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REVISED FINAL

CORRECTIVE ACTION PLAN FOR OPERABLE UNIT NO. 1 (SITES 21, 24 and 78)

MARINE CORPS BASE,
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0177

OCTOBER 9, 1996

Prepared For:

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

Under the:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared By:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	area of concern
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
Baker	Baker Environmental, Inc.
BRA	Baseline Risk Assessment
BTEX	benzene, toluene, ethylbenzene, xylene
CAP	Corrective Action Plan
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
COC	contaminant of concern
COPC	contaminant of potential concern
1,1-DCE	1,1-dichloroethene
4,4'-DDD	dichloro-diphenyl-dichloroethane
4,4'-DDE	dichloro-diphenyl-trichloroethane
4,4'-DDT	dichloro-diphenyl-chloroethane
DON	Department of the Navy
Eh	Oxidation-Reduction Potential
FFA	Federal Facilities Agreement
FS	feasibility study
gpm	gallons per minute
HA	health advisory
HI	hazard index
HPIA	Hadnot Point Industrial Area
IAS	Initial Assessment Study
ICR	incremental cancer risk
IRA	interim remedial action
IRP	Installation Restoration Program
MCB	Marine Corps Base
MCL	Maximum Contaminant Levels (for drinking water)
MI	Mobility Index
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
NPW	net present worth
O&M	operation and maintenance

OU	operable unit
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
ppm	parts per million
PRAP	proposed remedial action plan
RA	risk assessment
RAA	remedial action alternative
RBC	risk-based concentration
RCRA	Resource Conservation Recovery Act
RI	remedial investigation
ROD	record of decision
STP	sewage treatment plant
SVOC	semivolatile organic compound
TAL	Target Analyte List
T-1,2-DCE	trans-1,2-dichloroethene
TCE	trichloroethane
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

DIVISION OF ENVIRONMENTAL MANAGEMENT
CERTIFICATION FOR THE SUBMITTAL OF A CORRECTIVE ACTION PLAN UNDER 15A NCAC 2L.0106(k)

Responsible Party: Department of the Navy, LANTDIV
Address: Naval Facilities Engineering Command
City: Norfolk, State: VA, Zip Code: 23511

Site Name: Marine Corps Base, Camp Lejeune
Address: Operable Unit No. 1, AOCs 2, 4, & 8
City: Camp Lejeune, Co.: Onslow, Zip Code: 23542

Groundwater Section Incident Number: ____________

I, Donald P. Joiner, a Professional Engineer/Licensed Geologist (circle one) for Baker Environmental, Inc. do hereby certify that the information indicated below is enclosed as part of the required Corrective Action Plan (CAP) and that to the best of my knowledge the data, site assessments, engineering plans and other associated materials are correct and accurate.

(Each item must be initialed by hand by the certifying licensed professional)

1. N/A A listing of the names and addresses of those individuals required to be notified to meet the notification requirements of 15A NCAC 2L .0114(b) are enclosed. Copies of letters and certified mail receipts are also enclosed.

2. ________ A Professional Engineer or Licensed Geologist has prepared, reviewed, and certified all applicable parts of the CAP in accordance with 15A NCAC 2L .0103(e).

3. ________ A site assessment is attached or on file at the appropriate Regional Office which provides the information required by 15A NCAC 2L .0106(g).

4. ________ A description of the proposed corrective action and supporting justification is enclosed.

5. ________ Specific plans and engineering details for the restoration of groundwater quality are enclosed. A listing of contaminants detected in groundwater in excess of standards prescribed in 15A NCAC 2L .0202 and the proposed cleanup goal for each contaminant is also enclosed.

6. ________ A schedule for the implementation of the CAP is enclosed.

7. ______ A monitoring plan is enclosed which has the capacity to evaluate the effectiveness of the remedial activity and the movement of the contaminant plume as specified in 2L .0106(k) and which meets the requirements of 15A NCAC 2L .0110.

8. ______ The activity which resulted in the contamination incident is not permitted by the State as defined in 15A NCAC 2L .0106(e).

In addition, the undersigned also certifies that to the best of my knowledge and professional judgement and in accordance with the requirements of 15A NCAC 2L .0106(k), the following determinations have been made and are documented in the CAP:

9. ______ all free product has been removed to the extent practicable in accordance with 15A NCAC 2L .0106(f). (See guidance document).

10. ______ all sources of contamination have been removed or controlled in accordance with 15A NCAC 2L .0106(f) and (k). (See guidance document).

11. ______ the time and direction of contaminant travel can be predicted with reasonable certainty.

12. ______ the contaminants have not and will not migrate onto adjacent properties, or adjacent properties are served by public water supplies which cannot be influenced by contaminants migrating off-site, or adjacent landowners have consented in writing to a request allowing the contaminant upon their property.

13. ______ the standards specified in 15A NCAC 2L .0202 will be met within one year time of travel upgradient from any receptor. This determination is based on the travel time and natural attenuation capacity of the contaminant, or on a physical barrier to groundwater migration that currently exists or will be installed.

14. ______ groundwater discharge of the contaminant plume to surface waters will not result in a violation of 15A NCAC 2B .0200.

(Please Affix Seal and Signature)

NORTH CAROLINA PROFESSIONAL ENGINEER
SEAL 16803
DON P. JOINER

DIVISION OF ENVIRONMENTAL MANAGEMENT
CERTIFICATION FOR THE SUBMITTAL OF A CORRECTIVE ACTION PLAN UNDER 15A NCAC 2L.0106(k)

Responsible Party: Department of the Navy, LANTDIV
Address: Naval Facilities Engineering Command
City: Norfolk, State: VA, Zip Code: 23511

Site Name: Marine Corps Base, Camp Lejeune
Address: Operable Unit No. 1, AOCs 6 & 7
City: Camp Lejeune, Co.: Onslow, Zip Code: 23542

Groundwater Section Incident Number: ____________

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5. ________ Specific plans and engineering details for the restoration of groundwater quality are enclosed. A listing of contaminants detected in groundwater in excess of standards prescribed in 15A NCAC 2L .0202 and the proposed cleanup goal for each contaminant is also enclosed.

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(OVER)

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(Please Affix Seal and Signature)

NORTH CAROLINA PROFESSIONAL SEAL 16803 ENGINEER DON P. JOINER

S. J. [illegible]/for

1.0 INTRODUCTION

This Corrective Action Plan (CAP) is issued to describe the Marine Corps Base (MCB), Camp Lejeune's and the Department of the Navy's (DoN's) preferred remedial action for Operable Unit (OU) No. 1 at MCB, Camp Lejeune. OU No. 1 is located approximately one mile east of the New River and two miles south of State Route 24, within MCB, Camp Lejeune, Onslow County, North Carolina. OU No. 1 consists of three sites, Site 21 (Transformer Storage Lot 140), Site 24 (Industrial Area Fly Ash Dump), and Site 78 (Hadnot Point Industrial Area or HPIA).

1.1 Purpose of the CAP

The purpose of this document is to describe and provide supporting documentation for a CAP that will address contaminated soil and groundwater at OU No. 1. MCB, Camp Lejeune and the DoN are issuing this CAP as part of the public participation responsibility established under Sections 104 and 117(a) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Federal Facilities Agreement (FFA) between the DoN, United States Environmental Protection Agency (USEPA) Region IV, and the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR). The CAP has also been prepared to meet the requirements of 15A NCAC 2L.0106, and the NC DEHNR, "Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater," NC DEHNR, Division of Environmental Management (DEM) - Groundwater Section, March 1993, revised November 1994.

1.2 Site Description

MCB, Camp Lejeune is a training base for the United States Marine Corps, located in Onslow County, North Carolina. The Base covers approximately 236 square miles and includes 14 miles of coastline. MCB, Camp Lejeune is bounded to the southeast by the Atlantic Ocean, to the northeast by State Route 24, and to the west by U.S. Route 17. The town of Jacksonville, North Carolina is located north of the Base.

OU No. 1 is one of 18 operable units within MCB, Camp Lejeune. An "operable unit" as defined by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) is a discrete action that comprises an incremental step toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action. With respect to MCB, Camp Lejeune, operable units were developed to combine one or more individual sites where Installation Restoration Program (IRP) activities are or will be implemented. The sites which are combined into an operable unit share a common element. OU No. 1 contains Sites 21, 24, and 78 which have geographical close proximity as their common element.

OU No. 1 covers an area of approximately 690 acres. It is located approximately one mile east of the New River and two miles south of State Route 24 (see Figure 1-1). OU No. 1 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.

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 site covers less than 10 acres. 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) 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. Surface cover within the site 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. 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 aerial photography study, as shown on Figure 1-2. The two primary areas of concern 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 in the southwestern portion of the site, and the Former Transformer PCB Disposal Area is located in the northeastern portion of the site. With the exception of a low depressed area at the northern portion of the site, there are no visual signs of past waste disposal throughout the site.

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 aerial photography study). The site is primarily a wooded area, approximately 100 acres in size, that is somewhat overgrown. The site is hilly and 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.

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. 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. The location of the Hadnot Point Fuel Farm (Site 22) is shown although it is not a part of the operable unit addressed in this CAP.

1.3 Site History

Site 21 has had a history of pesticide usage and reported transformer oil disposal. The site was used as a pesticide mixing area and as a cleaning area for pesticide application equipment from 1958 to 1977. This area, 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. Chemicals reportedly stored and handled at this site included diazinon, chlordane, lindane, DDT, malathion (46 percent 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.

Aerial photographs from 1944, 1964, and 1984 revealed several areas which appear as ground stains possibly resulting from the pesticide mixing. The approximate stain areas are shown on Figure 1-2. The stains appear as long narrow dark patches which are adjacent to the suspected pesticide mixing area. These stains are no longer visible.

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.

Site 24 was used for the disposal of fly ash, cinders, solvents, used paint stripping compounds, sewage sludge, water treatment spiractor sludge, and construction debris from the late 1940s to 1980. 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 in 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.

The HPIA (Site 78), 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.

1.4 Previous Investigations and Remedial Actions

Table 1-1 lists the reports that were submitted under previous investigations, and Table 1-2 lists the remedial actions that have been conducted at OU No. 1 to date. The following paragraphs briefly describe the previous investigations and remedial actions.

1.4.1 Initial Assessment Study

In 1983, an Initial Assessment Study (IAS) was conducted at MCB, Camp Lejeune. The study identified a number of areas within MCB, Camp Lejeune, including Sites 21 and 24, as potential sources of contamination (WAR, 1983). Site 78 was later added to the list of sites to be further evaluated. As a result of this study, the DON initiated further investigations at the three sites as summarized below.

1.4.2 Confirmation Study

During 1984 through 1987, Confirmation Studies at OU No. 1 were conducted which focused on potential source areas identified in the IAS (ESE, 1988). The results of the Confirmation Study conducted for Site 21 indicated that the soil within the site may be contaminated with pesticides and possibly polychlorinated biphenyls (PCBs). Groundwater at Site 21 did not appear to be impacted by these contaminants. The results of the Confirmation Study conducted for Site 24 indicated that several metals were present in the groundwater. Metals were also detected in the surface water and sediment samples collected from Cogdels Creek. No soil samples were collected at Site 24 during this study. 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. In addition, VOCs such as trichloroethene (TCE), benzene, trans-1,2-dichloroethene (T-1,2-DCE), and tetrachloroethylene (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 additional investigations under the Confirmation Study. 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 surficial aquifer, centered in the vicinity of Building 902, Site 22, and Building 1601.

1.4.3 Groundwater Study at Hadnot Point Fuel Farm

A groundwater study was conducted at the Hadnot Point Fuel Farm (Site 22) as part of the MCB, Camp Lejeune UST Program (ESE, 1990). 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 consisted of several USTs which had contained either diesel fuel, leaded gasoline, unleaded gasoline, or kerosene. The study concluded that fuel losses of gasoline/fuels have likely occurred predominantly through leaks in the transfer lines or valves. Laboratory analyses indicated that floating product had contributed significant levels of dissolved petroleum compounds including benzene, toluene, ethylbenzene, xylenes (BTEX) into the groundwater. Trace levels of non-petroleum VOCs including TCE and PCE were also detected within the fuel farm area. Based on the results of this study, a product recovery/groundwater treatment system was designed for the fuel farm. The system began operation in the latter part of 1991.

1.4.4 Supplemental Characterization Step

A Supplemental Characterization Step was performed in 1990 and 1991 for Site 78 to further evaluate the extent of contamination in the shallow and deeper portions of the aquifer and to characterize the contamination within the shallow soils at suspected source locations (ESE, 1992). The soil sample results from this study detected VOCs and a few semivolatile organic compounds (SVOCs) near Building 902. Fuel-related VOCs 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.

1.4.5 RI for the Shallow Soils and Castle Hayne Aquifer

An RI was conducted in 1991 to investigate shallow soils and the deeper portion of the aquifer (the Castle Hayne aquifer) at Site 78 (Baker, 1994a). This RI did not involve any additional field investigations. The RI was conducted using data from the previous Confirmation Study and Supplemental Characterization Step. 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 detected in soils appeared to be associated with a UST at Building 902, which reportedly was used to store spent solvents. The detected SVOCs were fuel related and fit with the use of the area (Building 1202) for vehicle repairs and maintenance. 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.

1.4.6 Interim Remedial Action RI and FS for the Surficial Aquifer

In 1992 Baker Environmental, Inc. (Baker) conducted an Interim Remedial Action (IRA) RI for the surficial aquifer at Site 78. 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 aquifer at Site 78; however, one plume was associated with the Hadnot Point Fuel Farm (Site 22) which is being remediated under a separate investigative program. The second plume was located east of Cedar Street and extended from the vicinity of the 901/903 Building area to the fuel farm. The plume exhibited solvent contamination (e.g., TCE) and low levels of fuel-related contamination (e.g., BTEX). The third plume was believed to originate in the vicinity of Buildings 1502, 1601, and 1602. This plume was contaminated with the same constituents as the second plume with the addition of lead.

As part of the IRA RI, a qualitative risk assessment (RA) was performed to identify receptors and exposure pathways, quantify exposure levels, and evaluate potential human and/or environmental risk. The qualitative RA concluded that benzene and TCE could impact human health if shallow groundwater were to migrate into the deep portions of the aquifer (used as a source of potable water), or if the shallow aquifer were to be utilized in the future as a potable water source.

Based on the results of the IRA RI for the shallow aquifer, Baker prepared an IRA FS Report in 1992. 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 to contain the two fuel/solvent-contaminated plumes at the site. Following extraction, the groundwater was to be treated on site via metals removal, air stripping, and carbon adsorption, then discharged to the Hadnot Point Sewage Treatment Plant (STP). This IRA alternative was accepted by the USEPA, the NC DEHNR, and the public. Design of the interim extraction/treatment systems was completed in 1993 and construction began in late 1993. Construction was completed during December 1994 and the IRA is currently being operated.

1.4.7 Pre-Investigation Study for RI/FS

Pre-investigation activities were conducted by Baker at Sites 24 and 78 in 1992 to assist in preparing the scope of work for the RI field program for OU No. 1. As part of the pre-investigation activities, groundwater samples were collected from several existing monitoring wells and water supply wells in the area of OU No. 1. Further, a geophysical survey was conducted at these sites by using surface investigative techniques. The geophysical investigation was conducted at Site 24 to delineate the boundaries of suspected buried metal disposal areas; the investigation was conducted at Site 78 to confirm the presence or absence of several suspected USTs. Suspected USTs were identified at Buildings 903, 1502, and 1601. BTEX and several metals were detected in the wells sampled during this investigation.

1.4.8 RI for OU No. 1

The RI field program conducted at OU No. 1 was initiated by Baker in 1993 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 (Site 21, Cogdels Creek/New River, and Beaver Dam Creek). The results of the RI are presented in Section 3.1 with respect to each site and the nearby surface water bodies.

The RI report was submitted to NC DEHNR during June 1994. The Final FS and Final PRAP were submitted to NC DEHNR on July 22, 1994. A final Record of Decision for Operable Unit No. 1 was submitted to NC DEHNR on September 8, 1994. A final Remedial Action Work Plan for the Hadnot Point Industrial Area Shallow Aquifer was submitted on July 19, 1993. A Remedial Design Expansion report was submitted on June 24, 1994.

2.0 OBJECTIVES OF THE CAP

This section presents remedial action goals, remediation levels, and a schedule for completing the remedial action.

2.1 Goals

The proposed remedial action identified in this CAP is the overall final cleanup strategy for the entire operable unit in that it remediates both media of concern at OU No. 1: groundwater and soil. The contaminant plumes will be remediated along with contaminated soils. The primary objectives of the selected remedy are to:

- Reduce groundwater and PCB-contaminated soils at OU No. 1.
- Reduce groundwater contaminant concentrations.
- Reduce the potential for contaminant migration.
- Protect nearby supply wells.
- Reduce the risk to human health and the environment.

Surface water and sediment will not be addressed under this action for the following reasons: 1) the overall risk to human health posed by either Cogdels Creek or Beaver Dam Creek is acceptable; 2) potential adverse impacts to terrestrial organisms at OU No. 1 appear to be low; and 3) there are no known spawning and nursery areas for resident fish species within Cogdels or Beaver Dam Creeks, therefore, there is no potential for decreased viability of fish spawning or nursing.

2.2 Remediation Levels

The selected remedy will be operated until the remediation levels (i.e., target cleanup levels) developed in the FS (Baker, 1994d) are met. The remediation levels for the groundwater COCs and the soil COCs are listed on Table 2-1. Where applicable, the groundwater remediation levels were based on Federal Maximum Contaminant Levels (MCLs) and North Carolina Groundwater standards. In the absence of the above-mentioned criteria, a risk-based remediation level (based on an incremental cancer risk (ICR) of 1.0E-4 and a hazard index (HI) of 1.0) was developed. For soil, the USEPA Region III risk-based soil screening criteria for industrial soils were used.

For groundwater, the monitoring results of the groundwater plumes will determine when the remedial action has met the remediation levels. Confirmation soil sampling results during excavation activities will be used to determine that soil exceeding the remediation levels has been removed from the site.

2.3 Schedule

Construction of the interim remedial action for OU No. 1, consisting of two groundwater extraction and treatment systems, began in September 1993. Construction, which included an expansion to the original design which will be described later in this report, was completed in

December 1994. Operation of this IRA and the IRA extension was also initiated in December 1994. This remedial action will be reviewed every five years.

Periodic groundwater monitoring began in July 1995. The first five-year review will occur in July 1999. If the groundwater analytical results show that additional remediation is required, the IRA will continue until the remedial action objectives are met. Based on the periodic groundwater monitoring data, the cap may be upgraded or downgraded as needed according to the USEPA "Guidance on Preparing Superfund Decision Documents" (EPA/540/G-89:007, July 1989). In addition, a less frequent sampling program may be implemented (such as annually), or it may be determined that sampling is no longer required in some areas. Once the remediation levels or steady state levels have been attained, monitoring will no longer be necessary. The longest possible period of remediation is 30 years from initiation of the remedial action or July 2024.

3.0 EXPOSURE ASSESSMENT

This section presents the exposure assessment performed for OU No. 1 at MCB Camp Lejeune. The topics that will be addressed in this section are: (1) evaluation of contaminant levels; (2) fate and transport assessment; (3) identification of potential human exposure pathways for the most mobile and/or toxic contaminants found; (4) identification of potential receptors at greatest risk from the existing contamination; and (5) the potential effects of residual contamination.

