetation	Establish a vegetative cover over contaminated areas to stabilize the ground surface	Potentially applicable - in conjunction with other process options. Alone, does not address soil contamination.	Retained
Excavation/Treatment Actions	Excavation	Soils Excavation	Mechanically remove contaminated soils from ground.	Potentially applicable - useful in conjunction with other process options.	Retained

TABLE 3-4 (Continued)

PRELIMINARY SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Excavation/Treatment Actions (Cont.)	Biological Treatment	Land Treatment	Spread contaminated soil over land and rely on natural microbial action to degrade waste.	Not applicable - not proven for PCB contaminated soils - extensive treatability studies required. Applicable primarily for organic compounds.	Eliminated
		Composting (Bio Piling)	Aboveground soil management technique where contaminated soils containing organic wastes are mixed with bulking agents, placed in large piles and aerated.	Not applicable - not proven for PCB contaminated soils. Applicable primarily for organic compounds.	Eliminated
	Physical/Chemical Treatment	Solidification/Stabilization • Cement-Based Processes • Polymer-Based Processes • Silicate-Based Processes • Thermoplastic Techniques • Surface Microencapsulation • Vitrification • Lime-Based Process	Methods by which additives are incorporated into the contaminated soils to encapsulate the compounds of concern.	Potentially applicable primarily for inorganic compounds. Technology is in developmental stage for most organic compounds.	Retained
		Soil Washing (Solvent Washing/Extraction)	The extraction of contaminants from excavated soil by mixing the soil with water, solvents, surfactants, or chelating agents.	Not applicable for PCB contaminated soils.	Eliminated
		Chemical Dechlorination (KPEG)	Process which uses specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them to form other less harmful compounds. Applicable to PCBs, chlorinated hydrocarbons and dioxins.	Potentially applicable for PCB contaminated soils.	Retained
	Thermal Treatment	Incineration • Rotary Kiln • Fluidized Bed	Combustion of waste at high temperatures. Suitable for soils, sludges and slurries.	Potentially applicable	Retained
		Low Temperature Thermal Stripper	Combustion of volatile compounds without heating the soil matrix to combustion temperatures.	Not applicable - potential formation of dioxins at low temperatures for PCB contaminated soils.	Eliminated
		Molten Salt	Advanced incineration; waste contacts hot molten salt to undergo catalytic destruction.	Potentially applicable	Retained

TABLE 3-4 (Continued)

PRELIMINARY SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Excavation/Treatment Actions (Cont.)	Thermal Treatment (Cont.)	Plasma Arc Torch	Advanced incineration; destroys wastes by pyrolyzing them into combustible gases in contact with a gas which has been energized.	Not applicable for soils - only for pumpable organic wastes and finely divided, fluidized sludges.	Eliminated
		Infrared Incineration	Advanced incineration; destroys wastes by using silicon carbide elements to generate thermal radiation.	Potentially applicable	Retained
		Pyrolysis	Advanced incineration; thermal conversion of organic material into solid, liquid, and gaseous components; takes place in oxygen-deficient atmosphere.	Potentially applicable	Retained
		Wet Air Oxidation	Advanced incineration; aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures.	Not applicable for soils - typically for wastewater sludges.	Eliminated
	In Situ Treatment	Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Applicable to a wide range of organic compounds.	Not applicable - not proven for PCB contaminated soils - extensive treatability studies required. Applicable primarily for organic compounds.	Eliminated
		Volatilization (Vapor Extraction)	Volatile compounds are removed from subsurface soils by mechanically drawing or venting air through the soil matrix.	Not applicable to PCB or pesticide contaminated soils.	Eliminated
		Soil Flushing	"In Situ" soil washing. An aqueous solution is injected into or sprayed onto the affected area and is collected downgradient, then treated.	Not applicable to PCB or pesticide contaminated soils.	Eliminated
		Chemical Immobilization • Polymerization • Precipitation	Techniques which render contaminants insoluble and thereby prevent migration.	Not applicable to PCB contaminated soils.	Eliminated
		In Situ Chemical Detoxification • Oxidation • Reduction • Neutralization • Hydrolysis	Techniques which destroy, degrade, or reduce the toxicity of contaminants by the use of various treatment agents.	Not applicable to PCB contaminated soils.	Eliminated

TABLE 3-4 (Continued)

PRELIMINARY SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Excavation/Treatment Actions (Cont.)	In Situ Treatment (Cont.)	Vitrification	Emerging technology; contaminated soil is converted into a durable glass and crystalline form by melting the soil by electrical heat.	Potentially applicable	Retained
		Heating	Emerging technology; destroys or removes organic contaminants in soil through thermal decomposition, vaporization, and distillation.	May not be applicable to PCB contaminated soils.	Eliminated
		Artificial Ground Freezing	Emerging technology; involves installing freezing loops in the ground with a self-contained refrigeration system that pumps coolant around the loops. Soils around the wastes are frozen. Temporary treatment.	May not be applicable to PCB contaminated soils. Not a permanent solution.	Eliminated
	Off-Site Treatment/Disposal	RCRA Facility	Excavated soils are transported to a licensed RCRA facility for treatment and/or disposal.	Potentially applicable	Retained
		Landfill	Excavated soils are transported to a permitted landfill for disposal either hazardous or nonhazardous.	Potentially applicable	Retained

characteristics and/or contaminant-specific characteristics of OU No. 1. The groundwater technologies/options that were eliminated include:

- Capping
- Vertical Barriers
- Horizontal Barriers
- Subsurface Drains
- Shallow Reinjection
- Shallow Injection Wells
- Reverse Osmosis
- Chemical Dechlorination
- Plasma Arc Torch
- Pyrolysis
- Wet Air Oxidation
- In Situ Biodegradation
- On-Site Surface Water Discharge

Please note, that since all of the "Containment Action" technologies were eliminated with the exception of extraction wells, the entire general response action will be eliminated from further consideration.

The soil technologies/options that were eliminated include:

- Land Treatment
- Composting
- Soil Washing
- Low Temperature Thermal Stripper
- Plasma Arc Torch
- Wet Air Oxidation
- In Situ Biodegradation
- Artificial Ground Freezing
- Volatilization
- Soil Flushing
- Chemical Immobilization
- In Situ Chemical Detoxification
- In Situ Heating

The screening evaluation for the soil technologies was primarily based on the applicability of the technology to handle PCBs. Therefore, some technologies that appear to be applicable to PAHs and/or pesticides may have been eliminated from further evaluation. Due to the limited volume of soil requiring remediation, it would not be practicable to treat the soils on site by more than one technology. Since PCBs are more difficult to treat than pesticides or PAHs, they were used as the determining factor.

The technologies and process options, for both groundwater and soil, that passed this preliminary screening are listed on Table 3-5.

TABLE 3-5

SET OF POTENTIAL TECHNOLOGIES/PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
			Fencing
	Collection/Treatment Actions	Extraction	Extraction Wells
		Biological Treatment	Aerobic
			Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			Ion Exchange
			Chemical Reduction
			Chemical Oxidation
			Neutralization
			Precipitation
			Oil/Water Separation
			Filtration
			Flocculation
			Sedimentation
		Thermal Treatment	Incineration
			Molten Salt
		Off-Site Treatment	POTW
			RCRA Facility
			Sewage Treatment Plant
		In Situ Treatment	Air Sparging
		On-Site Discharge	Reinjection ● Injection wells
		Off-Site Discharge	POTW
			Pipeline to River
			Sewage Treatment Plant
			Deep Well Injection

TABLE 3-5 (Continued)

SET OF POTENTIAL TECHNOLOGIES/PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Soils	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Monitoring
		Access Restrictions	Deed Restrictions
			Fencing
	Containment Actions	Capping	Clay/Soil Cap
			Asphalt/Concrete Cap
			Soil Cover
			Multilayered Cap
		Surface Controls	Grading
			Revegetation
	Excavation/Treatment Actions	Excavation	Soils Excavation
		Physical/Chemical Treatment	Solidification/Stabilization
			Chemical Dechlorination (KPEG)
		Thermal Treatment	Incineration
			Molten Salt
			Infrared Incineration
			Pyrolysis
		In Situ Treatment	Vitrification
		Off-Site Treatment/Disposal	RCRA Facility
			Landfill ● Hazardous ● Nonhazardous

3.4 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. The representative process provides a basis for developing performance specifications during preliminary design; however the specific process option used to implement the remedial action may not be selected until the remedial design phase.

The process options listed on Table 3-5 were evaluated based on effectiveness, implementability, and relative cost. The effectiveness evaluation focused on: the potential effectiveness of process options in meeting the remedial action objectives; the potential impacts to human health and the environment during the construction and implementation phase; and how reliable the process is with respect to the contaminants of concern. The implementability evaluation focused on the administrative feasibility of implementing a technology (e.g., obtaining permits), since the technical implementability was previously considered in the preliminary screening. The cost evaluation played a limited role in this screening. Only relative capital and operating and maintenance (O&M) costs were used instead of detailed estimates. Per the USEPA guidance, the cost analysis was made on the basis of engineering judgment.

A summary of the results of the process option evaluation is presented on Tables 3-6 and 3-7 for groundwater and soil, respectively. 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.

TABLE 3-6

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
No Action	No Action	Not Applicable	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Retained
Institutional Controls	Monitoring	Groundwater Monitoring	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Retained
	Ordinances	Aquifer-Use Restrictions	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Evaluation not necessary since only one process option	Retained
	Access Restrictions	Deed Restrictions	● Does not meet remediation goals alone ● No exposures during implementation ● Effectiveness dependent on continued future implementation	● Easily implemented ● Legal requirements	Negligible cost	Retained
		Fencing	● Does not meet remediation goals alone ● Minimal to low exposures during implementation	● Due to the physical barriers at Site 78, installation of fencing around the plumes would be difficult.	Low - medium capital, low O&M	Eliminated
Collection/ Treatment Actions	Extraction	Extraction Wells	● Effective for collecting and/or containing a contaminated groundwater plume ● Potential exposures during implementation	● Easily implemented ● Equipment readily available	Moderate capital, low O&M	Retained
	Biological Treatment	Aerobic	● May be able to meet remediation goals ● Potential exposures during implementation ● Effectiveness dependent on biodegradability of contaminants	● Equipment should be easily obtainable ● Mobile units available ● May require bench-scale testing	Moderate capital, moderate O&M	Retained
		Anaerobic	● May be able to meet remediation goals ● Potential exposures during implementation ● Effectiveness dependent on anaerobic biodegradability of contaminants ● Very slow process	● Equipment should be easily obtainable ● Mobile units available ● May require bench-scale testing	Moderate capital, moderate O&M	Retained

TABLE 3-6 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Collection/ Treatment Actions (Cont)	Physical/ Chemical Treatment	Air Stripping	• Can potentially meet remediation goals for organics • Feasible for large volumes of moderate to low soluble VOC-contaminated water • Lower efficiency in cold weather • Proven and widely used technology • Potential exposures during implementation • May require pretreatment for metals	• Equipment readily available • Many mobile units available • May require bench-scale testing • Off-gas and/or tower scale treatment may be required • May require air emissions permit • Included in the existing treatment train for the interim action at Site 78	Moderate capital, low to moderate O&M	Retained
		Steam Stripping	• Can potentially meet remediation goals • Feasible for large volumes of VOC-contaminated water • Lower efficiency in cold weather • May require pretreatment for metals and oils and grease • Typically used for less volatile or highly soluble compounds	• Readily available, not as common as air stripping • May require air emissions permits • Off-gas and/or tower scale treatment may be required	Moderate capital, moderate to high O&M	Eliminated
		Carbon Adsorption	• Can potentially meet remediation goals • Applicable to a wide variety of organics and inorganics • Can be used as a polishing step following air stripping • Proven and widely used technology	• Equipment readily available • Many prefabricated mobile units available • May require bench-scale testing • Spent carbon must be properly handled • Included in the existing treatment train for the interim action at Site 78	Moderate capital (dependent on loading requirements), moderate to high O&M	Retained
		Ion Exchange	• May not meet all remediation goals • Effective and reliable; proper pretreatment required • Typically used as a polishing step for removal of selected dissolved metals • Insensitive to variations in flow rates • Pretreatment for oil and grease required	• Full-scale industrial use for recovery of valuable metals • Equipment is widely available • Regeneration solutions are generally readily available • Bench-testing required • Residuals include waste solutions and spent resins	Moderate to high capital, moderate to high O&M	Eliminated

TABLE 3-6 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Collection/ Treatment Actions (Cont)	Physical/ Chemical Treatment (Cont)	Chemical Reduction	• May not meet all remediation goals • Well studied and understood reaction • It is not a selective process • Limited to a few selected metals (chromium, mercury, lead) • Typically followed by precipitation • If complex wastewater - oxidized chemicals may be reduced to more toxic forms	• Simple and readily available equipment • The continuous process configuration is easily automated • Easily implemented	Low to moderate capital, moderate to high O&M	Eliminated
		Chemical Oxidation	• May not meet all remediation goals • Reliable and proven on industrial wastewaters for metals (manganese, iron) treatment. Can be used alone or in conjunction with precipitation	• Well-demonstrated at hazardous waste sites in pilot- and full-scale • Readily available, conventional equipment required • Bench scale testing normally required	Low to moderate capital, moderate to high O&M	Eliminated
		Neutralization	• Will not meet all remediation goals • Can be used in a treatment train for pH adjustment	• Widely used and well demonstrated • Simple and readily available equipment/materials • Bench-scale studies may be required	Low capital, low to moderate O&M	Retained
		Precipitation	• May meet inorganic remediation goals • Effective, reliable, permanent, and conventional technology • Typically used for removal of heavy metals • Followed by solids-separation method • Generates sludge which can be voluminous, difficult to dewater, and may require treatment	• Widely used and well demonstrated • Equipment is basic and easily designed • Compact, single units that are deliverable to the site • Requires bench- or pilot-scale tests	Low capital, moderate O&M	Retained
		Oil/Water Separation	• Reliable and well demonstrated • Typically used for the separation of two phased aqueous material	• Readily available • Easy to install • Available in packaged units • Low maintenance • Oils and sludge must be properly handled/disposed • Included in the existing treatment train for the interim action at Site 78	Low capital, low O&M	Retained

TABLE 3-6 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Collection/ Treatment Actions (Cont)	Physical/ Chemical Treatment (Cont)	Filtration	• Will not meet inorganic remediation goals alone • Conventional, proven method of removing suspended solids from wastewater • Does not remove other contaminants • Pretreatment for oil and grease required • Generates a sludge which requires proper handling	• Equipment is relatively simple to install and no chemicals are required • Pilot study is required • Package units available	Low capital, low O&M	Retained
		Flocculation	• May not meet inorganic remediation goals • Well established 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	Eliminated
		Sedimentation	• Will not meet inorganic remediation goals alone • 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 rejection time • Feasible for large volumes of water to be treated	• Sedimentation tanks demonstrated and proven successful at hazardous waste sites • Effluent streams include the effluent water, scum, and settled solids	Moderate capital, moderate O&M	Eliminated

TABLE 3-6 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Collection/ Treatment Actions (Cont)	Thermal Treatment	Incineration	• May meet remediation goals • Capable of burning waste in any physical form • Susceptible to thermal shock • Low thermal efficiency • Potential exposures during operation	• Commercially available and widely used • Requires air emission controls and extensive maintenance • Skilled workers required • Generates exhaust gases and ash residue	High capital, moderate to high O&M	Retained
		Molten Salt	• May meet remediation goals • Applicable for the destruction of liquids and solids • Appears to be sensitive to materials containing high ash content or high chlorine content • Molten salt produced may be corrosive • Potential exposures during operation	• Emerging technology • Developmental, pilot-scale units available • Requires frequent bed replacement	High capital, moderate to high O&M	Eliminated
	Off-Site Treatment	POTW	• Effectiveness and reliability require pilot test to determine	• Existing POTW may need upgraded • Readily implementable if POTW will grant permission; otherwise may not be feasible • Permit required	Lot capital, moderate O&M	Eliminated
		RCRA Facility	• Effective and reliable treatment • Transportation required	• Dependent on availability of and distance to nearest RCRA facility	Moderate capital, moderate O&M	Retained
		Sewage Treatment Plant	• Effectiveness and reliability require pilot test to determine	• Readily implementable if STP will accept waste; otherwise may not be feasible • Modifications to permits may be required	Low capital, low O&M	Eliminated
	In Situ Treatment	Air Sparging	• Not a proven technology since the concept is new (emerging technology) • Highly dependent on geology • Monitoring via wells may not be effective • Generally considered a shallow aquifer technology only	• Emerging technology • Equipment and materials should be readily available • Treatability studies required • May reduce the remediation time as compared to bioremediation alone	Moderate capital, low to moderate O&M	Retained

TABLE 3-6 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Collection/ Treatment Actions (Cont)	On-Site Discharge	Reinjection - Injection Wells	• Injection wells effectiveness is highly dependent on site geology/hydrogeology • Wells tend to clog in time • Potential exposures during implementation	• Easily installed • Equipment readily available • Require pilot test • Significant maintenance • Requires a permit	Moderate capital, moderate to high O&M	Eliminated
	Off-Site Discharge	POTW	• Effective and reliable discharge method	• Discharge permits required • Acceptance by a local POTW may be difficult to obtain	Low capital, moderate to high O&M	Eliminated
		Pipeline to River	• Effective and reliable discharge method	• Discharge permits required • Distance to New River from operable unit may make this option difficult to implement	Moderate to high capital, low O&M	Eliminated
		Sewage Treatment Plant	• Effective and reliable discharge method	• Discharge permit may need modified • Existing capacity of the Hadnot Point STP must be considered • The interim action for Site 78 includes discharge of treated water to the Hadnot Point STP	Low capital, low O&M	Retained
		Deep Well Injection	• Injection wells effectiveness is highly dependent on site geology/hydrogeology • Wells may clog in time	• Discharge permit required • Injection wells must be installed	Moderate Capital, moderate O&M	Eliminated

TABLE 3-7

SUMMARY OF SOIL PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
No Action	No Action	Not Applicable	Evaluation not necessary since only one process option.	Evaluation not necessary since only one process option.	Evaluation not necessary since only one process option.	Retained
Institutional Controls	Monitoring	Monitoring	Evaluation not necessary since only one process option.	Evaluation not necessary since only one process option.	Evaluation not necessary since only one process option.	Retained
	Access Restrictions	Deed Restrictions	• Does not meet remediation goals alone • No exposures during implementation • Effectiveness dependent on continued future implementation	• Easily implemented • Legal requirements	Negligible Cost	Retained
		Fencing	• Does not meet remediation goals alone • Minimal to low exposures during implementation	• Easily implemented • Partial existing fence around Lot 140 • No legal requirements	Low Capital, Low O&M	Retained
Containment Action	Capping	Clay/Soil Cap	• Does not eliminate contamination but effectively seals off surface • Reliable capping technology	• Easily implemented • Materials, workers, equipment easily obtainable • Restrictions on future land use required	Low Capital, Moderate O&M	Eliminated
		Asphalt/Concrete Cap	• Does not eliminate contamination, but is an effective sealant • Reliable capping technology, but it is susceptible to weathering and cracking	• Easily implemented • Materials, equipment, workers easily obtainable • Restrictions on future land use required	Low Capital; Moderate O&M	Retained
		Soil Cover	• Does not eliminate contamination, but is an effective direct contact barrier • Reliable technology for a contact barrier, but it is susceptible to cracking	• Easily implemented • Materials, equipment, workers easily obtainable • Restrictions on future land use required	Low Capital; Moderate O&M	Eliminated
		Multilayered Cap	• Does not eliminate contamination, but is an effective sealant • Reliable capping technology	• Easily implemented • Materials, equipment, workers easily obtainable • Restrictions on future land use required	Moderate Capital; Moderate O&M	Eliminated

TABLE 3-7 (Continued)

SUMMARY OF SOIL PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Containment Action (Cont.)	Surface Controls	Grading	• Does not meet remediation goals, but is a proven method for controlling infiltration and erosion	• Easily implemented • Equipment and workers easily obtainable	Low Capital; Low O&M	Retained
		Revegetation	• Does not meet remediation goals, but is an effective method for stabilizing the surface of a waste site • Minimal impacts during construction	• Easily implemented • Materials, equipment, workers easily obtainable	Low Capital; Low O&M	Retained
Excavation/ Treatment Actions	Excavation	Soil Excavation	• Can remove soils with contamination above the remediation goals • High potential impacts during implementation • Effective technology	• Easily implemented • Equipment and workers easily obtainable	Low Capital, No O&M	Retained
	Physical/ Chemical Treatment	Solidification/Stabilization	• Reduces migration potential of contaminants (primarily inorganics) • Contaminants still present in waste • Long term reliability is uncertain	• Skilled workers required • May require bench scale testing • Complex design and evaluation required • Requires adequate land space for disposal following treatment	High Capital; Moderate O&M	Eliminated
		Chemical Dechlorination (KPEG)	• Achieves performance levels that are considered equivalent to incineration • Treatment efficiency varies with Aroclor type • Products of treatment reaction are non-toxic, non-mutagenic, and non-bioaccumulative • Treated waste may still require chemical waste landfill disposal	• Treatability study may be required • Skilled workers required • May require transportation • Cost varies with reagent recyclability	High Capital; Low O&M	Retained

TABLE 3-7 (Continued)

SUMMARY OF SOIL PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Excavation/ Treatment Actions	Thermal Treatment	Incineration	● Should be capable of meeting remediation goals ● Capable of burning waste in any physical form ● Potential exposures during operation and monitoring	● Mobile units commercially available and widely used ● Requires air emission controls and extensive maintenance ● Skilled workers required ● Generates residuals: exhaust gas and ash	High Capital; Low O&M	Retained
		Molten Salt	● May be able to meet remediation goals ● Sensitive to materials containing high ash content or high chlorine content ● Molten salt produced may be corrosive	● Innovative technology ● Departmental stage; pilot-scale units available ● Requires frequent bed replacement	High Capital; High O&M	Eliminated
		Infrared Incineration	● May be able to meet remediation goals ● Effectively treated halogenated and nonhalogenated organics ● Soils and sludges must be greater than 22 percent solids or must be dewatered ● Nonuniform feed size requires pretreatment prior to entering unit ● Heavy metals are not fixed in ash	● Generated residuals include flue gases, ash, scrubber effluents ● Mobile units are available	High Capital; High O&M	Eliminated
		Pyrolysis	● May be able to meet remediation goals ● Not effective for wastes with nitrogen, sulfur, or sodium contents ● Requires homogeneous waste input	● Mobile units are commercially available	High Capital; High O&M	Eliminated

TABLE 3-7 (Continued)

SUMMARY OF SOIL PROCESS OPTION EVALUATION
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Cost	
Excavation/ Treatment Actions (Cont.)	In Situ Treatment	Biodegradation	• More suited to non-PCB organic contaminants and may not meet PCB remediation goals • Treatment can be inconsistent due to variations in biological activity	• PCBs may be toxic to microorganisms • Requires treatability studies • Dependent upon site hydrogeology	Moderate to High Capital; Moderate to High O&M	Eliminated
		Vitrification	• Retention of volatile metals in melt is reduced as surface is approached • Groundwater should not be present in soils to be treated • Feasibility tests must be performed to determine soil's conductance	• Buried metals may result in shorting of electrodes • Loosely packed rubbish may result in underground fires	High Capital; Minimal O&M	Eliminated
	Off-Site Treatment/ Disposal	RCRA Facility	• Will meet remediation goals • Potential exposure during excavation and transportation activities	• Dependent upon facility availability • Requires transportation • Adequate testing required	High Capital; Minimal O&M	Retained
		Landfill	• Will meet remediation goals at the site but does not destroy the contaminants • "Cradle to Grave" problem • Potential exposures during excavation and transportation activities	• Dependent upon landfill capacity • Requires transportation • Adequate testing required	Moderate to High Capital; Minimal O&M for hazardous waste landfill Low to Moderate Capital; Minimal O&M for nonhazardous waste landfill	Retained

3.5 Final Set of Remedial Technologies/Process Options Retained for OU No. 1

The final set of remedial technologies/process options retained for OU No. 1 are listed on Table 3-8. A brief description of each of the process options is presented below with respect to groundwater and soil.

3.5.1 Groundwater Process Options

3.5.1.1 Groundwater Monitoring

A long-term groundwater monitoring program could be implemented at OU No. 1 as an institutional control. This program would continue to provide information regarding the effectiveness of any remedial activities conducted on site.

3.5.1.2 Aquifer-Use Restrictions

An ordinance restricting the use of the deep aquifer (i.e., Castle Hayne Aquifer) at OU No. 1 as a drinking water source could be implemented as an institutional control. This restriction would help reduce the risk to both human and ecological populations from ingestion and direct contact with the contaminants in the aquifer.

3.5.1.3 Deed Restrictions

Deed restrictions or land use restrictions may be used as an institutional control measure. Selected areas within a site may be subject to a deed restriction thereby limiting the future use of that land. A typical example of such a restriction is a RCRA landfill. After a landfill has been closed, that area of land becomes subject to a deed restriction providing that no future disturbance (development, excavation, etc.) is permitted.

3.5.1.4 Extraction Wells

The extent and migration of a contaminated groundwater plume may be contained or controlled via pumping techniques. Existing wells or additional extraction wells, strategically located according to the hydrogeologic and chemical characteristics of an aquifer and contaminants of concern, are typically used. The extraction wells are pumped at specific rates

TABLE 3-8

FINAL SET OF POTENTIAL REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
	Collection/Treatment Actions	Extraction	Extraction Wells
		Biological Treatment	Aerobic
			Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Carbon Adsorption
			Neutralization
			Precipitation
			Oil/Water Separation
			Filtration
		Thermal Treatment	Incineration
		Off-Site Treatment	RCRA Facility
		In Situ Treatment	Air Sparging
		Off-Site Discharge	Hadnot Point STP
Soil	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Monitoring
		Access Restrictions	Deed Restrictions
			Fencing
	Containment Actions	Capping	Asphalt/Concrete Cap
		Surface Controls	Grading
			Revegetation
	Excavation/Treatment Actions	Excavation	Soil Excavation
		Physical/Chemical Treatment	Chemical Dechlorination (KPEG)
			Incineration
		Off-Site Treatment/Disposal	RCRA Facility
			Landfill

such that the cone of influence from the well system intercepts the contaminant plume. Groundwater pumping may be combined with treatment technologies to allow for discharge.

Pumping techniques utilizing extraction wells are reliable and proven techniques for the management of groundwater contamination and aquifer restoration. Installation is relatively easy and quick (Wagner, 1986).

3.5.1.5 Biological Treatment

Aerobic Treatment

In general, aerobic biological treatment can effectively remove organic compounds such as benzene, methylene chloride, toluene, TCE, and vinyl chloride. Lead removal is typically not removed through this type of treatment, and may even be inhibitory to biological populations at concentrations greater than 10 mg/L. Xylenes may also be inhibitory to microbial populations at concentrations greater than 500 mg/L (ESE, 1988b).

There are several methods of aerobic treatment such as aerated lagoons, activated sludge, powdered activated carbon treatment, trickling filters, and rotating biological contactors. Aerated lagoons are mixed biological reactors without biomass recycle. The primary purpose of this type of treatment lagoon is to remove soluble organic matter by conversion to biological mass.

The activated sludge process uses microorganisms to degrade organic constituents. This system is the most widely used biological wastewater treatment process. It utilizes solids settling and recycling as part of the entire process. Organic matter is converted to microbial cell tissue and carbon dioxide. The mixture of microbial mass and wastewater (i.e., sludge) is settled out, and a portion is recycled back into the treatment system while the remaining sludge requires proper disposal (Wagner, 1986).

Powdered activated carbon treatment (PACT) may be used in conjunction with another biological treatment such as activated sludge. PACT is the addition of powdered activated carbon to a biological system (such as the aeration tank of an activated sludge system). Following aeration, the solids are separated in the final clarifier, and a portion of the solids are recycled to meet the requirements of the biological system (USEPA, 1990e).

A trickling filter typically consists of a bed of crushed rocks, or other medium, coated with biological film. Contaminated water is sprayed over this filter medium. As the contaminated water passes over the microbial growths, an appreciable amount of the organic material is removed along with molecular oxygen. Aerobic processes occur and the oxidized organic and inorganic end products are released into the moving water film. The wastewater passes through a filter, while the organic materials are retained for several hours as they undergo bio-oxidation (Wentz, 1989).

Rotating biological contactors (or RBCs) provide a fixed-film biological treatment method for the removal of biological oxygen demand (BOD) from wastewaters. The most common type of RBC consists of corrugated plastic discs mounted on horizontal shafts to which a biological mass attaches. The biological mass adsorbs, coagulates, and biodegrades organics from the wastewater (USEPA, 1990e).

Anaerobic Treatment

Anaerobic biological treatment involves bacterial reduction or organic matter in an oxygen-free environment. There are two main types of anaerobic reactors: suspended-growth and fixed-film. Anaerobic treatment is best utilized specifically to reduce high strength organic wastewaters to concentrations that can be degraded aerobically.

3.5.1.6 Physical/Chemical Treatment

Air Stripping

Air stripping is a treatment process in which water and air are brought into contact with each other for the purpose of transferring volatile substances from solution in a liquid to solution in gas. Air stripping has been most cost-effectively used for the treatment of low concentrations of VOCs or as a pretreatment step prior to activated carbon. The gas stream generated during the treatment process may require collection and subsequent treatment.

Carbon Adsorption

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

Neutralization

Neutralization is the interaction of an acid with a base or vice versa to yield a final pH of approximately 7.0. This technology is one of the most common types of chemical treatments used by industrial wastewater treatment facilities. Pretreatment of the waste stream may be needed for large amounts of suspended solids and oils and grease. The major limitation of neutralization is that it is subject to the influence of temperature (USEPA, 1990e).