3.1 Evaluation of Contaminant Levels

Tables 3-1 through 3-10 summarize the contaminants that were detected in soil, groundwater, surface water, and sediment at OU No. 1. The following paragraphs briefly describe the nature and extent of contamination.

Site 21 - Transformer Storage Lot 140

Soils

- Pesticides and 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 concentration was 34,000 micrograms per kilogram (µg/kg).

- 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 concentration was 4,600 µg/kg.

- VOCs and 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, chromium, beryllium, lead, 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 (TCE and BTEX) in the groundwater were primarily limited to the northeastern portion of the site. Note that 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. Note that pesticides and PCBs, which were found in site soils, were not detected in the groundwater at Site 21.

Surface Water and Sediments

- Surface water at the site (which was only present 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.

Site 24 - Industrial Fly Ash Dump

Soils

- Analytical results indicated that pesticides and metals were the predominant contaminants detected in the soils at Site 24. 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 and widespread detections throughout the Base.

- The highest concentrations of metals, in both surface and subsurface soils, were detected within the Fly Ash Disposal Area and one of the Buried Metal Areas (an area covering approximately 180,000 square feet). The metals that exceeded base-specific background levels included: arsenic, beryllium, copper, chromium, lead, and manganese. 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 Resource Conservation and Recovery Act (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 the RCRA for ignitability, corrosivity, and reactivity. Low levels of TCE, the pesticides 4,4'-dichloro-diphenyl-dichloroethane (4,4'-DDD), and 4,4'-dichloro-diphenyl-trichloroethane (4,4'-DDT), and several metals were detected in some of the samples collected from the test pits.

Groundwater

- Metals were the predominant contaminants detected in the shallow groundwater at Site 24. 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.

- 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. Heptachlor epoxide (5.0 J µg/kg) was only detected in one soil sample collected at the site. Although the concentration appeared to be low, it exceeded the State groundwater standard of 0.038 µg/L for heptachlor epoxide.

Site 78 - HPIA

Soils

- The soil around the suspected UST at Building 903 was primarily contaminated with SVOCs. The extent of the contamination appeared to be limited to the UST area.

- Pesticides and SVOCs were the primary contaminants detected in the soil samples collected around Building 1103. The impacted area appeared to be limited, approximately 400 square feet.

- Although PCBs were expected to be found in the soils near Building 1300, only one detection was found. The PCB concentration does not appear to present a contamination problem at this building area.

- Pesticides were the primary contaminants detected in the soils around Building 1502. A limited area (approximately 400 square feet) at the northeastern side of the building and near the southern edge of the building (approximately 400 square feet) had the highest level of pesticide contamination. The pesticide levels at this building are higher than typical levels detected throughout the Base, but disposal is not documented.

- The soils sampled near Buildings 1601 and 1608 did not appear to be impacted.

Groundwater

- The analytical findings indicated that shallow groundwater at Site 78 was impacted by organic compounds and inorganic elements. The primary organic contaminants were VOCs, including: BTEX, PCE, TCE, vinyl chloride, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), 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 901/903 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.

- Benzene, TCE, 1,2-DCE, vinyl chloride, and dichloromethane were the most prevalent VOCs detected in the intermediate wells (screened at the deeper portion of the surficial aquifer) at Site 78. The concentrations of the detected VOCs were less than those concentrations found from the shallow wells.

- Benzene, 1,2-DCE, cis-1,2-DCE, T-1,2-DCE, and TCE were 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.

- Contamination levels in the shallow groundwater appear to have decreased over time. An increase in the contamination levels in several of the deeper monitoring wells has been noted.

Cogdels Creek and New River

- The surface water within Cogdels Creek and the New River did not appear to be impacted with the exception of a few VOCs, pesticides, and metals. VOCs (TCE, and 1,2-DCE) were detected at a limited number of locations in the upper portion of Cogdels Creek. Pesticides were detected at a few random locations throughout. Copper was detected throughout the creek and river at concentrations above Federal and/or State surface water standards. Lead, zinc, and chromium were detected above the standards at random locations. No trends were detected. The highest metals concentrations were detected near the Hadnot Point Sewage Treatment Plant.

- The most prevalent contaminants found in Cogdels Creek and New River sediments were polynuclear aromatic hydrocarbon compounds (PAHs), pesticides (particularly 4,4'-DDD), and several inorganic analytes. A number of inorganic elements were detected at every sediment sample location. Lead and zinc most often exceeded of sediment screening values of 35 and 120 mg/kg, respectively. No trends or source areas were identified.

Beaver Dam Creek

- The only contaminants that were present in Beaver Dam Creek surface water were inorganic elements. 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 concentrations was east of the northern portion of Site 78.

- The most prevalent contaminants found in Beaver Dam Creek sediments were PAHs, pesticides, and inorganic elements (lead was the only element to exceed sediment screening values). No trends or source areas could be identified.

3.2 Fate and Transport Properties

Table 3-11 presents the physical and chemical properties associated with the organic contaminants detected at the site which determine inherent environmental mobility and fate. These properties include:

- Vapor pressure
- Water solubility
- Octanol/water partition coefficient

- Organic carbon adsorption coefficient (sediment partition)
- Specific gravity
- Henry's Law constant
- Mobility index

3.3 Contaminant Transport Pathways

Based on the evaluation of existing conditions at Sites 21, 24, and 78, the following potential contaminant transport pathways have been identified.

- On-site atmospheric deposition of windblown dust.
- Leaching of sediment contaminants to surface water.
- Migration of contaminants in surface water.
- Leaching of soil contaminants to groundwater.
- Migration of groundwater contaminants off site.
- Groundwater infiltration from the shallow aquifer to the deep aquifer.

Contaminants released to the environment could also undergo the following during transportation:

- Physical transformations: volatilization, precipitation
- Chemical transformations: photolysis, hydrolysis, oxidation, reduction
- Biological transformation: biodegradation
- Accumulation in one or more media

The following paragraphs summarize the contaminant group fate and transport data for contaminants detected in media collected at OU No. 1.

3.3.1 Volatile Organic Compounds

VOCs (i.e., vinyl chloride, TCE, and PCA) tend to be mobile in environmental media as indicated by their presence in groundwater and their corresponding MI values. Their environmental mobility is a function of high water solubilities, high vapor pressures, low K_{ow} and K_{oc} values, and high mobility indices.

Without a continuing source, VOCs do not generally tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal.

3.3.2 Polynuclear Aromatic Hydrocarbons

Low water solubilities, high K_{ow} and K_{oc} indicate a strong tendency for PAHs to adsorb to soils. Of the PAHs, fluoranthene, is probably the best marker compound, since it is consistently the most abundant of the PAHs measured and provides the strongest correlation with total PAH values. Benzo(g,h,i) perylene is usually the most abundant compound in soils with low PAH values but becomes less important with increasing total PAH values. Other PAHs are benzo(a)anthracene, chrysene, pyrene, benzo(g,h,i) perylene, benzo(b)fluoranthene and phenanthrene. Their mobility indices indicate that they are relatively immobile from a physical-chemical standpoint. An exception is naphthalene, which is considered only slightly immobile because of somewhat higher water solubility.

PAHs generally lack adequate vapor pressures to be transmitted via vaporization and subsequent airborne transport. However, surface and shallow surface soil particles containing PAHs could potentially be subject to airborne transport and subsequent deposition, especially during mechanical disturbances such as vehicle traffic or digging.

PAHs are somewhat persistent in the environment. In general their persistence increases with increasing ring numbers. Photolysis and oxidation may be important removal mechanisms in surface waters and surficial soils, while biodegradation could be an important fate process in groundwater, surface soils or deeper soils. PAHs are ubiquitous in nature. The presence of PAHs in the soil may be the result of aerially deposited material, and the chemical and biological conditions in the soil which result in selective microbial degradation/breakdown.

3.3.3 Pesticides/Polychlorinated Biphenyls

Pesticides/PCBs are persistent and immobile contaminants in environmental media. Pesticides travel at varying rates through soil, mainly due to their affinity for soil surfaces. The soil sorption coefficient (K_d) is the distribution of a pesticide between soil and water. In general, the K_d values are higher for high organic carbon soil than for low organic carbon soils. Therefore, soils with high K_d values will retain pesticides (i.e., 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD). As evidenced by the ubiquitous nature of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, volatilization is an important transport process from soils and waters.

PCBs have low vapor pressures, low water solubilities, and high K_{oc} and K_{ow} values. Adsorption of these contaminants to soil and sediment is the major fate of these contaminants in the environment.

3.3.4 Inorganics

Inorganics can be found as solid complexes at ambient temperature and pressure in soils at the site. Inorganic ions exist in pure solutions as hydrated ions. Groundwater, as opposed to a pure solution, is a highly complex chemical system which is heavily influenced by the mineralogy of the substrate. Factors affecting the transport of inorganics in saturated soils are interactive and far more complex and numerous than those affecting the transport of organic contaminants.

The most complicated pathway for inorganic contaminants is migration in subsurface soils and groundwaters, where oxidation-reduction potential (Eh) and pH play critical roles. Table 3-12 presents an assessment of relative inorganic environmental mobilities as a function of Eh and pH. Soils at MCB Camp Lejeune are relatively neutral, therefore, inorganics in the subsurface soil should be relatively immobile.

Transport of inorganic species in groundwater is mainly a function of the inorganic's solubility in solution under the chemical conditions of the soil-solution matrix. The inorganic must be dissolved (i.e. in solution) for leaching and transport by advection with the groundwater to occur. Generally, dynamic and reversible processes control solubility and transport of the dissolved metal ions. Such process include precipitation/dissolution, adsorption/desorption, and ion exchange.

Inorganics could be sorbed onto colloidal materials, theoretically increasing their inherent mobility in saturated porous media. It is important to note, however, that colloids themselves are not mobile in most soil/water systems.

Inorganics such as arsenic and chromium depend upon speciation to influence their mobility. Speciation varies with the chemistry of the environmental medium and temporal factors. These variables make the site-specific mobility of an inorganic constituent difficult to assess.

3.4 Exposure Assessment

This exposure assessment section contains a description of the human health risk assessment and the potential exposure pathways and receptors.

3.4.1 Human Health Risk Assessment

In order to estimate potential human health effects associated with contaminants identified at OU No. 1, the study area has been divided into three areas of concern: Site 21 (Transformer Storage Lot 140); Site 24 (Industrial Fly Ash Dump); and Site 78 (Hadnot Point Industrial Area). The OU was divided into these areas based upon their current accessibility and usage. Following is a description of these areas of concern:

- Site 21 has a history of pesticide usage and transformer oil disposal. The approximately 7-acre area was used as a pesticide mixing area and as a cleaning area for pesticide application. It is currently used by the Base as a storage area for investigation-derived wastes. A fence restricts trespassers.

- Site 24 was used for disposal of fly ash, cinders, solvents, used paint stripping compounds, sewage sludge, and water treatment spiractor sludge. The 100-acre area is no longer used for disposal. Currently, the heavily wooded area is used for military training exercises (i.e., tanks). Access is unrestricted.

- Site 78 is comprised of maintenance facilities, warehouses, painting shops, printing shops, auto body shops, and other similar facilities. Much of the 590 acre area is paved (i.e., roadways, parking lots, loading docks, and storage lots); however, there are small lawn areas associated with individual buildings at the HPIA and along stretches of roadways. Military personnel and civilians utilize the area for various activities.

The Baseline Risk Assessment (BRA) is part of the RI report (Baker, 1994) and is summarized in this section. The BRA investigates the potential for contaminants of potential concern to affect human health and/or the environment, both now and in the future, under a "no further remedial action scenario." The BRA process evaluates the data generated during the sampling and analytical phase of the RI, identifying areas of interest and contaminants of concern with respect to geographical, demographic, and physical and biological characteristics of the study area. These, combined with the current understanding of physical and chemical properties of the site-associated constituents (with respect to environmental fate and transport processes), are then used to estimate the concentrations of contaminants at the end points of logical exposure pathways. Finally, contaminant intakes by hypothetical receptors are determined and combined with the toxicological properties of the contaminants to estimate (inferentially) the potential public health impacts posed by constituents detected at the sites.

The BRA for OU No. 1 has been conducted in accordance with current USEPA's Risk Assessment Guidance (USEPA, 1989b and USEPA, 1991a), and USEPA Region IV Supplemental Risk Guidance (USEPA, 1992g).

3.4.2 Potential Exposure Pathways and Receptors

A site conceptual model of potential sources, migration pathways and human receptors was developed to encompasses all current and future potential routes of exposure. Figure 3-1 presents the conceptual site model for OU No. 1. Inputs to the site conceptual site model included qualitative descriptions of current and future land use patterns in the vicinity of OU No. 1. All available analytical data and meteorological data were considered in addition to general understanding demographics of surrounding habitats. For this information, the following list of potential receptors were developed for inclusion in the quantitative health risk analysis:

- On-site military personnel
- Future recreational users (child and adult) of Cogdels Creek and Beaver Dam Creek
- Future on-site residents (child and adult)

3.4.3 Conclusions of the BRA for OU No. 1

The BRA highlights the media of interest from the human health standpoint at OU No. 1 by identifying areas with elevated ICR and HI values. Current and future potential receptors at the site include current military personnel, future residents (i.e., children and adults), and future construction workers. The total risk from each site for the these receptors was estimated by logically summing the multiple pathways likely to affect the receptor during a given activity. The following algorithms defined the total site risk for the current and future potential receptor groups assessed in a quantitative manner. The risk associated with each site was derived using the estimated risk from multiple areas of interest.

1. Current Military Personnel

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

2. Future Residents (Children and Adults)

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

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

    c. Incidental ingestion of COPCs in site related surface water + dermal contact with COPCs in site related surface water + incidental ingestion of site related sediment + dermal contact with site related sediment

3. Future Construction Worker

a. Incidental ingestion of COPCs in subsurface soil + dermal contact with COPCs in subsurface soil

The total ICRs and HIs associated with current and future potential receptors at Site 21 are presented in Table 3-13. Exposures to soil (i.e., incidental ingestion and dermal contact) and groundwater (i.e., ingestion and dermal contact) were considered in the overall site risk. All total risks fell within the USEPA's acceptable risk range. Therefore, the contaminants detected at Site 21 do not appear to present an unacceptable risk to human health.

Future potential residential exposure (i.e., children and adults) to surface water and sediments (Beaver Dam 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 is not necessary.

Table 3-14 presents the total ICRs and HIs associated with Site 24 potential current and future receptors. With the exception of future adult and child resident total site risk associated with groundwater exposure, all total site risks fall within the USEPA's acceptable risk range. The majority of the total site risk (greater than 90 percent) was associated with the ingestion and dermal contact of Operable Unit groundwater by future residents. Future potential exposure to OU No. 1 groundwater produced ICRs and HIs for future adult residents of 2E-03 and 13, respectively. The ICRs and HIs for future child residents were 7E-04 and 29, respectively. Therefore, OU No. 1 groundwater must be considered a medium of interest for which remediation levels for protection of human health will be needed.

Future potential residential exposure (i.e., children and adults) to surface water and sediments (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 is not necessary.

No risk values were calculated specifically for Site 78 since the only medium of concern was groundwater. The risks associated with groundwater were presented for the entire operable unit (Table 3-14).

Although lead could not be quantitatively evaluated in the BRA, lead was mainly detected in the shallow groundwater and not the deeper portions of the aquifer. Exposure is unlikely since the shallow groundwater is not conducive to usage due to its slow recharge.

With respect to surface water and groundwater, fish, crab, benthic macroinvertebrates, birds, and other aquatic and terrestrial life were evaluated as potentially exposed populations. Bottom feeding fish and crabs, benthic macroinvertebrates, aquatic vegetation, and other aquatic life were evaluated with respect to sediment exposure. For soil, terrestrial species were evaluated as the potentially exposed population.

It is important to note that actual or threatened releases of hazardous substances from OU No. 1, if not addressed by the preferred alternative or one of the other active measures considered, may present a current or potential threat to public health, welfare, or the environment.

4.0 EVALUATION OF REMEDIAL ALTERNATIVES

4.1 Description of Alternatives

Several Remedial Action Alternatives (RAAs) have been developed to address the contaminated groundwater and/or soils at various areas of concern (AOCs) within OU No. 1. The AOCs were identified based on a comparison of the media-specific contaminant concentrations detected at the operable unit to the media-specific remediation levels developed in the FS. The AOCs identified for OU No. 1 include:

- VOC-contaminated plume located near the 900-Series Building area within Site 78 (referred to as Groundwater AOC 1).
- 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 AOC 3).
- A VOC-contaminated plume located near the 1600 and 1700 Series Building area of Site 78 (Groundwater AOC 5).
- Two areas of groundwater contamination located within Site 24 (heptachlor epoxide only) (Groundwater AOCs 6 and 7).
- Northern portion of Site 21 with elevated levels of PCBs in soil (Soil AOC 1).
- Southwest portion of Site 21 with elevated PCB concentrations in surface soil (Soil AOC 2).
- Southwest portion of Site 21 with elevated pesticides concentrations in surface soil (Soil AOC 3).
- Northeastern edge of Building 1502 within Site 78 with elevated levels of pesticides in surface soil (Soil AOC 4).

Figures 4-1 and 4-2 show the general location of the above-mentioned AOCs for groundwater and soil, respectively.

Based on the AOCs identified above, five groundwater RAAs and four soil RAAs were developed and evaluated in the FS.

The groundwater RAAs only include remediation of the groundwater from Groundwater AOCs 1 and 5. No additional remedial actions, other than 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 low contaminant concentrations, the lack of a source area, the technical impracticality of remediation, and the lack of human health or environmental exposure. 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 State groundwater standard for PCE is 0.7 µg/L and the Federal drinking water standard is 5.0 µg/L. Since the detected level of PCE was below the Federal standard and only slightly above the State standard, 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 is deteriorating, additional measures will be taken. Once the remediation levels or steady state levels have been attained for these areas, monitoring will no longer be necessary.

With respect to Groundwater AOCs 6 and 7, only one contaminant, heptachlor epoxide, was detected in the groundwater samples. The detected concentrations of this contaminant were 0.083 µg/L at 24GW08, 0.13 µg/L at 24GW09, and 0.078 µg/L at 24GW10. The State groundwater standard for heptachlor epoxide is 0.038 µg/L and the Federal drinking water standard is 0.20 µg/L. The detected levels were all below the Federal standard, but exceeded the State standard. 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 Groundwater AOCs 6 and 7 appears to be the most appropriate measure at this time. If monitoring indicates that the groundwater at these areas is deteriorating, additional measures will be taken. Once the remediation levels or steady state levels have been attained 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. Therefore, only monitoring will be conducted near this area.

Several potable water supply wells are located near or within OU No. 1. All of the wells, except HP-637 and HP-642, are either abandoned or in the process of being abandoned. Once abandoned, these wells will no longer be potential pathways for human exposure to groundwater contaminants. Potable water supply wells HP-637 and HP-642, however, will not be abandoned. Instead, these wells will remain active and in service. To ensure that groundwater contaminants from OU No. 1 do not affect these active supply wells, a Two-Dimensional Horizontal Flow Model Assuming a Slug Source (Wilson and Miller, 1978) was conducted and its results are presented in Appendix B. The results show contaminant concentrations over time at HP-637 and HP-642 assuming groundwater flows directly from OU No. 1 to these supply wells. Based on the model results, contaminants from OU No. 1 are not expected to adversely impact groundwater being collected by HP-637 and HP-642 and these supply wells are considered to be safe for further use. The groundwater RAAs may further ensure their safety through long-term groundwater monitoring or active groundwater treatment systems.

A brief overview of each of the RAAs per media is included below. All costs and implementation times are estimated.

Groundwater RAAs

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

- RAA No. 1 No Action
- RAA No. 2 Institutional Controls
- 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 IRA 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. Each of the common elements are briefly discussed below.

The IRA includes 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 is intended to contain the shallow groundwater contamination from Groundwater AOCs 1 and 5.

The IRA groundwater treatment systems include air stripping, carbon adsorption, oil/water separation, and metals removal. One treatment system is located within the northeast contaminated plume (Groundwater AOC 1). Six extraction wells were installed near the downgradient edge of this plume. The second treatment system is located within the southwest contaminated plume (Groundwater AOC 5). Six extraction wells were installed along the downgradient edge of this second plume. Approximately three to five gallons of groundwater per minute are anticipated to be extracted from each well. Each of the treatment systems is designed to handle a maximum influent of 80 gallons per minute (gpm).

In addition to the pump and treat systems, the IRA includes a long-term groundwater monitoring program as an institutional control. Under this program, the following monitoring wells are sampled for the contaminants of concern (i.e., VOCs and inorganics) on a quarterly basis:

Shallow Wells	Intermediate Wells	Deep Wells
24GW08	78GW09-2	78GW09-3
24GW10	78GW24-2	78GW24-3
78GW01		78GW31-3
78GW04-1		
78GW05		
78GW08		
78GW09-1		
78GW10		
78GW11		
78GW14		
78GW15		
78GW17-1		
78GW19		
78GW21		
78GW22		
78GW22-1		
78GW23		
78GW24-1		
78GW25		
78GW39		

Supply wells HP-601, HP-602, HP-603, HP-608, HP-630, HP-634, HP-637, and HP-642 are also included under the monitoring program. (However, eventually the supply wells in the vicinity of OU No. 1, with the exception of HP-637 and HP-642, will be abandoned.) Additional wells may be added to the monitoring program, if necessary.

All groundwater samples are analyzed for Target Compound List (TCL) VOCs, Target Analyte List (TAL) inorganics, oil and grease, total dissolved solids (TDS) and total suspended solids (TSS). As required, after five years the remedial action will be re-evaluated to determine its effectiveness. Based on 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.

The institutional controls under RAA Nos. 2 through 5 will also include deed restrictions restricting the placement of additional water supply wells within the entire OU No. 1.

The Groundwater RAAs will only include active 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. As previously discussed, this decision for most of the AOCs was based on the contaminant concentrations and since no apparent source(s) were identified (e.g., PCE was the only contaminant detected at three of the Groundwater AOCs at levels above the State groundwater standard). 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 or steady state levels have been attained for these 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.

The FS provides a detailed discussion evaluating the RAAs, including the assumptions for calculating capital costs, annual operating and maintenance costs, and net present worth. A summary 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 be evaluated through the nine point evaluation criteria summarized on Table 4-1. This RAA provides a baseline for comparison. Under this RAA, no further action at the operable unit will be implemented (note that the IRA to contain the migration of two shallow plumes and prevent exposure to groundwater contamination would still be implemented under this RAA).

- **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 contaminants at OU No. 1. This RAA will include only the common institutional controls of monitoring and access 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. This alternative was developed to extend the original IRA treatment system design by adding more recovery wells. The alternative provides for additional shallow extraction wells in areas exhibiting the highest VOC contamination. Specifically, two additional wells were planned for the original north treatment plant, and one additional well was planned for the south treatment plant. (Note that in December 1994, the two northern wells were installed near existing monitoring wells 78GW24-1 and 78GW23 within Groundwater AOC 1, and the southern well was installed near existing monitoring well 78GW09-1 within Groundwater AOC 5.) The extraction wells were designed the same as for the interim action wells (i.e., 6-inch minimum diameter, approximately 35 feet deep) with a pumping rate of three to five gpm.

  No extraction wells were planned for the deeper portions of the aquifer under this alternative. It is believed that once the contaminants in the source of deep groundwater contamination (i.e., the shallow aquifer) are 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. The deeper aquifer would be monitored to determine the effectiveness of the RAA.

- **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 the 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. 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 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 systems. 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 IRA wells (i.e., 6-inch minimum diameter, approximately 35 feet deep). Based on site geology, it is anticipated that the wells will produce a flow of approximately three to five gpm.

  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. 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.

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

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 within Site 21 and Site 78. The thickness of the cap will be approximately four to eight inches. 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 prevention of migration of the COCs), groundwater sampling will be conducted semiannually. Groundwater samples will be collected from six monitoring wells: 21GW01, 21GW02, 21GW03, 21GW04, 78GW09-1, and 78GW10. 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 AOC 3. 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 area. 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.

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 (based on final treatment 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) of PCBs and pesticides.

4.2 Summary of Comparative Analysis of Alternatives

A detailed analysis was performed on the Groundwater and Soil RAAs using the nine evaluation criteria in order to select a site remedy. A glossary of the evaluation criteria has previously been noted on Table 4-1. Tables 4-2 and 4-3 present a summary of the detailed analysis for Groundwater RAAs and Soil RAAs, respectively. A brief summary of each RAA's strengths and weaknesses with respect to the evaluation criteria follows.

Groundwater RAA Comparative Analysis

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. The No Action RAA will provide protection through the implementation of the IRA. In addition, all of the RAAs except RAA No. 1 will 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 surficial and the deeper portions of the aquifer), it may not provide the most protection to human health and the environment. Since the primary source of groundwater contamination is in the surficial aquifer, the operation of "deep" extraction wells could cause increased migration of the shallow VOCs into the deeper portion of the aquifer.

Compliance with ARARs

Groundwater RAA Nos. 1 and 2 may not be able to 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 except for the chemical-specific ARARs associated with total metals and some organics in limited areas of the operable unit. This CAP has been prepared in accordance with Title 15A NCAC 2L.0106(k) and (l). Due to the complex nature of groundwater contamination, the time to reach the remediation levels cannot be determined.

Note that both inorganic and organic contaminants above State and/or Federal Standards will not be remediated in some portions of the operable unit due to the impracticality of remediation, and/or the lack of human health and ecological exposure to the contaminants. All of the Groundwater RAAs will met the location-specific and action-specific ARARs.

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, but the permanent effectiveness of a pump and treat system is unknown. Contaminant levels will initially decrease until equilibrium is reached; however, once pumping is terminated, contaminant levels could increase. All of the RAAs include treatment of the COCs in the groundwater aquifer. All of the RAAs will require a five-year review to determine their effectiveness. This review may not be needed for RAAs No. 3, 4, and 5 once the remediation levels are met and maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment

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

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 piping for the groundwater extraction and/or 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 that 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 will vary. It is estimated that RAA Nos. 1, 2, 3, and 5 will be implemented for up to 30 years and RAA No. 4 for 5 years.

Implementability

No additional construction, operation, or administrative activities other than the ones associated with the IRA are associated with RAA No. 1. The only additional site activities associated with RAA No. 2 are groundwater sampling activities, which can be easily performed. The implementation of RAA Nos. 3 and 5 requires the installation of additional extraction wells and connection to the IRA treatment systems. RAA No. 3 requires the installation of three additional extraction wells (shallow) and their associated piping. RAA No. 5 requires 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 (primarily since the other "additional treatment" alternatives only require connection to an existing treatment system). RAA No. 4 requires a pilot study to determine the effectiveness of air sparging/soil vapor extraction at Site 78.

Cost

In terms of the 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).

Soil RAA Comparative Analysis

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.

Compliance with ARARs

All of the RAAs should meet all of the chemical-, action-, and location-specific ARARs. The (risk-based) remediation levels for the soil COCs will not be met with RAA Nos. 1 and 2.

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 caps are 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 will only require a 5-year review if the duration of the treatment process is greater than five years. RAA No. 4 will not require the 5-year review.

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 RAA Nos. 3 and 4. 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 two RAAs do satisfy the preference.

Short-Term Effectiveness

Risks to community and workers are not increased with the implementation of RAA No. 1, but current potential human health risks 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 caps/covers (RAA No. 2). With respect to RAA No. 3, risks will be increased during the operation of the treatment options.

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.

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).

5.0 PROPOSED CORRECTIVE ACTION PLAN

This section of the CAP focuses on the selected remedies for OU No. 1. First, the major treatment components, engineering controls, and institutional controls of the remedies for AOCs No. 1, 3, and 5 and AOCs No. 2, 4, 6, 7, and 8 are discussed. The groundwater monitoring remedy for AOCs 2, 4, 6, 7, and 8 is discussed with respect to CAP criteria. Next, the issue concerning nearby potable water supply wells is discussed. Finally, conceptual system layouts for the groundwater and soil remedies are presented. The remediation levels to be attained at the conclusion of the remedial action are also discussed.

5.1 Remedy Description - AOCs No. 1, 3, and 5

The selected remedy for OU No. 1 is a combination of Groundwater RAA No. 3 [Source Control (Interim Remedial Action Treatment System Extension)] and Soil RAA No. 4 (Off-Site Disposal). Overall, the major components of the selected remedy include:

- Collecting additional contaminated groundwater in the surficial aquifer by installing three additional extraction wells within the areas with the highest contaminant levels. (Note that the three extraction wells were installed in December 1994 and are currently operating in conjunction with the IRA treatment systems.)

- Restricting the installation of any new water supply wells within the Operable Unit area. (It is assumed that all supply wells located within or in the vicinity of OU No. 1 will be abandoned, with the exception of HP-637 and HP-642.)

- Implementing a long-term groundwater monitoring program to monitor the effectiveness of the groundwater remedy and to monitor the two nearby water supply wells. Additional wells may be added to the monitoring program, if necessary. (Note that the monitoring program at OU No. 1 was initiated in July 1995.)

- Groundwater samples will be collected quarterly for five years and analyzed for TCL VOCs, TAL metals, oil and grease, TDS, and TSS. After five years, the data will be evaluated to determine the effectiveness of the remediation. A less frequent sampling program (such as annually) may be implemented, or it may be determined that sampling is no longer required from certain areas.

- Excavating approximately 1,050 cubic yards of PCB- and pesticide-contaminated soils for off-site disposal. A possible off-site landfill which may be capable of receiving these soils is located in Pinewood, South Carolina, approximately 200 miles away from the operable unit.

The proposed locations of the major components of the selected remedy are presented on Figures 4-4 and 4-5.

5.2 Remedy Description - AOCs No. 2, 4, 6, 7, and 8

The groundwater monitoring remedy has been selected for AOCs 2, 4, 6, 7, and 8 for several reasons. AOCs 2, 4, and 8 are contaminated with PCE at levels slightly above the NC DEHNR groundwater standard of 0.7 µg/L, but below the federal MCL of 5.0 µg/L. AOCs 6 and 7 are contaminated with heptachlor epoxide at a maximum level of 0.13 µg/L, which is above the NC DEHNR groundwater standard of 0.038 µg/L, but below the federal MCL of 0.2 µg/L.

No source of PCE or heptachlor epoxide was found in subsurface soil samples in Sites 21 or 24. Site 78 soils had been sampled previously and soil gas was sampled during the RI, with no source of PCE being identified. Potable water is supplied from on-site wells screened in the deeper aquifer, which has not been effected by the shallow groundwater contaminants identified in AOCs 2, 4, 6, 7, and 8.

For the contaminants in AOCs 2, 4, 6, 7, and 8, one-dimensional groundwater modeling was performed to demonstrate the following:

- Time and direction of travel can be reasonably predicted;
- It will take hundreds to thousands of years for the contaminants to reach the nearest receptor (Cogdels Creek); and
- Contaminants will not migrate off-site.

A description of the one-dimensional groundwater model (ONED1), model input parameters, and results are provided in Appendix A. Input parameters were obtained from the RI (Baker, 1994) and certain assumptions. Retardation factors were calculated, but no degradation of the contaminants was assumed. If no degradation of the contaminants occurs, the model predicts that PCE will reach Cogdels Creek in 600 to 700 years and heptachlor epoxide will reach the creek in 2,000 years or more.

Long before the PCE reaches Cogdels Creek it is expected that the concentration will have naturally attenuated to below the NC DEHNR groundwater protection standard at AOCs 2, 4, and 8. CERCLA requires a technical review of this remedy every five years after commencement of the remedy. Additional groundwater modeling will be performed, during this review, if compliance cannot be directly shown with the groundwater data collected during the five year period.

The calculated retardation factor and one-dimensional groundwater modeling show that heptachlor epoxide is tightly bound to soil particles. Thus, it will migrate so slowly that heptachlor epoxide concentrations at AOCs 6 and 7 are expected to remain above the NC DEHNR groundwater standards for the foreseeable future. Because of potential sampling and analysis variations, it is anticipated that the long-term average concentration of heptachlor epoxide will be below 0.15 µg/L, but that there will be considerable variability in specific sample results. This remedy will be reviewed every five years under CERCLA and groundwater modeling will be included as part of the review.

5.3 Impacts on Nearby Supply Wells

The Base currently has plans to abandon all supply wells located within or in the vicinity of OU No. 1. Once abandoned, these wells will no longer be potential pathways for human exposure to groundwater contaminants. Potable water supply wells HP-637 and HP-642, however, will not be abandoned. Instead, these wells will remain active and in service. To ensure that groundwater contaminants from OU No. 1 will not affect these active supply wells, a 2-dimensional model (2-D Horizontal Flow Model Assuming a Slug Source [Wilson and Miller, 1978]) was conducted and its results are presented in Appendix B.

Because the groundwater areas of concern at OU No. 1 contain chlorinated solvent and fuel contaminants, the model was run for both TCE and benzene. TCE was the most mobile chlorinated solvent that was detected, and benzene was the most volatile fuel contaminant that was detected. The monitoring well locations where TCE and benzene were detected at maximum concentrations were selected as the slug source locations. Thus, the model was run for four source-receptor combinations or scenarios:

- A TCE slug source at 78-GW23 and a receptor at supply well HP-637.
- A benzene slug source at 78GW22-1 and a receptor at supply well HP-637.
- A TCE slug source at 78-GW23 and a receptor at supply well HP-642.
- A benzene slug source at 78GW22-1 and a receptor at supply well HP-642.

For each source-receptor scenario, 2 runs of the model were conducted: one assuming no decay and one assuming decay (decay refers to biodegradation). In addition, each source-receptor scenario and decay assumption was run using four different time periods: t=365 days (1 year), t=1,850 days (5 years), t=10,950 days (10 years), and t=36,500 days (100 years) to model contaminant concentrations over time.

For the purposes of this CAP, three extremely conservative assumptions were made to run the model. First, the shallow and Castle Hayne aquifers were assumed to be one continuous aquifer with no confining unit to impede the flow of groundwater contaminants. In reality, however, there is likely to be a semi-confining unit impeding contaminant migration. It was also assumed that groundwater flows directly from the source locations to the receptor supply wells. Based on water level measurements, however, groundwater appears to flow in a generally southwestern direction. Finally, it was assumed that there is no IRA being conducted at OU No. 1. In reality, a groundwater treatment system is currently being operated near 78-GW23 (the TCE source location) under the IRA. The model does not take into account the effects that this treatment system may be having on TCE contaminant levels. Most likely, the treatment system is lowering contaminant levels and reducing the contaminant plume's mobility. Because of these assumptions, the model results most likely err on the conservative side.

The model results presented in Appendix B indicate that over time, TCE and benzene concentrations at HP-637 and HP-642 will not exceed federal and state standards. In fact, the concentrations were far below the standards under both the degradation and no degradation assumptions. Based on these results, it appears that contaminants from OU No. 1 will not adversely impact groundwater being collected by HP-637 and HP-642 and these supply wells are considered to be safe for further use. The selected remedy will further ensure the supply wells' safety through long-term groundwater monitoring and an active pump and treat system.

5.4 Estimated Costs

Capital costs have been estimated for three parts of the overall remedy for OU No. 1. The interim remedial action costs, including soil removal and groundwater treatment system installation was estimated at $1,100,000 in the remedial design document (Baker, 1994b). In the FS (Baker, 1994d) capital cost for the additional groundwater treatment system (RAA No. 3 - Groundwater) was estimated to be $188,000 and the estimated capital cost for the soil removal and disposal (RAA No. 4 - Soil) was $480,000.

Annual O&M costs of approximately $30,000 are projected for the sampling of the monitoring wells and supply wells for the first 5 years. The annual O&M costs will be reduced to approximately $15,000 for years 6 through 30. Assuming an annual percentage rate of 5 percent, these costs equate to a NPW of approximately $1.0 million. Table 4-4 presents a summary of the FS cost estimate for the major components of the selected remedy.

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. The two supply wells that are not scheduled to be abandoned, HP-637 and HP-642, will also 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 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 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.

5.5 Groundwater RAA No. 3: Source Control (Interim 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, the interim action groundwater treatment systems are extended as shown on Figure 4-3. The extraction wells were designed the same as for the interim action wells (i.e., 6-inch minimum diameter, 35 feet deep) with a pumping rate of 3 to 5 gpm.

No extraction wells were 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 was planned in the deeper portions of the aquifer to evaluate if the conditions are deteriorating or improving. 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.

A treatability study was performed to evaluate treatment parameters (Baker, 1993a). The design documents for the groundwater IRA are contained in the Remedial Action Work Plan for the Hadnot Point Industrial Area Shallow Aquifer (Baker, 1993b) submitted to NC DEHNR on July 19, 1993. This report provided the remedial action design, implementation, and operation and maintenance plan. The design of the expansion to the groundwater treatment system, shown on Figure 4-3, is provided in the Pre-Final Design, Construction Cost Estimate, and Remedial Design Expansion for the Hadnot Point Industrial Area, Shallow Groundwater Treatment System (Baker, 1994b). Construction was completed and operation began in December 1994.

5.6 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 locations to be excavated are shown on Figure 4-2. The technologies/process options included under this RAA include soil excavation, grading, revegetation, and off-site treatment/disposal at a permitted facility. The main components of this alternative are described below.

Excavation - Excavation of soil at Site 21 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 Site 21, it appears that any of these machinery would be applicable for the shallow soil excavation activities required under 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/disposal facility. The limits of the excavations will be defined by constituent concentrations in excess of the specified remediation goals. For FS estimating purposes, approximately 3,000 cubic yards of soil were assumed to 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/Disposal - 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-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.

Design documents for soil remediation have been previously submitted to the NC DEHNR. The 100 Percent Design Package, Basis of Design Report for Remediation of Pesticide and PCB - Contaminated Soil at Sites 21 and 78 (Baker, 1994c) was submitted on November 11, 1994. The Design and Specification documents (Baker, 1994d) were submitted on the same date and have been approved by the DoN, Atlantic Division, Naval Facilities Engineering Command, as of January 11, 1995.