Precipitation

Precipitation is a process in which materials in solution are transferred into a solid phase for removal. Removal of heavy metals is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents such as alum, ferric chloride, and ferric sulfate. The wastewater then flows to a flocculation chamber where additional mixing is conducted and retention time provided resulting in the agglomeration of precipitate particles (Rich, 1987). The insoluble precipitate is then removed for recovery or disposal using solids separation technologies such as sedimentation or filtration.

Oil/Water Separation

Separation is a physical technology primarily used to treat two-phased aqueous wastes such as oil in water or fuel oil in a fuel contaminated aquifer. Oil/water separation involves retaining wastewater in a holding tank and allowing oil and other materials with a specific gravity less than or greater than water to float to the surface or to sink, respectively. Separated oil is removed by surface skimming and bottom collection systems in the holding tank (GRI, 1990). Typical design configurations of a gravity separator include horizontal cylindrical decanters, vertical cylindrical decanters, and cone bottomed settlers. Baffles are frequently installed to provide additional surface area which promotes oil droplet coalescence (Wagner, 1986).

Filtration

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

3.5.1.7 Incineration

Incineration uses high temperature oxidation under controlled conditions to degrade a substance into other products (Wagner, 1986). Most organic-contaminated wastes can be treated by incineration. Unlikely candidates for destruction include heavy metals and other wastes high in inorganics. Several types of incinerators exist such as liquid injection incinerators, rotary kilns, fluidized bed incinerators, and multiple hearth incinerators (Wagner, 1986).

Liquid injection systems typically consist of a double refractory-lined combustion chamber and a series or atomizing nozzles. Combustible liquids and gases are generally introduced in the first combustion chamber (the burner). Noncombustible wastes are introduced downstream of the burner in the secondary chamber. These incinerators can destroy most pumpable waste or gas (Wagner, 1986).

A rotary kiln is a cylindrical, refractory-lined shell. Waste is fed into the higher end of the rotating, tilted cylinder. As the cylinder rotates, the waste proceeds toward the other end of the cylinder where it exits the system. Rotary kilns can process a large variety of waste (solids and liquids) with minimal preprocessing (Wagner, 1986).

A fluidized bed incinerator consists of a cylindrical vertical refractory-lined vessel containing a bed of inert granular material (usually sand on a perforated metal plate). Combustion air is introduced at the bottom of the incinerator and rises vertically fluidizing the bed and maintaining turbulent mixing of bed particles. Waste material is injected into the bed and combustion occurs within the bubbling bed. Heat is transferred from the bed into the injected wastes. These types of incinerators are typically used for the treatment of slurries and sludges (Wagner, 1986).

A multiple hearth incinerator consists of a refractory-lined shell with a rotating central shaft. Rabble arms with teeth are used to move waste down a series of solid flat hearts as it is burned. Multiple hearths can be used for the destruction of all forms of combustible waste materials including sludges, tars, solids, liquids, and gases. Although, it is best suited for sludges (Wagner, 1986).

3.5.1.8 In Situ Treatment - Air Sparging

Air sparging is the in situ removal and bioremediation of volatile organics from saturated soils and/or groundwater via injecting air under pressure. Nutrients are injected along with the air stream. This allows for the effective removal of VOCs without groundwater recovery or treatment (USEPA, 1992c). This technology is typically used in conjunction with soil vapor extraction (SVE) to eliminate the off-site migration of vapors (Johnson, et. al., 1993).

This technology is effective in treating petroleum hydrocarbons and solvents (chlorinated and non-chlorinated). Treatment is accomplished by both volatilization and bioremediation (USEPA, 1992c).

Air sparging is relatively simple to implement and capital costs are modest (Johnson, et. al., 1993). The basic equipment needs for this technology include a vent sparge well, a vacuum blower, and an air compressor (USEPA, 1992c). Vent sparge wells (or air injection wells) are usually similar in construction to standard groundwater monitoring wells except that the screened section of the air sparging well must be located entirely within the saturated zone. Typically, 1 to 2 inch diameter sparging wells are used. If SVE is used in conjunction with air sparging, air extraction wells, vacuum pumps, and an off-gas treatment system (such as activated carbon or combustion) are also needed (Johnson, et. al., 1993).

Air sparging wells are typically placed a few meters below the water table in the hope of inducing lateral spreading of air away from the injection well. As air moves up through the groundwater zone, contaminants partition into the gas phase and are swept out of the groundwater zone to the vadose zone. At the same time, oxygen in the injected sparge air partitions into the groundwater. This oxygen may then serve to stimulate the aerobic microbial degradation of contaminants (Johnson, et. al., 1993).

Air sparging relies on the interactions between complex physical, chemical, and biological processes (many of which are not well understood). It is important to recognize that the design of most air sparging systems will be based on relatively limited site-specific information. Therefore, it is imperative that the potential for flexible operation and system expansion be incorporated into any system design (Johnson, et. al., 1993).

3.5.1.9 Off-Site Treatment - RCRA Facility

Extracted groundwater can be transported off-site to a RCRA-permitted facility for treatment and ultimate disposal/discharge.

3.5.1.10 Off-Site Discharge - Hadnot Point STP

Treated groundwater can be discharged to the Hadnot Point STP for ultimate discharge to the New River. The Hadnot Point STP is currently being used as a discharge point for treated water from the Fuel Farm (Site 22) recovery system. In addition, treated water from the interim action groundwater treatment system for Site 78 will also be discharged to the Hadnot Point STP once the system is in operation.

3.5.2 Soil Process Options

The following provides a brief description of the soil process options retained as potential remedial action technologies.

3.5.2.1 Monitoring

This process option involves collecting soil and/or groundwater samples, on a periodic basis, from the contaminated areas. The samples are collected to determine if the contaminants are migrating to other portions of the site, or if the contaminant levels are increasing in concentration. If it is determined that the contaminants are migrating to other areas within the site, or if the contaminant levels are increasing, other soil remediation options may have to be reevaluated for the site to address the ongoing problem.

3.5.2.2 Access Restrictions

Deed Restrictions

Deed restrictions or land use restrictions may be used as an institutional control measure. Selected areas within a site may be subject to a deed restriction thereby limiting the future use of that land. A typical example of such a restriction is a RCRA landfill. After a landfill has been closed, that area of land becomes subject to a deed restriction providing that no future disturbance (development, excavation, etc.) is permitted.

Fencing

Fencing provides a low cost method of limiting the access to the contaminated areas. This process requires minimal to low exposure during implementation but typically does not meet the remediation goals alone. Note that some areas within OU No. 1 (e.g., Lot 140) are completely or partially fenced off.

3.5.2.3 Asphalt/Concrete Cap

Asphalt/concrete materials can be used to cap or seal off contaminated areas. The method does not eliminate the contamination, but it is an effective sealant for limiting the potential exposure to fugitive airborne particles and potential exposure due to dermal contact. This method is most applicable where the area of contaminated soils is relatively small.

3.5.2.4 Surface Controls

Grading

Grading is a method which modifies the natural topography and runoff characteristics on and around contaminated areas to control infiltration and erosion due to surface water. This option is most effective when it is used in conjunction with capping. Note that this method does not meet the remediation goals or reduce the contaminant levels in the soil. In most cases, a backhoe or bull dozer can be used to perform the soil grading.

Revegetation

This method is used to stabilize the ground surface around the contaminated area. In most cases, grass is used as a surface cover. Although the method does not eliminate the contamination, it does provide an effective method for stabilizing the ground surface.

3.5.2.5 Soil Excavation

Physical removal of soil is an effective method to remove contaminants from the source and the affected areas. Contaminated soils are excavated with conventional construction equipment such as a backhoe, draglines, and in some cases a hand shovel. There are no limitations placed on the materials that can be excavated and removed, but worker health and safety issues are a strong consideration especially for highly-contaminated soils. Other factors to consider are mobility the material, the feasibility of on-site containment or in situ treatment, and the cost of disposing the soil after it has been excavated. In general this method is applicable to most site conditions, however, it may be cost-prohibited at great depths (i.e., limited to 30 feet in most cases) or in complex hydrogeologic environments (USEPA, 1987a).

3.5.2.6 Physical/Chemical Treatment

Chemical Dechlorination

Dechlorination is a process which stabilizes organochlorine compounds such as PCBs. The most widely known dechlorination methods are collectively called alkaline polyethylene glycol (APEG) treatment. In the potassium (KPEG) process, potassium hydroxide (KOH) reacts with PEG to form a potassium glycolate. The glycolate reacts with PCBs by nucleophilic substitution to yield a less-chlorinated, glycolate-substituted PCB. The process can be performed by mixing the PCB contaminated soils with hot (150°F) KPEG reagent in a rotating industrial mixer (USEPA, 1990a).

Incineration

Thermal destruction is the high-temperature oxidation of recovered wastes. One of the most common type of incinerator is the rotary kiln. With this type of incinerator, wastes are burned in a rotating refractory cylinder. This type of incinerator can be used to destroy a variety of wastes including PCBs. After burners are often used to destroy the organic by-products and ash disposal is necessary. Mobile incinerators are available for sites where wastes are particularly toxic or difficult to handle or transport. In some cases, laboratory and field-scale testing are required (USEPA, 1987a).

3.5.2.7 Off-Site Treatment/Disposal

RCRA Facility

Contaminated soils can be excavated and transported to an off-site facility permitted to treat/dispose hazardous waste. This type of facility is typically referred to as a RCRA facility, meaning that the facility has RCRA Part A and B permits.

Incineration (treatment) facilities may be commercially permitted for PCB treatment. Based on the USEPA guidance document, Guidance on Remedial Actions for Superfund Sites with PCB Contamination (USEPA, 1990a), incinerator companies in the closest vicinity to MCB Camp Lejeune include ENSCO in Little Rock, Arkansas; Rollins in Deer Park, Texas; and the U.S. Department of Energy/Martin Marietta Energy Systems in Oak Ridge, Tennessee.

Landfill

Landfilling is a process where contaminated soils are excavated, transported, and buried in the ground at a permitted facility. This method will meet remediation goals, but does not destroy the contaminants. In most cases, laboratory analysis of the waste is required to determine if the material is hazardous or nonhazardous. If the material is disposed of as hazardous waste, cradle-to-grave liability is a potential concern for the waste generator.

Landfilling has historically been the method of choice for the disposal of contaminated materials both hazardous and nonhazardous. The 1984 Hazardous and Solid Waste Amendments to RCRA have reduced the availability of landfilling as an option. The legislation shows a strong preference for treatment, recycling, or destruction as opposed to landfilling (USEPA, 1987a).

Solid waste (RCRA Subtitle D) or hazardous waste (RCRA Subtitle C) landfills may be utilized depending on the characteristics of the contaminated soils to be disposed. Solid waste landfills include sanitary, industrial, and construction landfills. The construction requirements (e.g., liners and caps) as well as recordkeeping and reporting requirements are typically not as stringent for solid waste landfills as they are for hazardous waste landfills. Therefore, the solid waste landfills do not offer a higher degree on long-term protection.

In order to be disposed in either a RCRA Subtitle C or D landfill, the soil must not contain any free liquids. In addition, solid waste landfills often place restrictions on the types and the concentrations of contaminants that they will accept in nonhazardous soil. A landfill located in Pinewood, South Carolina may be capable of handling nonhazardous PCB-contaminated soils.

4.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

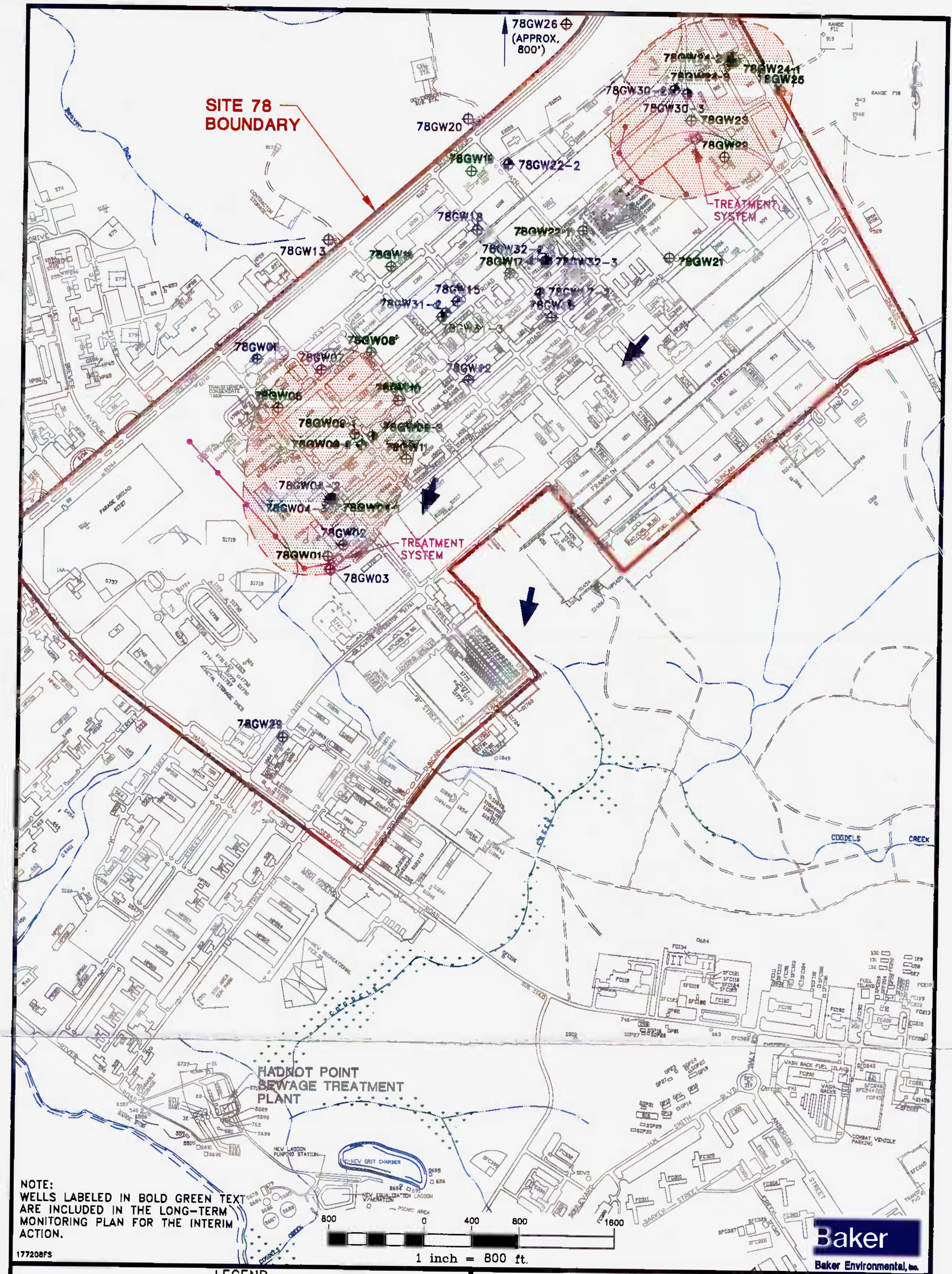
In this section, general response actions and the process options chosen to represent the various technology types applicable for OU No. 1 will be combined to form remedial action alternatives (RAAs) for the site. Following development, each alternative may be evaluated against the short-term and long-term aspects of three criteria: effectiveness, implementability, and cost (Section 4.3). The alternatives with the most favorable composite evaluation of all criteria will be retained for further consideration during the detailed evaluation (Section 5.0). Note that the screening evaluation at this step of the FS is optional. It will only be conducted if too many alternatives are initially developed.

Prior to developing individual RAAs for OU No. 1, it is important to describe the details of the interim remedial action (IRA) to be implemented at Site 78 for the surficial aquifer. The IRA will affect what other RAAs are developed for the entire operable unit. Section 4.1 presents the details of the IRA.

4.1 Interim Remedial Action For the Shallow Aquifer at Site 78

As mentioned in Section 1.0, an IRA RI Report and FS Report were prepared for the surficial aquifer within Site 78 by Baker in 1992. The Record of Decision (ROD) was signed the same year. The preferred interim action included the installation of two groundwater pump and treat systems within Site 78, a long-term groundwater monitoring program, and institutional controls. The primary objective of the interim action was to contain the migration of the two shallow VOC contaminant plumes located within Site 78. In terms of this FS, the IRA will contain the shallow groundwater contamination from Groundwater AOCs 1 and 5.

The treatment systems will include a treatment train of technologies including air stripping, carbon adsorption, oil/water separation, and metals removal. As shown on Figure 4-1, one treatment system is to be located within the northeast contaminated plume. Four extraction wells will be initially installed near the downgradient edge of this plume. The second treatment system is to be located within the southwest contaminated plume. Five extraction wells will be initially installed along the downgradient edge of this second plume. Approximately three to five gpm are anticipated to be extracted from each well. Each of the treatment units will be designed to handle a maximum influent of 80 gpm.



NOTE:
WELLS LABELED IN BOLD GREEN TEXT ARE INCLUDED IN THE LONG-TERM MONITORING PLAN FOR THE INTERIM ACTION.

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LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL	➤	ESTIMATED DIRECTION OF GROUNDWATER FLOW
78GW04-2 ⊕	INTERMEDIATE MONITORING	◇	TREATMENT SYSTEM
78GW04-3 ⊕	DEEP MONITORING WELL	●—	EXTRACTION WELLS AND PIPING
▨	APPROXIMATE AREA OF SHALLOW GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS (BASED ON 1991 ESE DATA)		

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 4-1
INTERIM REMEDIAL ACTION TO BE IMPLEMENTED FOR THE SURFICIAL AQUIFER AT SITE 78
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

In addition to the pump and treat systems, the IRA will include a long-term groundwater monitoring program. Under this program, 20 existing monitoring wells will be sampled for the contaminants of concern (i.e., VOCs and inorganics) on a quarterly basis. For FS purposes, a monitoring period of 30 years has been assumed. As shown on Figure 4-1 and listed below, the wells to be monitored include 16 shallow monitoring wells, two intermediate wells, and two deep wells.

Shallow Wells	Intermediate Wells	Deep Wells
78GW01	78GW09-2	78GW09-3
78GW04-1	78GW24-2	78GW24-3
78GW05		
78GW08		
78GW09-1		
78GW10		
78GW11		
78GW14		
78GW17-1		
78GW19		
78GW21		
78GW22		
78GW22-1		
78GW23		
78GW24-1		
78GW25		

The institutional controls under the interim action include: placing aquifer-use restrictions on the shallow aquifer; and keeping the existing closed water supply wells out of service.

4.2 Development of Alternatives

This section of the FS typically combines the general response actions and process options chosen to represent the various applicable technologies into separate RAAs potentially applicable for the contaminated media at a site. For this FS, this process was slightly altered due to the above-mentioned IRA to be conducted for the surficial aquifer at Site 78.

The IRA FS previously evaluated several of the groundwater technologies/process options listed on Table 3-8. The results of the IRA FS indicated that the treatment train consisting of air stripping, carbon adsorption, oil/water separation, and metals removal presented the best overall option as compared to biological treatment, on-site thermal treatment, and off-site treatment at a RCRA Facility. Therefore, these three technologies/process options will not be included under any RAA developed for OU No. 1 in this section. Air sparging will be evaluated in this FS since it was not included in the IRA FS Report.

Please note that RAAs will be developed for groundwater and soil separately. The categorization of the RAAs into separate media-specific RAAs will allow for the independent evaluation of various alternatives for each affected medium. A completely developed RAA for OU No. 1 will consist of an RAA from both response media.

The developed sets of RAAs for groundwater and soil are shown on Tables 4-1 and 4-2, respectively. As shown on the tables, five RAAs have been identified for groundwater, and four RAAs for soil. A description of each of the RAAs with respect to each media of concern is presented below.

4.2.1 Groundwater RAAs

As shown on Table 4-1, five Groundwater RAAs have been developed for OU No. 1. The RAAs range from no action to complete source control with vertical containment. The groundwater RAAs will include active remediation of the groundwater from Groundwater AOCs 1 and 5. Long-term monitoring will be performed for Groundwater AOCs 2, 3, 4, 6, 7, and 8 under any of the Groundwater RAAs. This decision for most of the AOCs was based on the contaminant concentrations and the lack of contaminants found. For example, PCE at a concentration of 1.0 µg/L was the only contaminant found above the remediation levels at Groundwater AOCs 2, 4, and 8. The NCWQS for PCE is 0.7 µg/L and the Federal MCL is 5.0 µg/L. Since the detected level of PCE was below the Federal MCL and only slightly above the NCWQS, additional monitoring of these areas appears to be the most appropriate measure at this time. If the monitoring indicates that the groundwater at these areas are deteriorating, additional measures will be taken. Once the remediation levels have been obtained for these areas, monitoring will no longer be necessary.

With respect to AOCs 6 and 7, only one contaminant, heptachlor epoxide, was detected in the groundwater samples. The detected concentrations of this contaminant were 0.083 J µg/L at

TABLE 4-1

Revised July 22, 1994

POTENTIAL SET OF GROUNDWATER REMEDIAL ACTION ALTERNATIVES FEASIBILITY STUDY CTO-0177 MCB CAMP LEJEUNE, NORTH CAROLINA

			Remedial Action Alternatives				
			RAA No. 1	RAA No. 2	RAA No. 3	RAA No. 4	RAA No. 5
Technology Type	Process Option	Area or Volume	No Action	Institutional Controls	Source Control (Interim Treatment System Extension)	Source Control (Air Sparging)	Source Control and Vertical Containment
Monitoring	Groundwater Monitoring	78GW15, 78GW39 24GW08, 24GW09, 24GW10, 8 water supply wells		X	X	X	X
		3 shallow extraction wells placed for source control			X		X
		2 deeper extraction wells placed for vertical containment					X
Ordinances	Aquifer-Use Restrictions	HP-608, HP-634, HP-630, HP-602, HP-601, HP-637		X	X	X	X
Access Restrictions	Deed Restrictions	OU No. 1		X	X	X	X
Extraction	Extraction Wells	3 shallow extraction wells placed for source control			X		X
		2 deeper extraction wells placed for vertical containment					X
Physical/Chemical Treatment	Treatment Train consisting of air stripping, carbon adsorption, oil/water separation, and metals removal (extension of interim treatment system)	Extracted groundwater from groundwater AOC1(1) and AOC5			X		X
In Situ Treatment	Air Sparging	Groundwater AOC1 and AOC5				X	
Off-Site Discharge	Hadnot Point STP	Treated Groundwater			X		X

(1) AOC = Area of Concern

TABLE 4-2

POTENTIAL SET OF SOIL REMEDIAL ACTION ALTERNATIVES
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

			Remedial Action Alternatives			
			RAA No. 1	RAA No. 2	RAA No. 3	RAA No. 4
Technology Type	Process Option	Area or Volume	No Action	Capping	On-Site Treatment	Off-Site Treatment/Dispoal
Monitoring	Groundwater Monitoring	4 Site 21 wells 2 Site 78 wells		X		
Access Restrictions	Deed Restrictions	AOCs 1 through 4		X		
	Fencing	AOCs 1 through 4		X		
Capping	Asphalt/Concrete Cap	AOCs 1 through 4		X		
Surface Controls	Grading	AOCs 1 through 4		X	X	X
	Revegetation	AOCs 1 through 4			X	X
Excavation	Soil Excavation	AOCs 1 through 4			X	X
On-Site Treatment	Incineration or Dechlorination	AOCs 1 through 4			X	
Off-Site Treatment/Disposal	Permitted Facility	AOCs 1 through 4				X

(1) AOC = Area of Concern

24GW08, 0.13 J µg/L at 24GW09, and 0.078 J µg/L at 24GW10. The NCWQS for heptachlor epoxide is 0.038 µg/L and the Federal MCL is 0.20 µg/L. The detected levels were all below the Federal MCL, but exceeded the NCWQS. There is no known source for this pesticide or any known history of the disposal of this contaminant. As with Groundwater AOCs 2, 4, and 8, additional monitoring of these two areas appears to be the most appropriate measure at this time. If the indicates that the groundwater at these areas are deteriorating, additional measures will be taken. Once the remediation levels have been obtained at these two areas, monitoring will no longer be necessary.

No additional actions will be implemented at Groundwater AOC 3 since this is the area of the Hadnot Point Fuel Farm (Site 22). A fuel recovery system/groundwater treatment is currently operating at this area. Investigations/remediations related to the Fuel Farm are being handled under the UST Program not CERCLA. Therefore, only monitoring will be conducted near this area for purposes of this FS. Additional information regarding this recovery system can be found in the Design Package prepared by O'Brien & Gere in 1990 or from MCB Pubic Works Department - Facilities Support Contracts.

In addition to the IRA, all of the Groundwater RAAs, with the exception of the No Action Alternative, have some common elements which are described below:

Common Elements Between RAA Nos. 2 Through 5 - Groundwater RAA Nos. 2 through 5 have several common remedial elements between them including aquifer-use restrictions, deed restrictions, long-term monitoring of existing monitoring wells and water supply wells, and the remedial actions to be implemented for Groundwater AOCs 2, 3, 4, 6, 7, and 8. Each of these common elements will be discussed below and will not be repeated under the discussion of each alternative.

Under RAA Nos. 2 through 5, aquifer-use restrictions will be remain on water supply wells HP-601, HP-602, HP-608, HP-630, HP-634, and HP-637. Deed restrictions restricting the placement of additional water supply wells within the entire OU No. 1 will also be included with these four RAAs.

In addition to the 20 wells included under the long-term monitoring program for the IRA for Site 78, five shallow monitoring wells and the nearby water supply wells will also be included under a long-term monitoring program for OU No. 1. The five shallow monitoring wells will include: 78GW15, 78GW39, 24GW08, 24GW09, and 24GW10. Several of these wells are associated with newly identified Groundwater AOCs. Both active and inactive water supply wells will be monitored. The active supply wells include HP-603 and HP-642. The inactive supply wells to be monitored include HP-601, HP-602, HP-608, HP-630, HP-634, and HP-637. Additional wells may be added to the monitoring program, if necessary.

Samples will be collected on a semiannual basis for five years and analyzed for TCL VOCs. As required, after five years the operable unit will be re-evaluated to determine the effectiveness of the implemented remedial action. Based on the the semiannual groundwater data and the data from the IRA, a less frequent sampling program may be implemented (such as annually), or it may be determined that sampling is no longer required at certain areas. In time, the results of the monitoring program may indicate that one or more of the currently inactive water supply wells can be activated.

In addition to the common elements, the remaining remedial actions associated with each of the five Groundwater RAAs are discussed below.

4.2.1.1 RAA No. 1: No Action

Under the No Action Alternative, no additional remedial actions will be performed to reduce the toxicity, mobility, or volume of the wastes at the operable unit. Under this alternative, the contaminants identified in the surficial and Castle Hayne aquifers at OU No. 1 will remain, which may result in the potential for further migration of the contaminated plumes. Keep in mind that the IRA will contain the shallow groundwater contamination from Groundwater AOCs 1 and 5. In addition, the fuel recovery system operating at the Hadnot Point Fuel Farm, will capture the Groundwater AOC 3 plume. Additional aquifer restoration may result through natural processes such as biological degradation, attenuation, and dispersion (primarily at Groundwater AOCs 2, 4, 6, 7, and 8).

The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs. Since contaminants will remain at the site under this alternative, the USEPA is required by the NCP [40 CFR 300.515(e)(ii)] to review the effects of this alternative no less often than every five years.

4.2.1.2 RAA No. 2: Institutional Controls

Under RAA No. 2, no additional remedial actions will be performed to reduce the toxicity, mobility, or volume of the wastes at OU No. 1. This RAA will include only the common institutional controls of monitoring, ordinances, and access restrictions which have previously been discussed. Figure 4-2 identifies the major components of this alternative, specifically the location of the additional wells to be monitored.