6.0 REFERENCES

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APPENDIX A
1-D MODEL

APPENDIX A - GROUNDWATER MODEL

1.0 TECHNICAL BASIS FOR NATURAL ATTENUATION REQUEST - TETRACHLOROETHENE IN AOCS 2, 4 & 8

Tetrachloroethene (a.k.a. perchloroethylene or tetrachloroethylene) was detected in groundwater at AOCs 2, 4 and 8 (Site 78) at a maximum concentration of 1.0 ppb. The NC DEHNR groundwater standard for tetrachloroethylene is 0.7 ppb. Pursuant to 15A NCAC 2L.0106(l), remediation by natural attenuation is proposed based on the information presented below.

It will be demonstrated that the maximum observed concentration of tetrachloroethylene in groundwater poses no practical threat of migration to the nearest identified potential receptor (Cogdels Creek, see Figure 4-1). The shortest distance from the source to the receptor is 600 feet (from well 78GW39 measuring south to the nearest branch of Cogdels Creek) and the greatest distance is 2,050 feet (from well 78GW15 measuring west to the nearest branch of Beaver Dam Creek).

For this demonstration, it was necessary to calculate contaminant travel times and contaminant concentration distributions in space and time; therefore, an appropriate form of the contaminant transport equation had to be used. A simple, one-dimensional, analytical (equation-based) model was considered to be the most appropriate for this demonstration because of the reduced data requirements necessary for its implementation. The model ONED1 is an analytical BASIC program code written by Milovan S. Beljin (1985) that uses the equation for conservation of mass to calculate concentrations at a given point in space and time. The basic equation is for solute transport with retardation in a semi-infinite column with constant concentrations as the inlet boundary condition and is given below:

$$C_{(x,t)} = C_i + (C_o + C_i)\{1/2\mathrm{erfc}[(Rx - vt)/2(DRt)^{1/2}]\} + \\ \{1/2\exp(v/D)\mathrm{erfc}[(Rx + vt)/2(DRt)^{1/2}]\}$$

where:

$C_{(x,t)}$ = solute concentration at distance x from the source and at time t
C_i = initial concentration of solute in aquifer (zero)
C_o = original source concentration
R = retardation factor
x = distance from source
v = seepage velocity
t = time since solute left the source
D = dispersion coefficient (longitudinal)
erfc = complimentary error function

The assumptions for this model are:

- The aquifer is homogeneous, isotropic, semi-infinite in areal extent, and constant in thickness
- A contaminant source fully penetrates the aquifer
- There is one-dimensional, steady-state, horizontal, uniform regional groundwater flow from the source

- The density and viscosity of solute in the source and the aquifer are the same - no solute advection or dispersion occurs through the aquitards into or out of the aquifer

The data input (and their sources) for the model are as follows:

- Darcy Velocity from Darcy's Equation (from the RI, Baker 1994, page 5-7, converted to ft/day):

  $$v_d = Q/A = KI = 6.804\text{e-}3 \text{ ft/day}$$

- Effective Porosity (from the RI, page 5-7):

  $$n_e = 0.28$$

  (NOTE: seepage velocity $v_s = KI/n_e = 0.0243$ ft/day)

- Longitudinal Dispersivity (where x = 600 feet, Federal Register, 1986):

  $$D = 0.1x = 60 \text{ feet}$$

- Organic Carbon Fraction in Aquifer (from Federal Register, 1986):

  $$f_{oc} = 0.005$$

- Partition Coefficient based on organic carbon (average of values from PHRED, USEPA, 1988 and Montgomery and Welkom, 1989):

  $$K_{oc} = (260 + 360 + 210)/3 = 280$$

- Distribution Coefficient based on organic carbon (from Federal Register, 1986):

  $$K_{DOC} = f_{oc} K_{oc} = 0.005\,(280) = 1.40$$

- Partition Coefficient based on octanol (average of values from PHRED, USEPA, 1988 and Montgomery and Welkom, 1989):

  $$K_{ow} = (400 + 760 + 125 + 340) / 4 = 400$$

- Distribution Coefficient based on octanol (from Montgomery and Welkom, 1989):

  $$K_{DOW} = f_{oc}(K_{ow})0.63 = 0.005\,(400)\,0.63 = 1.26$$

- Bulk Density (from the RI, Baker 1994):

  $$\rho = 1.6 \text{ g/cm}^3$$

- Volumetric Water Content of Aquifer (assumed equal to effective porosity, n_e):

  $$\theta = 0.28$$

- Retardation Factor for tetrachloroethylene (calculated using the average of the two types of distribution coefficients):

  $$\begin{aligned} R_d &= 1 + [(K_{DOC} + K_{DOW})/2]\rho/\theta \\ &= 1 + [(1.26 + 1.4)/2]\ 1.6 / 0.28 \\ &= 1 + 1.33(1.6)/0.28 \\ &= 1 + 7.6 \\ &= 8.6 \end{aligned}$$

The model was run three times with the above input data looking at concentrations every 10 feet as far as 600 feet from the source for 10 time periods. The first run had 10 time periods of 1 year each for a total of 10 years; subsequent runs had total times of 100, and 1,000 years. The output file is attached as Appendix A1.

The results indicate that detectable levels of tetrachloroethylene would travel about 30 feet in 1 year; in 5 years it would travel 90 feet; in 10 years, 135 feet. In 100 years detectable levels would have migrated 525 feet from the source. It would take between 600 and 700 years to travel 600 feet to reach the nearest receptor (Cogdels Creek south of well 78GW39).

For all practical purposes, the observed levels of tetrachloroethylene at AOCs 2, 4, and 8 within Site 78 pose no threat of migration through groundwater to nearby streams. This evaluation is based on the analytical model described above and on input data gathered from peer-reviewed literature. Based on this evaluation, natural attenuation is the selected groundwater remediation mechanism at AOCs 2, 4, and 8 within Site 78.

2.0 TECHNICAL BASIS FOR HIGHER STANDARD REQUEST – HEPTACHLOR EPOXIDE IN AOCS 6 & 7

Heptachlor epoxide was detected in groundwater at AOCs 6 and 7 (Site 24) at a maximum concentration of 0.13 ppb. The state groundwater standard for heptachlor epoxide is 0.038 ppb. Pursuant to 15A NCAC 2L.0106(k), a higher groundwater standard is proposed based on the information presented below.

It will be demonstrated that the maximum observed concentration of heptachlor epoxide in groundwater poses no practical threat of migration to the nearest identified potential receptor (Cogdels Creek, see Figure 4-1). The shortest distance from the source to the receptor is 140 feet (from well 24GW08 measuring north to the nearest branch of Cogdels Creek) and the greatest distance is 400 feet (from well 24GW10 measuring south to the nearest branch of Cogdels Creek).

For this demonstration, it was necessary to calculate contaminant travel times and contaminant concentration distributions in space and time; therefore, an appropriate form of the contaminant transport equation had to be used. A simple, one-dimensional, analytical (equation-based) model was considered to be the most appropriate for this demonstration because of the reduced data requirements necessary for its implementation. The model ONED1 is an analytical BASIC program code written by Milovan S. Beljin (1985) that uses the equation for conservation of mass to calculate concentrations at a given point in space and time. The basic equation is for solute transport with retardation in a semi-infinite column with constant concentrations as the inlet boundary condition and is given below:

$$C_{(x,t)} = C_i + (C_o + C_i)\{1/2\mathrm{erfc}[(Rx - vt)/2(DRt)^{1/2}]\} + \{1/2\exp(v/D)\mathrm{erfc}[(Rx + vt)/2(DRt)^{1/2}]\}$$

where:

$C_{(x,t)}$ = solute concentration at distance x from the source and at time t
C_i = initial concentration of solute in aquifer (zero)
C_o = original source concentration
R = retardation factor
x = distance from source
v = seepage velocity
t = time since solute left the source
D = dispersion coefficient (longitudinal)
erfc = complimentary error function

The assumptions for this model are:

- The aquifer is homogeneous, isotropic, semi-infinite in areal extent, and constant in thickness
- A contaminant source fully penetrates the aquifer
- There is one-dimensional, steady-state, horizontal, uniform regional groundwater flow from the source
- The density and viscosity of solute in the source and the aquifer are the same

- No solute advection or dispersion occurs through the aquitards into or out of the aquifer

The data input (and their sources) for the model are as follows:

- Darcy Velocity from Darcy's Equation (from the RI, Baker 1994, page 5-7, converted to ft/day):
  $$v_d = Q/A = KI = 6.804\text{e-}3 \text{ ft/day}$$

- Effective Porosity (from the RI, page 5-7):
  $$n_e = 0.28$$

  (NOTE: seepage velocity $v_s = KI/n_e = 0.0243$ ft/day)

- Longitudinal Dispersivity (where x = 400 feet, Federal Register, 1986):
  $$D = 0.1x = 40 \text{ feet}$$

- Organic Carbon Fraction in Aquifer (from Federal Register, 1986):
  $$f_{oc} = 0.005$$

- Partition Coefficient based on organic carbon (average of values from PHRED, USEPA, 1988 and Montgomery and Welkom, 1989):
  $$K_{oc} = (220+21{,}000)/2 = 11{,}000$$

- Distribution Coefficient based on organic carbon (from Federal Register, 1986):
  $$K_{DOC} = f_{oc}\, K_{oc} = 0.005\ (11{,}000) = 55$$

- Partition Coefficient based on octanol (average of values from PHRED, USEPA, 1988 and Montgomery and Welkom, 1989):
  $$K_{ow} = (500 + 4{,}500 + 250{,}000) / 3 = 85{,}000$$

- Distribution Coefficient based on octanol (from Montgomery and Welkom, 1989):
  $$K_{DOW} = f_{oc}(K_{ow})0.63 = 0.005\ (85{,}000)\ 0.63 = 268$$

- Bulk Density (from the RI, Baker 1994):
  $$\rho = 1.6 \text{ g/cm}^3$$

- Volumetric Water Content of Aquifer (assumed equal to effective porosity, n_e):
  $$\theta = 0.28$$

- Retardation Factor for Heptachlor Epoxide (calculated using the average of the two types of distribution coefficients):
  $$\begin{aligned} R_d &= 1 + [(K_{DOC} + K_{DOW})/2]\rho/\theta \\ &= 1 + [(268 + 55)/2]\ 1.6 / 0.28 \\ &= 1 + 162(1.6)/0.28 \\ &= 1 + 926 \\ &= 927 \end{aligned}$$

The model was run four times with the above input data looking at concentrations every 10 feet as far as 400 feet from the source for 10 time periods. The first run had 10 time periods of 10 years each for a total of 100 years; subsequent runs had total times of 1,000, 10,000, and 100,000 years. The output file is attached as Appendix A2.

The results indicate that, with such a high retardation factor, detectable levels of heptachlor epoxide would travel only about 30 feet in 100 years; in 1,000 years it would travel 100 feet. It would take almost 2,000 years to travel 140 feet to reach the nearest receptor (Cogdels Creek north of well 24 GW08). It would take 30,000 years to travel the 400 feet from well 24GW10 south to Cogdels Creek.

For all practical purposes, the observed levels of heptachlor epoxide at Site 24 pose no threat of migration through groundwater to nearby streams. The pesticide is so tightly bound to soil material in the aquifer that it does not migrate readily. This evaluation is based on the analytical model described above and on input data gathered from peer-reviewed literature. Based on this evaluation, a higher groundwater remediation standard (0.13 ppb +/- analytical error) is selected for the groundwater at Site 24.

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APPENDIX A1
TETRACHLOROETHENE IN AOCs 2, 4 AND 8

```
************************************************
*                                              *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION  *
*   FIRST-TYPE BOUNDARY CONDITION              *
*                                              *
*   MODEL: ONED1.BAS                           *
*                                              *
************************************************


USER:     Daniel S. Fisher
-----
LOCATION: Baker Environmental, Inc.
---------
DATE:     March 15, 1995
-----


                INPUT DATA:


DARCY VELOCITY......................:   0.01  ft/d
EFFECTIVE POROSITY..................:    .28
LONGITUDINAL DISPERSIVITY...........:  60.00  ft
RETARDATION FACTOR..................:   8.60
INITIAL CONCENTRATION...............:   0.00  ppb
CONCENTRATION AT THE SOURCE.........:   1.00  ppb
DISTANCE INCREMENT DELX.............:  15.00  ft
NUMBER OF DISTANCE INCREMENTS.......:  40
INITIAL TIME........................:   0.00  d
TIME INCREMENT DELT.................: 365.24  d
NUMBER OF TIME INCREMENTS...........:  10
```

PCE

6.804 e-3

1 year
x10

10 years

```
******************************** RESULTS ***********************************

+------> distance X       CONCENTRATION in ug/l (ppb)
|
 time


                     15.00 ft    30.00 ft    45.00 ft    60.00 ft    75.00 ft

    0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
  365.24  d          0.2008      0.0090      0.0000      0.0000      0.0000
  730.48  d          0.3842      0.0722      0.0061      0.0002      0.0000
 1095.73  d          0.4917      0.1523      0.0282      0.0030      0.0002
 1460.97  d          0.5631      0.2257      0.0620      0.0114      0.0014
 1826.21  d          0.6145      0.2891      0.1011      0.0258      0.0047
 2191.45  d          0.6538      0.3431      0.1412      0.0448      0.0109
 2556.69  d          0.6850      0.3895      0.1803      0.0670      0.0198
 2921.94  d          0.7105      0.4297      0.2175      0.0910      0.0312
 3287.18  d          0.7318      0.4647      0.2524      0.1160      0.0447
 3652.42  d          0.7500      0.4957      0.2849      0.1411      0.0598


                     90.00 ft   105.00 ft   120.00 ft   135.00 ft   150.00 ft

    0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
  365.24  d          0.0000      0.0000      0.0000      0.0000      0.0000
  730.48  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1095.73  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1460.97  d          0.0001      0.0000      0.0000      0.0000      0.0000
 1826.21  d          0.0006      0.0000      0.0000      0.0000      0.0000
 2191.45  d          0.0020      0.0003      0.0000      0.0000      0.0000
 2556.69  d          0.0046      0.0008      0.0001      0.0000      0.0000
 2921.94  d          0.0087      0.0020      0.0004      0.0000      0.0000
 3287.18  d          0.0144      0.0039      0.0009      0.0002      0.0000
 3652.42  d          0.0216      0.0066      0.0017      0.0004      0.0000


                    165.00 ft   180.00 ft   195.00 ft   210.00 ft   225.00 ft

    0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
  365.24  d          0.0000      0.0000      0.0000      0.0000      0.0000
  730.48  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1095.73  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1460.97  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1826.21  d          0.0000      0.0000      0.0000      0.0000      0.0000
 2191.45  d          0.0000      0.0000      0.0000      0.0000      0.0000
 2556.69  d          0.0000      0.0000      0.0000      0.0000      0.0000
 2921.94  d          0.0000      0.0000      0.0000      0.0000      0.0000
 3287.18  d          0.0000      0.0000      0.0000      0.0000      0.0000
 3652.42  d          0.0000      0.0000      0.0000      0.0000      0.0000


                    240.00 ft   255.00 ft   270.00 ft   285.00 ft   300.00 ft

    0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
  365.24  d          0.0000      0.0000      0.0000      0.0000      0.0000
  730.48  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1095.73  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1460.97  d          0.0000      0.0000      0.0000      0.0000      0.0000
 1826.21  d          0.0000      0.0000      0.0000      0.0000      0.0000
 2191.45  d          0.0000      0.0000      0.0000      0.0000      0.0000
 2556.69  d          0.0000      0.0000      0.0000      0.0000      0.0000
```

```
  2921.94  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3287.18  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3652.42  d       0.0000       0.0000       0.0000       0.0000       0.0000


                 315.00 ft    330.00 ft    345.00 ft    360.00 ft    375.00 ft

     0.00  d       0.0000       0.0000       0.0000       0.0000       0.0000
   365.24  d       0.0000       0.0000       0.0000       0.0000       0.0000
   730.48  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1095.73  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1460.97  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1826.21  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2191.45  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2556.69  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2921.94  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3287.18  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3652.42  d       0.0000       0.0000       0.0000       0.0000       0.0000


                 390.00 ft    405.00 ft    420.00 ft    435.00 ft    450.00 ft

     0.00  d       0.0000       0.0000       0.0000       0.0000       0.0000
   365.24  d       0.0000       0.0000       0.0000       0.0000       0.0000
   730.48  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1095.73  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1460.97  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1826.21  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2191.45  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2556.69  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2921.94  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3287.18  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3652.42  d       0.0000       0.0000       0.0000       0.0000       0.0000


                 465.00 ft    480.00 ft    495.00 ft    510.00 ft    525.00 ft

     0.00  d       0.0000       0.0000       0.0000       0.0000       0.0000
   365.24  d       0.0000       0.0000       0.0000       0.0000       0.0000
   730.48  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1095.73  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1460.97  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1826.21  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2191.45  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2556.69  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2921.94  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3287.18  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3652.42  d       0.0000       0.0000       0.0000       0.0000       0.0000


                 540.00 ft    555.00 ft    570.00 ft    585.00 ft    600.00 ft

     0.00  d       0.0000       0.0000       0.0000       0.0000       0.0000
   365.24  d       0.0000       0.0000       0.0000       0.0000       0.0000
   730.48  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1095.73  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1460.97  d       0.0000       0.0000       0.0000       0.0000       0.0000
  1826.21  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2191.45  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2556.69  d       0.0000       0.0000       0.0000       0.0000       0.0000
  2921.94  d       0.0000       0.0000       0.0000       0.0000       0.0000
  3287.18  d       0.0000       0.0000       0.0000       0.0000       0.0000
```

3652.42 d	0.0000	0.0000	0.0000	0.0000	0.0000

```
************************************************
*                                              *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION  *
*   FIRST-TYPE BOUNDARY CONDITION              *
*                                              *
*   MODEL: ONED1.BAS                           *
*                                              *
************************************************
```

PCE

```
USER:     Daniel S. Fisher
-----
LOCATION: Baker Environmental, Inc.
---------
DATE:     March 15, 1995
-----

               INPUT DATA:
```

6.804e-3

```
DARCY VELOCITY......................:   0.01  ft/d
EFFECTIVE POROSITY..................:    .28
LONGITUDINAL DISPERSIVITY...........:  60.00  ft
RETARDATION FACTOR..................:   8.60
INITIAL CONCENTRATION...............:   0.00  ppb
CONCENTRATION AT THE SOURCE.........:   1.00  ppb
DISTANCE INCREMENT DELX.............:  15.00  ft
NUMBER OF DISTANCE INCREMENTS.......:  40
INITIAL TIME........................:   0.00  d
TIME INCREMENT DELT.................:3652.42  d
NUMBER OF TIME INCREMENTS...........:  10
```