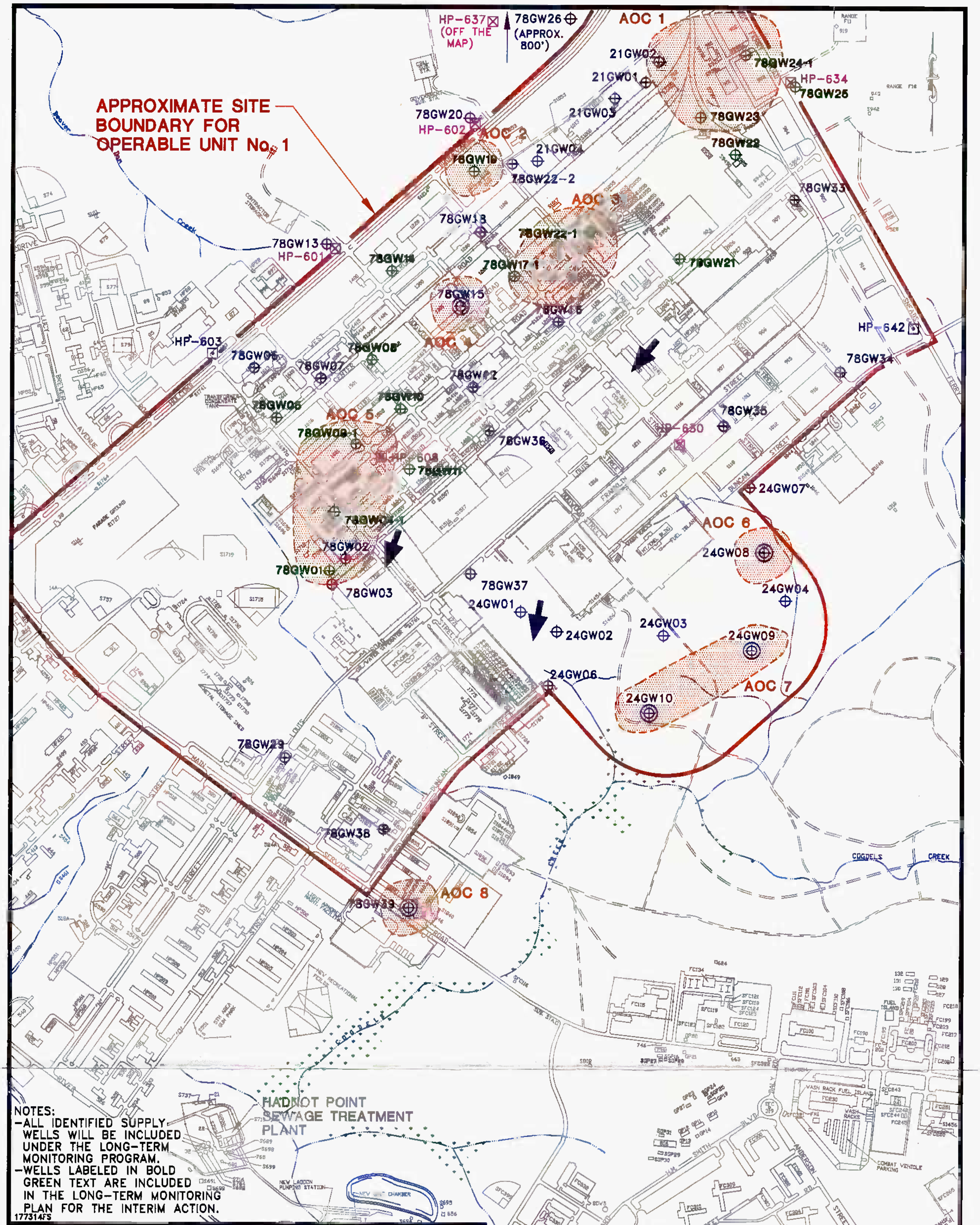
Since contaminants will remain at the site under this alternative, the USEPA is required by the NCP [40 CFR 300.515(e)(ii)] to review the effects of this alternative no less often than every five years.

4.2.1.3 RAA No. 3: Source Control (Interim Remedial Action Treatment System Extension)

In general, RAA No. 3 is a source control alternative with the primary objective to remediate the source(s) of groundwater contamination. Under this alternative three additional shallow extraction wells will be installed at areas of the highest VOC contamination and connected to the interim action groundwater treatment system. As shown on Figure 4-3, two of the extraction wells will be installed near existing monitoring wells 78GW24-1 and 78GW23 within Groundwater AOC 1. The third extraction well will be installed near existing monitoring well 78GW09-1 within Groundwater AOC 5. The extraction wells will be designed the same as for the interim action wells (i.e., 6-inch minimum diameter, 35 feet deep). Based on site geology, it is anticipated that the wells will be pumped at 3 to 5 gpm.

No extraction wells will be placed in the Castle Hayne aquifer under this alternative. Deeper extraction wells could actually draw the existing shallow contamination down into the Castle Hayne aquifer, and thereby increase the vertical extent of the contaminant plume. Routine monitoring will be performed in the deeper portions of the aquifer to evaluate if the conditions are deteriorating or getting better. The five-year review will determine if further actions are needed at the deeper aquifer areas.

Figure 4-3 identifies the major elements associated with RAA No. 3. The location of the extraction wells and treatment systems associated with the IRA are also identified on the figure.



NOTES:
- ALL IDENTIFIED SUPPLY WELLS WILL BE INCLUDED UNDER THE LONG-TERM MONITORING PROGRAM.
- WELLS LABELED IN BOLD GREEN TEXT ARE INCLUDED IN THE LONG-TERM MONITORING PLAN FOR THE INTERIM ACTION.

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LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL
78GW15 ⊕	SHALLOW MONITORING WELL INCLUDED IN THE LONG-TERM MONITORING PROGRAM EXPECTED AREA OF CONCERN BASED ON 1991 DATA
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN
➡	ESTIMATED DIRECTION OF GROUNDWATER FLOW
HP-603 ⊡	WATER SUPPLY WELL (ACTIVE)
HP-601 ☒	WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, FEBRUARY 1992

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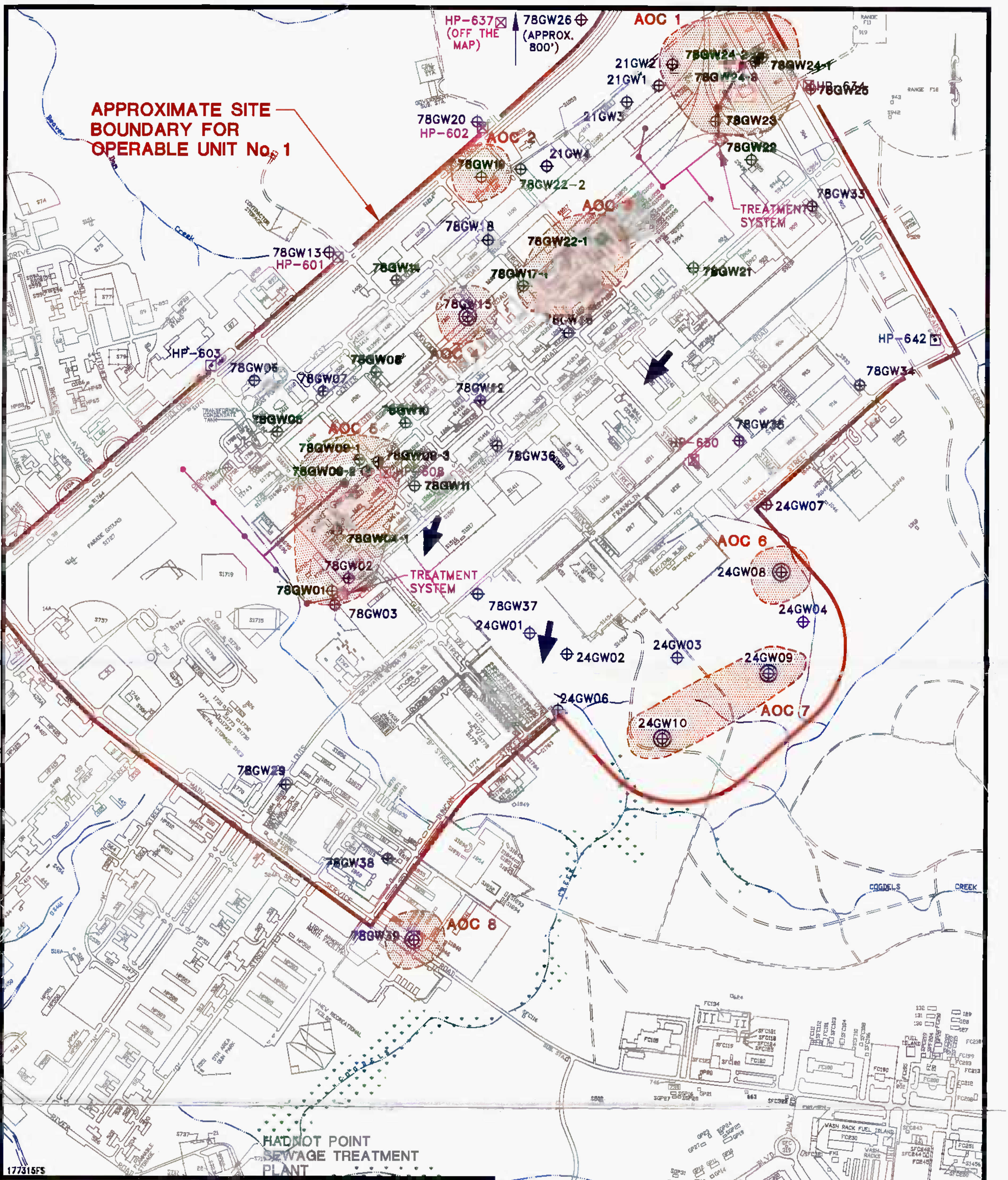
FIGURE 4-2
GROUNDWATER RAA No. 2: LIMITED ACTION
OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01256GG.B3Y



LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL
78GW15 ⊕	SHALLOW MONITORING WELL INCLUDED IN THE LONG-TERM MONITORING PROGRAM
78GW09-2 ⊕	INTERMEDIATE MONITORING WELL
78GW09-3 ⊕	DEEP MONITORING WELL
HP-603 ⊡	WATER SUPPLY WELL (ACTIVE)
HP-601 ☒	WATER SUPPLY WELL (INACTIVE)
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN
➔	ESTIMATED DIRECTION OF GROUNDWATER FLOW
◇	TREATMENT SYSTEM
●—●	IRA EXTRACTION WELLS AND PIPING
●—	RAA EXTRACTION WELLS AND PIPING

SOURCE: LANTDIV, FEBRUARY 1992

NOTES:
- ALL IDENTIFIED SUPPLY WELLS WILL BE INCLUDED UNDER THE LONG-TERM MONITORING PROGRAM.
- WELLS LABELED IN BOLD GREEN TEXT ARE INCLUDED IN THE LONG-TERM MONITORING PLAN FOR THE INTERIM ACTION.

800 0 400 800 1600

1 inch = 800 ft.

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FIGURE 4-3
GROUNDWATER RAA No. 3: SOURCE CONTROL
(INTERIM TREATMENT SYSTEM EXTENSION)
OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

4.2.1.4 RAA No. 4: Source Control (Air Sparging)

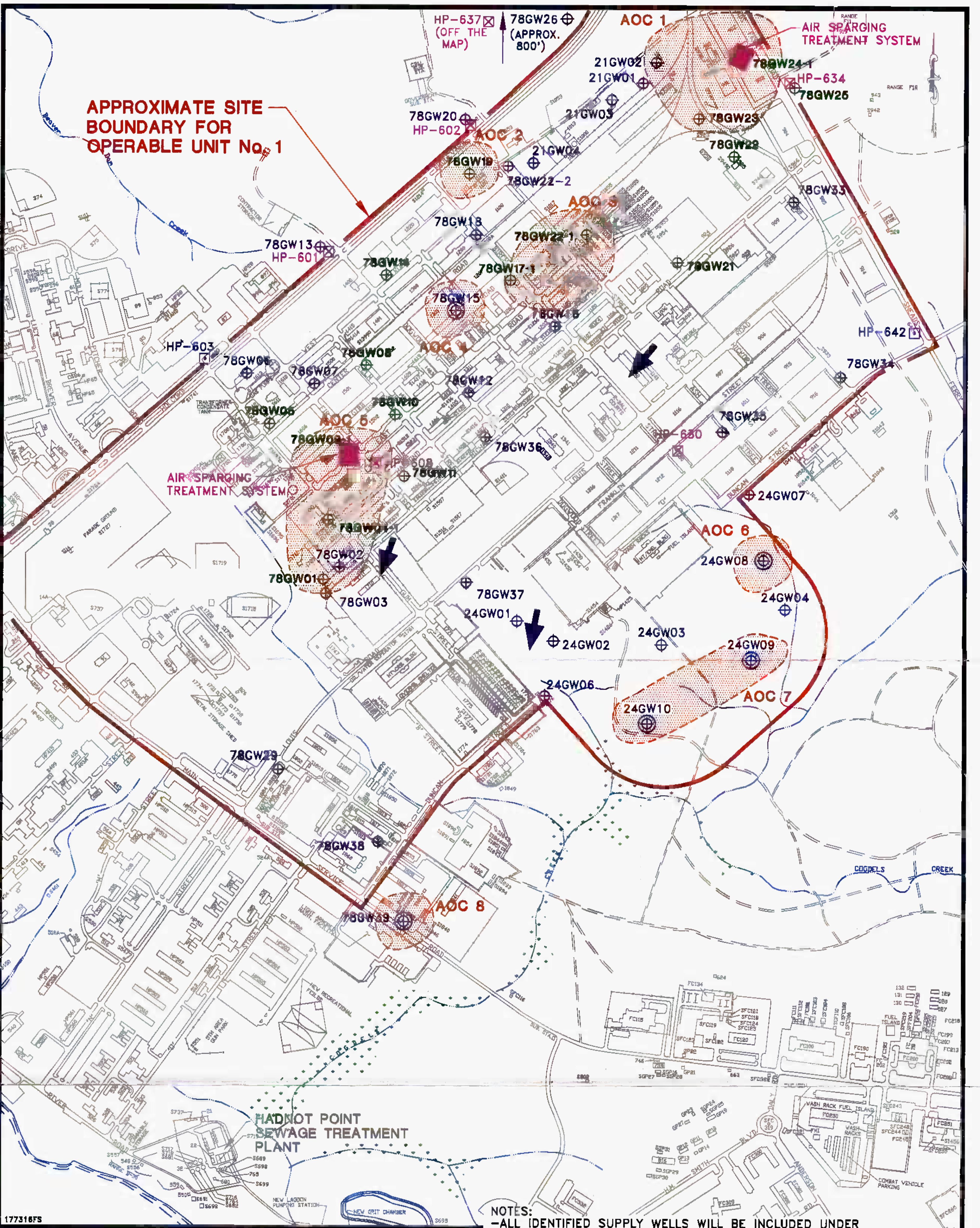
In general, RAA No. 4 is a source control alternative with the primary objective to remediate the source(s) of groundwater contamination. Under this alternative, two in situ air sparging/soil venting treatment systems will be installed at areas of the highest VOC contamination. As shown on Figure 4-4, one of the units will be installed near existing monitoring well 78GW24-1 (Groundwater AOC 1). The other treatment system will be installed near existing monitoring well 78GW09-1 (Groundwater AOC 5).

The treatment systems will be designed to primarily treat the sources of the contamination which are located in the shallow aquifer. As with RAA No. 3, no active treatment will be conducted on the deeper portions of the aquifer. Routine monitoring will be performed to determine if the water quality in the deeper portions of the aquifer are deteriorating. The five-year review will determine if further actions are needed for the deeper aquifer.

Under this RAA, the air sparging/venting systems will be operated for approximately five years or until remediation levels are met. It is anticipated that this type of treatment system will be able to meet the remediation goals within a 5-year time frame. After five years, the effectiveness of the sparging/venting system will be evaluated. Another remedial option may be selected at that time if the contaminated groundwater has not been remediated.

Figure 4-4 identifies the location of the air sparging systems associated with RAA No. 4. The major elements of the interim remedial action are also identified on Figure 4-4. Additional information regarding the remedial technology of air sparging follows.

Air sparging is based on the movement of air within saturated and vadose.zones. With sparging, air bubbles traverse horizontally and vertically through the soil column, creating a transient air-filled porosity in the saturated zone. Air sparging effectively creates a crude air stripper in the subsurface, with the soil acting as the "packing". Air is injected and allowed to flow through the water column over the packing. Air bubbles that come into contact with the dissolved phase contaminants in the aquifer cause the VOCs to volatilize. The volatilized organics are then carried by the air bubbles into the vadose zone, where they can be captured by a vapor extraction system or, if permitted, allowed to escape through the ground surface. The sparged air maintains a high dissolved oxygen content, which enhances natural biodegradation (Brown, et. al, 1992).



LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL
78GW15 ⊕	SHALLOW MONITORING WELL INCLUDED IN THE LONG-TERM MONITORING PROGRAM
HP-603 ⊡	WATER SUPPLY WELL (ACTIVE)
HP-601 ☒	WATER SUPPLY WELL (INACTIVE)
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN
→	ESTIMATED DIRECTION OF GROUNDWATER FLOW
■	AIR SPARGING TREATMENT AREA

SOURCE: LANTDIV, FEBRUARY 1992

NOTES:
- ALL IDENTIFIED SUPPLY WELLS WILL BE INCLUDED UNDER THE LONG-TERM MONITORING PROGRAM.
- WELLS LABELED IN BOLD GREEN TEXT ARE INCLUDED IN THE LONG-TERM MONITORING PROGRAM FOR THE INTERIM ACTION.

800 0 400 800 1600

1 inch = 800 ft.

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FIGURE 4-4
GROUNDWATER RAA No. 4: SOURCE
CONTROL (AIR SPARGING)
OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

A soil vapor extraction system is typically combined with an air sparging system. Compounds mobilized by the air sparging system could discharge near or at the ground surface if not effectively captured in the vadose zone. The SVE system is the mechanism that prevents such a discharge (Brown, et. al, 1992). Figure 4-5 shows a typical air sparging/soil vapor extraction system schematic.

Potential concerns with the use of air sparging include the possibility of spreading dissolved contamination, and the possible accumulation of vapors in buildings due to the acceleration of vapor phase transport. Geologic conditions, especially the presence of a low permeable clay, can affect air flow. If the low permeable soil constricts vertical air flow, sparging can then push the dissolved contamination downgradient. Any permeability differential above the zone of air injection may severely reduce the effectiveness of air sparging. In this situation, sparging may require a groundwater recovery system to prevent the spread of dissolved contamination. Changes in the site hydrogeology due to sparging, such as water table mounding, could increase downgradient dissolved contamination. Another potential concern of air sparging is accelerated vapor travel (especially where receptors are located nearby). Since air sparging increases pressure in the vadose zone, any exhausted vapors can be drawn into building basements. In this situation, sparging should be done with a concurrent vent system (Brown, et. al., 1992).

4.2.1.5 RAA No. 5: Source Control and Vertical Containment

In general, RAA No. 5 is a source control and vertical containment alternative with the primary objectives to remediate the source(s) of groundwater contamination and to mitigate the vertical migration of the contamination.

The source control component of this alternative is the same as with RAA No. 3. In such, three additional shallow extraction wells will be installed at areas of the highest VOC contamination and connected to the interim action groundwater treatment system. As shown on Figure 4-6, two of the extraction wells will be installed near existing monitoring wells 78GW24-1 and 78GW23 within Groundwater AOC 1. The third extraction well will be installed near existing monitoring well 78GW09-1 within Groundwater AOC 5. The extraction wells will be designed the same as for the interim action wells (i.e., 6-inch minimum diameter, 35 feet deep). Based on site geology, it is anticipated that the wells will be pumped at 3 to 5 gpm.

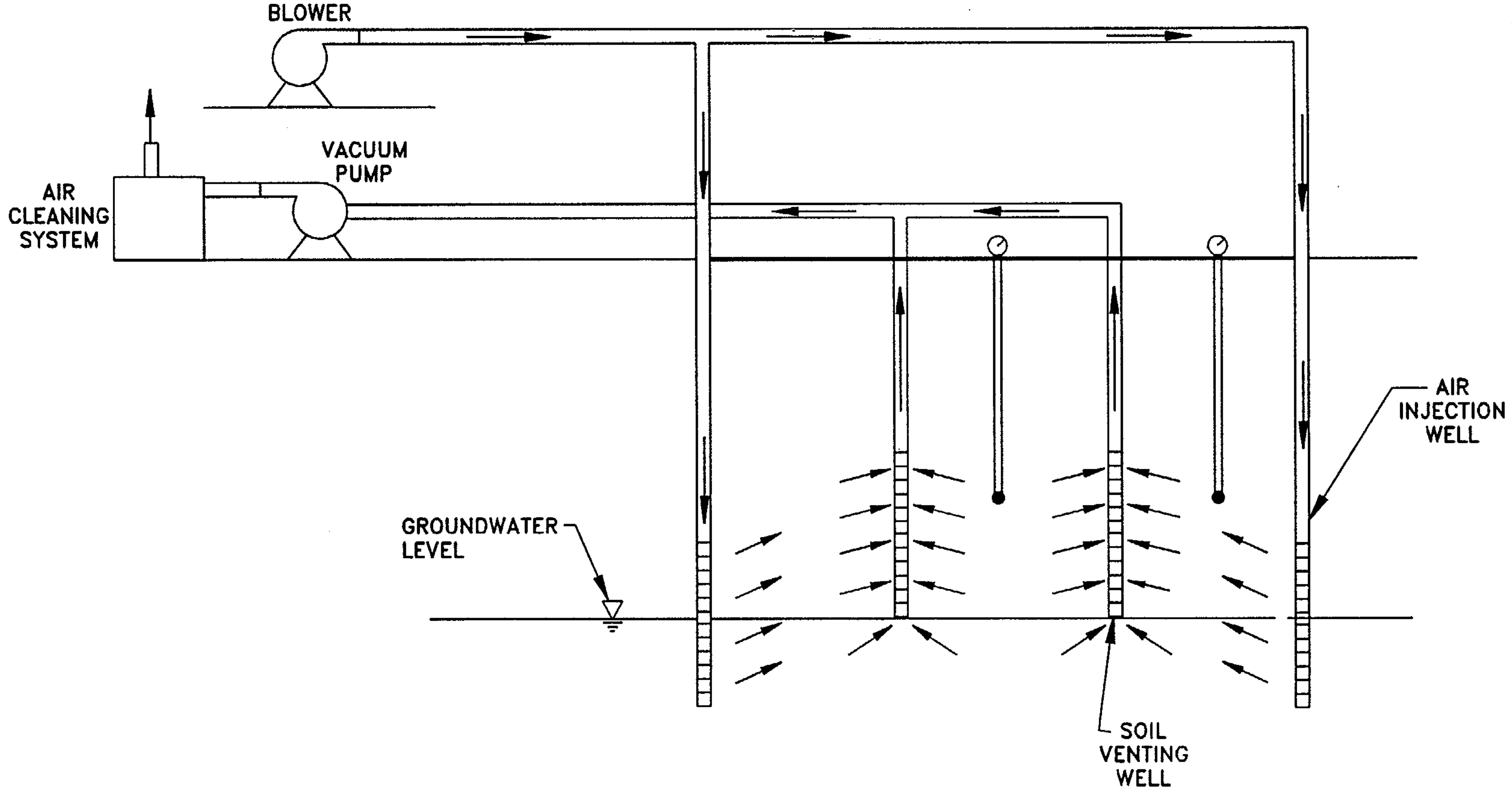

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FIGURE 4-5
TYPICAL AIR SPARGING/VAPOR EXTRACTION SCHEMATIC
FEASIBILITY STUDY CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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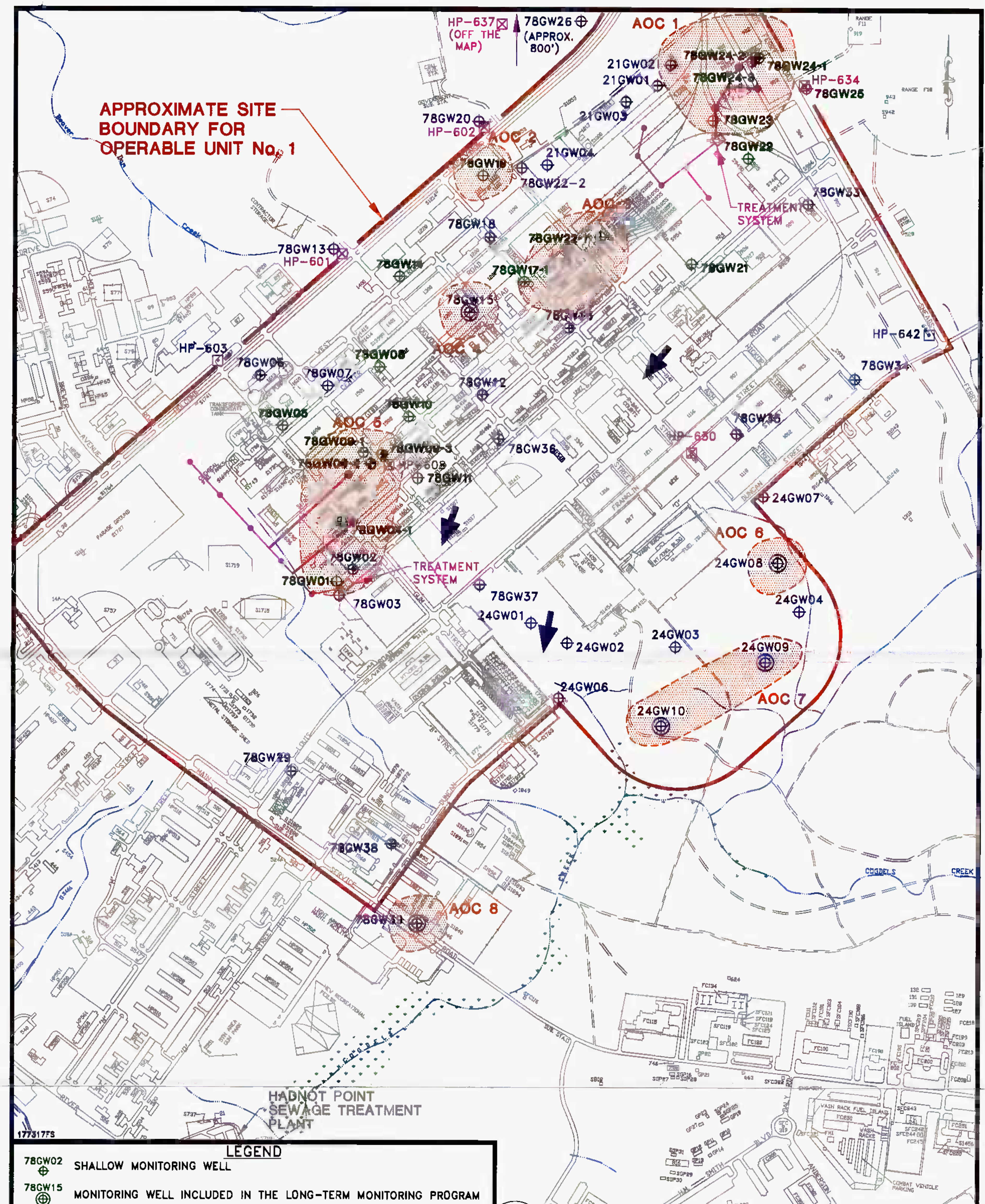

LEGEND

78GW02 ⊕	SHALLOW MONITORING WELL
78GW15 ⊕	MONITORING WELL INCLUDED IN THE LONG-TERM MONITORING PROGRAM
78GW09-2 ⊕	INTERMEDIATE MONITORING WELL
78GW09-3 ⊕	DEEP MONITORING WELL
HP-603 ⊡	WATER SUPPLY WELL (ACTIVE)
HP-601 ☒	WATER SUPPLY WELL (INACTIVE)
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN
➜	ESTIMATED DIRECTION OF GROUNDWATER FLOW
◇	TREATMENT SYSTEM
●—	IRA SHALLOW EXTRACTION WELLS AND PIPING
●—	RAA SHALLOW EXTRACTION WELLS AND PIPING
◆—	RAA DEEP EXTRACTION WELLS AND PIPING

SOURCE: LANTDIV, FEBRUARY 1992

NOTES:
- ALL IDENTIFIED SUPPLY WELLS WILL BE INCLUDED UNDER THE LONG-TERM MONITORING PROGRAM.
- WELLS LABELED IN BOLD GREEN TEXT ARE INCLUDED IN THE LONG-TERM MONITORING PLAN FOR THE INTERIM ACTION.

800 0 400 800 1600

1 inch = 800 ft.

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FIGURE 4-6
GROUNDWATER RAA No. 5: SOURCE CONTROL AND VERTICAL CONTAINMENT
OPERABLE UNIT No. 1
FEASIBILITY STUDY CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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The vertical containment component of this alternative includes the installation of two extraction wells at the areas of the highest VOC contamination in the lower portion of the surficial aquifer at OU No. 1. As shown on Figure 4-6, one of the wells will be installed near existing monitoring well 78GW24-3 within Groundwater AOC 1. The second extraction well will be installed near existing monitoring wells 78GW4-2 and 78GW4-3 within Groundwater AOC 5. The extraction wells will be 6 inch minimum diameter and installed at approximately 75 feet below ground surface. This RAA will address both the shallow (source) and deeper groundwater contamination. Implementation of this RAA may result in the migration of the shallow contamination in the deeper portions due to drawdown effects.

Figure 4-6 identifies the major elements associated with RAA No. 5. The location of the extraction wells and treatment systems associated with the IRA are also identified on the figure.

4.2.2 Soil RAAs

As shown on Table 4-2, four Soil RAAs have been developed for OU No. 1 (specifically Site 21). No other areas within OU No. 1 require soil remediation. Each of these RAAs are described below.

4.2.2.1 Soil RAA No. 1: No Action

Under Soil RAA No. 1, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants in the soil at OU No. 1. The No Action RAA is required by the NCP to provide a baseline for comparison with other soil alternatives that provide a greater level of response. Soil RAA No. 1 involves leaving the contaminated soils throughout OU No. 1 in place. Under this RAA, the pesticide concentrations in the soil may slowly decrease as a result of natural biodegradation. The natural degradation of the PCB-contaminated soils is unknown.

The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs. Since contaminants will remain at the site under this alternative, the USEPA is required by the NCP [40 CFR 300.515(e)(ii)] to review the effects of this alternative no less often than every five years.

4.2.2.2 Soil RAA No. 2: Capping

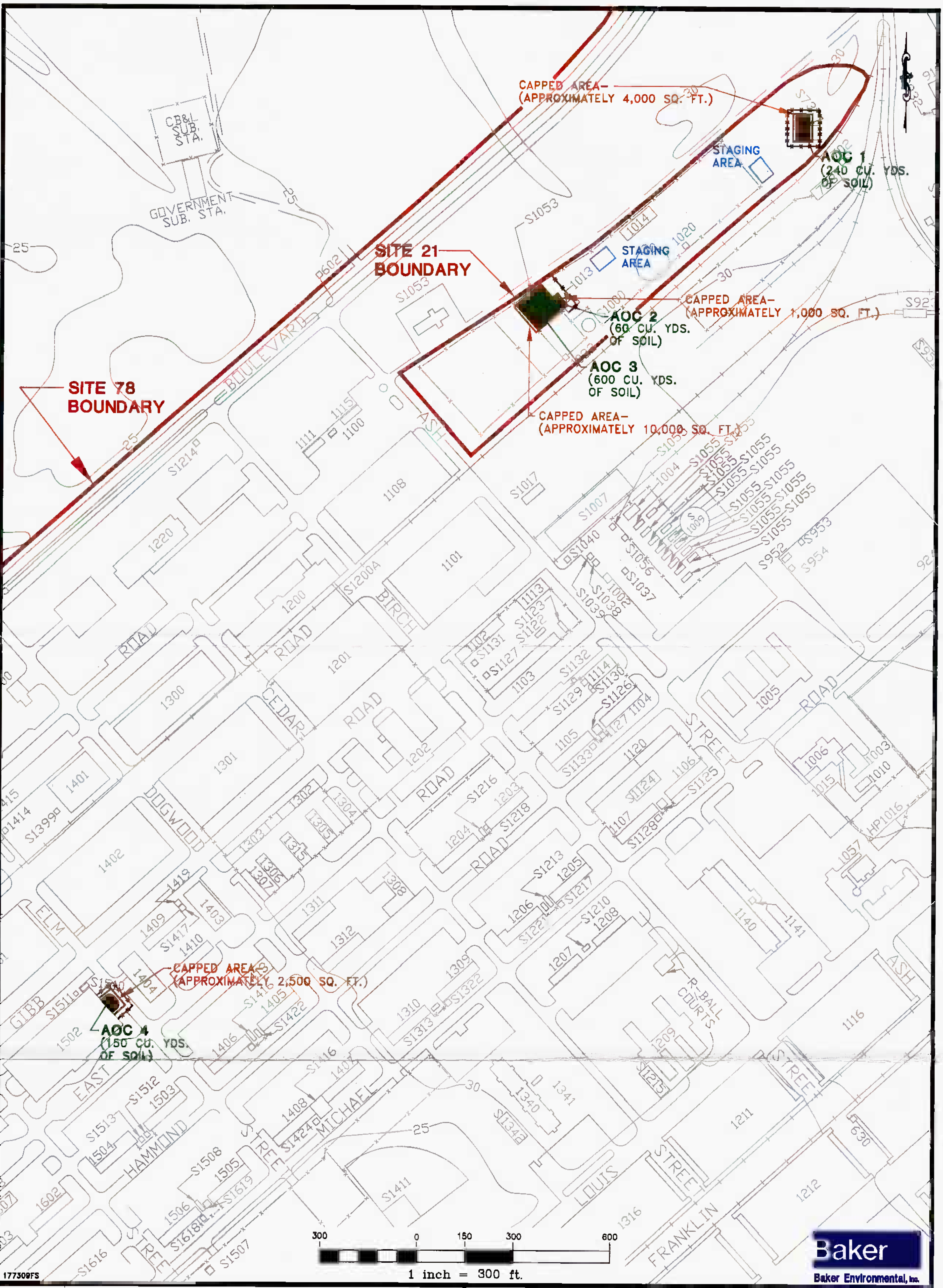
Soil RAA No. 2 includes the installation of an asphalt or concrete cap over the soil contaminated areas. [Please note that there is no correlation (i.e., different source of contaminants) between Soil AOCs and Groundwater AOCs.] This RAA will reduce the mobility of the COCs in the soil, but will not reduce the toxicity or the volume of the contaminants. As shown on Table 4-2, the technologies/process options included with this RAA include: monitoring, deed restriction, fencing, capping, and grading. These technologies/process options are described below.

Monitoring - In order to monitor the effectiveness of the cap (i.e., the migration of the COCs), groundwater sampling will be conducted semiannually. Groundwater samples will be collected from the following monitoring wells: 21GW01, 21GW02, 21GW03, 21GW04, 78GW09-1 and 78GW10.

Access Restrictions - The capped areas will be fenced to restrict access to the capped areas and reduce damage to the caps. As shown in Figure 4-7, the existing fence at Soil AOC 3 should be adequate. This RAA will require approximately 900 linear feet of new chain-link fence to be installed. The fence will be of sufficient height and construction so as to limit access to the caps. In addition, "No Trespassing" signs will be posted along the fences to further deter access. Routine maintenance and repairs of the fence, as necessary, are also included under this RAA. In addition to the fence, deed restrictions restricting the use of the area in and around the capped areas will be implemented. Any soil excavated during potential future construction activities will require appropriate disposal in accordance with applicable Federal and State regulations.

Capping - A concrete or asphalt cap will be installed over the contaminated soils. For purposes of this FS, the area of each of the caps will be approximately 4,000 square feet for AOC 1, 1,000 square feet for AOC 2, 10,000 square feet for AOC 3, and 2,500 square feet for AOC 4. This totals 17,500 square feet of capped areas. The thickness of the cap will be approximately four to eight inches in the capped area. To ensure the integrity of the capping system, periodic maintenance (e.g., applying a sealant over asphalt) will be required.

Surface Controls - A minimal amount of surface grading will be required during the installation of the caps. No soils will be removed from the areas to be capped.



LEGEND

● AOC 1 APPROXIMATE LOCATION OF SOIL EXCEEDING REMEDIATION LEVELS.

🟥 AREA TO BE CAPPED

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-7
SOIL RAA No. 2: CAPPING
OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

In the event that the long-term groundwater monitoring program indicates that the groundwater conditions are deteriorating, other actions will be taken. In addition, since contaminants will remain at the site under this alternative, the USEPA is required by the NCP [40 CFR 300.515(e)(ii)] to review the effects of this alternative no less often than every five years.

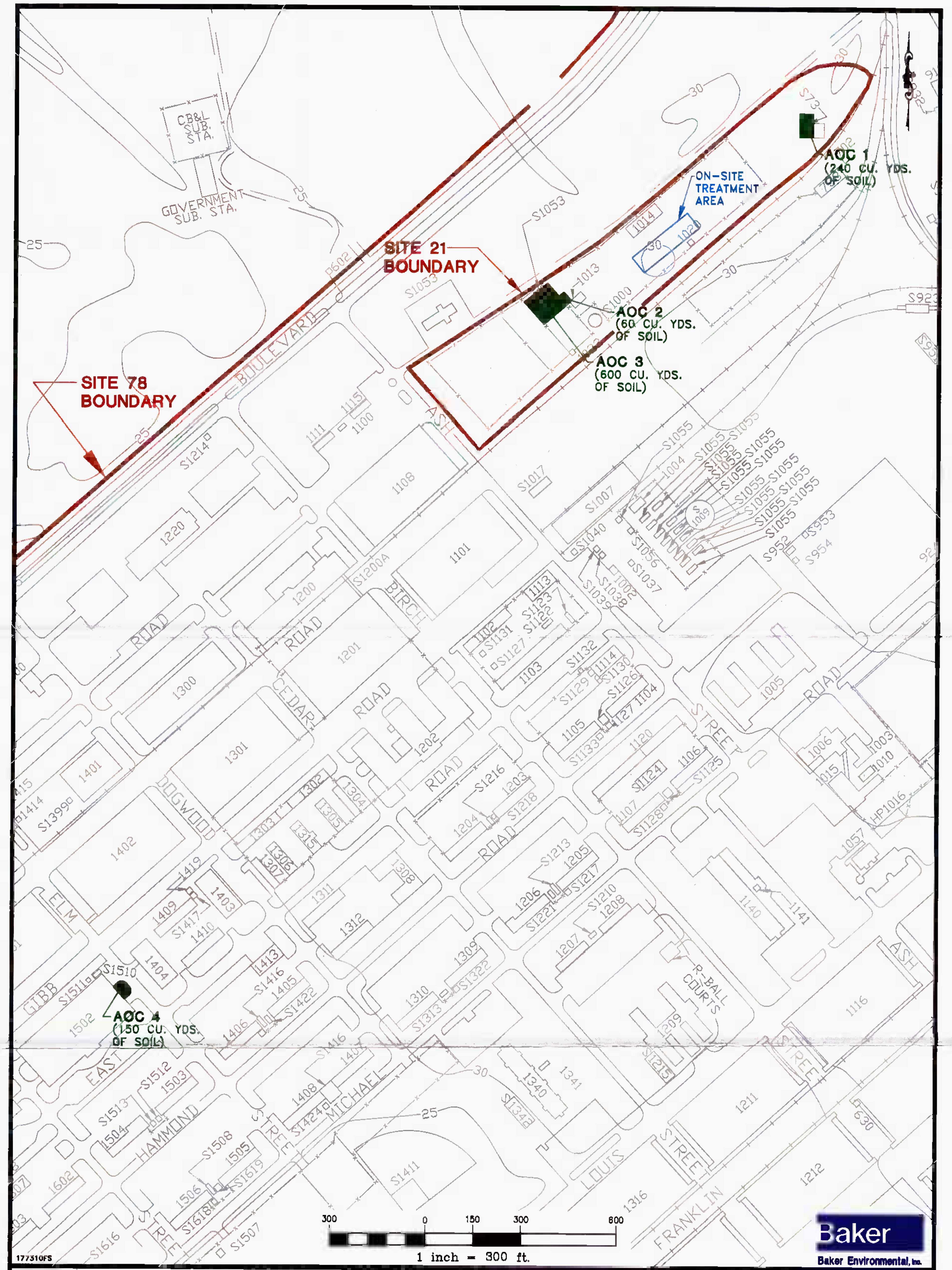
4.2.2.3 Soil RAA No. 3: On-Site Treatment

Soil RAA No. 3 includes the excavation and treatment of the soils from all Soil AOCs via on-site treatment. As shown in Table 4-2, the technologies/process options included with this RAA include soil excavation, grading, revegetation, and on-site treatment. Figure 4-8 depicts the approximate areas of the site from which soil will be excavated, and also shows the proposed location of the on-site treatment area. The main components of this alternative are described below.

Excavation - Excavation of soil could be accomplished by utilizing several different types of equipment and typical construction activities. Typical excavation machinery include backhoes, dozers, scrapers, and loaders. A backhoe can excavate soils to a maximum depth of approximately 30 feet. Dozers and loaders are typically used for grading and earth-moving operations. Scrapers are generally used to excavate surface soils and respreading and compacting cover soils. For OU No. 1, it appears that any of these machinery would be applicable for the shallow soil excavation activities required under this RAA.

The contaminated soils within the Soil AOCs will be excavated to a depth of approximately two feet, placed into dump trucks, transported to the on-site treatment area (or soil staging area). The limits of the excavations will be defined by constituent concentrations in excess of the specified remediation levels. For FS estimating purposes, approximately 1,050 cubic yards of soil will be excavated. This estimation was based on the following volumes of soil per each AOC: AOC 1 - 240 cubic yards; AOC 2 - 60 cubic yards; AOC 3 - 600 cubic yards; and AOC 4, - 150 cubic yards. Confirmation soil sampling will be conducted during the excavation activities to determine the lateral and vertical extent of each soil excavation. The samples will be analyzed for the specific COCs within each Soil AOC (i.e., PCBs, or pesticides).

Prior to any excavation activities, site operating areas for soil staging and for decontamination will be constructed. The staging area will be used for the interim storage of excavated soils prior to treatment, if applicable. During storage periods, the soil will be



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LEGEND

● AOC 1 APPROXIMATE LOCATION OF SOIL EXCEEDING REMEDIATION LEVELS. EXCAVATION TO TAKE PLACE WITHIN THIS AREA

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-8
SOIL RAA No. 3: ON-SITE TREATMENT
OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177

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NORTH CAROLINA

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covered to prevent the potential leaching of contaminants, dust generation, and potential for surface water runoff contamination. The equipment decontamination area will be equipped with a steam cleaning pad with proper containment for rinse water.

Treatment - Following excavation activities, the soils will be transported to the on-site treatment area. For the purpose of this FS, the soils will be treated either by chemical dechlorination or by incineration. Both of these are discussed below.

- Chemical Dechlorination - KPEG dechlorination is a chemical treatment technology used to dehalogenate certain classes of chlorinated organics such as PCBs. The end products of this chemical reaction should be a lower toxic, water soluble material. The KPEG solution reacts with the chlorinated organic and displaces a chlorine molecule. The KPEG process involves mixing equal portions of contaminated soil and KPEG reactants in a heated reactor. The slurry is then heated and mixed while the reaction occurs. The reaction time can range from 0.5 to five hours, depending on the type and concentration of the contaminants and the amount of dechlorination desired. The excess reagent is then decanted and the soil is washed two to three times with water to remove excess reagent and the products of the reaction. The decontaminated soil is then removed from the reactor. The decanted reagent and washes can be recycled to treat additional soil (USEPA, 1988c). A typical schematic of the dechlorination process is shown on Figure 4-9.

  KPEG reduces the toxicity of the waste, but it also increases the volume of waste that must be further treated as wastewater (USEPA, 1988c). Treatability studies will have to be performed to determine the effectiveness of this technology on the type of PCB-contaminated soils that are at Site 21. The reaction is highly dependent on sufficient reaction time. The PCB-contaminated AOCs within Site 21 appear to be applicable for this type of treatment.

- Incineration - Incineration is a complete destruction technology that can be used to treat soils contaminated with a wide range of hazardous organic wastes. There are several types of combustion chambers that can be used in the incineration process such as rotary kiln, fluidized bed, multiple hearth, and liquid injection. The most conventional unit used for the treatment of soils on site is the rotary kiln incinerator. Rotary kiln incinerators consist of a mobile rotating kiln which is slightly tilted. Waste is typically introduced at the top of the kiln and burns as it slowly falls to the

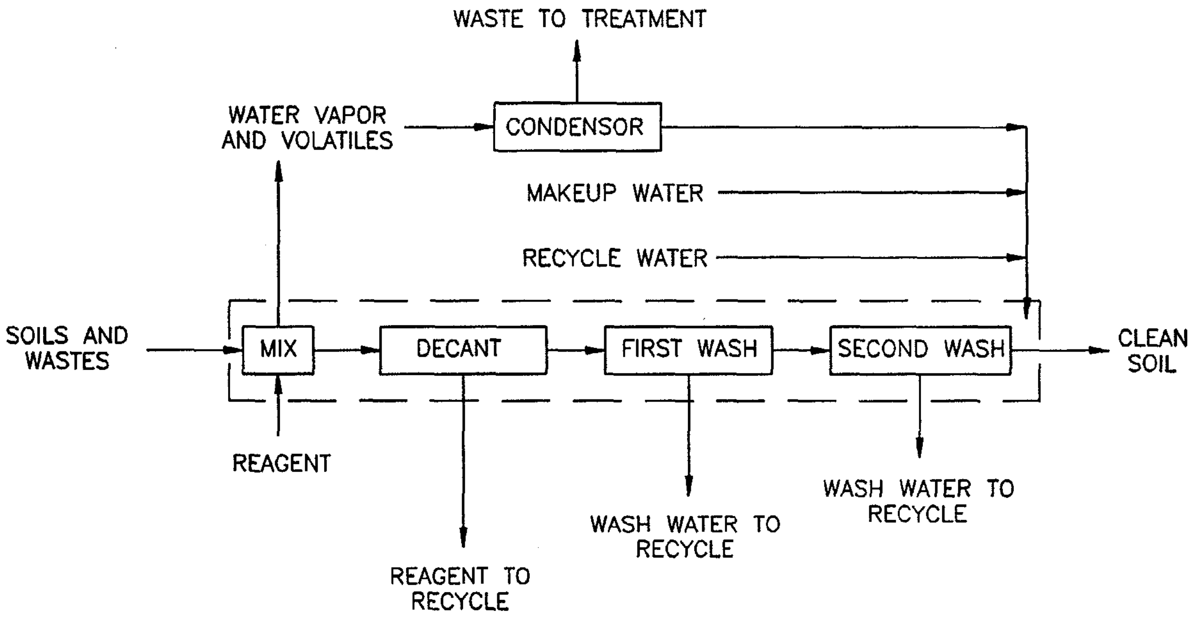

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FIGURE 4-9
CHEMICAL DECHLORINATION
SCHEMATIC
FEASIBILITY STUDY CTO-0177

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NORTH CAROLINA

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SOURCE: EPA/540/2-88/004

bottom of the unit, where it is removed as ash (typically has the appearance of fine beach sand). During operation, the kiln rotation exposes fresh soil surfaces to oxidation. Unburned gaseous and suspended particulate organics are burned in a secondary combustion chamber or afterburner. The off-gases require quenching and scrubbing prior to discharge into the environment. A mobile incinerator may be able to handle approximately 150 pounds of dry solids per minute. The operation of an incineration system results in the generation of residuals consisting of ash, scrubber water, and flue gases. The ash must be tested in accordance with TCLP and RCRA characteristic analyses to determine its proper disposal options. If the ash cannot be delisted, it will require handling as a hazardous waste. A general schematic of an incinerator process is presented on Figure 4-10. For purposes of this FS, it is assumed that the ash can be used as fill material within Site 21 during restoration activities. Scrubber water will be treated in conjunction with a groundwater RAA. The flue gases emitted during the incineration process will be required to meet the standards set forth in RCRA regulations. Incineration appears to be applicable to all of the Soil AOCs.

Following treatment, any residual soils will be removed from the treatment unit, analyzed, and if permitted, used as backfill at the site. If not permitted, the treated soils will be properly disposed off site. Note that air emissions will be monitored during all soil remediation activities.

Surface Controls - The excavated areas will be graded to conform to the surrounding terrain. Clean fill may be added to the excavated areas as necessary to bring the areas up to grade. The excavated areas will be revegetated.

Access Restrictions - As shown on Figure 4-8, the treatment area will be located within a previously fenced area within Lot 140. No additional fencing will be necessary to restrict access. "No Trespassing" signs will be posted along the fence to further deter access. Routine maintenance and repairs of the fence, as necessary, are also included under this RAA.

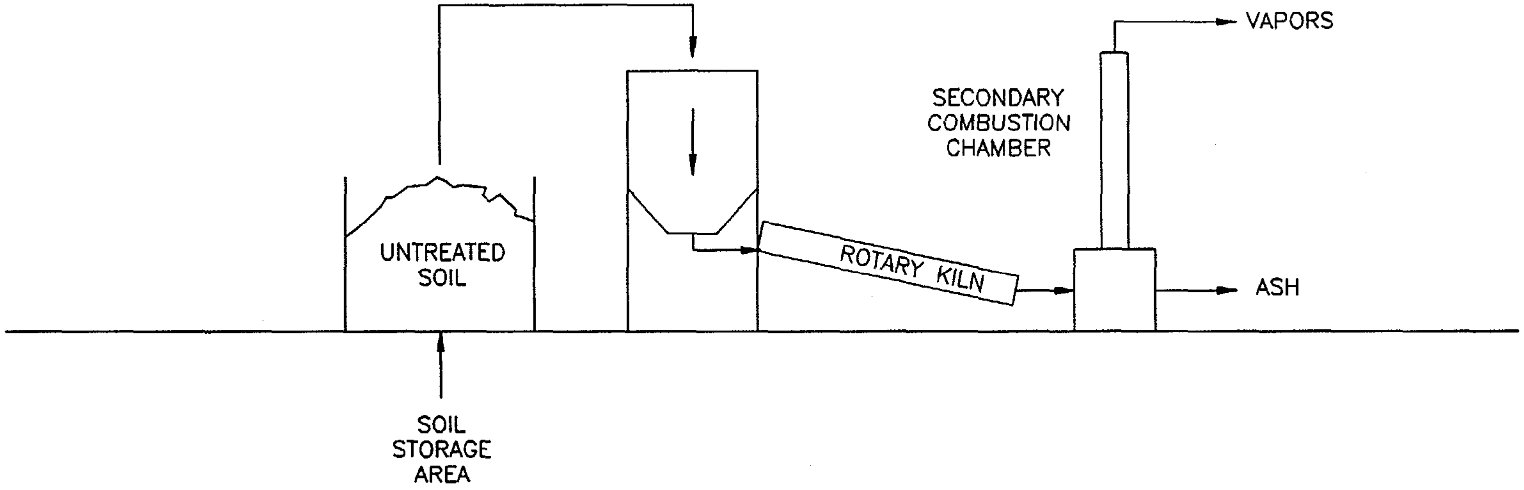

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FIGURE 4-10
INCINERATION SCHEMATIC
FEASIBILITY STUDY CTO-0177

MARINE CORPS CORPS, CAMP LEJEUNE
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4.2.2.4 Soil RAA No. 4: Off-Site Treatment/Disposal

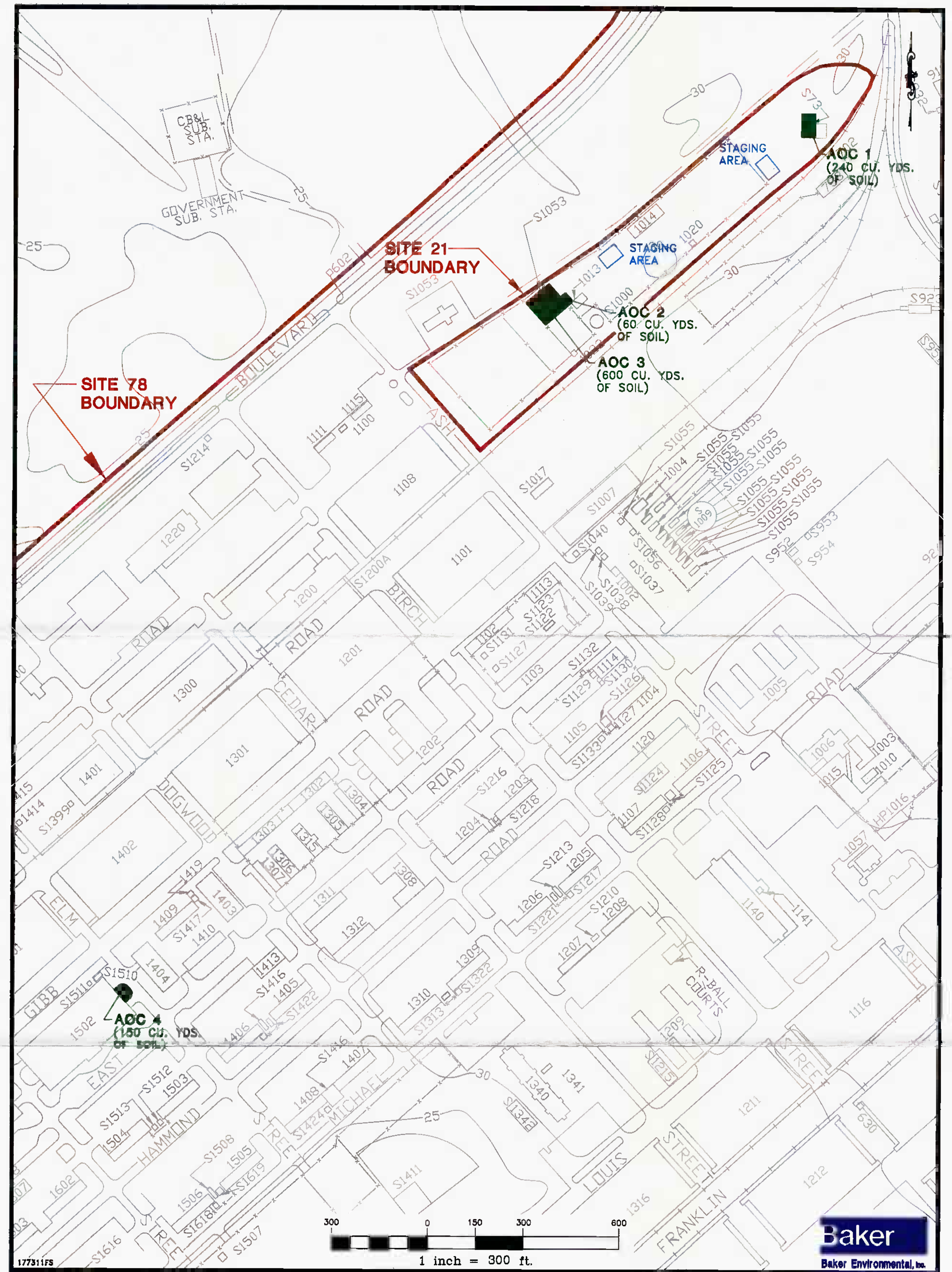
In general, Soil RAA No. 4 includes the excavation and off-site treatment/disposal of the contaminated soils from all of the Soil AOCs. The approximate area of soils to be excavated is the same as for Soil RAA No. 3 (refer to Figure 4-11). As shown on Table 4-2, the technologies/process options included under this RAA include soil excavation, grading, revegetation, and off-site treatment at a permitted facility. The main components of this alternative are described below.

Excavation - The same excavation measures discussed under Soil RAA No. 3 will be implemented with this RAA. The contaminated soils within both Soil AOCs will be excavated to a depth of two feet, placed into dump trucks, transported to an approved off-site treatment facility. The limits of the excavations will be defined by constituent concentrations in excess of the specified remediation goals. For FS estimating purposes, approximately 1,050 cubic yards of soil will be excavated. Confirmation soil sampling will be conducted during the excavation activities to determine the lateral and vertical extent of each soil excavation. The samples will be analyzed for the specific COCs and any other analyses required by the off-site facility (e.g., BTU value, moisture content, metals).

Note that prior to any excavation activities, site operating areas for decontamination will be constructed. The equipment decontamination area will be equipped with a steam cleaning pad with proper containment for rinse water. Air emissions will be monitored during soil remediation activities.

Treatment - Following excavation activities, the soils will be transported to the off-site treatment/disposal facility. Under this alternative, there are no residuals generated that will require additional treatment or management. The off-site facility will have to be capable of treating or disposing PCBs, and pesticides. The most limiting contaminant for finding an applicable treatment facility is PCBs. Based on the available data, the levels of PCBs detected at the operable unit are below the limit regulated under TSCA (i.e., 50 mg/kg), therefore it may be possible to landfill the soils in a Subtitle C Landfill. A landfill located in Pinewood, South Carolina may be capable of handling these soils.

If necessary, there are several commercially permitted PCB disposal/treatment companies throughout the United States. Based on the USEPA guidance document, Guidance on Remedial Actions for Superfund Sites with PCB Contamination, the closest commercially-



LEGEND

● AOC 1 APPROXIMATE LOCATION OF SOIL EXCEEDING REMEDIATION LEVELS. EXCAVATION TO TAKE PLACE WITHIN THIS AREA

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-11
SOIL RAA No. 4: OFF-SITE TREATMENT/DISPOSAL
OPERABLE UNIT NO. 1
FEASIBILITY STUDY CTO-0177

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permitted chemical waste landfill is the Chemical Waste Management Emelle, Alabama facility. The closest incinerator companies include: ENSCO in Little Rock, Arkansas; Rollins in Deer Park, Texas; and U.S. Department of Energy/Martin Marietta Energy Systems in Oak Ridge, Tennessee.

Surface Controls - The excavated areas will be graded to conform to the surrounding terrain. Clean fill may be added to the excavated areas as necessary to bring the areas up to grade. The excavated areas will be revegetated.

4.3 Screening of Alternatives

Typically, this section of the FS presents the initial screening of the potential RAAs. The objective of this screening is to make comparisons between similar alternatives, so that only the most promising ones are carried forward for further evaluation (USEPA, 1988a). This screening is an optional step in the FS process, and is usually conducted if there are too many RAAs to perform the detailed evaluation on. For OU NO. 1, the decision was made not to conduct this preliminary RAA screening step, and therefore, all of the developed RAAs will undergo the detailed evaluation presented in the next section.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

This section of the FS contains the detailed analysis of the set of RAAs developed in Section 4.0. This 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 (USEPA, 1988a).

The extent to which alternatives are assessed during this 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, 1988a).

The following nine evaluation criteria serve as the basis for conducting the detailed analysis:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume
5. Short-term effectiveness
6. Implementability
7. Cost
8. USEPA/State acceptance
9. Community acceptance

The first two criteria (referred to as the Threshold Criteria) relate directly to statutory findings; the next five criteria (referred to as the Primary Balancing Criteria) are the primary criteria upon which the analysis is based; and the final two criteria (referred to as the Modifying Criteria) are typically evaluated following comment on the RI/FS report and the proposed plan.

5.1 Individual Analysis of Alternatives

The individual analysis of the RAAs is presented in the following subsections. This analysis includes an assessment and a summary profile of each of the RAAs against the evaluation criteria, and a comparative analysis among the alternatives to assess the relative performance of each with respect to each of the evaluation criterion.

The cost estimates that have been developed for each of the alternatives include both capital and operational expenditures. The cost evaluation presents the net present worth (NPW) values for each of the alternatives such that the options can be easily compared. The accuracy of each cost estimate depends upon the assumptions made and the availability of costing information. The present worth costs were calculated assuming a 30-year operational period (based on USEPA guidance) for all of the alternatives, a five percent discount factor, and a zero percent inflation rate. All costs presented in the following sections have been updated to 1993 dollar values. Please note that cost estimates are presented in Appendix C.

For this FS, it has been assumed that groundwater monitoring will be conducted semiannually for the first five years of implementation followed by annual sampling for years 6 through 30. This assumption has been made for costing purposes only.

5.1.1 Groundwater RAAs

A brief description of each of the Groundwater RAAs along with the detailed assessment are presented below.

5.1.1.1 RAA No. 1: No Action

Description

Under the Groundwater No Action Alternative, the groundwater at the operable unit will remain as is. Excluding the IRA, no additional remedial actions will be implemented.