10 years
x 10

100 years

```
********************************* RESULTS ***********************************

+------> distance X       CONCENTRATION in ug/l (ppb)
|
 time


                    15.00 ft     30.00 ft     45.00 ft     60.00 ft     75.00 ft

   0.00  d           0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d           0.7500       0.4957       0.2849       0.1411       0.0598
7304.84  d           0.8494       0.6801       0.5104       0.3574       0.2327
%10957.26  d           0.8927       0.7678       0.6340       0.5012       0.3783
%14609.68  d           0.9177       0.8202       0.7121       0.5992       0.4879
%18262.10  d           0.9342       0.8552       0.7659       0.6697       0.5710
%21914.52  d           0.9459       0.8804       0.8052       0.7226       0.6355
%25566.94  d           0.9546       0.8993       0.8352       0.7637       0.6868
%29219.36  d           0.9613       0.9141       0.8587       0.7963       0.7282
%32871.78  d           0.9667       0.9258       0.8777       0.8229       0.7623
%36524.20  d           0.9710       0.9354       0.8932       0.8448       0.7908


                    90.00 ft    105.00 ft    120.00 ft    135.00 ft    150.00 ft

   0.00  d           0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d           0.0216       0.0066       0.0017       0.0004       0.0000
7304.84  d           0.1404       0.0784       0.0404       0.0192       0.0084
%10957.26  d           0.2721       0.1862       0.1210       0.0746       0.0436
%14609.68  d           0.3837       0.2911       0.2127       0.1497       0.1012
%18262.10  d           0.4740       0.3827       0.3003       0.2287       0.1690
 21914.52  d           0.5471       0.4606       0.3789       0.3043       0.2384
%25566.94  d           0.6068       0.5264       0.4479       0.3736       0.3053
%29219.36  d           0.6562       0.5821       0.5080       0.4359       0.3676
%32871.78  d           0.6974       0.6295       0.5603       0.4915       0.4247
%36524.20  d           0.7322       0.6701       0.6059       0.5408       0.4765


                   165.00 ft    180.00 ft    195.00 ft    210.00 ft    225.00 ft

   0.00  d           0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d           0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d           0.0034       0.0012       0.0004       0.0001       0.0000
%10957.26  d           0.0241       0.0126       0.0063       0.0029       0.0013
%14609.68  d           0.0658       0.0411       0.0246       0.0142       0.0078
%18262.10  d           0.1210       0.0840       0.0565       0.0367       0.0231
%21914.52  d           0.1822       0.1357       0.0984       0.0695       0.0478
%25566.94  d           0.2443       0.1913       0.1466       0.1098       0.0804
%29219.36  d           0.3045       0.2476       0.1976       0.1547       0.1188
%32871.78  d           0.3613       0.3025       0.2492       0.2018       0.1607
%36524.20  d           0.4141       0.3549       0.2998       0.2495       0.2046


                   240.00 ft    255.00 ft    270.00 ft    285.00 ft    300.00 ft

   0.00  d           0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d           0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d           0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d           0.0005       0.0002       0.0000       0.0000       0.0000
%14609.68  d           0.0041       0.0021       0.0010       0.0005       0.0002
%18262.10  d           0.0141       0.0083       0.0047       0.0026       0.0014
%21914.52  d           0.0320       0.0208       0.0132       0.0081       0.0049
%25566.94  d           0.0576       0.0403       0.0275       0.0184       0.0120
```

```
%29219.36  d      0.0894      0.0660      0.0477      0.0338      0.0235
%32871.78  d      0.1258      0.0968      0.0732      0.0543      0.0396
%36524.20  d      0.1652      0.1314      0.1029      0.0793      0.0601


               315.00 ft   330.00 ft   345.00 ft   360.00 ft   375.00 ft

  0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
3652.42  d       0.0000      0.0000      0.0000      0.0000      0.0000
7304.84  d       0.0000      0.0000      0.0000      0.0000      0.0000
%10957.26  d      0.0000      0.0000      0.0000      0.0000      0.0000
%14609.68  d      0.0000      0.0000      0.0000      0.0000      0.0000
%18262.10  d      0.0007      0.0004      0.0002      0.0000      0.0000
%21914.52  d      0.0028      0.0016      0.0009      0.0005      0.0002
%25566.94  d      0.0076      0.0047      0.0029      0.0017      0.0010
%29219.36  d      0.0160      0.0106      0.0069      0.0044      0.0028
%32871.78  d      0.0284      0.0200      0.0138      0.0093      0.0062
%36524.20  d      0.0449      0.0329      0.0238      0.0169      0.0118


               390.00 ft   405.00 ft   420.00 ft   435.00 ft   450.00 ft

  0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
3652.42  d       0.0000      0.0000      0.0000      0.0000      0.0000
7304.84  d       0.0000      0.0000      0.0000      0.0000      0.0000
%10957.26  d      0.0000      0.0000      0.0000      0.0000      0.0000
%14609.68  d      0.0000      0.0000      0.0000      0.0000      0.0000
%18262.10  d      0.0000      0.0000      0.0000      0.0000      0.0000
%21914.52  d      0.0001      0.0000      0.0000      0.0000      0.0000
%25566.94  d      0.0006      0.0003      0.0002      0.0000      0.0000
%29219.36  d      0.0017      0.0010      0.0006      0.0003      0.0002
%32871.78  d      0.0040      0.0026      0.0016      0.0010      0.0006
%36524.20  d      0.0081      0.0055      0.0036      0.0024      0.0015


               465.00 ft   480.00 ft   495.00 ft   510.00 ft   525.00 ft

  0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
3652.42  d       0.0000      0.0000      0.0000      0.0000      0.0000
7304.84  d       0.0000      0.0000      0.0000      0.0000      0.0000
%10957.26  d      0.0000      0.0000      0.0000      0.0000      0.0000
%14609.68  d      0.0000      0.0000      0.0000      0.0000      0.0000
%18262.10  d      0.0000      0.0000      0.0000      0.0000      0.0000
%21914.52  d      0.0000      0.0000      0.0000      0.0000      0.0000
%25566.94  d      0.0000      0.0000      0.0000      0.0000      0.0000
%29219.36  d      0.0001      0.0000      0.0000      0.0000      0.0000
%32871.78  d      0.0004      0.0002      0.0001      0.0000      0.0000
%36524.20  d      0.0010      0.0006      0.0004      0.0002      0.0001


               540.00 ft   555.00 ft   570.00 ft   585.00 ft   600.00 ft

  0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
3652.42  d       0.0000      0.0000      0.0000      0.0000      0.0000
7304.84  d       0.0000      0.0000      0.0000      0.0000      0.0000
%10957.26  d      0.0000      0.0000      0.0000      0.0000      0.0000
%14609.68  d      0.0000      0.0000      0.0000      0.0000      0.0000
%18262.10  d      0.0000      0.0000      0.0000      0.0000      0.0000
%21914.52  d      0.0000      0.0000      0.0000      0.0000      0.0000
%25566.94  d      0.0000      0.0000      0.0000      0.0000      0.0000
%29219.36  d      0.0000      0.0000      0.0000      0.0000      0.000
%32871.78  d      0.0000      0.0000      0.0000      0.0000      0.000
```

```
%36524.20  d        0.0000      0.0000      0.0000      0.0000      0.0000
```

```
*************************************************
*                                               *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION   *
*   FIRST-TYPE BOUNDARY CONDITION               *
*                                               *
*   MODEL: ONED1.BAS                            *
*                                               *
*************************************************

USER:     Daniel S. Fisher
-----
LOCATION: Bake Environmental, Inc.
---------
DATE:     March 15, 1995
-----

                 INPUT DATA:

DARCY VELOCITY.....................:   0.01  ft/d
EFFECTIVE POROSITY.................:    .28
LONGITUDINAL DISPERSIVITY..........:  60.00  ft
RETARDATION FACTOR.................:   8.60
INITIAL CONCENTRATION..............:   0.00  ppb
CONCENTRATION AT THE SOURCE........:   1.00  ppb
DISTANCE INCREMENT DELX............:  15.00  ft
NUMBER OF DISTANCE INCREMENTS......:  40
INITIAL TIME.......................:   0.00  d
TIME INCREMENT DELT................:%36524.20  d
NUMBER OF TIME INCREMENTS..........:  10
```

PCE

6.404e-3

100 years
x 10

1,000 years

```
********************************** RESULTS ************************************

+------> distance X       CONCENTRATION in ug/l (ppb)
|
  time



                        15.00 ft      30.00 ft      45.00 ft      60.00 ft      75.00 ft

   0.00  d               0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d               0.9710        0.9354        0.8932        0.8448        0.7908
%73048.40  d               0.9904        0.9785        0.9641        0.9469        0.9269
%109572.60  d               0.9960        0.9909        0.9848        0.9773        0.9685
%146096.80  d               0.9981        0.9957        0.9928        0.9893        0.9850
%182621.00  d               0.9991        0.9979        0.9964        0.9946        0.9924
%219145.20  d               0.9995        0.9989        0.9981        0.9972        0.9960
%255669.40  d               0.9997        0.9994        0.9990        0.9985        0.9979
%292193.60  d               0.9999        0.9997        0.9994        0.9992        0.9988
%328717.80  d               0.9999        0.9998        0.9997        0.9995        0.9993
%365242.00  d               1.0000        0.9999        0.9998        0.9997        0.9996



                        90.00 ft     105.00 ft     120.00 ft     135.00 ft     150.00 ft

   0.00  d               0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d               0.7322        0.6701        0.6059        0.5408        0.4765
%73048.40  d               0.9039        0.8780        0.8492        0.8176        0.7833
%109572.60  d               0.9582        0.9463        0.9328        0.9175        0.9004
%146096.80  d               0.9800        0.9742        0.9674        0.9597        0.9509
%182621.00  d               0.9899        0.9869        0.9834        0.9793        0.9747
%219145.20  d               0.9947        0.9931        0.9912        0.9890        0.9865
%255669.40  d               0.9971        0.9962        0.9952        0.9940        0.9926
%292193.60  d               0.9984        0.9979        0.9973        0.9967        0.9959
%328717.80  d               0.9991        0.9988        0.9985        0.9981        0.9977
%365242.00  d               0.9995        0.9993        0.9991        0.9989        0.9987



                       165.00 ft     180.00 ft     195.00 ft     210.00 ft     225.00 ft

   0.00  d               0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d               0.4141        0.3549        0.2998        0.2495        0.2046
%73048.40  d               0.7467        0.7080        0.6676        0.6258        0.5831
%109572.60  d               0.8814        0.8606        0.8380        0.8136        0.7875
%146096.80  d               0.9410        0.9299        0.9176        0.9040        0.889
%182621.00  d               0.9693        0.9633        0.9566        0.9490        0.940
%219145.20  d               0.9836        0.9803        0.9765        0.9723        0.967
%255669.40  d               0.9910        0.9891        0.9870        0.9846        0.981
%292193.60  d               0.9950        0.9939        0.9927        0.9913        0.989
%328717.80  d               0.9972        0.9966        0.9959        0.9951        0.994
%365242.00  d               0.9984        0.9980        0.9976        0.9972        0.996



                       240.00 ft     255.00 ft     270.00 ft     285.00 ft     300.00 ft

   0.00  d               0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d               0.1652        0.1314        0.1029        0.0793        0.0601
%73048.40  d               0.5400        0.4969        0.4542        0.4124        0.3719
%109572.60  d               0.7598        0.7306        0.7001        0.6685        0.635
%146096.80  d               0.8729        0.8553        0.8365        0.8163        0.794
%182621.00  d               0.9313        0.9211        0.9099        0.8977        0.884
%219145.20  d               0.9622        0.9563        0.9497        0.9425        0.934
%255669.40  d               0.9788        0.9754        0.9716        0.9673        0.962
```

```
%292193.60  d       0.9880      0.9860      0.9837      0.9812      0.9784
%328717.80  d       0.9931      0.9919      0.9906      0.9891      0.9875
%365242.00  d       0.9960      0.9953      0.9945      0.9937      0.9927


                 315.00 ft   330.00 ft   345.00 ft   360.00 ft   375.00 ft

   0.00  d       0.0000      0.0000      0.0000      0.0000      0.0000
%36524.20  d       0.0449      0.0329      0.0238      0.0169      0.0118
%73048.40  d       0.3330      0.2961      0.2614      0.2290      0.1992
%109572.60  d       0.6025      0.5687      0.5345      0.5004      0.4664
%146096.80  d       0.7723      0.7485      0.7237      0.6979      0.6713
%182621.00  d       0.8704      0.8551      0.8389      0.8216      0.8034
%219145.20  d       0.9259      0.9165      0.9063      0.8954      0.8836
%255669.40  d       0.9574      0.9517      0.9454      0.9386      0.9312
%292193.60  d       0.9753      0.9719      0.9681      0.9639      0.9593
%328717.80  d       0.9856      0.9835      0.9812      0.9787      0.9759
%365242.00  d       0.9915      0.9903      0.9889      0.9874      0.9856


                 390.00 ft   405.00 ft   420.00 ft   435.00 ft   450.00 ft

   0.00  d       0.0000      0.0000      0.0000      0.0000      0.0000
%36524.20  d       0.0081      0.0055      0.0036      0.0024      0.0015
%73048.40  d       0.1720      0.1473      0.1252      0.1057      0.0884
%109572.60  d       0.4328      0.3999      0.3678      0.3367      0.306
%146096.80  d       0.6439      0.6159      0.5874      0.5586      0.529
%182621.00  d       0.7841      0.7640      0.7429      0.7211      0.698
%219145.20  d       0.8709      0.8575      0.8432      0.8280      0.812
%255669.40  d       0.9232      0.9145      0.9052      0.8952      0.884
%292193.60  d       0.9543      0.9488      0.9429      0.9365      0.929
%328717.80  d       0.9728      0.9694      0.9657      0.9616      0.957
%365242.00  d       0.9837      0.9816      0.9793      0.9768      0.974


                 465.00 ft   480.00 ft   495.00 ft   510.00 ft   525.00 ft

   0.00  d       0.0000      0.0000      0.0000      0.0000      0.0000
%36524.20  d       0.0010      0.0006      0.0004      0.0002      0.0001
%73048.40  d       0.0733      0.0603      0.0493      0.0399      0.0321
%109572.60  d       0.2783      0.2512      0.2256      0.2013      0.178
%146096.80  d       0.5006      0.4717      0.4430      0.4147      0.387
%182621.00  d       0.6752      0.6513      0.6268      0.6020      0.576
%219145.20  d       0.7954      0.7778      0.7596      0.7406      0.720
%255669.40  d       0.8732      0.8612      0.8484      0.8350      0.820
%292193.60  d       0.9222      0.9142      0.9057      0.8961      0.886
%328717.80  d       0.9525      0.9473      0.9414      0.9353      0.928
%365242.00  d       0.9708      0.9675      0.9639      0.9599      0.955


                 540.00 ft   555.00 ft   570.00 ft   585.00 ft   600.00 ft

   0.00  d       0.0000      0.0000      0.0000      0.0000      0.0000
%36524.20  d       0.0000      0.0000      0.0000      0.0000      0.000
%73048.40  d       0.0256      0.0202      0.0158      0.0123      0.009
%109572.60  d       0.1583      0.1393      0.1220      0.1062      0.09
%146096.80  d       0.3592      0.3328      0.3073      0.2827      0.25
%182621.00  d       0.5507      0.5250      0.4993      0.4737      0.44
%219145.20  d       0.6999      0.6790      0.6575      0.6355      0.61
%255669.40  d       0.8054      0.7898      0.7735      0.7566      0.73
%292193.60  d       0.8760      0.8650      0.8534      0.8413      0.82
%328717.80  d       0.9219      0.9144      0.9065      0.8980      0.88
```

%365242.00	d	0.9511	0.9461	0.9408	0.9351	0.9290

APPENDIX A2
HEPTACHLOR EPOXIDE IN AOCs 6 AND 7

```
************************************************
*                                              *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION  *
*   FIRST-TYPE BOUNDARY CONDITION              *
*                                              *
*   MODEL: ONED1.BAS                           *
*                                              *
************************************************


USER:     Daniel S. Fisher
-----
LOCATION: Baker Environmental, Inc.
----------
DATE:     March 15, 1995
-----


                INPUT DATA:


DARCY VELOCITY......................:   0.01  ft/d
EFFECTIVE POROSITY..................:    .28
LONGITUDINAL DISPERSIVITY...........:  40.00  ft
RETARDATION FACTOR..................: 926.70
INITIAL CONCENTRATION...............:   0.00  ppb
CONCENTRATION AT THE SOURCE.........:   0.13  ppb
DISTANCE INCREMENT DELX.............:  10.00  ft
NUMBER OF DISTANCE INCREMENTS.......:  40
INITIAL TIME........................:   0.00  d
TIME INCREMENT DELT.................:3652.42  d
NUMBER OF TIME INCREMENTS...........:  10
```

Heptachlor
Epoxide

6.804e-3

10 years
x10
100 years

```
********************************** RESULTS ***********************************

+------> distance X        CONCENTRATION in ug/l (ppb)
 time


                     10.00 ft     20.00 ft     30.00 ft     40.00 ft     50.00 ft

  0.00   d            0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d            0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d            0.0016       0.0000       0.0000       0.0000       0.0000
%10957.26  d            0.0054       0.0000       0.0000       0.0000       0.0000
%14609.68  d            0.0104       0.0000       0.0000       0.0000       0.0000
%18262.10  d            0.0156       0.0002       0.0000       0.0000       0.0000
%21914.52  d            0.0206       0.0005       0.0000       0.0000       0.0000
%25566.94  d            0.0253       0.0011       0.0000       0.0000       0.0000
%29219.36  d            0.0296       0.0018       0.0000       0.0000       0.0000
%32871.78  d            0.0336       0.0027       0.0000       0.0000       0.0000
%36524.20  d            0.0372       0.0037       0.0001       0.0000       0.0000


                     60.00 ft     70.00 ft     80.00 ft     90.00 ft    100.00 ft

  0.00   d            0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d            0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d            0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d            0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d            0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d            0.0000       0.0000       0.0000       0.0000       0.0000
 21914.52  d            0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d            0.0000       0.0000       0.0000       0.0000       0.0000
%29219.36  d            0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d            0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d            0.0000       0.0000       0.0000       0.0000       0.0000


                    110.00 ft    120.00 ft    130.00 ft    140.00 ft    150.00 ft

  0.00   d            0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d            0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d            0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d            0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d            0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d            0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d            0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d            0.0000       0.0000       0.0000       0.0000       0.0000
%29219.36  d            0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d            0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d            0.0000       0.0000       0.0000       0.0000       0.0000


                    160.00 ft    170.00 ft    180.00 ft    190.00 ft    200.00 ft

  0.00   d            0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d            0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d            0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d            0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d            0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d            0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d            0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d            0.0000       0.0000       0.0000       0.0000       0.0000
```

```
%29219.36  d        0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d        0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d        0.0000       0.0000       0.0000       0.0000       0.0000


                210.00 ft    220.00 ft    230.00 ft    240.00 ft    250.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d        0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d        0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d        0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d        0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d        0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d        0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d        0.0000       0.0000       0.0000       0.0000       0.0000
%29219.36  d        0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d        0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d        0.0000       0.0000       0.0000       0.0000       0.0000


                260.00 ft    270.00 ft    280.00 ft    290.00 ft    300.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d        0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d        0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d        0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d        0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d        0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d        0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d        0.0000       0.0000       0.0000       0.0000       0.0000
 29219.36  d        0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d        0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d        0.0000       0.0000       0.0000       0.0000       0.0000


                310.00 ft    320.00 ft    330.00 ft    340.00 ft    350.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d        0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d        0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d        0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d        0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d        0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d        0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d        0.0000       0.0000       0.0000       0.0000       0.0000
%29219.36  d        0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d        0.0000       0.0000       0.0000       0.0000       0.0000
%36524.20  d        0.0000       0.0000       0.0000       0.0000       0.0000


                360.00 ft    370.00 ft    380.00 ft    390.00 ft    400.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
3652.42  d        0.0000       0.0000       0.0000       0.0000       0.0000
7304.84  d        0.0000       0.0000       0.0000       0.0000       0.0000
%10957.26  d        0.0000       0.0000       0.0000       0.0000       0.0000
%14609.68  d        0.0000       0.0000       0.0000       0.0000       0.0000
%18262.10  d        0.0000       0.0000       0.0000       0.0000       0.0000
%21914.52  d        0.0000       0.0000       0.0000       0.0000       0.0000
%25566.94  d        0.0000       0.0000       0.0000       0.0000       0.0000
%29219.36  d        0.0000       0.0000       0.0000       0.0000       0.0000
%32871.78  d        0.0000       0.0000       0.0000       0.0000       0.0000
```

```
%36524.20  d          0.0000        0.0000        0.0000        0.0000        0.0000
```

```
*************************************************
*                                               *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION   *
*   FIRST-TYPE BOUNDARY CONDITION               *
*                                               *
*   MODEL: ONED1.BAS                            *
*                                               *
*************************************************


USER:     Daniel S.Fisher
-----
LOCATION: Baker Environmental, Inc.
---------
DATE:     March 15, 1995
-----


                  INPUT DATA:


DARCY VELOCITY......................:   0.01  ft/d
EFFECTIVE POROSITY..................:    .28
LONGITUDINAL DISPERSIVITY...........:  40.00  ft
RETARDATION FACTOR..................: 926.70
INITIAL CONCENTRATION...............:   0.00  ppb
CONCENTRATION AT THE SOURCE.........:   0.13  ppb
DISTANCE INCREMENT DELX.............:  10.00  ft
NUMBER OF DISTANCE INCREMENTS.......:  40
INITIAL TIME........................:   0.00  d
TIME INCREMENT DELT.................:%36524.20  d
NUMBER OF TIME INCREMENTS...........:  10
```