Assessment

Overall Protection of Human Health and the Environment

Under this alternative, the horizontal migration of the contaminated plumes (AOCs 1 and 5) will be mitigated (due to the IRA), thereby reducing the potential risks associated with groundwater exposure. In addition, if the aquifer use restrictions, deed restrictions, and monitoring program associated with the interim action are strictly enforced, this RAA will prevent groundwater ingestion via existing institutional controls. Since the IRA alternative reduces the continued migration (at least horizontally) of the contaminant plumes, the No Action alternative will provide protection to the environment via the existing IRA.

Therefore, this alternative provides protection to both human health and the environment.

Compliance With ARARs

Under the No Action Alternative, the groundwater quality in the aquifer will be improved by the initiation of the IRA. Since the IRA is only designed to be a containment option and does not remediate the source(s) of groundwater contamination, RAA No. 1 will exceed the Federal and/or North Carolina contaminant-specific ARARs established for the COCs. No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this RAA will reduce potential risks to human health for the following reasons: (1) the horizontal migration of the contaminant plumes will be mitigated by the IRA, and (2) the use of the groundwater as a potable water source near the operable unit will be restricted by the IRA.

In terms of the adequacy and reliability of controls used to manage treatment residuals or untreated wastes that will remain at the operable unit, the No Action Alternative does not include any type of controls.

Since this RAA is not designed to be a complete removal option, it will require USEPA's 5-year review to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume

Under RAA No. 1, the contamination within the outer boundaries of the shallow contamination within Groundwater AOCs 1 and 5 will be treated on site via one of two interim action treatment systems. The treatment systems include air stripping, carbon adsorption, oil/water separation, and metals removal. This RAA will then reduce the volume and toxicity of the contaminants in the surficial aquifer. The source areas will a continuing source of contamination. This RAA satisfies the statutory preference for treatment, even though the treatment is part of an interim action.

Short-Term Effectiveness

Since there are no additional remedial action activities associated with RAA No. 1, the risks to the community are not increased by the implementation of this RAA. In addition, there are no significant risks to workers with respect to implementation. Continued impacts to the environment will be posed by this alternative. The time required to meet the remedial response objectives for this alternative has been estimated to be 30 years.

Implementability

With respect to technical implementability, the No Action Alternative will be the easiest alternative to implement since no additional construction or operation activities will be conducted. This alternative does not include adequate monitoring of all of the Groundwater AOCs. Therefore, the effectiveness of this alternative cannot be monitored completely. In terms of administrative feasibility, this alternative should not require additional coordination with other agencies. The availability of services, materials, and/or technologies is not applicable to this alternative.

Cost

There are no capital costs or operation and maintenance (O&M) costs associated with this alternative. Therefore, the NPW is $0.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.1.2 RAA No. 2: Institutional Controls

Description

RAA No. 2 differs from the No Action Alternative by including the institutional controls of monitoring, ordinances, and access restrictions. Under this alternative, five existing monitoring wells and up to eight water supply wells (over and above the number of wells being monitored under the IRA) will be sampled on a semiannual basis.

The five shallow monitoring wells will include: 78GW15, 78GW39, 24GW08, 24GW09, and 24GW10. Both active and inactive water supply wells will be monitored. This will include HP-601, HP-602, HP-603, HP-608, HP-630, HP-634, HP-637, and HP-642. Additional wells may be added to the monitoring program, if necessary. The groundwater will be analyzed for TCL VOCs. Aquifer-use restrictions and deed restrictions will apply for the entire operable unit.

Assessment

Overall Protection of Human Health and the Environment

Under this alternative, the horizontal migration of the contaminated plumes (AOCs 1 and 5) will be mitigated (due to the IRA), thereby reducing the potential risks associated with groundwater exposure. In addition, if the aquifer use restrictions, deed restrictions, and monitoring program associated with both the IRA and with this final alternative are strictly enforced, this RAA will provide additional reduction in the potential for groundwater ingestion. Since this alternative reduces the continued migration (at least horizontally) of the contaminant plumes, it will provide protection to the environment.

Therefore, this alternative provides protection to both human health and the environment.

Compliance With ARARs

Under the Limited Action Alternative, the groundwater quality in the aquifer will be improved at the initiation of the IRA. The Federal and/or North Carolina contaminant-specific ARARs established for the COCs will not be met under this RAA since the IRA is only a containment option and not a source control option. No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this RAA will reduce potential risks to human health for the following reasons: (1) the horizontal migration of the contaminant plumes will be mitigated via the IRA, (2) the use of the groundwater as a potable water source near the operable unit will be restricted, and (3) the active and inactive supply wells in the area will be monitored.

In terms of the adequacy and reliability of controls used to manage treatment residuals or untreated wastes that will remain at the operable unit, the Limited Action Alternative provides additional monitoring at areas within the operable unit which currently exceed the remediation levels. This monitoring is an adequate and reliable control. In addition, the adequacy and reliability of the other institutional controls (i.e., aquifer-use and deed restrictions) are effective.

RAA No. 2 will require USEPA's 5-year review to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume

Under RAA No. 2, the contamination within the outer boundaries of the shallow contamination within Groundwater AOCs 1 and 5 will be treated on site via one of two interim action treatment systems. The treatment systems include air stripping, carbon adsorption, oil/water separation, and metals removal. This RAA will then reduce the volume and toxicity of the contaminants in the surficial aquifer. The source areas will be a continuing source of contamination. This RAA satisfies the statutory preference for treatment, even though the treatment is part of an interim action.

Short-Term Effectiveness

Since there are minimal additional remedial action activities associated with RAA No. 2 (additional groundwater monitoring), the risks to the community are not increased by the implementation of this RAA. In addition, there are no significant risks to workers with respect to implementation. Continued impacts to the environment will be posed by this alternative. The time required to meet the remedial response objectives for this alternative has been estimated to be 30 years.

Implementability

With respect to technical implementability, the RAA No. 2 will be easy to implement since the only additional activities are associated with sampling additional monitoring wells on a semiannual basis. Since additional wells are included in the monitoring plan for this alternative, the effectiveness of this RAA can be adequately monitored. In terms of administrative feasibility, this alternative should not require additional coordination with other agencies. All required services, materials, and/or technologies should be readily available.

Cost

The estimated capital cost associated with RAA No. 2 is $0. O&M costs of approximately $26,000 annually for the first five years are projected for the sampling included in the long-term groundwater monitoring plan (13 wells sampled semiannually). The O&M costs for years 6 through 30 are estimated to be $13,000 (13 wells sampled annually). Assuming an operating period of 30 years and an annual percentage rate of 5 percent, the NPW of this alternative is $260,000.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.1.3 RAA No. 3: Source Control (Interim Remedial Action Treatment System Extension)

Description

In general, RAA No. 3 includes the installation of three additional shallow extraction wells which will be connected to the interim action groundwater treatment systems. No additional remedial actions will be conducted on the lower portion of the surficial aquifer or the Castle Hayne aquifer under this alternative with the exception of monitoring. The institutional controls associated with RAA No. 2 will be implemented with the alternative.

Assessment

Overall Protection of Human Health and the Environment

Under this RAA, the sources of the groundwater contamination will be remediated with the installation of additional extraction wells. This source reduction implemented in conjunction with the interim action will provide overall remediation of the shallow groundwater contamination from within Groundwater AOCs 1 and 5. The deeper portions of the aquifer will be monitored to determine the effectiveness of the alternative. Overall potential risks to human health and the environment will be reduced when the contaminant levels meet the remediation levels.

If the aquifer-use restrictions, deed restrictions, and monitoring program are strictly enforced, this RAA will provide additional reduction in the potential for groundwater ingestion. This RAA reduces the continued contamination of the groundwater via source removal, therefore, it provides protection to the environment. Over time, the groundwater may be restored for future beneficial use.

Compliance With ARARs

Under RAA No. 3, the groundwater quality in the aquifer will be improved at the initiation of the IRA and the initiation of this RAA. The Federal and/or North Carolina contaminant-specific ARARs established for the COCs within the primary VOC plumes will be met under this RAA over time. A waiver will be required since organics and inorganics exceeding the

Federal and/or NC groundwater quality standards will remain untreated in some portions of the operable unit. This RAA will meet the location-specific and action-specific ARARs.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this RAA will reduce potential risks to human health for the following reasons: (1) the highly contaminated shallow groundwater contamination will be directly remediated; (2) the source of deep groundwater contamination will be mitigated; (3) the horizontal migration of the contaminant plumes will be mitigated; (4) the use of the groundwater as a potable water source near the operable unit will be restricted; and (5) the active and nonactive water supply wells will be monitored. Shallow groundwater that will not be actively remediated under this RAA poses no current risk since the shallow aquifer is not utilized for potable supply. In addition, future use of the shallow aquifer is unlikely due to poor transmissivity.

Groundwater pump and treat methods are both adequate and reliable to some extent. All of the technologies/process options included under the IRA treatment system are proven for treating the COCs in the groundwater. Technologies for completely extracting contaminants from groundwater are not proven (considering that contaminants may continue to leach from solids to groundwater below the vadose zone). At best, the technologies for extracting contaminated groundwater are reliable from the standpoint of collecting the water, but are not reliable for mitigating groundwater degradation due to the partitioning of contaminants in the water column (below the vadose zone). As with most equipment, there is a potential for replacement and/or repairs.

RAA No. 3 provides additional monitoring at areas within the operable unit which currently exceed the remediation levels. This monitoring is an adequate and reliable control. In addition, the adequacy and reliability of the other institutional controls (i.e., aquifer-use and deed restrictions) is effective.

This RAA will not require the USEPA's 5-year review once the remediation levels are met.

Reduction of Toxicity, Mobility, or Volume

Under RAA No. 3, the contamination within Groundwater AOCs 1 and 5 (shallow) will be treated on site via one of two interim action treatment systems. The treatment systems include air stripping, carbon adsorption, oil/water separation, and metals removal. This RAA will then reduce the toxicity and volume of the contaminants in the surficial aquifer. This RAA satisfies the statutory preference for treatment.

Short-Term Effectiveness

The risks to the community will be minimal due to a temporary increase in dust production and volatilization during the installation of underground piping for the groundwater extraction system. Workers will require additional protection during the installation and operation of the extraction/treatment system. Environmental impacts will include aquifer drawdown during groundwater extraction. No significant impacts to Beaver Dam Creek and Cogdels Creek are anticipated due to this drawdown. With respect to time to complete the remedial action, the groundwater pump and treat system will be operated for many years prior to achieving complete groundwater restoration. For costing purposes, 30 years of operation have been estimated.

Implementability

With respect to technical implementability, no significant difficulties are anticipated to construct or operate in the treatment system. However, extensive coordination with Base Public Works/Planning Department will be required. The interim remedial action pump and treat system was designed to allow for expansion. The monitoring wells have already been installed. The proposed monitoring program will indicate if the groundwater quality is significantly deteriorating. In terms of administrative feasibility, this RAA should not require additional coordination with other agencies. All required services, materials, and/or technologies should be readily available.

Cost

The estimated capital cost associated with RAA No. 3 is approximately $180,000. O&M costs of approximately $30,000 annually for the first five years are projected for the sampling included in the long-term groundwater monitoring plan (16 wells sampled semiannually). The O&M costs for years 6 through 30 are estimated to be $15,000 (16 wells sampled annually). Assuming an operating period of 30 years and an annual percentage rate of 5 percent, the NPW of this alternative is $460,000.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.1.4 RAA No. 4: Source Control (Air Sparging)

Description

In general, RAA No. 4 includes treatment of the source areas within Groundwater AOCs 1 and 5 via in situ air sparging. No additional remedial actions will be conducted on the lower portion of the surficial aquifer or the Castle Hayne aquifer under this alternative with the exception of monitoring. The institutional controls associated with RAA No. 2 will be implemented with the alternative.

Assessment

Overall Protection of Human Health and the Environment

Under this RAA, the sources of the groundwater contamination will be remediated with the installation of two in situ air sparging treatment systems. This source reduction implemented in conjunction with the interim action will provide overall remediation of the shallow groundwater contamination from within Groundwater AOCs 1 and 5. The deeper portions of the aquifer will be monitored. If the monitoring data indicates that water quality in the deeper portion of the aquifer are deteriorating, further action will be taken. Potential risks to human health and the environment would be reduced when the contaminant levels meet the remediation levels.

If the aquifer-use restrictions, deed restrictions, and monitoring program are strictly enforced, this RAA will provide additional reduction in the potential for groundwater ingestion. This RAA reduces the continued contamination of the groundwater via source removal, therefore, it provides protection to the environment. Over time, the groundwater may be restored for future beneficial use.

Compliance With ARARs

Under RAA No. 4, the groundwater quality in the aquifer will be improved at the initiation of the IRA and at the initiation of the air sparging systems. The Federal and/or North Carolina contaminant-specific ARARs established for the COCs within the primary VOC plumes will be met under this RAA over time. A waiver will be required since organics and inorganics exceeding Federal and/or NC groundwater standards will remain untreated in some portions of the operable unit. This RAA will meet the location-specific and action-specific ARARs.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this RAA will reduce potential risks to human health for the following reasons: (1) the highly contaminated shallow contamination will be directly remediated, (2) the source of deep groundwater contamination will be mitigated, (3) the horizontal migration of the contaminant plumes will be mitigated, (4) the use of the groundwater as a potable water source near the operable unit will be restricted, and (5) the active and nonactive water supply wells will be monitored. Shallow groundwater that will not be actively remediated under this RAA poses no current risk since the shallow aquifer is not utilized for potable supply. In addition, future use of the shallow aquifer is unlikely due to poor transmissivity.

Air sparging is an emerging technology which has only recently gained recognition as being a potential remediation alternative for VOC contaminated aquifers and soils. A pilot test study will be required to determine how effective air sparging may be at OU No. 1. In addition, there are several concerns with respect to air sparging. First, if low permeable soil constricts vertical air flow, sparging can then push the dissolved contamination horizontally downgradient. In low permeable/heterogeneous formations, sparging may require a groundwater recovery system to prevent the spread of dissolved contamination. Water table mounding can result from air sparging which in turn can also increase downgradient dissolved contamination. Another potential danger of air sparging is accelerated vapor travel. Exhausted air sparging vapors can be drawn into nearby building basements. There are numerous buildings within Site 78 which could be effected by this manner.

RAA No. 4 provides additional monitoring at areas within the operable unit which currently exceed the remediation levels. This monitoring is an adequate and reliable control. In addition, the adequacy and reliability of the other institutional controls (i.e., aquifer-use and deed restrictions) is effective. This RAA will not require the USEPA's 5-year review once the remediation levels are met.

Reduction of Toxicity, Mobility, or Volume

Under RAA No. 4, the contamination within Groundwater AOCs 1 and 5 (shallow) will be treated on site via in situ air sparging. In order to be most effective, a soil vapor extraction system will be included as part of the air sparging treatment system design. An air sparging/vapor extraction unit will be installed within both Groundwater AOC 1 and AOC 5. This RAA will then reduce the toxicity and volume of the contaminants in the surficial aquifer. This RAA satisfies the statutory preference for treatment.

Short-Term Effectiveness

The risks to the community will be slightly increased due to a temporary increase in volatilization during the installation of the sparging/venting systems and during the treatment system operation. Workers will require additional protection during the installation and operation of the sparging/venting systems. Air sparging does not generate a treated water effluent that requires discharge. Environmental impacts will include uncontrolled migration of vapors caused by the treatment system. These impacts should be minimal since a soil vapor extraction system will be used in conjunction with the air sparging system. With respect to time to complete the remedial action, remediation via air sparging has been reportedly quicker than with conventional pump and treat methods. For costing purposes only, 5 years of operation has been estimated. After 5 years, the effectiveness of this treatment method will be evaluated. Another option may be selected if the contaminated groundwater has not been remediated within this time.

Implementability

With respect to technical implementability, no significant difficulties are anticipated to construct or operate in the treatment system. However, extensive coordination with Base Public Works/Planning Department will be required. If necessary, the sparging system could be easily expanded. The monitoring wells have already been installed. The proposed monitoring program will indicate if the groundwater quality is significantly deteriorating. In terms of administrative feasibility, this RAA should not require additional coordination with other agencies. All required services, materials, and/or technologies should be readily available. Note that air sparging is a new technology which has been gaining use. It has typically been used for the remediation of fuel and solvent related contamination.

Cost

The estimated capital cost associated with RAA No. 4 is approximately $230,000. O&M costs of approximately $110,000 annually for the first five years are projected for the sampling included in the long-term groundwater monitoring plan and for the operation of the air sparging/venting systems. No O&M costs have been included for years 6 through 20 since it is assumed that the remediation goals will be met by this time. Assuming an operating period of 5 years and an annual percentage rate of 5 percent, the NPW of this alternative is $690,000.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.1.5 RAA No. 5: Source Control and Vertical Containment

Description

RAA No. 5 includes the installation of three additional shallow extraction wells and two deep extraction wells which will all be connected to the interim action groundwater treatment systems. This alternative will be both a source control and a vertical containment option. The institutional controls associated with RAA No. 2 will be implemented with the alternative.

Assessment

Overall Protection of Human Health and the Environment

Under this RAA, the sources of the groundwater contamination will be remediated with the installation of additional extraction wells. This source reduction implemented in conjunction with the interim action will provide overall remediation of the shallow groundwater contamination and the deeper contamination from within Groundwater AOCs 1 and 5. Potential risks to human health and the environment will be reduced when the remediation levels are met.

If the aquifer-use restrictions, deed restrictions, and monitoring program are strictly enforced, this RAA will provide additional reduction in the potential for groundwater ingestion. This RAA reduces the continued contamination of the groundwater via source removal and containment, therefore, it provides protection to the environment. Over time, the groundwater may be restored for future beneficial use.

Compliance With ARARs

Under RAA No. 5, the groundwater quality in the aquifer will be improved at the initiation of the IRA and the initiation of this RAA. The Federal and/or North Carolina contaminant-specific ARARs established for the COCs within the primary VOC plumes will be met under this RAA over time. A waiver will be required since organics and inorganics exceeding the Federal and/or NC groundwater quality standards will remain untreated in some portions of the operable unit. This RAA will meet the location-specific and action-specific ARARs.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this RAA will reduce potential risks to human health for the following reasons: (1) the highly contaminated shallow contamination will be directly remediated, (2) the source of deep groundwater contamination will be mitigated, (3) the horizontal migration of the contaminant plumes will be mitigated, (4) the use of the groundwater as a potable water source near the operable unit will be restricted, and (5) the active and nonactive water supply wells will be monitored. Shallow groundwater that will not be actively remediated under this RAA poses no current risk since the shallow aquifer is not utilized for potable supply. In addition, future use of the shallow aquifer is unlikely due to poor transmissivity.

Groundwater pump and treat methods are both adequate and reliable to some extent. All of the technologies/process options included under the IRA treatment system are proven for treating the COCs in the groundwater. Technologies for completely extracting contaminants from groundwater are not proven (considering that contaminants may continue to leach from solids to groundwater below the vadose zone). At best, the technologies for extracting contaminated groundwater are reliable from the standpoint of collecting the water, but are not reliable for mitigating groundwater degradation due to the partitioning of contaminants in the water column (below the vadose zone). As with most equipment, there is a potential for replacement and/or repairs.

RAA No. 5 provides additional monitoring at areas within the operable unit which currently exceed the remediation levels. This monitoring is an adequate and reliable control. In addition, the adequacy and reliability of the other institutional controls (i.e., aquifer-use and deed restrictions) is effective. This RAA will not require the USEPA's 5-year review once the remediation levels are met.

Reduction of Toxicity, Mobility, or Volume

Under RAA No. 5, the contamination within Groundwater AOCs 1 and 5 will be treated on site via one of two interim action treatment systems. The treatment systems include air stripping, carbon adsorption, oil/water separation, and metals removal. Initially, this RAA will reduce the toxicity and volume of the contaminants in the surficial aquifer. It is important to note that RAA No. 5 may actually increase the mobility of the VOC contamination in the surficial aquifer since the RAA includes the installation and operation of deeper extraction wells. These wells may drawdown the more contaminated portions of the aquifer into the deeper zones. This RAA satisfies the statutory preference for treatment.

Short-Term Effectiveness

The risks to the community will be minimal due to a temporary increase in dust production and volatilization during the installation of underground piping for the groundwater extraction system. Workers will require additional protection during the installation and operation of the extraction/treatment system. Environmental impacts will include aquifer drawdown during groundwater extraction. No significant impacts to Beaver Dam Creek and Cogdels Creek are anticipated due to this draw down. With respect to time to complete the remedial action, the groundwater pump and treat system will be operated for many years prior to achieving complete groundwater restoration. For costing purposes, 30 years of operation has been estimated.

Implementability

With respect to technical implementability, no significant difficulties are anticipated to construct or operate in the treatment system. However, extensive coordination with Base Public Works/Planning Department will be required. If necessary, the extraction system could be easily expanded. The monitoring wells have already been installed. The proposed monitoring program will indicate if the groundwater quality is significantly deteriorating. In terms of administrative feasibility, this RAA should not require additional coordination with other agencies. All required services, materials, and/or technologies should be readily available.

Cost

The estimated capital cost associated with RAA No. 5 is approximately $310,000. O&M costs of approximately $32,000 annually for the first five years are projected for the sampling included in the long-term groundwater monitoring plan (18 wells sampled semiannually). The O&M costs for years 6 through 30 are estimated to be $16,000 (18 wells sampled annually). Assuming an operating period of 30 years and an annual percentage rate of 5 percent, the NPW of this alternative is $615,000.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.2 Soil RAAs

The soil areas of concern within OU No. 1 are Site 21 and Site 78. The detailed evaluation of the four soil RAAs to address these AOCs is presented below.

5.1.2.1 RAA No. 1: No Action

Description

Under Soil RAA No. 1 no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants in the soil. The No Action RAA is required by the NCP to provide a baseline for comparison with other soil alternatives that provide a greater level of response. Soil RAA No. 1 involves leaving the contaminated soils which exceed the remediation levels in place.

Assessment

Overall Protection of Human Health and the Environment

Under this alternative, the existing contamination in the soil that exceeds the remediation levels will have the potential for further migration both horizontally and vertically. Therefore, this alternative does not provide for any protection to human health or the environment.

Compliance With ARARs

Under the No Action Alternative, the soils will potentially exceed the remediation level established for PCBs and pesticides in soil. No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence

In terms of the magnitude of residual risks remaining at the operable unit, this alternative will not reduce any potential risks present at the sites with respect to the contaminants in the soils.

In terms of the adequacy and reliability of controls used to manage treatment residuals or untreated wastes that will remain at the operable unit, Soil RAA No. 1 does not include any type of controls.

Soil RAA No. 1 will require USEPA's 5-year review to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume

No form of treatment is included under the No Action Alternative. Therefore, no soils are expected to be destroyed or reduced under this RAA. This RAA does not satisfy the statutory preference for treatment.

Short-Term Effectiveness

Since there are no remedial action activities associated with RAA No. 1, the risks to the community are not increased by the implementation of this RAA. In addition, there are no significant risks to workers. The current impacts from the existing conditions to the environment will continue. The time required to meet the remedial response objectives can not be estimated.

Implementability

With respect to technical implementability, RAA No. 1 is the easiest alternative to implement since there are no construction or operation activities. This RAA does not include actions to monitor its effectiveness. In terms of administrative feasibility, this alternative should not require coordination with other agencies following the ROD (i.e., no approvals are necessary). The availability of services, materials, and/or technologies is not applicable to this alternative.

Cost

There are no capital costs or O&M costs associated with this alternative. Therefore, the NPW is $0.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.2.2 RAA No. 2: Capping

Description

RAA No. 2 involves placing a concrete or asphalt cap over the contaminated soil areas at OU No. 1. The technologies/process options under this RAA include monitoring, deed restrictions, fencing, capping, grading, and revegetation. The principal objectives of this RAA are to prevent the potential for direct physical contact with the contaminated soils, and to minimize the potential for the migration of contaminants by infiltration and overland transport.

Assessment

Overall Protection of Human Health and the Environment

Soil RAA No. 2 provides protection to human health and to the environment in the form of reducing the potential for direct contact with the contaminated soil and reducing (to a limited extent) the mobility of the contaminated soil.

Compliance With ARARs

Under this alternative, contaminated soil exceeding the remediation levels will remain at the operable unit, and they will not be treated. Therefore, the contaminant-specific ARARs will not be met. Location-specific and action-specific ARARs will be met.

Long-Term Effectiveness and Permanence

As long as the caps are maintained, potential risks due to exposure and migration to the contaminated soils is reduced. Because the contaminated soil is only contained, the inherent hazards related to the contamination still exist to some degree under this RAA. However, the cap can be both adequate and reliable if it is maintained.

Since the contaminated soils will remain on site, Soil RAA No. 2 will require USEPA's 5-year review to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume

No treatment is included under this RAA, therefore, no reduction in the toxicity or volume of the contaminated soil will occur. This alternative will reduce the mobility of soil contaminants by design of the caps (concrete or asphalt cover). This RAA does not satisfy the statutory preference for treatment, but does meet the criteria for consideration of at least one containment alternative.

Short-Term Effectiveness

There will be a temporary increase in the risks to the community/base personnel during the grading of the soils and the installation of the caps. Worker's protection against dermal contact particulates will be required during the grading and cap installation activities. Once the caps are in place, minimal additional risks are anticipated to the community or to workers.

No additional environmental impacts are expected with respect to implementing this alternative.

The time to complete this remedial action is estimated to be within one year for the construction of the caps. A 30 year monitoring program has been assumed.

Implementability

With respect to technical feasibility, this alternative should be easily implemented. The caps are simple to construct and maintain. The groundwater monitoring included under this RAA will provide notice of failure before significant migration and exposure occurs.

In terms of administrative feasibility, this alternative should require minimal coordination with other agencies following the ROD. No problems with the availability of required materials and/or equipment are anticipated.

Cost

The estimated capital cost associated with RAA No. 2 is approximately $260,000. O&M costs of approximately $60,000 annually are projected for the maintenance and inspections of the cap and for the sampling included in the long-term groundwater monitoring plan. Assuming an operating period of 30 years and an annual percentage rate of 5 percent, the NPW of this alternative is $1.2 million.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.2.3 RAA No. 3: On-Site Treatment

Description

Soil RAA No. 3 includes the excavation and treatment of soil from the Soil AOCs via on-site treatment. The technologies/process options included with this RAA include soil excavation, grading, revegetation, fencing, and on-site treatment. The on-site treatment options may include either chemical dechlorination (PCBs only) or incineration.

Assessment

Overall Protection of Human Health and the Environment

This alternative will provide overall protection to human health and to the environment since the contaminated soils from the various areas of concern will be excavated, treated, and disposed of properly. Therefore, the potential risks associated with exposure to the contaminated soils is eliminated.

Compliance With ARARs

All chemical-specific, action-specific, and location-specific ARARs will be met by this alternative.

Long-Term Effectiveness and Permanence

Following the completion of the RAA, there should be no significant risks (with respect to soil contamination) remaining at the site since the contaminated soils will be removed from the AOCs and treated.

Either treatment technology (dechlorination or incineration) will result in this RAA being adequate for treating PCBs. Chemical dechlorination may not be effective for pesticides. The reliability of either of the two treatment options is high, but bench or pilot scale treatability studies are required to determine final treatment levels. This alternative may be an effective and permanent option. A 5-year review will not be necessary with this RAA unless the treatment process takes longer than 5 years.

Reduction of Toxicity, Mobility, or Volume

Significant reduction in the toxicity, mobility, and volume of toxic compounds will occur with the implementation of this RAA. Both treatment options are irreversible methods. The level of this RAA is that no residuals with concentrations exceeding the remediation level will remain within the soil at the completion of the remedial action. Pilot and/or bench-scale testing will be required to ensure that the remediation levels are feasible. This RAA satisfies the statutory preference for treatment.

Short-Term Effectiveness

There will be a temporary increase in the risks to the community during the excavation of the soils and the operation of the treatment systems. Workers protection against dermal contact and inhalation will be required during the excavation and treatment operation activities.

With respect to environmental impacts, incineration may impact air quality (i.e., odors) although they will be designed to meet emission standards.

Once implemented, this alternative will immediately reduce the levels of the COCs in the soils. The time to obtain the remedial objectives is estimated to be within one year.

Implementability

If incineration is selected, the technical intent of an incineration permit must be demonstrated. In addition, this RAA will require coordination with other agencies for meeting the intent of an air permit. The availability of a mobile incinerator may present a problem.

Dechlorination equipment and material should be readily available. Both treatment options will required trained operators.

Cost

Cost estimates have been calculated for both treatment options:

- Option A - On-site incineration of soils from all of the AOCs at OU No. 1
- Option B - Chemical dechlorination of soils from all of the AOCs at OU No. 1

The estimated capital costs for Option A and Option B are $650,000 and $1.4 million, respectively. No long-term monitoring will be required since the COCs will be excavated and treated. No O&M costs have been included since the duration of the remedial activity is anticipated to be less than one year. Therefore, the NPW values are the same as the capital costs. The details of the cost evaluation are presented in Appendix C.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.1.2.4 RAA No. 4: Off-Site Treatment/Disposal

Description

In general, Soil RAA No. 4 includes the excavation and off-site treatment/disposal of the contaminated soils from the Soil AOCs. The approximate area of soils to be excavated and treated is the same as for Soil RAA No. 3. The technologies/process options included under this RAA include soil excavation, grading, revegetation, and off-site treatment and/or disposal at a permitted facility.

Assessment

Overall Protection of Human Health and the Environment

This alternative will provide overall protection to human health and to the environment since the contaminated AOC soils will be excavated and removed from the sites. Therefore, the potential risks associated with the contaminated soils is eliminated.

Compliance With ARARs

All chemical-specific, action-specific, and location-specific ARARs will be met by this alternative.

Long-Term Effectiveness and Permanence

Following the completion of the RAA, there should be a reduction in overall human health and environmental risks (with respect to soil contamination) remaining at the site since the contaminated soils at the various AOCs will be removed.

Off-site treatment/disposal is both adequate and reliable. This alternative is an effective and permanent option. No 5-year review is necessary with this RAA.

Reduction of Toxicity, Mobility, or Volume

Significant reduction in the toxicity, mobility, and volume of toxic compounds will occur with the implementation of this RAA. Excavation is an irreversible option. No residuals with concentrations exceeding the remediation levels will remain within the soil at the completion of the remedial action. This RAA satisfies the statutory preference for treatment.

Short-Term Effectiveness

There will be a temporary increase in the risks to the community during the excavation of the soils. Worker's protection against dermal contact and inhalation will be required during the excavation activities. Minimal impacts to the environment are expected under this RAA.

Once implemented, this alternative will immediately reduce the levels of the COCs in the soils. The time to obtain the remedial objectives is estimated to be several months to a year following the design of this action (i.e., as soon as all of the excavated soils are excavated and removed from the sites).

Implementability

Long-term monitoring is not required for this RAA.

In terms of administrative feasibility, this alternative will require coordination with other agencies such as the Department of Transportation for the off-site transport of the soils. USEPA and State approval of the off-site facility would be required.

No problems with the availability of the excavation equipment are anticipated. The availability and capacity of a permitted facility capable of treating PCB-contaminated and pesticide-contaminated soils may present a problem in implementing this alternative in a timely manner.

Cost

The estimated capital cost associated with this RAA is approximately $480,000 for disposal and $1.3 million for treatment. No O&M costs have been included with this alternative since the duration of the remedial activity is anticipated to be less than one year. No long-term monitoring will be required since the COCs will be removed from the sites. Since there are no O&M costs for this alternative, the NPW is the same as the capital costs: $480,000 and $1.3 million.

USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

Community Acceptance

To be assessed following the public comment period.

5.2 Comparative Analysis

This FS has identified and evaluated a range of RAAs potentially applicable to the soil and groundwater concerns at OU No. 1. Tables 5-1 and 5-2 present a summary of this evaluation for groundwater and soil, respectively. A comparative analysis in which the alternatives are evaluated in relation to one another with respect to the nine evaluation criteria is presented below. The comparison is presented per media. The purpose of this analysis is to identify the relative advantages and disadvantages of each RAA.

5.2.1 Comparative Analysis of Groundwater RAAs

5.2.1.1 Overall Protection of Human Health and the Environment

All of the groundwater RAAs evaluated in the detailed evaluation will provide adequate protection of human health and the environment. At a minimum, all of the RAAs will contain the horizontal migration of the shallow contamination within Groundwater AOCs 1 and 5. In addition, all of the RAAs provide protection via applying aquifer-use and deed restrictions. RAA Nos. 3, 4, and 5 provide additional protection since the primary sources of contamination are remediated.

Although, initially RAA No. 5 appears to present a more complete remediation plan (i.e., remediating both the shallow and deep portions of the aquifer), it may not provide the most protection to human health and the environment. Since the primary source of groundwater

TABLE 5-1

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
OVERALL PROTECTIVENESS					
• Human Health Protection	Potential risks associated with groundwater exposure are mitigated due to the interim remedial action and long-term monitoring program.	Potential risks associated with groundwater exposure are mitigated due to the interim remedial action and long-term monitoring program.	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).	Although treatment is employed, aquifer is not usable until remediation levels are met. The alternative is protective of public health by implementing institutional controls (i.e., monitoring and restrictions on potable supply wells).
• Environmental Protection	Migration of contamination is reduced via the interim remedial action.	Migration of contamination is reduced via the interim remedial action.	Migration of contaminated groundwater is reduced by pump and treat.	Migration of contaminated groundwater is reduced by in situ treatment.	Migration of contaminated groundwater is reduced by pump and treat.
COMPLIANCE WITH ARARS					
• Chemical-Specific ARARs	Will exceed Federal and/or NC groundwater quality ARARs.	Will exceed Federal and/or NC groundwater quality ARARs.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	A waiver will be required since organics and inorganics above State and Federal standards will remain untreated in some portions of the operable unit. These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.
• Location-Specific ARARs	Not applicable.	Not applicable.	Will meet location-specific ARARs.	Will meet location-specific ARARs.	Will meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Not applicable.	Will meet action-specific ARARs.	Will meet action-specific ARARs.	Will meet action-specific ARARs.

Revised July 22, 1994

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	Risk reduced via the interim remedial action.	Risk reduced via the interim remedial action.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.	Shallow groundwater in the operable unit that will not be addressed pose no current risk since the shallow aquifer is not utilized for potable supply. Future use of the shallow aquifer is unlikely due to poor transmissivity. The long term effectiveness of pump and treat is unknown. Contaminant levels may decrease in time, but could potentially increase if the extraction/treatment system is shut down. Institutional controls will prevent residual risk.
• Adequacy and Reliability of Controls	Not applicable - no additional controls.	Additional monitoring is adequate to determine effectiveness of alternative.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.	Institutional controls are reliable to prevent potential human health exposure. Periodic operation and maintenance and monitoring will ensure that the treatment system is effective.
• Need for 5-year Review	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review not needed once remediation levels are met.	Review not needed once remediation levels are met.	Review not needed once remediation levels are met.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	No additional treatment other than the IRA treatment system. The IRA treatment train consisting of air striping, activated carbon, and metals removal.	No additional treatment other than the IRA treatment system. The IRA treatment train consisting of air striping, activated carbon, and metals removal.	Treatment train for metals removal, air stripping, and activated carbon.	In addition to IRA treatment train, includes air sparging and soil vapor extraction.	Treatment train for metals removal, air stripping, and activated carbon.
• Amount Destroyed or Treated	Contaminants in groundwater at the outer edges of two plumes.	Contaminants in groundwater at the outer edges of two plumes.	Majority of contaminants in groundwater plumes.	Majority of contaminants in groundwater.	Majority of contaminant in groundwater plumes.
• Reduction of Toxicity, Mobility or Volume	Reduced volume and toxicity of contaminated groundwater via the IRA.	Reduced volume and toxicity of contaminated groundwater via the IRA.	Reduced volume and toxicity of contaminated groundwater.	Reduced volume and toxicity of contaminated groundwater.	The mobility of the VOC contamination in the shallow aquifer may be increased due to operating extraction wells in the deeper zones.
• Residuals Remaining After Treatment	Source areas will be a continuing source of contamination.	Source areas will be a continuing source of contamination.	Potentially minimal residuals after goals are met.	Potentially minimal residuals after goals are met.	Potentially minimal residuals after goals are met.
• Statutory Preference for Treatment	Satisfied via the IRA.	Satisfied via the IRA.	Satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS					
• Community Protection	Risks to community not increased by remedy implementation.	Risks to community not increased by remedy implementation.	Minimal, if any, risks during extraction and treatment.	Possible migration of toxic vapors, should be controlled with the soil vapor extraction systems.	Minimal, if any, risks during extraction and treatment.
• Worker Protection	No significant risk to workers.	No significant risk to workers.	Protection required during treatment.	Protection required during treatment.	Protection required during treatment.
• Environmental Impacts	Continued impacts from existing conditions.	Continued impacts from existing conditions.	Aquifer drawdown during extraction. This is not expected to be an environmental concern.	Possible migration of toxic vapors, should be controlled with the soil vapor extraction systems.	Aquifer drawdown during extraction. This is not expected to be an environmental concern. Potential vertical migration of contaminants may occur via remediation of the Castle Hayne aquifer.
• Time Until Action is Complete	Estimated 30 years.	Estimated 30 years.	Estimated 30 years.	Estimated 5 years.	Estimated 30 years.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Source Control (Interim Remedial Action Treatment System Extension)	RAA No. 4 Source Control (Air Sparging)	RAA No. 5 Source Control and Vertical Containment
IMPLEMENTABILITY					
• Ability to Construct and Operate; Reliability	No construction or operation activities.	No construction or operation activities.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.	No significant difficulties are anticipated to construct or operate the system. Construction within a highly-developed area like the HPIA will pose minor problems due to infrastructure. Extensive coordination with Base Public Works/Planning Department will be required.
• Ability to Monitor Effectiveness	No monitoring. Failure to detect contamination will result in potential ingestion of contaminated groundwater.	Proposed monitoring will give notice of failure before significant exposure occurs.	Adequate system monitoring.	Adequate system monitoring.	Adequate system monitoring.
• Availability of Services and Capacities; Equipment	None required.	None required.	Services and materials are available.	Services and materials are available.	Services and materials are available.
COSTS NPW	$0	$260,000	$460,000	$690,000	$615,000

TABLE 5-2

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
OVERALL PROTECTIVENESS				
• Human Health Protection	No reduction in risk.	Would reduce potential for human exposure.	Reduces overall risk to human health.	Reduces overall risk to human health.
• Environmental Protection	No reduction in risk to ecological receptors.	Would reduce potential for exposure and migration.	Reduces overall risk to ecological receptors.	Reduces overall risk to ecological receptors.
COMPLIANCE WITH ARARs				
• Chemical-Specific ARARs	Will exceed ARARs.	Will exceed ARARs.	Will meet contaminant-specific ARARs.	Will meet ARARs.
• Location-Specific ARARs	Not applicable.	Will meet location-specific ARARs.	Will meet location-specific ARARs.	Will meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Will meet action-specific ARARs.	Will meet action-specific ARARs.	Will meet action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE				
• Magnitude of Residual Risk	Source has not been removed. Potential risks not reduced.	Contaminated soils are not removed from the site, but potential risk due to exposure to COCs are reduced as long as the cap is maintained.	Soil AOCs will be remediated. Remaining contaminants do not present an unacceptable human health or environmental risk.	Contaminated soil is removed from the site. No residual wastes will remain onsite.
• Adequacy and Reliability of Controls	Not applicable - no controls.	Multilayered cap controls contaminated soil - can be a reliable option if maintained properly.	Soil will be treated to meet risk-based action levels. Treated soil will be analyzed to ensure that remediation levels are met.	No residual wastes will remain onsite. Wastes will be treated offsite and disposed of in a suitable landfill.
• Need for 5-year Review	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review not needed since contaminated soil treated.	Review not needed since contaminated soil removed.

TABLE 5-2 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT				
• Treatment Process Used	None.	None.	Chemical dechlorination, or incineration.	Off-site treatment.
• Amount Destroyed or Treated	None.	None.	Majority of soil COCs.	Majority of soil COCs.
• Reduction of Toxicity, Mobility or Volume	None.	No reduction in toxicity or volume. However; capping will mitigate contaminant migration.	Reduction in toxicity, mobility and volume of contaminated soil.	Reduction in toxicity, mobility and volume of contaminated soil.
• Residuals Remaining After Treatment	Not applicable - no treatment.	Residuals are capped.	Residuals remaining onsite will be below remediation goals.	No residuals will remain onsite.
• Statutory Preference for Treatment	Not satisfied.	Not satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS				
• Community Protection	Risks to community not increased by remedy implementation.	Temporary potential risks during soil grading and cap installation activities.	Limited potential risks during soil excavation and treatment activities.	Limited potential risks during soil excavation and transport activities.
• Worker Protection	No significant risks to workers.	Temporary potential risks during soil grading and cap installation activities.	Potential risks during soil excavation and treatment activities.	Potential risks during excavation and transportation activities.
• Environmental Impacts	Continued impacts from existing conditions.	No additional environmental impacts.	Air quality and odors - but treatment system will be designed to meet standards.	No additional environmental impacts.
• Time Until Action is Complete	Not applicable.	Less than one year. Monitor for 30 years.	Less than one year.	Less than one year.

TABLE 5-2 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
FEASIBILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Capping	RAA No. 3 On-Site Treatment	RAA No. 4 Off-Site Treatment/Disposal
IMPLEMENTABILITY				
• Ability to Construct and Operate	No construction or operation activities.	Simple to construct and maintain. Requires materials handling procedures.	Requires soil excavation activities. Requires assembly of treatment systems.	Requires soil excavation activities. No other on-site operations.
• Ability to Monitor Effectiveness	No monitoring included.	Cap maintenance and groundwater monitoring will adequately monitor effectiveness.	Adequate system monitoring.	No monitoring other than confirmation soil sampling.
• Availability of Services and Capacities; Equipment	None required.	No special services or equipment required. Cap materials should be readily available.	Qualified vendors available to perform on-site treatment.	Off-site treatment and disposal facilities should have adequate capacity.
COSTS NPW	$0	$1.2 million	$650,000 (incineration) $1.4 million (dechlorination)	$480,000 (disposal) $1.3 million (treatment)

contamination is in the surficial aquifer, the operation of "deep" extraction wells could cause increased migration of the shallow VOCs into the Castle Hayne aquifer.

5.2.1.2 Compliance with ARARs

Groundwater RAA Nos. 1 and 2 will not meet the chemical-specific ARARs since these two RAAs are containment options and do not specifically remediate the source(s) of contamination. Groundwater RAA Nos. 3, 4, and 5 should be able to meet their respective Federal and State ARARs with respect to the primary VOC-contaminated plumes. A waiver will need to be invoked for other areas within the operable unit that exceed the ARARs. Note that attaining the chemical-specific ARARs for all of the groundwater COCs is technically impracticable from an engineering perspective. For instance, it would not be practicable to install extraction wells and associated piping at the three isolated well locations that slightly exceed state water quality standard for PCE. The time it takes to meet the chemical-specific ARARs will vary for each of the alternatives. Due to the complex nature of groundwater contamination, the time to reach the remediation levels cannot be determined.

5.2.1.3 Long-Term Effectiveness and Permanence

Risks will be reduced under all of the RAAs through the implementation of the IRA, institutional controls, and/or other forms of treatment. In time, RAA Nos. 3, 4, and 5 will be effective and permanent. All of the RAAs include treatment of the COCs in the groundwater aquifer. All of the RAAs will require a five year evaluation review to determine their effectiveness.

5.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

All of the RAAs will provide reduction of toxicity, mobility and/or volume of contaminants in the groundwater aquifer via treatment. All of the RAAs will utilize the IRA treatment system consisting of air stripping, carbon adsorption, oil/water separation, and metals removal. RAA No. 4 will also include air sparging/soil venting, a relatively new remedial technology. RAA Nos. 3 and 4 should provide for the greatest extent of reduction. RAA No. 5 may actually increase the mobility of the VOC contamination in the shallow portion of the aquifer since this alternative includes the installation and operation of deeper extraction wells. All of the RAAs will satisfy the statutory preference for treatment.

5.2.1.5 Short-Term Effectiveness

Risks to community and workers will not be increased with the implementation of RAA Nos. 1 and 2 since no additional site activities will be included (except for additional groundwater sampling for RAA No. 2). Under RAA Nos. 3 and 5, risks to the community and workers will be slightly increased due to the temporary increase in dust production and volatilization during the installation of the extra piping for the groundwater extraction/treatment systems. Additional aquifer drawdown will occur under RAA Nos. 3 and 5. This drawdown is not anticipated to affect Beaver Dam or Cogdels Creek. The discharge of the treated effluent to the Hadnot Point STP and ultimately to the New River is not expected to increase risks to the environment. Under RAA No. 4, there is a potential for the migration of contaminated vapors to off site areas. This is due to the fact the it is difficult to anticipate and control the movement of the vapors generated during in situ air sparging.

With respect to the time required to meet the remedial response objectives, for all of the RAAs, once implemented, it is expected that the alternatives will immediately reduce the levels of the contaminants in the groundwater. The time to reach the remedial response objectives would most likely be over 10 years for all of the RAAs. For purposes of this FS, it is estimated that RAA Nos. 1, 2, 3, and 5 will be implemented for at least 30 years and RAA No. 4 for 5 years.

5.2.1.6 Implementability

No additional construction, operation, or administrative activities other than the ones associated with the interim remedial action are associated with RAA No. 1. The only site activities associated with RAA No. 2 are additional groundwater sampling activities, which are easily performed. The implementation of RAA Nos. 3 and 5 should be relatively easy since they only require the installation of additional extraction wells and hook up to the interim remedial action treatment systems. RAA No. 3 will require the installation of three additional extraction wells (shallow) and their associated piping. RAA No. 5 will require the installation of three additional shallow extraction wells and two deeper extraction wells and their associated piping. RAA No. 4 may be the most difficult alternative to implement under this FS (primarily since the other "additional treatment" alternatives will only require hook up to an existing treatment system). RAA No. 4 will require a pilot study to determine the effectiveness of air sparging/soil vapor extraction at Site 78. In addition, this RAA will require equipment and experience that may not be as available as with conventional pump and treat methods.

5.2.1.7 Cost

In terms of NPW, the No Action Alternative (RAA No. 1) would be the least expensive RAA to implement, followed by RAA No. 2, RAA No. 3, RAA No. 5, and then RAA No. 4. The estimated NPW values in increasing order are $0 (RAA No. 1), $260,000 (RAA No. 2), $460,000 (RAA No. 3), $615,000 (RAA No. 5), and $690,000 (RAA No. 4).

5.2.1.8 USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

5.2.1.9 Community Acceptance

To be addressed following the public comment period.

5.2.2 Comparative Analysis of Soil RAAs

5.2.2.1 Overall Protection of Human Health and the Environment

All of the Soil RAAs, with the exception of the No Action RAA (No.1), provide some type of protection to human health and the environment. RAA No. 2 (Capping) provides protection in the form of reducing the potential for direct contact with the contaminated soil and reducing the mobility of the contaminated soil. RAA Nos. 3 and 4 provide protection through removing and/or treating the contaminated soils.

5.2.2.2 Compliance with ARARs

RAA Nos. 1 and 2 will not meet all of the chemical-specific ARARs for the soil COCs remaining at the sites. RAA Nos. 3 and 4 will meet all of the chemical-specific ARARs. Action-specific and location-specific ARARs should be met by all of the RAAs evaluated, if applicable.

5.2.2.3 Long-Term Effectiveness and Permanence

RAA No. 1 is not an effective or permanent alternative. RAA No. 2 will provide long-term effectiveness as long as the cap is maintained. RAA Nos. 3 and 4 provide the highest degree of long-term effectiveness and permanence since the contaminated soils are removed and/or treated.

RAA Nos. 1 and 2 will require a 5-year review. RAA No. 3 may require a 5-year review based on the duration of the treatment process. RAA No. 4 will not require the 5-year review.

5.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

No form of treatment is included under RAA Nos. 1 and 2. Even though RAA No. 2 does not implement any form of treatment, the contaminated soils will be capped. Treatment is included under the other RAAs. Therefore, these "treatment" RAAs will reduce the toxicity, mobility, and/or volume of the COCs through treatment.

RAA Nos. 1 and 2 do not satisfy the statutory preference for treatment, whereas the other RAAs do satisfy the preference.

5.2.2.5 Short-Term Effectiveness

Risks to community and workers are not increased with the implementation of RAA No. 1, but current impacts from existing conditions will continue to exist. Under RAA Nos. 2, 3, and 4 risks to the community and workers will be temporarily increased during soil grading and/or excavation activities. Risks will also be increased temporarily during the installation of the cap/cover (RAA No. 2). With respect to RAA No. 3, risks will be increased during the operation of the treatment options.

5.2.2.6 Implementability

With respect to implementability, RAA No. 1 would be the easiest alternative to implement since there are no activities associated with it. RAA No. 2 should be the next easiest to implement since the primary construction activities only require common earth construction equipment. RAA No. 4 may be more difficult to implement due to the unknown availability/capacity of an appropriate treatment and/or disposal facility. The implementability of RAA No. 3 is dependent on the availability of mobile treatment units.

5.2.2.7 Cost

No costs are associated with RAA No. 1. The estimated NPW of the other Soil RAAs, in increasing order are: $480,000 (RAA No. 4 - off-site disposal); $650,000 (RAA No. 3 - incineration); $1.2 million (RAA No. 2 - capping); $1.3 million (RAA No. 4 - off-site treatment); and $1.4 million (RAA No. 3 - chemical dechlorination).

5.2.2.8 USEPA/State Acceptance

To be assessed following USEPA/NC DEHNR review of the ROD.

5.2.2.9 Community Acceptance

To be assessed following the public comment period.

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APPENDIX A
ANALYTICAL DATA SUMMARY TABLES

SURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Acetone	300	1/9
Xylenes (Total)	1,100	1/9
Naphthalene	3,200	1/9
2-Methylnaphthalene	13,000	1/9
Fluorene	1,300	1/9
Phenanthrene	41 - 1,800	5/9
Anthracene	47	1/9
Fluoranthene	51 - 560	5/9
Pyrene	69 - 520	5/9
3,3'-Dichlorobenzidine	82	1/9
Benzo(a)anthracene	73 - 510	4/9
Chrysene	46 - 450	6/9
Bis(2-ethylhexyl)phthalate	51 - 650	2/9
Benzo(b)fluoranthene	80 - 560	5/9
Benzo(k)fluoranthene	48 - 320	5/9
Benzo(a)pyrene	60 - 310	5/9
Indeno(1,2,3-cd)pyrene	40 - 180	5/9
Dibenz(a,h)anthracene	62	1/9
Benzo(g,h,i)perylene	44 - 160	5/9
4,4'-DDE	4.5 - 160	12/27
4,4'-DDD	3.6 - 34,000	14/27
4,4'-DDT	15 - 4,100	11/27
Alpha-Chlordane	6.2 - 1,800	4/27
Gamma-Chlordane	4.6 - 2,200	6/27
PCB 1260	34 - 4,600	10/30

Notes: Concentrations expressed in microgram per kilogram (µg/kg)

SURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Surface Soil (0-6 inches)				
	Base-Specific Background Concentration Range(1)	Twice the Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Background
Aluminum	<90.5 - 1,490	2,980	1,120 - 7,320	9/9	4
Arsenic	<0.44 - 0.91	1.82	0.76 - 3.9	9/9	1
Barium	3.5 - 16.5	33	9.1 - 31.6	9/9	0
Beryllium	<0.06 - <0.22	0.44	0.21 - 0.22	4/9	0
Cadmium	<0.35 - <1.1	2.2	1	1/9	0
Calcium	108 - 10,700	21,400	14,000-183,000	9/9	7
Chromium	<0.06 - <3.2	6.4	5.8 - 19.9	9/9	7
Cobalt	<0.31 - <1.8	3.6	2.1 - 2.4	2/9	0
Copper	<1.1 - 3.1	6.2	3.1 - 16.3	9/9	2
Iron	160 - 1,020	2,040	2,030 - 6,730	9/9	8
Lead	2.0 - 20.4	40.8	10.9 - 252	9/9	3
Magnesium	<20.2 - 200	400	344 - 2,700	9/9	8
Manganese	<2.0 - 11.1	22.2	13.8 - 70	9/9	7
Mercury	<0.02 - <0.12	0.24	0.54	1/9	1
Nickel	<1.5 - <4.4	8.8	4.8 - 6	2/9	0
Potassium	54.5 - 102	204	121 - 451	9/9	6
Selenium	<0.31 - <1.0	2	0.32 - 0.59	6/9	0
Silver	<0.37 - 62	124	ND	0/9	0
Sodium	<9.4 - 67.5	135	67.8 - 429	9/9	5
Vanadium	<2.1 - 5.3	10.6	4.2 - 17.4	9/9	4
Zinc	<1.1 - 28.3	56.6	14.5 - 67.7	9/9	1

Notes: Concentrations expressed in milligram per kilogram (mg/kg).

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.

SURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Acetone	14 - 780	8/25
Styrene	5	1/25
2-Methylnaphthalene	110	1/25
Acenaphthene	68	1/25
Fluorene	47	1/25
Phenanthrene	380	1/25
Anthracene	73	1/25
Carbazole	36	1/25
Fluoranthene	39 - 520	4/25
Pyrene	57 - 870	3/25
Butyl Benzyl Phthalate	39	1/25
Benzo(a)anthracene	330	1/25
Chrysene	63 - 260	2/25
Bis(2-ethylhexyl)phthalate	36 - 60	2/25
Benzo(b)fluoranthene	91 - 350	2/25
Benzo(k)fluoranthene	140	1/25
Benzo(a)pyrene	240	1/25
Indeno(1,2,3-cd)pyrene	240	1/25
Benzo(g,h,i)perylene	140	1/25
Heptachlor	1.8	1/25
Heptachlor epoxide	5	1/25
Dieldren	4.1 - 13	5/25
4,4'-DDE	8.4 - 350	9/25
4,4'-DDD	4.9 - 130	9/25
4,4'-DDT	5.2 - 320	10/25
Alpha-chlordane	2.2 - 26	8/25
Gamma-chlordane	2.2 - 24	7/25
PCB 1254	85	1/25
PCB 1260	130	1/25

Notes: Concentrations expressed in microgram per kilogram (µg/kg)

SURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Surface Soil (0-6 inches)				
	Base-Specific Background Concentration Range(1)	Twice the Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Background
Aluminum	<90.5 - 1,490	2,980	88.2 - 18,700	38/38	22
Arsenic	<0.44 - 0.91	1.82	0.43 - 35.2	31/38	6
Barium	3.5 - 16.5	33	4.4 - 502	38/38	11
Beryllium	<0.06 - <0.22	0.44	0.2 - 4	18/38	5
Cadmium	<0.35 - <1.1	2.2	1.6 - 1.9	2/38	0
Calcium	108 - 10,700	21,400	73.2 - 356,000	37/38	9
Chromium	<0.06 - <3.2	6.4	2 - 23	30/38	14
Cobalt	<0.31 - <1.8	3.6	2 - 14.4	7/38	4
Copper	<1.1 - 3.1	6.2	0.45 - 314	38/38	9
Iron	160 - 1,020	2,040	249 - 13,900	38/38	18
Lead	2.0 - 20.4	40.8	1.5 - 393	38/38	2
Magnesium	<20.2 - 200	400	22.7 - 3,330	38/38	12
Manganese	<2.0 - 11.1	22.2	3 - 93.4	38/38	14
Mercury	<0.02 - <0.12	0.24	0.15 - 1.2	7/38	3
Nickel	<1.5 - <4.4	8.8	6 - 80.8	6/38	5
Potassium	54.5 - 102	204	24.8 - 1,890	36/38	14
Selenium	<0.31 - <1.0	2	0.25 - 18	18/38	4
Silver	<0.37 - 62	124	1.3	1/38	0
Sodium	<9.4 - 67.5	135	16.5 - 373	36/38	7
Vanadium	<2.1 - 5.3	10.6	1.3 - 634	38/38	11
Zinc	<1.1 - 28.3	56.6	2.4 - 93.8	36/38	3

Notes: Concentrations expressed in milligram per kilogram (mg/kg).

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Subsurface Soil	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Methylene Chloride	12	1/15
Acetone	470	1/15
Toluene	37	1/15
Ethylbenzene	570	1/15
Xylenes (Total)	3,400	1/15
Naphthalene	2,100	1/15
2-Methylnaphthalene	10,000	1/15
Bis(2-ethylhexyl)phthalate	57 - 190	3/15
4,4'-DDD	5.7 - 2,800	3/33
4,4'-DDT	4.6 - 12	3/33
Alpha-Chlordane	59	1/33
Gamma-Chlordane	90	1/33

Notes: Concentrations expressed in microgram per kilogram (µg/kg)

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Subsurface Soil (6 inches and below)				
	Base-Specific Background Concentration Range(1)	Twice the Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Background
Aluminum	672 - 10,200	20,400	1,150 - 14,500	15/15	0
Arsenic	<0.47 - <0.65	1.3	0.48 - 5.2	15/15	8
Barium	<4.0 - 10.9	22	2.1 - 15.6	15/15	0
Beryllium	<0.05 - <0.23	0.46	0.23 - 0.26	8/15	0
Cadmium	<0.34 - <1.2	2.4	1.5	1/15	0
Calcium	<10.7 - 81.3	163	44.6 - 37,200	14/15	8
Chromium	<3.2 - 8.7	17	2.6 - 19.7	15/15	1
Cobalt	<0.35 - <1.9	4	1.8 - 2.2	4/15	0
Copper	<0.47 - 1.2	2.4	0.96 - 3.4	15/15	2
Iron	126 - 2,840	5,680	791 - 9,720	15/15	3
Lead	1.2 - 6.1	12	2.6 - 24.8	15/15	3
Magnesium	<25.4 - 260	520	33.3 - 926	15/15	3
Manganese	1.2 - 5.2	10.4	2.9 - 40.6	15/15	0
Mercury	<0.02 - <0.11	0.22	ND	0/15	0
Nickel	<1.4 - <4.8	9.6	4.6 - 5.8	2/15	0
Potassium	<81.6 - 187	374	49.2 - 574	15/15	6
Selenium	0.23 - <1.0	2	0.23 - 0.46	11/15	0
Sodium	<14.5 - <44.9	90	41.4 - 108	13/15	1
Vanadium	<1.5 - 13.4	27	3.6 - 22.4	15/15	0
Zinc	<0.19 - 11.6	23	2.5 - 18.1	15/15	0

Notes: Concentrations expressed in milligram per kilogram (mg/kg).