Heptachlor Epoxide

6.804 e-3

100 years
x 10

1,000 years

```
********************************** RESULTS ************************************

+------> distance X       CONCENTRATION in ug/l (ppb)

  time


                     10.00 ft      20.00 ft      30.00 ft      40.00 ft      50.00 ft

   0.00  d            0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d            0.0372        0.0037        0.0001        0.0000        0.0000
%73048.40  d            0.0614        0.0176        0.0029        0.0003        0.0000
%109572.60  d            0.0745        0.0309        0.0089        0.0018        0.0002
%146096.80  d            0.0829        0.0417        0.0161        0.0047        0.0010
%182621.00  d            0.0889        0.0504        0.0232        0.0086        0.0025
%219145.20  d            0.0934        0.0575        0.0299        0.0130        0.0047
%255669.40  d            0.0969        0.0635        0.0360        0.0175        0.0073
%292193.60  d            0.0998        0.0685        0.0415        0.0220        0.0102
%328717.80  d            0.1022        0.0728        0.0465        0.0264        0.0133
%365242.00  d            0.1042        0.0765        0.0510        0.0306        0.0165


                     60.00 ft      70.00 ft      80.00 ft      90.00 ft     100.00 ft

   0.00  d            0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d            0.0000        0.0000        0.0000        0.0000        0.0000
%73048.40  d            0.0000        0.0000        0.0000        0.0000        0.0000
%109572.60  d            0.0000        0.0000        0.0000        0.0000        0.0000
%146096.80  d            0.0002        0.0000        0.0000        0.0000        0.0000
%182621.00  d            0.0006        0.0001        0.0000        0.0000        0.0000
%219145.20  d            0.0014        0.0003        0.0000        0.0000        0.0000
%255669.40  d            0.0025        0.0008        0.0002        0.0000        0.0000
%292193.60  d            0.0041        0.0014        0.0004        0.0001        0.0000
%328717.80  d            0.0059        0.0023        0.0008        0.0002        0.0000
%365242.00  d            0.0079        0.0034        0.0013        0.0004        0.0001


                    110.00 ft     120.00 ft     130.00 ft     140.00 ft     150.00 ft

   0.00  d            0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d            0.0000        0.0000        0.0000        0.0000        0.0000
%73048.40  d            0.0000        0.0000        0.0000        0.0000        0.0000
%109572.60  d            0.0000        0.0000        0.0000        0.0000        0.0000
%146096.80  d            0.0000        0.0000        0.0000        0.0000        0.0000
%182621.00  d            0.0000        0.0000        0.0000        0.0000        0.0000
%219145.20  d            0.0000        0.0000        0.0000        0.0000        0.0000
%255669.40  d            0.0000        0.0000        0.0000        0.0000        0.000
%292193.60  d            0.0000        0.0000        0.0000        0.0000        0.000
%328717.80  d            0.0000        0.0000        0.0000        0.0000        0.000
%365242.00  d            0.0000        0.0000        0.0000        0.0000        0.000


                    160.00 ft     170.00 ft     180.00 ft     190.00 ft     200.00 ft

   0.00  d            0.0000        0.0000        0.0000        0.0000        0.0000
%36524.20  d            0.0000        0.0000        0.0000        0.0000        0.0000
%73048.40  d            0.0000        0.0000        0.0000        0.0000        0.0000
%109572.60  d            0.0000        0.0000        0.0000        0.0000        0.000
%146096.80  d            0.0000        0.0000        0.0000        0.0000        0.000
%182621.00  d            0.0000        0.0000        0.0000        0.0000        0.000
%219145.20  d            0.0000        0.0000        0.0000        0.0000        0.000
%255669.40  d            0.0000        0.0000        0.0000        0.0000        0.000
```

```
 %292193.60  d        0.0000      0.0000      0.0000      0.0000      0.0000
 %328717.80  d        0.0000      0.0000      0.0000      0.0000      0.0000
 %365242.00  d        0.0000      0.0000      0.0000      0.0000      0.0000


                  210.00 ft   220.00 ft   230.00 ft   240.00 ft   250.00 ft

    0.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %36524.20  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %73048.40  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %109572.60  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %146096.80  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %182621.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %219145.20  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %255669.40  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %292193.60  d          0.0000      0.0000      0.0000      0.0000      0.0000
 %328717.80  d          0.0000      0.0000      0.0000      0.0000      0.000
 %365242.00  d          0.0000      0.0000      0.0000      0.0000      0.000


                  260.00 ft   270.00 ft   280.00 ft   290.00 ft   300.00 ft

    0.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %36524.20  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %73048.40  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %109572.60  d          0.0000      0.0000      0.0000      0.0000      0.000
 %146096.80  d          0.0000      0.0000      0.0000      0.0000      0.000
 %182621.00  d          0.0000      0.0000      0.0000      0.0000      0.000
 %219145.20  d          0.0000      0.0000      0.0000      0.0000      0.000
 %255669.40  d          0.0000      0.0000      0.0000      0.0000      0.000
 %292193.60  d          0.0000      0.0000      0.0000      0.0000      0.000
 %328717.80  d          0.0000      0.0000      0.0000      0.0000      0.000
 %365242.00  d          0.0000      0.0000      0.0000      0.0000      0.000


                  310.00 ft   320.00 ft   330.00 ft   340.00 ft   350.00 ft

    0.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %36524.20  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %73048.40  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %109572.60  d          0.0000      0.0000      0.0000      0.0000      0.000
 %146096.80  d          0.0000      0.0000      0.0000      0.0000      0.000
 %182621.00  d          0.0000      0.0000      0.0000      0.0000      0.000
 %219145.20  d          0.0000      0.0000      0.0000      0.0000      0.000
 %255669.40  d          0.0000      0.0000      0.0000      0.0000      0.000
 %292193.60  d          0.0000      0.0000      0.0000      0.0000      0.000
 %328717.80  d          0.0000      0.0000      0.0000      0.0000      0.000
 %365242.00  d          0.0000      0.0000      0.0000      0.0000      0.000


                  360.00 ft   370.00 ft   380.00 ft   390.00 ft   400.00 ft

    0.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
 %36524.20  d         0.0000      0.0000      0.0000      0.0000      0.000
 %73048.40  d         0.0000      0.0000      0.0000      0.0000      0.000
 %109572.60  d          0.0000      0.0000      0.0000      0.0000      0.00
 %146096.80  d          0.0000      0.0000      0.0000      0.0000      0.00
 %182621.00  d          0.0000      0.0000      0.0000      0.0000      0.00
 %219145.20  d          0.0000      0.0000      0.0000      0.0000      0.00
 %255669.40  d          0.0000      0.0000      0.0000      0.0000      0.00
 %292193.60  d          0.0000      0.0000      0.0000      0.0000      0.00
 %328717.80  d          0.0000      0.0000      0.0000      0.0000      0.00
```

```
%365242.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
```

```
************************************************
*                                              *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION  *
*   FIRST-TYPE BOUNDARY CONDITION              *
*                                              *
*   MODEL: ONED1.BAS                           *
*                                              *
************************************************


USER:     Daniel S. Fisher
-----
LOCATION: Baker Environmental, Inc.
---------
DATE:     March 15, 1995
-----


                INPUT DATA:

DARCY VELOCITY.....................:   0.01  ft/d
EFFECTIVE POROSITY.................:    .28
LONGITUDINAL DISPERSIVITY..........:  40.00  ft
RETARDATION FACTOR.................: 926.70
INITIAL CONCENTRATION..............:   0.00  ppb
CONCENTRATION AT THE SOURCE........:   0.13  ppb
DISTANCE INCREMENT DELX............:  10.00  ft
NUMBER OF DISTANCE INCREMENTS......:  40
INITIAL TIME.......................:   0.00  d
TIME INCREMENT DELT................:%365242.00  d
NUMBER OF TIME INCREMENTS..........:  10
```

Heptachlor Epoxide

6.804e-3

1,000 years
x 10
10,000 years

```
********************************* RESULTS ************************************

+------> distance X       CONCENTRATION in ug/l (ppb)
|
  time


                      10.00 ft     20.00 ft     30.00 ft     40.00 ft     50.00 ft

    0.00  d            0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d             0.1042       0.0765       0.0510       0.0306       0.0165
%730484.00  d             0.1151       0.0979       0.0796       0.0617       0.0455
%1095726.00  d             0.1197       0.1076       0.0940       0.0797       0.065

%1460968.00  d             0.1224       0.1132       0.1026       0.0912       0.07

%1826210.00  d             0.1241       0.1168       0.1084       0.0991       0.08

%2191452.00  d             0.1252       0.1194       0.1126       0.1048       0.09

%2556694.00  d             0.1261       0.1213       0.1156       0.1091       0.101

%2921936.00  d             0.1268       0.1228       0.1180       0.1125       0.106

%3287178.00  d             0.1273       0.1239       0.1198       0.1152       0.109

%3652420.00  d             0.1277       0.1248       0.1213       0.1173       0.112


                      60.00 ft     70.00 ft     80.00 ft     90.00 ft    100.00 ft

    0.00  d            0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d             0.0079       0.0034       0.0013       0.0004       0.0001
%730484.00  d             0.0319       0.0211       0.0132       0.0078       0.0044
%1095726.00  d             0.0521       0.0401       0.0297       0.0213       0.014

%1460968.00  d             0.0673       0.0557       0.0450       0.0354       0.027

%1826210.00  d             0.0786       0.0681       0.0579       0.0482       0.039

%2191452.00  d             0.0873       0.0780       0.0685       0.0593       0.05

%2556694.00  d             0.0941       0.0858       0.0773       0.0687       0.06

%2921936.00  d             0.0995       0.0922       0.0846       0.0767       0.068

%3287178.00  d             0.1039       0.0975       0.0906       0.0835       0.07

%3652420.00  d             0.1075       0.1018       0.0957       0.0893       0.08


                     110.00 ft    120.00 ft    130.00 ft    140.00 ft    150.00 ft

    0.00  d            0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d             0.0000       0.0000       0.0000       0.0000       0.000
%730484.00  d             0.0023       0.0011       0.0005       0.0002       0.000
%1095726.00  d             0.0097       0.0062       0.0038       0.0023       0.00

%1460968.00  d             0.0202       0.0146       0.0103       0.0071       0.00

%1826210.00  d             0.0314       0.0246       0.0188       0.0141       0.01
```

```
%2191452.00  d        0.0422       0.0347       0.0281       0.0222       0.017
%2556694.00  d        0.0521       0.0444       0.0373       0.0309       0.025
%2921936.00  d        0.0610       0.0534       0.0461       0.0394       0.033
%3287178.00  d        0.0688       0.0615       0.0543       0.0475       0.041
%3652420.00  d        0.0757       0.0687       0.0618       0.0551       0.048


                  160.00 ft    170.00 ft    180.00 ft    190.00 ft    200.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
%730484.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
%1095726.00  d        0.0007       0.0004       0.0002       0.0000       0.000

%1460968.00  d        0.0030       0.0019       0.0012       0.0007       0.000

%1826210.00  d        0.0073       0.0051       0.0035       0.0023       0.001

%2191452.00  d        0.0132       0.0099       0.0073       0.0053       0.003

%2556694.00  d        0.0201       0.0159       0.0123       0.0094       0.007

%2921936.00  d        0.0275       0.0226       0.0183       0.0146       0.011

%3287178.00  d        0.0351       0.0296       0.0247       0.0204       0.016

%3652420.00  d        0.0424       0.0367       0.0314       0.0265       0.022


                  210.00 ft    220.00 ft    230.00 ft    240.00 ft    250.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d        0.0000       0.0000       0.0000       0.0000       0.000
%730484.00  d        0.0000       0.0000       0.0000       0.0000       0.000
%1095726.00  d        0.0000       0.0000       0.0000       0.0000       0.00

%1460968.00  d        0.0002       0.0001       0.0000       0.0000       0.00

%1826210.00  d        0.0010       0.0006       0.0004       0.0002       0.00

%2191452.00  d        0.0026       0.0018       0.0012       0.0008       0.00

%2556694.00  d        0.0052       0.0038       0.0027       0.0019       0.00

%2921936.00  d        0.0089       0.0068       0.0051       0.0038       0.00

%3287178.00  d        0.0133       0.0106       0.0083       0.0064       0.00

%3652420.00  d        0.0184       0.0151       0.0122       0.0097       0.00


                  260.00 ft    270.00 ft    280.00 ft    290.00 ft    300.00 ft

   0.00  d        0.0000       0.0000       0.0000       0.0000       0.0000
%365242.00  d        0.0000       0.0000       0.0000       0.0000       0.000
```

```
%730484.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
%1095726.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%1460968.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%1826210.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%2191452.00  d         0.0003      0.0002      0.0001      0.0000      0.000

%2556694.00  d         0.0009      0.0006      0.0004      0.0003      0.000

%2921936.00  d         0.0020      0.0014      0.0010      0.0007      0.000

%3287178.00  d         0.0037      0.0027      0.0020      0.0015      0.001

%3652420.00  d         0.0060      0.0047      0.0036      0.0027      0.002


                  310.00 ft   320.00 ft   330.00 ft   340.00 ft   350.00 ft

   0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
%365242.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
%730484.00  d         0.0000      0.0000      0.0000      0.0000      0.0000
%1095726.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%1460968.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%1826210.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%2191452.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%2556694.00  d         0.0000      0.0000      0.0000      0.0000      0.000

%2921936.00  d         0.0003      0.0002      0.0001      0.0000      0.000

%3287178.00  d         0.0007      0.0005      0.0004      0.0002      0.000

%3652420.00  d         0.0015      0.0011      0.0008      0.0005      0.000


                  360.00 ft   370.00 ft   380.00 ft   390.00 ft   400.00 ft

   0.00  d          0.0000      0.0000      0.0000      0.0000      0.0000
%365242.00  d         0.0000      0.0000      0.0000      0.0000      0.000
%730484.00  d         0.0000      0.0000      0.0000      0.0000      0.000
%1095726.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%1460968.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%1826210.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%2191452.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%2556694.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%2921936.00  d         0.0000      0.0000      0.0000      0.0000      0.00

%3287178.00  d         0.0001      0.0000      0.0000      0.0000      0.00

%3652420.00  d         0.0003      0.0002      0.0001      0.0000      0.00
```

```
*************************************************
*                                               *
*   ONE-DIMENSIONAL SOLUTE TRANSPORT EQUATION   *
*   FIRST-TYPE BOUNDARY CONDITION               *
*                                               *
*   MODEL: ONED1.BAS                            *
*                                               *
*************************************************


USER:     Daniel S. Fisher
-----
LOCATION: Baker Environmental, Inc.
---------
DATE:     March 15, 1995
-----

                  INPUT DATA:

DARCY VELOCITY.....................:   0.01  ft/d
EFFECTIVE POROSITY.................:    .28
LONGITUDINAL DISPERSIVITY..........:  40.00  ft
RETARDATION FACTOR.................: 926.70
INITIAL CONCENTRATION..............:   0.00  ppb
CONCENTRATION AT THE SOURCE........:   0.13  ppb
DISTANCE INCREMENT DELX............:  10.00  ft
NUMBER OF DISTANCE INCREMENTS......:  40
INITIAL TIME.......................:   0.00  d
TIME INCREMENT DELT................:%3652420.00  d
NUMBER OF TIME INCREMENTS..........:  10
```