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Subsurface Soil	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Methylene Chloride	33 - 120	3/44
Acetone	12 - 1,800	15/44
Carbon Disulfide	4 - 8	4/44
2-Butanone	480	1/44
Di-n-butyl phthalate	74	1/44
Fluoranthene	45	1/44
Bis(2-ethylhexyl)phthalate	44 - 1,000	8/44
4,4'-DDD	4.4 - 19	7/44
4,4'-DDT	4 - 220	10/44

Notes: Concentrations expressed in microgram per kilogram (μg/kg)

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Subsurface Soil (6 inches and below)				
	Base-Specific Background Concentration Range(1)	Twice the Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Background
Aluminum	672 - 10,200	20,400	964 - 19,800	59/59	0
Arsenic	<0.47 - <0.65	1.3	0.46 - 15	39/59	17
Barium	<4.0 - 10.9	22	3 - 628	59/59	6
Beryllium	<0.05 - <0.23	0.46	0.2 - 3.8	29/59	5
Cadmium	<0.34 - <1.2	2.4	ND	0/59	0
Calcium	<10.7 - 81.3	163	20.9 - 62,200	46/59	22
Chromium	<3.2 - 8.7	17	2.1 - 32.8	57/59	1
Cobalt	<0.35 - <1.9	4	1.8 - 13.8	12/59	5
Copper	<0.47 - 1.2	2.4	0.44 - 55	59/59	10
Iron	126 - 2,840	5,680	411 - 17,300	59/59	6
Lead	1.2 - 6.1	12	1.3 - 19.3	59/59	2
Magnesium	<25.4 - 260	520	29.8 - 2,950	57/59	4
Manganese	1.2 - 5.2	10.4	1.6 - 113	52/59	6
Mercury	<0.02 - <0.11	0.22	0.11 - 0.29	4/59	2
Nickel	<1.4 - <4.8	9.6	8 - 96.2	4/59	2
Potassium	<81.6 - 187	374	51.6 - 1,710	59/59	20
Selenium	0.23 - <1.0	2	0.25 - 11.9	19/59	4
Sodium	<14.5 - <44.9	90	16.6 - 729	58/59	5
Vanadium	<1.5 - 13.4	27	2 - 594	59/59	17
Zinc	<0.19 - 11.6	23	1.3 - 20.1	46/59	0

Notes: Concentrations expressed in milligram per kilogram (mg/kg).

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 78
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Subsurface Soil	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Acetone	14 - 210	15/29
Total 1,2-Dichloroethene	6 - 16	2/29
Toluene	3	1/29
Ethylbenzene	55	1/29
Xylenes (total)	450	1/29
Naphthalene	74 - 850	2/29
2-Methyl naphthalene	890	1/29
Acenaphthene	97	1/29
Phenanthrene	220 - 590	2/29
Anthracene	150	1/29
Carbazole	89	1/29
Di-n-butyl phthalate	83 - 100	2/29
Fluoranthene	160 - 700	2/29
Pyrene	110 - 480	2/29
Benzo(a)anthracene	320	1/29
Chrysene	300	1/29
Bis(2-ethylhexyl)phthalate	81 - 120	2/29
Benzo(b)fluoranthene	170	1/29
Benzo(k)fluoranthene	190	1/29
Benzo(a)pyrene	170	1/29
Indeno(1,2,3-cd)pyrene	100	1/29
Benzo(g,h,i)perylene	95	1/29
Dieldren	1.3	1/44
4,4'-DDE	2.1 - 34	4/44
4,4'-DDD	4 - 48	4/44
4,4'-DDT	3.1 - 9.7	4/44

Notes: Concentrations expressed in microgram per kilogram (µg/kg)

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 78
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Subsurface Soil (6 inches and below)				
Inorganic	Base-Specific Background Concentration Range(1)	Twice the Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Background
Aluminum	672 - 10,200	20,400	2,730 - 14,100	16/16	0
Arsenic	<0.47 - <0.65	1.3	0.49 - 6.2	10/16	2
Barium	<4.0 - 10.9	22	2.8 - 13	16/16	0
Beryllium	<0.05 - <0.23	0.46	0.26	1/16	0
Cadmium	<0.34 - <1.2	2.4	ND	0/16	0
Calcium	<10.7 - 81.3	163	29.1 - 297	16/16	3
Chromium	<3.2 - 8.7	17	4.2 - 18.5	15/16	2
Cobalt	<0.35 - <1.9	4	ND	0/16	0
Copper	<0.47 - 1.2	2.4	0.51 - 3.4	16/16	2
Iron	126 - 2,840	5,680	462 - 5,890	16/16	2
Lead	1.2 - 6.1	12	1 - 6.5	16/16	0
Magnesium	<25.4 - 260	520	101 - 458	16/16	0
Manganese	1.2 - 5.2	10.4	1.6 - 9.2	16/16	0
Mercury	<0.02 - <0.11	0.22	ND	0/16	0
Nickel	<1.4 - <4.8	9.6	ND	0/16	0
Potassium	<81.6 - 187	374	88 - 280	16/16	4
Selenium	0.23 - <1.0	2	0.26 - 1.2	5/16	0
Sodium	<14.5 - <44.9	90	30.2 - 93	16/16	1
Vanadium	<1.5 - 13.4	27	2.2 - 19.2	16/16	0
Zinc	<0.19 - 11.6	23	1.4 - 7.9	16/16	0

Notes: Concentrations expressed in milligram per kilogram (mg/kg).

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.

GROUNDWATER DATA SUMMARY
OPERABLE UNIT NO. 1
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Groundwater Criteria				Frequency/Range		Comparison to Criteria			
	NCWQS(1)	MCL(2)	Federal Health Advisories(3)		No. of Positive Detects/ No. of Samples	Concentration Range	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above Health Advisories	
			10 kg Child	70 kg Adult					10 kg Child	70 kg Adult
Vinyl Chloride	0.015	2.0	3,000	50	1/51	97	1	1	0	1
Dichlorodifluoromethane	0.19	--	9,000	30,000	1/51	2	1	NA	0	0
Trichlorofluoromethane	--	--	--	--	1/51	1	NA	NA	NA	NA
Dichloromethane	5.0	5.0	--	--	6/51	1 - 2	0	0	NA	NA
1,1-Dichloroethene	7.0	7.0	1,000	4,000	1/51	7	0	0	0	0
cis-1,2-Dichloroethene	70	70	3,000	11,000	5/51	1 - 14,000	1	1	1	1
trans-1,2-Dichloroethene	70	100	2,000	6,000	3/51	1 - 190	2	2	0	0
Chloroform	0.19	100	100	400	2/51	1 - 8	2	0	0	0
1,2-Dichloroethane	0.38	5.0	700	2,600	1/51	1	1	0	0	0
Bromodichloromethane	--	100	7,000	13,000	1/51	1	NA	0	0	0
1,2-Dichloropropane	0.56	5.0	--	--	1/51	1	1	0	NA	NA
Trichloroethene	2.8	5.0	--	--	9/51	1 - 440	5	4	NA	NA
Benzene	1.0	5.0	--	--	7/51	5 - 9,200	7	7	NA	NA
1,1,2-Trichloroethane	--	5.0	600	1,000	1/51	2	NA	0	0	0
Tetrachloroethene	0.7	5.0	2,000	5,000	3/51	1	1	0	0	0
Toluene	1,000	1,000	2,000	7,000	3/51	2 - 18,000	1	1	1	1
Ethylbenzene	29	700	30,000	3,000	3/51	5 - 3,000	2	1	0	1
Total Xylenes	400	10,000	40,000	100,000	4/51	1 - 16,000	2	1	0	0
Phenol	--	--	6,000	20,000	8/51	2 - 8	NA	NA	0	0
2-Methylphenol	--	--	--	--	1/51	2	NA	NA	NA	NA
4-Methylphenol	--	--	--	--	1/51	2	NA	NA	NA	NA

Notes: Concentrations expressed in microgram per liter (µg/l)

(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) Longer Term Health Advisories for a 10kg Child and 70 kg Adult
(4) SMCL = Secondary Maximum Contaminant Level
(5) -- = No Criteria Published
(6) NA = Not Applicable

GROUNDWATER DATA SUMMARY
OPERABLE UNIT NO. 1
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Groundwater Criteria				Frequency/Range		Comparison to Criteria			
	NCWQS(1)	MCL(2)	Federal Health Advisories(3)		No. of Positive Detects/ No. of Samples	Concentration Range	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above Health Advisories	
			10 kg Child	70 kg Adult					10 kg Child	70 kg Adult
2-4-Dimethylphenol	--	--	--	--	1/51	6	NA	NA	NA	NA
Naphthalene	--	--	400	1,000	6/51	2 - 260	NA	NA	0	0
2-Methylnaphthalene	--	--	--	--	2/51	20 - 36	NA	NA	NA	NA
Acenaphthene	--	--	--	--	1/51	3	NA	NA	NA	NA
Phenanthrene	--	--	--	--	1/51	2	NA	NA	NA	NA
Carbazole	--	--	--	--	2/51	3 - 12	NA	NA	NA	NA
Fluoranthene	--	--	--	--	1/51	2	NA	NA	NA	NA
Butyl Benzyl Phthalate	--	100	--	--	1/51	3	NA	0	NA	NA
Bis(2-ethylhexyl)phthalate	--	--	--	--	5/51	2 - 18	NA	0	NA	NA
Di-n-octyl phthalate	--	--	--	--	1/51	2	NA	0	NA	NA
Benzo(b)fluoranthene	--	0.2	--	--	1/51	2	NA	1	NA	NA
Heptachlor Epoxide	0.038	0.2	0.1	0.1	3/54	0.078 - 0.13	3	0	1	1
Dieldren	--	--	0.5	2.0	1/54	0.2	NA	NA	0	0
Alpha-Chlordane	0.027	2.0	--	--	1/54	0.11	1	0	NA	NA
Antimony	--	6.0	15	15	7.33	3.3 - 169	NA	3	2	2
Arsenic	50	50	--	--	44/48	2.3 - 405	8	8	NA	NA
Barium	1,000	2,000	--	--	59/59	17 - 1,250	4	0	NA	NA
Beryllium	--	4.0	30,000	20,000	52/59	1 - 19	NA	18	0	0
Cadmium	5.0	5.0	40	20	9/59	5 - 21	9	9	0	1
Chromium	5.0	100	1,000	800	46/59	10-858	27	26	0	1
Cobalt	--	--	--	--	25/59	8-170	NA	NA	NA	NA

Notes: Concentrations expressed in microgram per liter (µg/l)

(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) Longer Term Health Advisories for a 10kg Child and 70 kg Adult
(4) SMCL = Secondary Maximum Contaminant Level
(5) -- = No Criteria Published
(6) NA = Not Applicable

GROUNDWATER DATA SUMMARY
OPERABLE UNIT NO. 1
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Groundwater Criteria				Frequency/Range		Comparison to Criteria			
			Federal Health Advisories(3)						No. of Detects Above Health Advisories	
Contaminant	NCWQS(1)	MCL(2)	10 kg Child	70 kg Adult	No. of Positive Detects/ No. of Samples	Concentration Range	No. of Detects Above NCWQS	No. of Detects Above MCL	10 kg Child	70 kg Adult
Copper	1,000	1,300	--	--	58/59	3-699	0	0	NA	NA
Lead	50	15	--	--	50/59	2.9-2000	20	37	NA	NA
Manganese	50	50(4)	--	--	57/59	2-714	44	44	NA	NA
Mercury	1.1	2.0	--	2.0	24/52	0.23-3.2	5	3	NA	3
Nickel	150	100	1.000	1.700	31/59	20-234	2	7	0	0
Vanadium	--	--	--	--	55/59	4-1700	NA	NA	NA	NA
Zinc	5,000	5,000	6,000	12,000	57/59	6-967	0	0	0	0

Notes: Concentrations expressed in microgram per liter (µg/l)

(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) Longer Term Health Advisories for a 10kg Child and 70 kg Adult
(4) SMCL = Secondary Maximum Contaminant Level
(5) -- = No Criteria Published
(6) NA = Not Applicable

SURFACE WATER DATA SUMMARY
OPERABLE UNIT NO. 1 - COGDELS CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Surface Water Criteria			Contaminant Frequency/Range		Comparison to Criteria		
		Federal Health AWQCs(2)		No. of Positive Detects/ No. of Samples	Contaminant Range	Positive Detects Above NCWQS	Positive Detects Above AWQC	
Contaminant	NCWQS(1)	Acute	Chronic				Acute	Chronic
Methylene Chloride	--	--	--	1/20	5	NA	NA	NA
Acetone	--	--	--	2/19	11-16	NA	NA	NA
Total 1,2-dichloroethene	--	--	--	1/20	6	NA	NA	NA
Trichloroethene	--	2,000(3)	--	4/20	3-47	NA	0	NA
Toluene	--	6,300(3)	5,000(3)	1/20	3	NA	0	0
Di-n-butylphthalate	--	--	--	2/20	2	NA	NA	NA
Bis (2-ethylhexyl) phthalate	--	--	--	4/20	2-33	NA	NA	NA
4,4'-DDD	--	--	--	2/20	0.13-0.19	NA	NA	NA
4,4'-DDT	0.001	0.13	0.001	1/20	0.18	1	1	1
Arsenic	50	--	--	3/20	2.2-4.9	0	NA	NA
Barium	--	--	--	20/20	13-68	NA	NA	NA
Beyllium,	--	--	--	3/20	1	NA	NA	NA
Chromium	20	1,100	50	3/20	12-30	1	0	0
Copper	3	2.9	--	20/20	2-42	15	18	NA
Lead	25	220	8.5	10/20	2-42	3	0	4
Manganese	--	--	--	20/20	15-162	NA	NA	NA
Nickel	83	75	8.3	1/20	29	0	0	1
Selenium	71	300	71	2/20	1-2	0	0	0
Vanadium	--	--	--	9/20	4-33	NA	NA	NA
Zine	86	95	86	14/20	11-152	2	2	2

Notes: (1) NCWQS = North Carolina Water Quality Standards for Surface Water

(2) AWQC = Ambient Water Quality Standard

(3) Insufficient data to develop criteria. Value presented is Lowest Observed Effect Level (LOEL).

Concentrations expressed in microgram per liter (µg/L)

SURFACE WATER DATA SUMMARY
OPERABLE UNIT NO. 1 - BEAVER DAM CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Surface Water Criteria			Contaminant Frequency/Range		Comparison to Criteria		
		Federal Health AWQCs(2)					Positive Detects Above AWQC	
Contaminant	NCWQS(1)	Acute	Chronic	No. of Positive Detects/ No. of Samples	Contaminant Range	Positive Detects Above NCWQS	Acute	Chronic
Arsenic	50	--	--	2/7	4.3-11.8	0	NA	NA
Barium	--	--	--	7/7	34-75	NA	NA	NA
Beryllium	--	--	--	1/7	1	NA	NA	NA
Chromium	20	1,100	50	1/7	18	0	0	0
Copper	3	2.9	--	7/7	3-17	7	7	7
Lead	25	220	8.5	2/7	7.4-22.2	0	0	2
Manganese	--	--	--	7/7	24-262	NA	NA	NA
Zinc	86	95	86	7/7	25-96	1	1	1

Notes: (1) NCWQS = North Carolina Water Quality Standards for Surface Water
(2) AWQC = Ambient Water Quality Standard
Concentrations expressed in microgram per liter (µg/L)

SEDIMENT DATA SUMMARY
OPERABLE UNIT NO. 1 - COGDELS CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Methylene Chloride	14-56	3/40
Acetone	50-250	10/40
2-Butanone	14-60	3/40
Ethylbenzene	16	1/40
4-Methylphenol	1,800	1/40
Naphthalene	240	1/40
Acenaphthene	65-550	2/40
Dibenzofuran	380	1/40
Fluorene	51-600	2/40
Phenanthrene	60-4,500	10/40
Anthracene	70-1,000	3/40
Carbazole	42-660	3/40
Di-n-butyl phthalate	120	1/40
Fluoranthene	79-6,800	14/40
Pyrene	50-4,500	14/40
Butyl benzyl phthalate	45-100	3/40
Benzo(a)arthracene	70-2,500	10/40
Chrysene	51-2,400	13/40
Bis(2-ethylhexyl) phthalate	75-620	10/40
Benzo(b) fluoranthene	59-2,800	12/40
Benzo(k) fluoranthene	72-1,800	10/40
Benzo(a)pyrene	84-1,700	11/40
Indeno(1,2,3-cd)pyrene	66-630	11/40
Dibenz(a,h)anthracene	65-160	3/40
Benzo(ghi)perylene	88-500	8/40

Notes: Organic concentrations expressed in microgram per Kilogram (μg/Kg)
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg)

SEDIMENT DATA SUMMARY
OPERABLE UNIT NO. 1 - COGDELS CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
4,4'-DDE	5-33	8/40
4,4'-DDD	4.4-400	20/40
4,4'-DDT	4.6-150	11/40
Alpha-Chlordane	2.5-5.9	5/40
Gamma-Chlordane	3.2-6.3	3/40
Arsenic	0.57-6.5	21/40
Barium	1-109	40/40
Beryllium	0.28-1.5	6/40
Cadmium	1.3-11.9	9/40
Chromium	2.5-4.2	29/40
Cobalt	2.1-3.2	2/40
Copper	0.77-116	40/40
Lead	2-359	40/40
Manganese	1.8-72.3	40/40
Mercury	0.73	1/40
Nickel	ND	0/40
Vanadium	1-59.4	36/40
Zinc	2.4-363	40/40

Notes: Organic concentrations expressed in microgram per Kilogram (µg/Kg)
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg)

SEDIMENT DATA SUMMARY
OPERABLE UNIT NO. 1 - BEAVER DAM CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Methylene Chloride	140	1/13
Acetone	33-260	6/13
Carbon Disulfide	68	1/13
Naphthalene	280	1/14
Acenaphthene	340	1/14
Dibenzofuran	200	1/14
Fluorene	270	1/14
Phenanthrene	160-1,900	3/14
Anthracene	410	1/14
Carbazole	340	1/14
Fluoranthene	74-2,100	6/14
Pyrene	70-1,500	4/14
Benzo(a)anthracene	170-950	2/14
Chrysene	74-920	3/14
Bis(2-ethylhexyl)phthalate	60-220	9/14
Benzo(b)fluoranthene	120-600	2/14
Benzo(k)fluoranthene	94-390	2/14
Benzo(a)pyrene	100-510	2/14
Indeno(1,2,3-cd)pyrene	86-520	2/14
Benzo(ghi)perylene	85-540	2/14
4,4'-DDE	4.8-93	6/14
4,4'-DDD	33-39	2/14
4,4'-DDT	8-47	3/14
Alpha-Chlordane	2.5-7.3	4/14
Gamma-Chlordane	2.4-5.6	6/214
PCB1260	70	1/14

Notes: Organic concentrations expressed in microgram per Kilogram (µg/Kg)
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg)

SEDIMENT DATA SUMMARY
OPERABLE UNIT NO. 1 - BEAVER DAM CREEK
REMEDIAL INVESTIGATION CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment	
	Range of Positive Detections	No. of Positive Detects/ No. of Samples
Arsenic	0.53-12.1	12/14
Barium	3.9-49.1	14/14
Beryllium	0.24-1.1	10/14
Chromium	3.4-41.2	12/14
Cobalt	3-7.6	4/14
Copper	1.3-24.7	14/14
Lead	4.4-50.7	14/14
Manganese	2.2-30.9	14/14
Nickel	6.2-10.1	3/14
Vanadium	2.1-50.5	14/14
Zinc	7.9-37.4	14/14

Notes: Organic concentrations expressed in microgram per Kilogram (µg/Kg)
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg)

APPENDIX B
ACTION LEVEL CALCULATIONS

DERMAL CONTACT WITH SOIL ACTION LEVEL
OPERABLE UNIT NO. 1
FEASABILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA
CURRENT MILITARY PERSONNEL

C = TR or THI * BW * ATc or ATnc * DY / CSF or RfD * 10E-6 * SA * AF * Abs * ED * EF

Where:	INPUTS
C = contaminant concentration in soil (ug/kg)	Calculated
10E-6 = conversion factor (kg/mg)	1E-06
SA = exposed skin surface area (cm2)	5800
AF = soil to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
TR = total lifetime risk for carcinogen (unitless)	1.0E-04
THI = total Hazard Index for noncarcinogen (unitless)	1
CSF = carcinogenic slope factor	Specific
RfD = reference dose for noncarcinogen	Specific
EF = exposure frequency (events/yr)	350
ED = expsosure duration (years)	4
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	4
DY = day per year (day/yr)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/year)	Slope Factor (mg/kg-day)-1	Total Lifetme Risk
Benzo(a)anthracene	3017241.38	1E-06	5800	1	0.01	350	4	70	70	365	7.30E-01	1.0E-04
Chrysene	30172413.79	1E-06	5800	1	0.01	350	4	70	70	365	7.30E-02	1.0E-04
Benzo(b)fluoranthene	3017241.38	1E-06	5800	1	0.01	350	4	70	70	365	7.30E-01	1.0E-04
Benzo(k)fluoranthene	3017241.38	1E-06	5800	1	0.01	350	4	70	70	365	7.30E-01	1.0E-04
Benzo(a)pyrene	301724.14	1E-06	5800	1	0.01	350	4	70	70	365	7.30E+00	1.0E-04
Indeno(1,2,3-cd)pyrene	3017241.38	1E-06	5800	1	0.01	350	4	70	70	365	7.30E-01	1.0E-04
4,4'-DDE	6478194.73	1E-06	5800	1	0.01	350	4	70	70	365	3.40E-01	1.0E-04
4,4'-DDD	9177442.53	1E-06	5800	1	0.01	350	4	70	70	365	2.40E-01	1.0E-04
4,4'-DDT	6478194.73	1E-06	5800	1	0.01	350	4	70	70	365	3.40E-01	1.0E-04
Total Chlordane	1694297.08	1E-06	5800	1	0.01	350	4	70	70	365	1.30E+00	1.0E-04
Total PCBs	286050.16	1E-06	5800	1	0.01	350	4	70	70	365	7.70E+00	1.0E-04
Arsenic	12956389.45	1E-06	5800	1	0.001	350	4	70	70	365	1.70E+00	1.0E-04
Beryllium	5122293.50	1E-06	5800	1	0.001	350	4	70	70	365	4.30E+00	1.0E-04

Contaminant	Concentration Noncarcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/year)	Reference Dose (mg/kg-day)	Hazard Index
Fluoranthene	50344827.59	1E-06	5800	1	0.01	350	4	70	4	365	4.00E-02	1
Pyrene	37758620.69	1E-06	5800	1	0.01	350	4	70	4	365	3.00E-02	1
4,4'-DDT	629310.34	1E-06	5800	1	0.01	350	4	70	4	365	5.00E-04	1
Total Chlordane	75517.24	1E-06	5800	1	0.01	350	4	70	4	365	6.00E-05	1
Total PCBs	88103.45	1E-06	5800	1	0.01	350	4	70	4	365	7.00E-05	1
Arsenic	3775862.07	1E-06	5800	1	0.001	350	4	70	4	365	3.00E-04	1
Barium	881034482.76	1E-06	5800	1	0.001	350	4	70	4	365	7.00E-02	1
Beryllium	62931034.48	1E-06	5800	1	0.001	350	4	70	4	365	5.00E-03	1
Chromium	62931034.48	1E-06	5800	1	0.001	350	4	70	4	365	5.00E-03	1
Manganese	62931034.48	1E-06	5800	1	0.001	350	4	70	4	365	5.00E-03	1
Vanadium	88103448.28	1E-06	5800	1	0.001	350	4	70	4	365	7.00E-03	1
Zinc	3775862068.97	1E-06	5800	1	0.001	350	4	70	4	365	3.00E-01	1

File Name: DCALC.WQ1

DERMAL CONTACT WITH SOIL ACTION LEVEL
OPERABLE UNIT NO. 1
FEASABILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA
FUTURE ADULT RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / CSF or RfD * 10E-6 * SA * AF * Abs * ED * EF

Where:	INPUTS
C = contaminant concentration in soil (ug/kg)	Calculated
10E-6 = conversion factor (kg/mg)	1E-06
SA = exposed skin surface area (cm2)	5800
AF = soil to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
TR = total lifetime risk for carcinogen (unitless)	1.0E-04
THI = total Hazard Index for noncarcinogen (unitless)	1
CSF = carcinogenic slope factor	Specific
RfD = reference dose for noncarcinogen	Specific
EF = exposure frequency (events/yr)	350
ED = expsosure duration (years)	24
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	24
DY = day per year (day/yr)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/year)	Slope Factor (mg/kg-day)-1	Total Lifetme Risk
Benzo(a)anthracene	502873.56	1E-06	5800	1	0.01	350	24	70	70	365	7.30E-01	1.0E-04
Chrysene	5028735.63	1E-06	5800	1	0.01	350	24	70	70	365	7.30E-02	1.0E-04
Benzo(b)fluoranthene	502873.56	1E-06	5800	1	0.01	350	24	70	70	365	7.30E-01	1.0E-04
Benzo(k)fluoranthene	502873.56	1E-06	5800	1	0.01	350	24	70	70	365	7.30E-01	1.0E-04
Benzo(a)pyrene	50287.36	1E-06	5800	1	0.01	350	24	70	70	365	7.30E+00	1.0E-04
Indeno(1,2,3-cd)pyrene	502873.56	1E-06	5800	1	0.01	350	24	70	70	365	7.30E-01	1.0E-04
4,4'-DDE	1079699.12	1E-06	5800	1	0.01	350	24	70	70	365	3.40E-01	1.0E-04
4,4'-DDD	1529573.75	1E-06	5800	1	0.01	350	24	70	70	365	2.40E-01	1.0E-04
4,4'-DDT	1079699.12	1E-06	5800	1	0.01	350	24	70	70	365	3.40E-01	1.0E-04
Total Chlordane	282382.85	1E-06	5800	1	0.01	350	24	70	70	365	1.30E+00	1.0E-04
Total PCBs	47675.03	1E-06	5800	1	0.01	350	24	70	70	365	7.70E+00	1.0E-04
Arsenic	2159398.24	1E-06	5800	1	0.001	350	24	70	70	365	1.70E+00	1.0E-04
Beryllium	853715.58	1E-06	5800	1	0.001	350	24	70	70	365	4.30E+00	1.0E-04

Contaminant	Concentration Noncarcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/year)	Reference Dose (mg/kg-day)	Hazard Index
Fluoranthene	50344827.59	1E-06	5800	1	0.01	350	24	70	24	365	4.00E-02	1
Pyrene	37758620.69	1E-06	5800	1	0.01	350	24	70	24	365	3.00E-02	1
4,4'-DDT	629310.34	1E-06	5800	1	0.01	350	24	70	24	365	5.00E-04	1
Total Chlordane	75517.24	1E-06	5800	1	0.01	350	24	70	24	365	6.00E-05	1
Total PCBs	88103.45	1E-06	5800	1	0.01	350	24	70	24	365	7.00E-05	1
Arsenic	3775862.07	1E-06	5800	1	0.001	350	24	70	24	365	3.00E-04	1
Barium	881034482.76	1E-06	5800	1	0.001	350	24	70	24	365	7.00E-02	1
Beryllium	62931034.48	1E-06	5800	1	0.001	350	24	70	24	365	5.00E-03	1
Chromium	62931034.48	1E-06	5800	1	0.001	350	24	70	24	365	5.00E-03	1
Manganese	62931034.48	1E-06	5800	1	0.001	350	24	70	24	365	5.00E-03	1
Vanadium	88103448.28	1E-06	5800	1	0.001	350	24	70	24	365	7.00E-03	1
Zinc	3775862068.97	1E-06	5800	1	0.001	350	24	70	24	365	3.00E-01	1

File Name: DCALC.WQ2

DERMAL CONTACT WITH SOIL ACTION LEVEL
OPERABLE UNIT NO. 1
FEASABILITY STUDY CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA
FUTURE CHILD RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / CSF or RfD * 10E-6 * SA * AF * Abs * ED * EF

Where:	INPUTS
C = contaminant concentration in soil (ug/kg)	Calculated
10E-6 = conversion factor (kg/mg)	1E-06
SA = exposed skin surface area (cm2)	2300
AF = soil to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
TR = total lifetime risk for carcinogen (unitless)	1.0E-04
THI = total Hazard Index for noncarcinogen (unitless)	1
CSF = carcinogenic slope factor	Specific
RfD = reference dose for noncarcinogen	Specific
EF = exposure frequency (events/yr)	350
ED = expsosure duration (years)	6
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = day per year (day/yr)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/year)	Slope Factor (mg/kg-day)-1	Total Lifetme Risk
Benzo(a)anthracene	5072463.77	1E-06	2300	1	0.01	350	6	70	70	365	7.30E-01	1.0E-04
Chrysene	50724637.68	1E-06	2300	1	0.01	350	6	70	70	365	7.30E-02	1.0E-04
Benzo(b)fluoranthene	5072463.77	1E-06	2300	1	0.01	350	6	70	70	365	7.30E-01	1.0E-04
Benzo(k)fluoranthene	5072463.77	1E-06	2300	1	0.01	350	6	70	70	365	7.30E-01	1.0E-04
Benzo(a)pyrene	507246.38	1E-06	2300	1	0.01	350	6	70	70	365	7.30E+00	1.0E-04
ndeno(1,2,3-cd)pyrene	5072463.77	1E-06	2300	1	0.01	350	6	70	70	365	7.30E-01	1.0E-04
4,4'-DDE	10890878.09	1E-06	2300	1	0.01	350	6	70	70	365	3.40E-01	1.0E-04
4,4'-DDD	15428743.96	1E-06	2300	1	0.01	350	6	70	70	365	2.40E-01	1.0E-04
4,4'-DDT	10890878.09	1E-06	2300	1	0.01	350	6	70	70	365	3.40E-01	1.0E-04
Total Chlordane	2848383.50	1E-06	2300	1	0.01	350	6	70	70	365	1.30E+00	1.0E-04
Total PCBs	480895.92	1E-06	2300	1	0.01	350	6	70	70	365	7.70E+00	1.0E-04
Arsenic	21781756.18	1E-06	2300	1	0.001	350	6	70	70	365	1.70E+00	1.0E-04
Beryllium	8611391.98	1E-06	2300	1	0.001	350	6	70	70	365	4.30E+00	1.0E-04