6.404 e-3

10,000 years
x 10

100,000 years

```
********************************** RESULTS ************************************

+------> distance X        CONCENTRATION in ug/l (ppb)
 time


                      10.00 ft     20.00 ft     30.00 ft     40.00 ft     50.00 ft

   0.00  d             0.0000       0.0000       0.0000       0.0000       0.0000
%3652420.00   d            0.1277       0.1248       0.1213       0.1173       0.112

%7304840.00   d            0.1294       0.1286       0.1276       0.1265       0.125

%10957260.00   d            0.1298       0.1295       0.1292       0.1288       0.12
3
%14609680.00   d            0.1299       0.1298       0.1297       0.1295       0.12
3
%18262100.00   d            0.1300       0.1299       0.1299       0.1298       0.1
7
%21914520.00   d            0.1300       0.1300       0.1299       0.1299       0.1
9
%25566940.00   d            0.1300       0.1300       0.1300       0.1300       0.1
9
%29219360.00   d            0.1300       0.1300       0.1300       0.1300       0.1
0
%32871780.00   d            0.1300       0.1300       0.1300       0.1300       0.1
0
%36524200.00   d            0.1300       0.1300       0.1300       0.1300       0.1
0


                      60.00 ft     70.00 ft     80.00 ft     90.00 ft    100.00 ft

   0.00  d             0.0000       0.0000       0.0000       0.0000       0.0000
%3652420.00   d            0.1075       0.1018       0.0957       0.0893       0.08

%7304840.00   d            0.1236       0.1217       0.1197       0.1174       0.11

%10957260.00   d            0.1277       0.1270       0.1263       0.1254       0.1
3
%14609680.00   d            0.1291       0.1288       0.1285       0.1281       0.1
7
%18262100.00   d            0.1296       0.1295       0.1294       0.1292       0.1
0
%21914520.00   d            0.1298       0.1298       0.1297       0.1296       0.1
6
%25566940.00   d            0.1299       0.1299       0.1299       0.1298       0.
8
%29219360.00   d            0.1300       0.1300       0.1299       0.1299       0.
9
%32871780.00   d            0.1300       0.1300       0.1300       0.1300       0.
0
%36524200.00   d            0.1300       0.1300       0.1300       0.1300       0.
0


                     110.00 ft    120.00 ft    130.00 ft    140.00 ft    150.00 ft

   0.00  d             0.0000       0.0000       0.0000       0.0000       0.0000
%3652420.00   d            0.0757       0.0687       0.0618       0.0551       0.0

%7304840.00   d            0.1119       0.1088       0.1055       0.1019       0.0
```

```
%10957260.00  d        0.1232       0.1219       0.1204       0.1189       0.11
1
%14609680.00  d        0.1272       0.1267       0.1260       0.1253       0.12

%18262100.00  d        0.1288       0.1286       0.1283       0.1280       0.12
6
%21914520.00  d        0.1295       0.1294       0.1292       0.1291       0.12
9
%25566940.00  d        0.1298       0.1297       0.1296       0.1296       0.12
5
%29219360.00  d        0.1299       0.1299       0.1298       0.1298       0.12
8
%32871780.00  d        0.1299       0.1299       0.1299       0.1299       0.1
9
%36524200.00  d        0.1300       0.1300       0.1300       0.1300       0.1
9


                  160.00 ft    170.00 ft    180.00 ft    190.00 ft    200.00 ft

   0.00  d          0.0000       0.0000       0.0000       0.0000       0.0000
%3652420.00  d        0.0424       0.0367       0.0314       0.0265       0.02

%7304840.00  d        0.0941       0.0899       0.0856       0.0811       0.07

%10957260.00  d        0.1152       0.1131       0.1109       0.1085       0.1
9
%14609680.00  d        0.1237       0.1227       0.1216       0.1204       0.1
1
%18262100.00  d        0.1272       0.1267       0.1262       0.1257       0.1
0
%21914520.00  d        0.1287       0.1285       0.1283       0.1280       0.1
7
%25566940.00  d        0.1294       0.1293       0.1292       0.1291       0.1
9
%29219360.00  d        0.1297       0.1297       0.1296       0.1295       0.1
5
%32871780.00  d        0.1299       0.1298       0.1298       0.1298       0.1
7
%36524200.00  d        0.1299       0.1299       0.1299       0.1299       0.
9


                  210.00 ft    220.00 ft    230.00 ft    240.00 ft    250.00 ft

   0.00  d          0.0000       0.0000       0.0000       0.0000       0.0000
%3652420.00  d        0.0184       0.0151       0.0122       0.0097       0.0

%7304840.00  d        0.0719       0.0673       0.0626       0.0581       0.0

%10957260.00  d        0.1032       0.1003       0.0973       0.0942       0.
9
%14609680.00  d        0.1177       0.1162       0.1146       0.1129       0.
0
%18262100.00  d        0.1243       0.1236       0.1228       0.1218       0.
9
%21914520.00  d        0.1273       0.1270       0.1266       0.1261       0.
6
%25566940.00  d        0.1287       0.1286       0.1284       0.1281       0.
9
%29219360.00  d        0.1294       0.1293       0.1292       0.1291       0.
0
%32871780.00  d        0.1297       0.1297       0.1296       0.1296       0.
```

```
5
%36524200.00  d       0.1299      0.1298      0.1298      0.1298      0.12
7


                   260.00 ft   270.00 ft   280.00 ft   290.00 ft   300.00 ft

   0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
%3652420.00  d        0.0060      0.0047      0.0036      0.0027      0.002

%7304840.00  d        0.0492      0.0449      0.0408      0.0369      0.033

%10957260.00  d       0.0875      0.0841      0.0805      0.0769      0.07
3
%14609680.00  d       0.1090      0.1069      0.1047      0.1024      0.10
0
%18262100.00  d       0.1198      0.1187      0.1174      0.1161      0.11
7
%21914520.00  d       0.1251      0.1245      0.1238      0.1231      0.1
3
%25566940.00  d       0.1276      0.1273      0.1269      0.1266      0.1
2
%29219360.00  d       0.1288      0.1287      0.1285      0.1283      0.1
1
%32871780.00  d       0.1294      0.1293      0.1292      0.1291      0.1
0
%36524200.00  d       0.1297      0.1297      0.1296      0.1296      0.1
5


                   310.00 ft   320.00 ft   330.00 ft   340.00 ft   350.00 ft

   0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
%3652420.00  d        0.0015      0.0011      0.0008      0.0005      0.00

%7304840.00  d        0.0297      0.0265      0.0234      0.0206      0.01

%10957260.00  d       0.0696      0.0659      0.0623      0.0586      0.0
0
%14609680.00  d       0.0974      0.0948      0.0921      0.0893      0.0
4
%18262100.00  d       0.1132      0.1116      0.1099      0.1082      0.1
3
%21914520.00  d       0.1215      0.1206      0.1196      0.1186      0.1
5
%25566940.00  d       0.1257      0.1252      0.1247      0.1241      0.1
5
%29219360.00  d       0.1278      0.1276      0.1273      0.1270      0.1
6
%32871780.00  d       0.1289      0.1288      0.1286      0.1285      0.
3
%36524200.00  d       0.1294      0.1294      0.1293      0.1292      0.
1


                   360.00 ft   370.00 ft   380.00 ft   390.00 ft   400.00 ft

   0.00  d        0.0000      0.0000      0.0000      0.0000      0.0000
%3652420.00  d        0.0003      0.0002      0.0001      0.0000      0.0

%7304840.00  d        0.0157      0.0136      0.0117      0.0100      0.0

%10957260.00  d       0.0514      0.0479      0.0445      0.0412      0.
```

```
0
%14609680.00  d       0.0834      0.0803      0.0773      0.0742      0.07
0
%18262100.00  d       0.1043      0.1022      0.1001      0.0978      0.09
 21914520.00  d       0.1163      0.1150      0.1137      0.1123      0.11
8
%25566940.00  d       0.1228      0.1221      0.1213      0.1205      0.11
6
%29219360.00  d       0.1263      0.1259      0.1255      0.1250      0.12
5
%32871780.00  d       0.1281      0.1279      0.1276      0.1274      0.12
1
%36524200.00  d       0.1290      0.1289      0.1288      0.1286      0.12
5
```

APPENDIX B
2-D MODEL

B.0 TWO-DIMENSIONAL HORIZONTAL FLOW MODEL ASSUMING A SLUG SOURCE (2-D MODEL)

The 2-D model (Wilson and Miller, 1978) evaluates a slug source, at which an instantaneous release once occurred, and incorporates certain source-specific, aquifer-specific, and chemical-specific information to calculate a predicted contaminant concentration that would occur at some designated downgradient receptor location. The term "instantaneous release" implies that the duration of the release is not continuous and is very short relative to the time since the release. Prior to discussing the model and its use in this effort, it should be noted that the derivation of the model was based on the following assumptions (Wilson and Miller, 1978):

Model Derivation Assumptions:

- The thickness of the saturated zone is assumed to be uniform.
- The aquifer properties (e.g., porosity, bulk density, organic carbon content) are relatively homogeneous.
- The density and viscosity of the contaminant solute are the same as those of the native groundwater.
- The regional flow in the aquifer is uniform and horizontal.
- The effect of the source on v_x is assumed to be negligible in comparison with the uniform regional flow rate.

Following release, the resultant groundwater contaminant concentration at the source, C_o, is assumed to be a slug of uniform depth with volume Q. The depth of mixing is typically considered to be the average thickness of the aquifer (b). The slug migrates toward the receptor location at a velocity, v_x, undergoing only horizontal variations over the traveled distance, x, and time, t. These horizontal variations are described as longitudinal and transverse spreading in the x- and y- directions, respectively. The spread of the contaminant slug is a function of dispersion (D) in the x- and y- directions (D_x and D_y, respectively) and chemical retardation (R_d) of the slug. Based on model assumptions, vertical dispersions are not considered significant and are not incorporated into any calculations. Therefore, the downgradient groundwater concentration, which is estimated to be a function of the longitudinal and transverse dispersion of the slug, as well as the assumed time of migration to the receptor location, is expressed as $C_{(x,y,t)}$. The equation used to estimate $C_{(x,y,t)}$ is presented below.

$$C_{x,y,t} = \frac{C_o Q}{b 4 \pi p t (D_x D_y)^{0.5}} \exp\left[-kt - \frac{(xR_d - v_x t)^2}{4 D_x t R_d} - \frac{(yR_d)^2}{4 D_y t R_d}\right]$$

In addition to those model assumptions discussed previously, the following site-specific assumptions were made:

Site-specific Assumptions:

- There is no confining unit between the shallow and Castle Hayne aquifers; the depth of mixing extends through both aquifers as if they are one.
- The groundwater contaminant concentration at the source is constant over the full saturated thickness of the aquifer.
- The groundwater flow direction is from the source location to the receptor.
- The slug geometry in the x- and y- directions is assumed to be rectangular.
- There is no lateral spread of the slug (i.e., the y-component equals zero).

For this Corrective Action Plan, the 2-D model was run for four source-receptor combinations or scenarios:

1. A TCE slug source at 78-GW23 and a receptor at supply well HP-637.
2. A benzene slug source at 78GW22-1 and a receptor at supply well HP-637.
3. A TCE slug source at 78-GW23 and a receptor at supply well HP-642.
4. A benzene slug source at 78GW22-1 and a receptor at supply well HP-642.

Because the groundwater areas of concern at OU No. 1 contain chlorinated solvent and fuel contaminants, the model was run for both TCE and benzene. TCE was the most mobile chlorinated solvent that was detected, and benzene was the most volatile fuel contaminant that was detected.

The monitoring well locations where TCE and benzene were detected at maximum concentrations were selected as the slug source locations. These source locations are monitoring well 78-GW23 where TCE was detected at 440 ug/L, and monitoring well 78GW22-1 where benzene was detected at 9,200 J ug/L. Both source wells are screened within the shallow aquifer. Active water supply wells HP-637 and HP-642 were selected as the receptors for both TCE and benzene. These are the only two active supply wells within a one-mile radius of OU No. 1. Both supply wells are screened within the Castle Hayne aquifer. (The screened intervals for HP-637 start at 112' bgs; the well's total depth is 210' bgs. The screened intervals for HP-642 start at 172' bgs; the well's total depth is 172' bgs.) However, for the purposes of this model, the shallow and Castle Hayne aquifers are assumed to be one continuous aquifer with no confining unit to impede the flow of groundwater contaminants. This assumption makes the model extremely conservative because in reality, there is likely to be a semi-confining unit impeding contaminant migration. For each source-receptor scenario, it is also assumed that groundwater flows directly from the source location to the supply well. Based on water level measurements, however, groundwater appears to flow in a generally southwestern direction (see the figures included in this appendix). Thus, the assumed direction of groundwater flow also makes the model extremely conservative.

For each source-receptor scenario, 2 runs of the model were conducted: one assuming no decay (k=0 d^{-1}) and one assuming decay (k=0.0004 d^{-1} for TCE, and k=0.001 d^{-1} for benzene). (Decay refers to biodegradation.) In addition, each source-receptor scenario and decay assumption was run using four different time periods: t=365 days (1 year), t=1,850 days (5 years), t=10,950 days (10 years), and t=36,500 days (100 years).

Figures B-1, B-2, B-3, and B-4 depict the source and receptor locations, and the direction of groundwater flow, assumed for each of the four modeling scenarios. Spreadsheets B-1, B-2, B-3, and B-4 present model calculations and results for the four scenarios.

It is important to note that under the IRA, a groundwater treatment system is currently being operated near 78-GW23 (the TCE source location). The model does not take into account the effects that this treatment system may be having on TCE contaminant levels. Most likely, the treatment system is lowering contaminant levels and reducing the contaminant plume's mobility. Because the model ignores the treatment system effects, the model results for TCE most likely err on the conservative side.

B.1 Model Results

As shown in Spreadsheets B-1, B-2, B-3, and B-4, the model results indicate the downgradient contaminant concentration ($C_{(x,y,t)}$) after varying periods of time assuming no decay and decay. Potential risks to human health are assumed to exist if the maximum estimated value of $C_{(x,y,t)}$ exceeds the following standards:

For TCE:

- 0.0028 mg/L (North Carolina Water Quality Standard for Groundwater)
- 0.005 mg/L (Safe Drinking Water Act Maximum Contaminant Level)

For Benzene:

- 0.001 mg/L (North Carolina Water Quality Standard for Groundwater)
- 0.005 mg/L (Safe Drinking Water Act Maximum Contaminant Level)

If the maximum estimated value of $C_{(x,y,t)}$ does not exceed these standards, the potential risks to human health associated with the site-related contaminants are within acceptable limits.

B.1.1 Downgradient Concentrations at Receptor HP-637

TCE and Benzene Assuming No Degradation

As shown in Spreadsheets B-1 and B-2, downgradient TCE and benzene concentrations assuming no degradation (i.e., k = 0 d^{-1}) gradually increase over time. However, after 100 years, the TCE concentration is only expected to be 1.1E-16 mg/L which is far below the North Carolina Standard of 2.8E-03 mg/L. After 100 years, the benzene concentration is only expected to be 1.3E-12 mg/L which is far below the North Carolina Standard of 5E-03 mg/L. Based on this information, it may be concluded that over time, TCE and benzene from OU No. 1 will not adversely impact supply well HP-637 assuming no degradation of the contaminants. In addition, TCE and benzene are not expected to present unacceptable human health risks over time. Assuming no contaminant degradation is the most conservative way to run the 2-D model. In reality, contaminants are likely to biodegrade to some extent which would lower their downgradient concentrations even further.

TCE and Benzene Assuming Degradation

As shown in Spreadsheets B-1 and B-2, TCE and benzene concentrations assuming degradation (i.e., k = 0.0004 d^{-1} and k = 0.001 d^{-1}, respectively) will gradually increase over time. However, after 100 years, the TCE concentration is only expected to be 4.9E-23 mg/L which is far below the North Carolina Standard of 2.8E-03 mg/L. After 100 years, the benzene concentration is only expected to be 1.8E-28 mg/L which is far below the North Carolina Standard of 5E-03 mg/L. Based on this information, it may be concluded that over time, TCE and benzene from OU No. 1 will not adversely impact supply well HP-637 assuming the contaminants degrade at the specified rates.

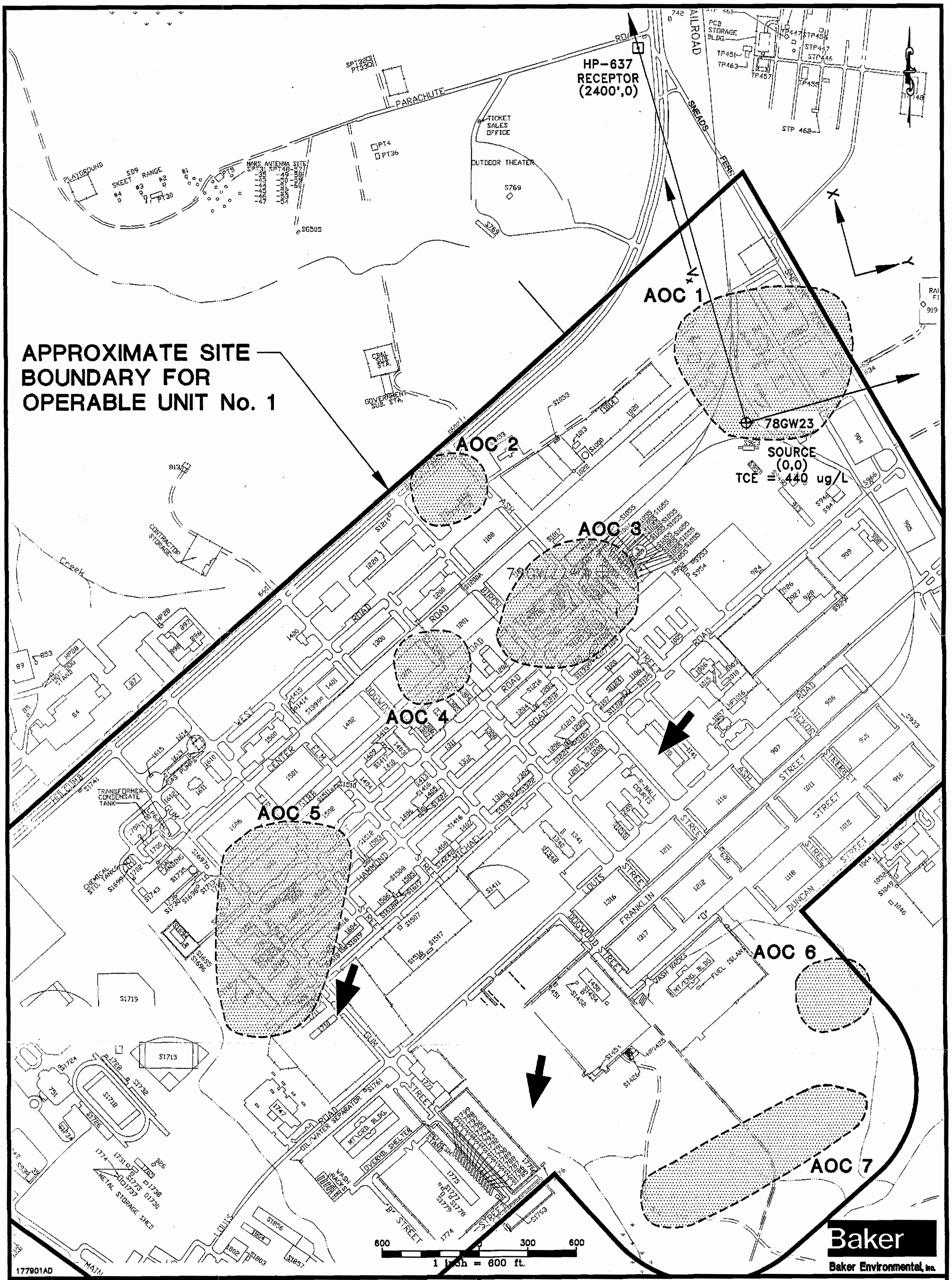
B.1.2 Downgradient Concentrations at Receptor HP-642

TCE and Benzene Assuming No Degradation

As shown in Spreadsheets B-3 and B-4, downgradient TCE and benzene concentrations assuming no degradation (i.e., k = 0 d^{-1}) gradually increase over time. However, after 100 years, the TCE concentration is only expected to be 1.0E-19 mg/L which is far below the North Carolina Standard of 2.8E-03 mg/L. After 100 years, the benzene concentration is only expected to be 2.7E-10 mg/L which is far below the North Carolina Standard of 5E-03 mg/L. Based on this information, it may be concluded that over time, TCE and benzene from OU No. 1 will not adversely impact supply well HP-642 assuming no degradation of the contaminants. In addition, TCE and benzene are not expected to present unacceptable human health risks over time. Assuming no contaminant degradation is the most conservative way to run the 2-D model. In reality, contaminants are likely to biodegrade to some extent which would lower their downgradient concentrations even further.

TCE and Benzene Assuming Degradation

As shown in Spreadsheets B-3 and B-4, TCE and benzene concentrations assuming degradation (i.e., k = 0.0004 d^{-1} and k = 0.001 d^{-1}, respectively) will gradually increase over time. However, after 100 years, the TCE concentration is only expected to be 4.7E-27 mg/L which is far below the North Carolina Standard of 2.8E-03 mg/L. After 100 years, the benzene concentration is only expected to be 3.8E-26 mg/L which is far below the North Carolina Standard of 5E-03 mg/L. Based on this information, it may be concluded that over time, TCE and benzene from OU No. 1 will not adversely impact supply well HP-642 assuming the contaminants degrade at the specified rates.