Contaminant	Concentration Noncarcinogen (ug/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/year)	Reference Dose (mg/kg-day)	Hazard Index
Fluoranthene	126956521.74	1E-06	2300	1	0.01	350	6	70	6	365	4.00E-02	1
Pyrene	95217391.30	1E-06	2300	1	0.01	350	6	70	6	365	3.00E-02	1
4,4'-DDT	1586956.52	1E-06	2300	1	0.01	350	6	70	6	365	5.00E-04	1
Total Chlordane	190434.78	1E-06	2300	1	0.01	350	6	70	6	365	6.00E-05	1
Total PCBs	222173.91	1E-06	2300	1	0.01	350	6	70	6	365	7.00E-05	1
Arsenic	9521739.13	1E-06	2300	1	0.001	350	6	70	6	365	3.00E-04	1
Barium	2221739130.43	1E-06	2300	1	0.001	350	6	70	6	365	7.00E-02	1
Beryllium	158695652.17	1E-06	2300	1	0.001	350	6	70	6	365	5.00E-03	1
Chromium	158695652.17	1E-06	2300	1	0.001	350	6	70	6	365	5.00E-03	1
Manganese	158695652.17	1E-06	2300	1	0.001	350	6	70	6	365	5.00E-03	1
Vanadium	222173913.04	1E-06	2300	1	0.001	350	6	70	6	365	7.00E-03	1
Zinc	9521739130.43	1E-06	2300	1	0.001	350	6	70	6	365	3.00E-01	1

File Name: DCALC.WQ3

INGESTION OF GROUNDWATER ACTION LEVEL
OPERABLE UNIT NO. 1
FEASABILITY STUDY CTO-0177
MCB CAMP LEJEUNE NORTH CAROLINA
FUTURE ADULT RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD

Where:	INPUTS
C = contaminant concentration in water ((ug/L)	
TR = total lifetime risk	1E-04
THI = total hazard index	1
CSF = carcinogenic slope factor	specific
RfD = reference dose	specific
IRw = daily water ingestion rate (L/Day)	2
EF = exposure frequency (days/yr)	350
ED = exposure duration (yr)	30
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (day/year)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/yr)	Slope Factor (mg/kg-day)-1	Target Excess Risk
Benzene	294	2	350	30	70	70	365	2.90E-02	1.0E-04
Trichloroethene	774	2	350	30	70	70	365	1.10E-02	1.0E-04
Tertrachloroethane	164	2	350	30	70	70	365	5.20E-02	1.0E-04
Vinyl Chloride	4	2	350	30	70	70	365	1.90E+00	1.0E-04
Arsenic	5	2	350	30	70	70	365	1.70E+00	1.0E-04
Beryllium	2	2	350	30	70	70	365	4.30E+00	1.0E-04

Contaminant	Concentration Noncarcinogen (ug/L)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/yr)	Reference Dose (mg/kg-day)	Target Hazard Index
Total 1,2-Dichloroethene	730	2	350	30	70	30	365	2.00E-02	1
Toluene	7300	2	350	30	70	30	365	2.00E-01	1
Ethylbenzene	3650	2	350	30	70	30	365	1.00E-01	1
Total Xylenes	73000	2	350	30	70	30	365	2.00E+00	1
Tetrachloroethene	365	2	350	30	70	30	365	1.00E-02	1
Phenol	21900	2	350	30	70	30	365	6.00E-01	1
Arsenic	11	2	350	30	70	30	365	3.00E-04	1
Barium	2555	2	350	30	70	30	365	7.00E-02	1
Beryllium	183	2	350	30	70	30	365	5.00E-03	1
Chromium	183	2	350	30	70	30	365	5.00E-03	1
Manganese	183	2	350	30	70	30	365	5.00E-03	1
Nickel	730	2	350	30	70	30	365	2.00E-02	1
Vanadium	256	2	350	30	70	30	365	7.00E-03	1
Zinc	10950	2	350	30	70	30	365	3.00E-01	1

File Name: GWIAR.WQ1

INGESTION OF GROUNDWATER ACTION LEVEL
OPERABLE UNIT NO. 1
FEASABILITY STUDY CTO-0177
MCB CAMP LEJEUNE NORTH CAROLINA
FUTURE CHILD RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD

Where:	INPUTS
C = contaminant concentration in water ((ug/L)	
TR = total lifetime risk	1E-04
THI = total hazard index	1
CSF = carcinogenic slope factor	specific
RfD = reference dose	specific
IRw = daily water ingestion rate (L/Day)	1
EF = exposure frequency (days/yr)	350
ED = exposure duration (yr)	6
BW = body weight (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = days per year (day/year)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/yr)	Slope Factor (mg/kg-day)-1	Target Excess Risk
Benzene	629	1	350	6	15	70	365	2.90E-02	1.0E-04
Trichloroethene	1659	1	350	6	15	70	365	1.10E-02	1.0E-04
Tertrachloroethane	351	1	350	6	15	70	365	5.20E-02	1.0E-04
Vinyl Chloride	10	1	350	6	15	70	365	1.90E+00	1.0E-04
Arsenic	11	1	350	6	15	70	365	1.70E+00	1.0E-04
Beryllium	4	1	350	6	15	70	365	4.30E+00	1.0E-04

Contaminant	Concentration Noncarcinogen (ug/L)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/yr)	Reference Dose (mg/kg-day)	Target Hazard Index
Total 1,2-Dichloroethene	313	1	350	6	15	6	365	2.00E-02	1
Toluene	3129	1	350	6	15	6	365	2.00E-01	1
Ethylbenzene	1564	1	350	6	15	6	365	1.00E-01	1
Total Xylenes	31286	1	350	6	15	6	365	2.00E+00	1
Tetrachloroethene	156	1	350	6	15	6	365	1.00E-02	1
Phenol	9386	1	350	6	15	6	365	6.00E-01	1
Arsenic	5	1	350	6	15	6	365	3.00E-04	1
Barium	1095	1	350	6	15	6	365	7.00E-02	1
Beryllium	78	1	350	6	15	6	365	5.00E-03	1
Chromium	78	1	350	6	15	6	365	5.00E-03	1
Manganese	78	1	350	6	15	6	365	5.00E-03	1
Nickel	313	1	350	6	15	6	365	2.00E-02	1
Vanadium	110	1	350	6	15	6	365	7.00E-03	1
Zinc	4693	1	350	6	15	6	365	3.00E-01	1

File Name: GWICR.WQ1

APPENDIX C
REMEDIAL ACTION ALTERNATIVE COST ESTIMATES

TABLE C-1
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 2
LIMITED ACTION

O & M COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Groundwater Monitoring - Years 1 through 5 (based on semiannual sampling)						Semiannual sampling of 13 wells	
Labor	Hours	156	$35.00	$5,460		2 samplers; 3 hrs/well average	Engineering Estimate
Laboratory Analyses - VOCs	Sample	26	$375	$9,750		13 samples - semiannually	Basic Ordering Agreement
Misc. Expense	Sample Event	2	$2,500	$5,000		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
					$26,210		
Groundwater Monitoring - Years 6 through 30 (based on annual sampling)						Annual sampling of 13 wells	
Labor	Hours	78	$35.00	$2,730		2 field techs, 3 hours/sample each, 13 sa	Engineering Estimate
Laboratory Analyses - VOCs	Sample	13	$375	$4,875			Basic Ordering Agreement
Misc. Expense	Sample Event	1	$2,500	$2,500		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
					$13,105		
Total Capital Costs					$0		
Annual O&M Costs (Years 1-5)					$26,210	For Years 1 through 5	
Annual O&M Costs (Years 6-30)					$13,105	For Years 6 through 30	
Approximate Present Worth Value					$260,000		

TABLE C-2
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 3
SOURCE CONTROL (INTERIM REMEDIAL ACTION TREATMENT SYSTEM EXTENSION)

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Mobilization							
Equipment	Lump Sum	1	$15,000	$15,000			Previous Estimate
Miscellaneous	Lump Sum	1	$10,000	$10,000	$25,000	Utilities hook-up, site preparation	Previous Estimate
Groundwater Extraction System							
Driller Mobilization	Lump Sum	1	$3,000	$3,000			Basic Ordering Agreement
Extraction Well - Shallow (3)	Per Foot	75	$450	$33,750		6" stainless steel, 25' deep	Engineering Estimate
Well Development	Per Well	3	$375	$1,125			Engineering Estimate
Extraction Pump at 3 Wells	Per Pump	3	$9,500	$28,500			Engineering Estimate
Piping From Wells	Per Foot	1500	$15	$22,500	$88,875	Stainless steel pipe w/tench	Basic Ordering Agreement
Pretreatment System							
Physical/Chemical Treatment System							
Air Stripper	Costs are included with the Interim Remedial Action						
Carbon Adsorption							
Misc. Equipment							
Treatment Building					$0		
Discharge of Treated Water	Costs are included with the Interim Remedial Action				$0		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Administrative reporting, etc.	Previous Estimate
Site Restoration	Lump Sum	1	$5,000	$5,000		General site cleanup, revegetation, etc.	Engineering Estimate
Equipment	Lump Sum	1	$2,000	$2,000	$17,000		Engineering Estimate
Subtotal Capital Cost					$130,875		
Engineering @ 10%				$13,088			
Contingencies @ 20%				$26,175			
Pilot Studies @ 5%				$6,544			
Total Capital Costs					$176,681		

TABLE C-2 (continued)
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 3
SOURCE CONTROL (INTERIM REMEDIAL ACTION TREATMENT SYSTEM EXTENSION)

O & M COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Groundwater Monitoring - Years 1 through 5 (based on semiannual sampling)						Semiannual sampling of 16 wells	
Labor	Hours	192	$35.00	$6,720		2 samplers; 3 hrs/well average	Engineering Estimate
Laboratory Analyses - VOCs	Sample	32	$375	$12,000		16 samples - semiannually	Basic Ordering Agreement
Misc. Expense	Sample Event	2	$2,500	$5,000		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000	$29,720	Laboratory reports, administration, etc.	Engineering Estimate
Groundwater Monitoring - Years 6 through 30 (based on annual sampling)						Annual sampling of 16 wells	
Labor	Hours	96	$35.00	$3,360		2 field techs, 3 hours/sample each, 16 sa	Engineering Estimate
Laboratory Analyses - VOCs	Sample	16	$375	$6,000		16 samples - annually	Basic Ordering Agreement
Misc. Expense	Sample Event	1	$2,500	$2,500		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000	$14,860	Laboratory reports, administration, etc.	Engineering Estimate
System Operation and Maintenance							
Electricity	Costs are included with the Interim Remedial Action						
Materials							
Material Handling							
Operating Labor							
Maintenance Labor							
Administration					$0		
Effluent Sampling							
Labor	Costs are included with the Interim Remedial Action						
Laboratory Analysis - TCL VOA							
Reporting					$0		
Total Capital Costs					$176,681		
Total Annual O&M Costs, Years 1-5					$29,720	For Year 1 through 5	
Total Annual O&M Costs, Years 6-30					$14,860	For Year 6 through 30	
Approximate Present Worth Value					$460,000		

TABLE C-3
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 4
SOURCE CONTROL (AIR SPARGING)

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Mobilization							
Equipment	Lump Sum	1	$15,000	$15,000			Previous Estimate
Miscellaneous	Lump Sum	1	$10,000	$10,000		Utilities hook-up, site preparation	Previous Estimate
					$25,000		
Groundwater Extraction System							
Driller Mobilization	Lump Sum	1	$3,000	$3,000			Basic Ordering Agreement
Air Sparging Well - (4)	Per Well	4	$4,000	$16,000		6" PVC, 25' deep	Engineering Estimate
Soil Venting Well - (4)	Per Well	4	$4,000	$16,000		6" PVC, 25' deep	Engineering Estimate
Well Development	Per Well	5	$375	$1,875			Engineering Estimate
Piping From Wells	Per Foot	600	$15	$9,000		PVC pipe w/trench	Basic Ordering Agreement
					$45,875		
Air Sparging/Soil Venting							
Equipment	Unit	2	$15,000	$30,000		Blowers, vacuum pumps, etc.	Previous Estimates
Carbon Adsorption	Unit	2	$10,000	$20,000		Carbon units, pumps, electric, etc.	Previous Estimates
Treatment Building (2)	Each	2	$15,000	$30,000		8 ft. by 16 ft each	Previous Estimates
					$80,000		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Administrative reporting, etc.	Previous Estimate
Site Restoration	Lump Sum	1	$5,000	$5,000		General site cleanup, revegetation, etc.	Engineering Estimate
Equipment	Lump Sum	1	$2,000	$2,000			Engineering Estimate
					$17,000		
Subtotal Capital Cost					$167,875		
Engineering @ 10%				$16,788			
Contingencies @ 20%				$33,575			
Piolot Studies @ 5%				$8,394			
Total Capital Costs					$226,631		

TABLE C-3 (continued)
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 4
SOURCE CONTROL (AIR SPARGING)

O & M COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Groundwater Monitoring - Years 1 through 5 (based on semiannual sampling)						Semiannual sampling of 13 wells	
Labor	Hours	156	$35.00	$5,460		2 samplers; 3 hrs/well average	Engineering Estimate
Laboratory Analyses - VOCs	Sample	26	$375	$9,750		13 samples - semiannually	Basic Ordering Agreement
Misc. Expense	Sample Event	2	$2,500	$5,000		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
					$26,210		
System Operation and Maintenance							
Electricity	Per Year	1	$16,000	$16,000		Blowers, vacuum pumps, etc.	Previous Estimate
Material Handling	Per Year	1	$9,000	$9,000		Spent carbon replacemnt	Previous Estimate
Operating Labor	Per Year	1	$7,200	$7,200		Approx. 10 hours/month @$30.00/hr	Previous Estimate
Maintenance Labor	Per Year	1	$5,760	$5,760		Approx. 8 hours/month @$30.00/hr	Previous Estimate
Administration	Per Year	1	$10,000	$10,000			Previous Estimate
					$47,960		
Treatment System Sampling							
Labor	Hours	96	$35	$3,360		8 hours/month	Engineering Estimate
Laboratory Analysis - TCL VOA	Sample	56	$375	$21,000		Samples: 1/week + 1/quarter	Engineering Estimate
Reporting	Per Quarter	4	$2,000	$8,000		Lab reports, etc (1 report/quarter)	Engineering Estimate
					$32,360		
Total Capital Costs					$226,631		
Total Annual O&M Costs, Years 1-5					$106,530	For Years 1 through 5	
Total Annual O&M Costs, Years 6-30					$0	For Years 6 through 30	
Approximate Present Worth Value					$690,000		

TABLE C-4
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 5
SOURCE CONTROL AND VERTICAL CONTAINMENT

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Mobilization							
Equipment	Lump Sum	1	$15,000	$15,000			Previous Estimate
Miscellaneous	Lump Sum	1	$10,000	$10,000	$25,000	Utilities hook-up, site preparation	Previous Estimate
Groundwater Extraction System							
Driller Mobilization	Lump Sum	1	$3,000	$3,000			Basic Ordering Agreement
Extraction Well - Deep (2)	Per Foot	150	$450	$67,500		6" stainless steel, 75' deep	Engineering Estimate
Extraction Well - Shallow (3)	Per Foot	75	$450	$33,750		6" stainless steel, 25 ' deep	Engineering Estimate
Well Development	Per Well	5	$375	$1,875			Engineering Estimate
Extraction Pumps	Per Pump	5	$9,500	$47,500			Engineering Estimate
Piping From Wells	Per Foot	2300	$15	$34,500	$188,125	Stainless steel pipe w/trench	Basic Ordering Agreement
Pretreatment System							
Physical/Chemical Treatment System	Costs are included with the Interim Remedial Action						
Air Stripper							
Carbon Adsorption							
Misc. Equipment							
Treatment Building							
Discharge of Treated Water							
Surface Infastructure	Costs are included with the Interim Remedial Action						
Effluent Pump							
Discharge Piping							
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Administrative reporting, etc.	Previous Estimate
Site Restoration	Lump Sum	1	$5,000	$5,000		General site cleanup, revegetation, etc.	Engineering Estimate
Equipment	Lump Sum	1	$2,000	$2,000	$17,000		Engineering Estimate
Subtotal Capital Cost					$230,125		
Engineering @ 10%				$23,013			
Contingencies @ 20%				$46,025			
Piolot Studies @ 5%				$11,506			
Total Capital Costs					$310,669		

TABLE C-4 (continued)
DETAIL COSTING EVALUATION
GROUNDWATER REMEDIAL ACTION ALTERNATIVE NO. 5
SOURCE CONTROL AND VERTICAL CONTAINMENT

O & M COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Groundwater Monitoring - Years 1 through 5 (based on semiannual sampling)						Semiannual sampling of 18 wells	
Labor	Hours	216	$35.00	$7,560		2 samplers; 3 hrs/well average	Engineering Estimate
Laboratory Analyses - VOCs	Sample	36	$375	$13,500		18 samples - semiannually	Basic Ordering Agreement
Misc. Expense	Sample Event	2	$2,500	$5,000		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
					$32,060		
Groundwater Monitoring - Years 6 through 30 (based on annual sampling)						Annual sampling of 18 wells	
Labor	Hours	108	$35.00	$3,780		2 samplers; 3 hrs/well average	Engineering Estimate
Laboratory Analyses - VOCs	Sample	18	$375	$6,750		18 samples - annually	Basic Ordering Agreement
Misc. Expense	Sample Event	1	$2,500	$2,500		Incl. travel, lodging, supplies	Engineering Estimate
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
					$16,030		
System Operation and Maintenance							
Electricity	Costs are included with the Interim Remedial Action						
Materials							
Material Handling							
Operating Labor							
Maintenance Labor							
Administration							
					$0		
Effluent Sampling							
Labor	Costs are included with the Interim Remedial Action						
Laboratory Analysis - TCL VOA							
Reporting							
					$0		
Total Capital Costs					$310,669		
Total Annual O&M Costs, Years 1-5					$32,060	For Year 1 through 5	
Total Annual O&M Costs, Years 6-30					$16,030	For Year 6 through 30	
Approximate Present Worth Value					$615,000		

TABLE C-5
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 2
CAPPING

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Site Preparation							
Work Plans, Permits, Approvals, etc	Lump Sum	1	$50,000	$50,000			Engineering estimate
Equipment Mobilization	Lump Sum	1	$15,000	$15,000		Construction equipment	Previous estimates
Site Grading	SY	1945	$0.45	$875		Cap Areas	NAVFAC CES
Miscellaneous Mobilization	Lump Sum	1	$10,000	$10,000		Utilities, site support operations	Previous estimates
					$75,875		
Access Restrictions							
Fencing	Per Foot	900	$12	$10,800		Cyclone fencing	Means 1993, p. 96
Signage	Each	16	$60	$960		4 per each area	Engineering estimate
					$11,760		
Asphalt Cap							
Confirmation Sampling	Per Sample	40	$450	$18,000		Ten samples per area	Previous estimates
Asphalt Paving	SY	1945	$34	$66,130		Capping AOCs 1 through 7	Means 1993, p. 58
Asphalt Sealant	SY	1945	$0.69	$1,342		Capping AOCs 1 through 7	Means 1993, p. 170
					$85,472		
Site Restoration							
Miscellaneous	Lump Sum	1	$10,000	$10,000		General site cleanup and close out	Engineering estimate
					$10,000		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Reporting, etc.	Previous estimates
Construction Equipment	Lump Sum	1	$5,000	$5,000		Excavation and cap equipment	Engineering estimate
					$15,000		
Subtotal Capital Cost					$198,107		
Engineering @ 10%				$19,811			
Contingencies @ 20%				$39,621			
Pilot Studies @ 0%				$0			
Total Capital Cost					$257,539		

TABLE C-5 (continued)
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 2
CAPPING

O & M COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Cap Maintenance							
Replace Asphalt	SY	194.5	$34	$6,613		Assume 4" over 1/10 of capped area	Means, 1993. p.58.
Asphalt Sealent	SY	972.5	$0.69	$671		Half of capped area annually	Means, 1993. p.170.
Inspection	Lump Sum	1	$6,000	$6,000			
					$13,284		
Groundwater Monitoring						Semi-annual sampling of 6 wells	
Labor	Hours	24	$35.00	$840		2 field techs, 1 hour/sample each, 12 samples/year	Engineering Estimate
Field Equipment	Event	2	$300.00	$600		Sampling equipment, meters, expendables, etc.	Engineering Estimate
Decontamination Items	Event	2	$225.00	$450		Decontamination expendables	Engineering Estimate
Derived Waste Handling	Event	2	$500.00	$1,000		Water handling, drums, etc.	Engineering Estimate
Laboratory Analyses							
-CLP VOA	Samples	12	$375.00	$9,000			Engineering Estimate
-CLP SVOA	Samples	12	$585.00	$14,040			Engineering Estimate
-CLP Metals	Samples	12	$339.00	$8,136			Engineering Estimate
Reporting	Report	2	$3,000.00	$12,000		Laboratory reports, administration, etc.	Engineering Estimate
					$46,066		
Total Capital Costs					$257,539		
Total Annual O & M Costs					$59,350	For 30 years	
Approximate Present Worth Value					$1,170,000		

TABLE C-6A
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 3
ON-SITE TREATMENT (Incineration for all AOCs)

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Site Preparation							
Work Plans, Permits, Approvals, etc.	Lump Sum	1	$100,000	$100,000		*Majority of cost due to incineration*	Engineering estimate
Equipment Mobilization	Lump Sum	1	$15,000	$30,000		Construction and treatment equipment	Previous estimates
Miscellaneous Mobilization	Lump Sum	1	$20,000	$20,000		Utilities, site support operations	Previous estimates
					$150,000		
Access Restrictions							
Signage	Each	5	$60	$300		Assume 1 sign per excavation area and one sign at the treatment area	Engineering estimate
					$300		
Incineration							
Excavation and Loading	Cubic Yard	1050	$15.00	$15,750		To a depth of 2 or 4 feet	Previous estimates
On-Site Hauling	Cubic Yard	1050	$6.00	$6,300		Hauling within Operable Unit No. 2	Previous estimates
Confirmation Sampling	Per Sample	11	$450	$4,950		1 sample/100 cy excavated soil	Previous estimates
Incineration	Ton	1680	$150.00	$252,000		Assume 1.6 tons/CY	Previous Estimate
					$279,000		
Monitoring							
Ash Testing	Per Sample	10	$170.00	$1,700			Previous estimates
					$1,700		
Site Restoration							
Fill and Compact	Cubic Yard	1680	$10.00	$16,800		Excavated areas	Engineering estimate
Grading	Square Yard	1570	$0.45	$707		Excavated Areas	NAVFAC CES
Revegetation	MSF	14.13	$18.25	$258		Excavated Areas	Means, 1993, p. 106
Miscellaneous	Lump Sum	1	$10,000	$10,000		General site cleanup and close out	Engineering estimate
					$27,764		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Reporting, etc.	Previous estimates
Equipment	Lump Sum	1	$10,000	$10,000		Construction and treatment equipment	Engineering estimate
					$20,000		
Subtotal Capital Cost					$478,764		
Engineering @ 10%				$47,876			
Contingencies @ 20%				$95,753			
Pilot Studies @ 5%				$23,938			
Total Capital Cost					$646,332		

Approximate Present Worth Value: $646,000

TABLE C-6B
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 3
Chemical Dechlorination

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Site Preparation							
Work Plans, Permits, Approvals, etc.	Lump Sum	1	$100,000	$100,000		Majority of cost due to dechlorination	Engineering estimate
Equipment Mobilization	Lump Sum	1	$15,000	$30,000		Construction and treatment equipment	Previous estimates
Miscellaneous Mobilization	Lump Sum	1	$20,000	$20,000		Utilities, site support operations	Previous estimates
					$150,000		
Access Restrictions							
Signage	Each	5	$60	$300		1 sign per excavation area	Engineering estimate
					$300	and 1 sign at the treatment area	
Incineration							
Excavation and Loading	Cubic Yard	1050	$15.00	$15,750		To a depth of 2 or 4 feet	Previous estimates
On-Site Hauling	Cubic Yard	1050	$6.00	$6,300		Hauling within Operable Unit No. 2	Previous estimates
Confirmation Sampling	Per Sample	11	$450	$4,950		1 sample/100 cy excavated soil	Previous estimates
Chemical Dechlorination	Cubic Yard	1050	$800.00	$840,000			EPA/540/6-90/007
					$867,000		
Monitoring							
Treated soil testing	Per Sample	10	$170.00	$1,700			Previous estimates
					$1,700		
Site Restoration							
Fill and Compact	Cubic Yard	1050	$10.00	$10,500		Excavated areas	Engineering estimate
Grading	Square Yard	1570	$0.45	$707		Excavated Areas	NAVFAC CES
Revegetation	MSF	14.13	$18.25	$258		Excavated Areas	Means, 1993, p. 106
Miscellaneous	Lump Sum	1	$10,000	$10,000		General site cleanup and close out	Engineering estimate
					$21,464		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Reporting, etc.	Previous estimates
Equipment	Lump Sum	1	$10,000	$10,000		Construction and treatment equipment	Engineering estimate
					$20,000		
Subtotal Capital Cost					$1,060,464		
Engineering @ 10%				$106,046			
Contingencies @ 20%				$212,093			
Pilot Studies @ 5%				$53,023			
Total Capital Cost					$1,431,627		

Approximate Present Worth Value: $1,430,000

TABLE C-7A
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 4A
OFF-SITE DISPOSAL

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Site Preparation							
Work Plans, Permits, Approvals, etc.	Lump Sum	1	$50,000	$50,000			Engineering estimate
Equipment Mobilization	Lump Sum	1	$15,000	$15,000		Construction equipment	Previous estimates
Miscellaneous	Lump Sum	1	$10,000	$10,000		Utilities hook up, site preparation	Previous estimates
					$75,000		
Off-Site Landfill							
Excavation and Loading	Cubic Yard	1050	$20.00	$21,000		AOCs 2 through 6	Previous estimates
Confirmation Sampling	Per Sample	11	$450	$4,950		1 sample/100 cy excavated soil	Previous estimates
Initial Acceptance Testing	Lump Sum	1	$20,000	$20,000		Landfill requirements and tests	Engineering estimate
Transportation (200 miles one way)	Loaded Mile	8400	$3	$25,200		Based on 25 cy/truck	Means, 1993, p. 26
Disposal (Nonhazardous)	Ton	1680	$110	$184,800		Landfill in Pinewood, SC	Vendor Quote
					$255,950	assume 1.6 tons/CY	
Site Restoration							
Fill and Compact	Cubic Yard	1050	$10.00	$10,500		Excavated areas	Engineering estimate
Grading	Square Yard	1570	$0.45	$707		Excavated Areas	NAVFAC CES
Revegetation	MSF	14.13	$18.25	$258		Excavated Areas	Means, 1993, p. 106
Miscellaneous	Lump Sum	1	$10,000	$10,000		General site cleanup and close out	Engineering estimate
					$21,464		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Reporting, etc.	Previous estimates
Equipment	Lump Sum	1	$5,000	$5,000		Construction equipment	Engineering estimate
					$15,000		
Subtotal Capital Cost					$367,414		
Engineering @ 10%				$36,741			
Contingencies @ 20%				$73,483			
Pilot Studies @ 0%				$0			
Total Capital Cost					$477,639		

Approximate Present Worth Value: $478,000

TABLE C-7B
DETAIL COSTING EVALUATION
SOIL REMEDIAL ACTION ALTERNATIVE No. 5B
OFF-SITE TREATMENT

CAPITAL COST ESTIMATE 28-Apr-94

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
Site Preparation							
Work Plans, Permits, Approvals, etc.	Lump Sum	1	$50,000	$50,000			Engineering estimate
Equipment Mobilization	Lump Sum	1	$15,000	$15,000		Construction equipment	Previous estimates
Miscellaneous	Lump Sum	1	$10,000	$10,000		Utilities hook up, site preparation	Previous estimates
					$75,000		
Off-Site TSDF							
Excavation and Loading	Cubic Yard	1050	$20.00	$21,000		AOCs 2 through 6	Previous estimates
Confirmation Sampling	Per Sample	11	$450	$4,950		1 sample/100 cy excavated soil	Previous estimates
Initial Acceptance Testing	Lump Sum	1	$20,000	$20,000		TSDF requirements and testing	Engineering estimate
Transportation (300 miles one way)	Loaded Mile	12600	$3	$37,800		Based on 25 cy/truck	Means, 1993, p. 26
Treatment	Ton	1680	$500	$840,000		Permitted TSDF, assume 1.6 tons/CY	Previous estimates
					$923,750		
Site Restoration							
Fill and Compact	Cubic Yard	1050	$10.00	$10,500		Excavated areas	Engineering estimate
Grading	Square Yard	1570	$0.45	$707		Excavated areas	NAVFAC CES
Revegetation	MSF	14.13	$18.25	$258		All disturbed (cleared) areas	Means, 1993, p. 106
Miscellaneous	Lump Sum	1	$10,000	$10,000		General site cleanup	Engineering estimate
					$21,464		
Demobilization							
Administrative Activities	Lump Sum	1	$10,000	$10,000		Reporting, etc.	Previous estimates
Equipment	Lump Sum	1	$5,000	$5,000		Construction equipment	Engineering estimate
					$15,000		
Subtotal Capital Cost					$1,035,214		
Engineering @ 10%				$103,521			
Contingencies @ 20%				$207,043			
Pilot Studies @ 0%				$0			
Total Capital Cost					$1,345,779		

Approximate Present Worth Value: $1,346,000