LEGEND

⊕ 78GW02 SHALLOW MONITORING WELL

→ DIRECTION OF GROUDWATER FLOW BASED ON WATER LEVEL MEASUREMENTS

▨ APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)

AOC 8 AREA OF CONCERN

HP-603 ⊡ WATER SUPPLY WELL (ACTIVE)

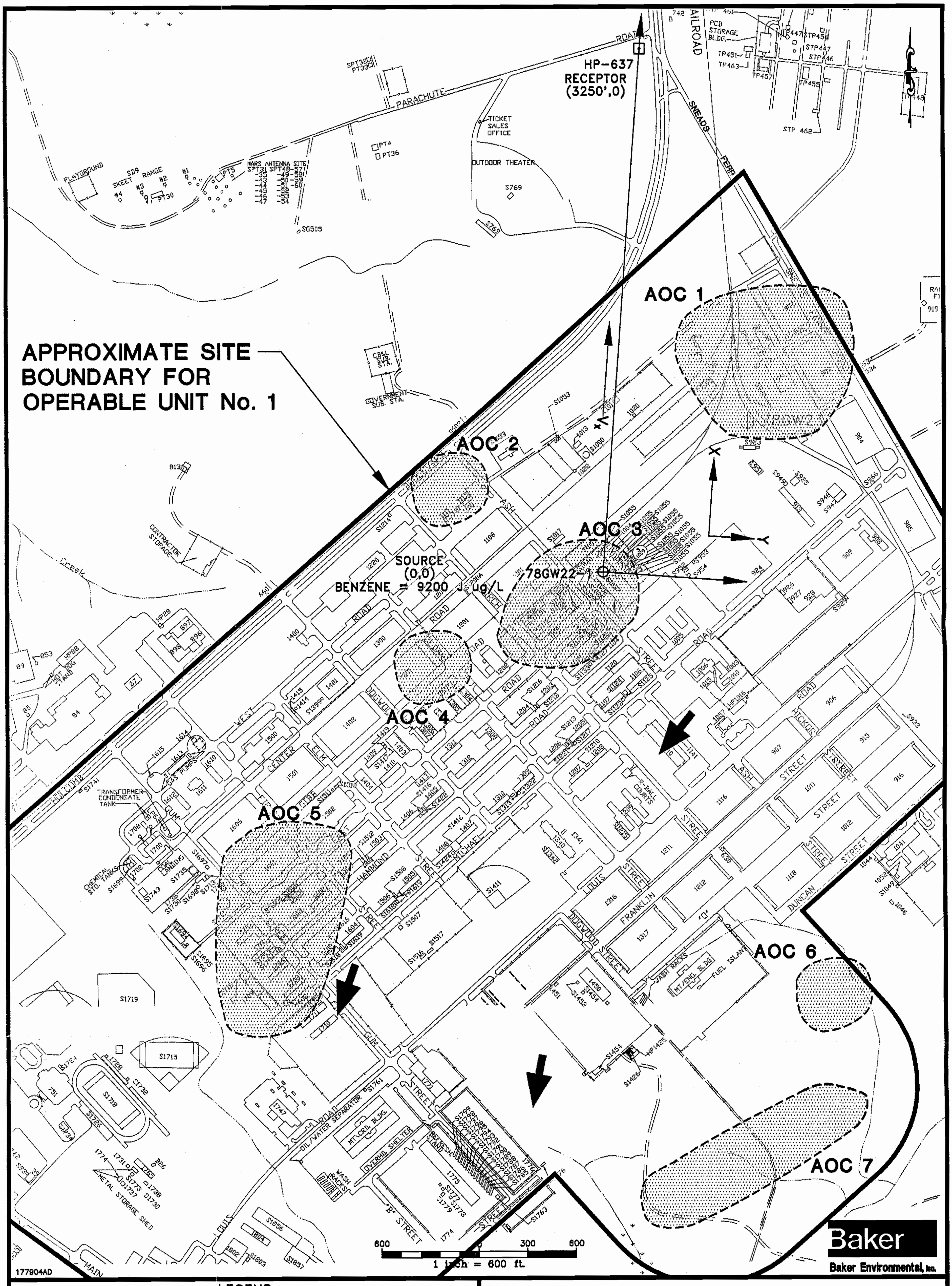
HP-601 ⊠ WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, OCT. 1991

FIGURE B-1
TCE SOURCE AT 78-GW23;
RECEPTOR AT HP-637

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01991DDB12



LEGEND

78GW02 ⊕ SHALLOW MONITORING WELL

→ DIRECTION OF GROUDWATER FLOW BASED ON WATER LEVEL MEASUREMENTS

▨ APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)

AOC 8 AREA OF CONCERN

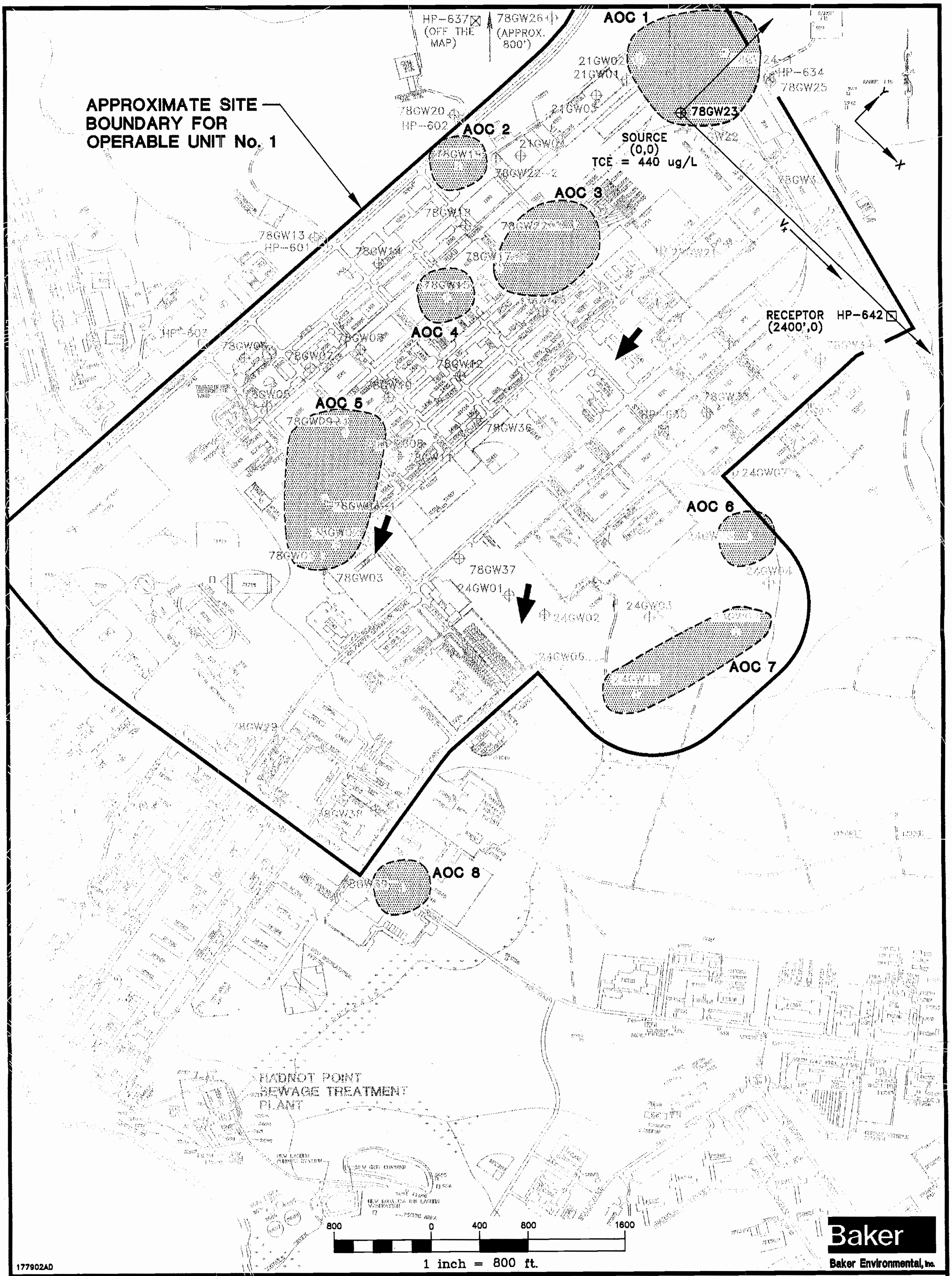
HP-603 ⊡ WATER SUPPLY WELL (ACTIVE)

HP-601 ☒ WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, OCT. 1991

FIGURE B-2
BENZENE SOURCE AT 78-GW22-1;
RECEPTOR AT HP-637

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker

Baker Environmental, Inc.

LEGEND

SHALLOW MONITORING WELL

➔ DIRECTION OF GROUDWATER FLOW BASED ON WATER LEVEL MEASUREMENTS

▨ APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)

AOC 8 AREA OF CONCERN

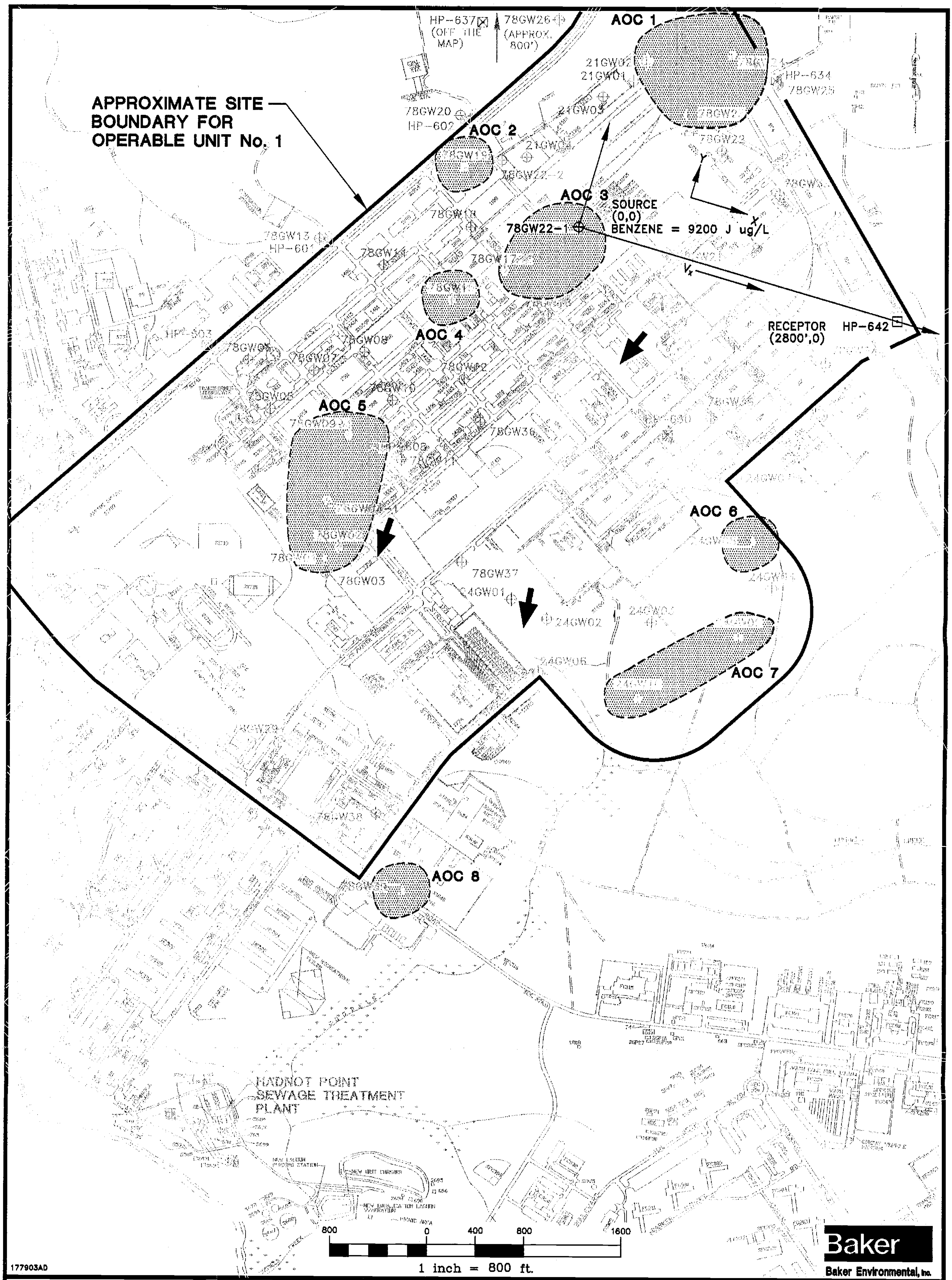
WATER SUPPLY WELL (ACTIVE)

WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE B-3
TCE SOURCE AT 78-GW23;
RECEPTOR AT HP-642

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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Baker
Baker Environmental, Inc.

LEGEND

⊕	SHALLOW MONITORING WELL
→	DIRECTION OF GROUDWATER FLOW BASED ON WATER LEVEL MEASUREMENTS
▨	APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)
AOC 8	AREA OF CONCERN
	WATER SUPPLY WELL (ACTIVE)
	WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE B-4
BENZENE SOURCE AT 78-GW22-1;
RECEPTOR AT HP-642

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

Spreadsheet B-1
Two-Dimensional Horizontal Flow Model Assuming a Slug Source (Wilson & Miller, 1978)
Source: TCE @ 440 ug/L in 78-GW23
Receptor: Supply Well HP-637

Model Assumptions:

1) Uniform steady regional groundwater flow in the X - direction.
2) There is no confining unit between the shallow and deep aquifers.
3) TCE concentration is assumed constant over the full saturated thickness.
4) Dimension of slug is estimated as rectangular in shape, with an average depth of 27.43 m.
4) y - Component = 0 throughout lateral spread of slug.
5) Contaminant decay is evaluated under two scenarios: decay occurrs and is first order aerobic (k = 0.0004/d); no decay occurs (k = 0/d).
6) Receptor location concentrations were estimated at t = 365 days (1 year), 1850 days (5 years), 10,950 days (30 years), and 36,500 days (100 years).

Equation:

$$C(x,y,t) = \frac{Co*Q}{b4*(pi)*P*t*(DxDy)^{0.5}} * \exp \{-kt - [(X*Rd - Vx*t)^{2}/(4Dx*t*Rd)] - [(y*Rd)^{2}/(4Dy*t*Rd)\}$$

Where:

Variable	Description	Value
Co	Initial Groundwater Concentration (mg/L)	0.44
Q	Volume of Slug Source (m3)	Derived (a)
b	Aquifer Thickness (m)	27.43
P	Porosity (Unitless)	0.28
t	Time (d)	Variable (b)
X	Longitudinal Distance to Receptor Location (m)	732
Dx	Longitudinal Dispersion Coefficient (m2/d)	Derived (a)
Dy	Lateral Dispersion Coefficient (m2/d)	Derived (a)
Vx	Seepage Velocity (m/d)	0.0021
k	First Order Decay Coefficient(1/d)	0, 0.0004
Rd	Retardation Coefficient (Unitless)	Derived (a)
y	Lateral Component (m)	0

Notes:
(a) Value derived below.
(b) Value is variable. See spreadsheet below for inputs.

---

(1) Calculate: Q for TCE slug

Q (m3) = L * W * D
Where:
L = Length of Slug Source (m) 121.92
W = Width of Slug Source (m) = 121.92
D = Depth of Slug Source (m) = 27.43

= $\boxed{407,733}$

---

(2) (a) Calculate: Dx for TCE slug

Dx (m2/d)= a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= $\boxed{0.2}$

(b) Calculate: Dy for TCE slug

Dy (m2/d)= 0.333 * a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= $\boxed{0.1}$

---

(3) Calculate: Rd for TCE slug

Rd = 1 + [(Kd *p)/P]
Where:
Kd = Soil-to-Water Distribution Coefficient (cm3/g) = 0.126
p = Bulk Density (g/cm3) = 1.6

= $\boxed{1.72}$

---

(4) Calculate: C(x,y,t) of TCE at receptor location, varying t, k

t (d)	k (1/d)	C(x,y,t) (mg/L)
365	0	0.0E+00
1,825	0	0.0E+00
10,950	0	9.8E-58
36,500	0	1.1E-16
365	0.0004	0.0E+00
1,825	0.0004	0.0E+00
10,950	0.0004	1.2E-59
36,500	0.0004	4.9E-23

Spreadsheet B-2
Two-Dimensional Horizontal Flow Model Assuming a Slug Source (Wilson & Miller, 1978)
Source: Benzene @ 9200J ug/L in 78GW22-1
Receptor: Supply Well HP-637

Model Assumptions:

1) Uniform steady regional groundwater flow in the X - direction.
2) There is no confining unit between the shallow and deep aquifers.
3) Benzene concentration is assumed constant over the full saturated thickness.
4) Dimension of slug is estimated as rectangular in shape, with an average depth of 27.43 m.
4) y - Component = 0 throughout lateral spread of slug.
5) Contaminant decay is evaluated under two scenarios: decay occurrs and is first order aerobic (k = 0.001/d); no decay occurs (k = 0/d).
6) Receptor location concentrations were estimated at t = 365 days (1 year), 1850 days (5 years), 10,950 days (30 years), and 36,500 days (100 years).

Equation:

$$C(x,y,t) = \frac{Co*Q}{b4*(pi)*P*t*(DxDy)\text{\textasciicircum}0.5} \quad * \ exp \quad \{-kt - [(X*Rd - Vx*t)\text{\textasciicircum}2/(4Dx*t*Rd)] - [(y*Rd)\text{\textasciicircum}2/(4Dy*t*Rd)$$

Where:

Variable	Description	Value
Co	Initial Groundwater Concentration (mg/L)	9.2
Q	Volume of Slug Source (m3)	Derived (a)
b	Aquifer Thickness (m)	27.43
P	Porosity (Unitless)	0.28
t	Time (d)	Variable (b)
X	Longitudinal Distance to Receptor Location (m)	1006
Dx	Longitudinal Dispersion Coefficient (m2/d)	Derived (a)
Dy	Lateral Dispersion Coefficient (m2/d)	Derived (a)
Vx	Seepage Velocity (m/d)	0.0021
k	First Order Decay Coefficient (1/d)	0, 0.001
Rd	Retardation Coefficient (Unitless)	Derived (a)
y	Lateral Component (m)	0

Notes:
(a) Value derived below:
(b) Value is variable. See spreadsheet below for inputs.

---

(1) Calculate: Q for Benzene slug

Q (m3) = L * W * D
Where:
L = Length of Slug Source (m) 121.92
W = Width of Slug Source (m) = 121.92
D = Depth of Slug Source (m) = 27.43

= 407,733

---

(2) (a) Calculate: Dx for Benzene slug

Dx (m2/d)= a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= 0.2

(b) Calculate: Dy for Benzene slug

Dy (m2/d)= 0.333 * a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= 0.1

---

(3) Calculate: Rd for Benzene slug

Rd = 1 + [(Kd *p)/P]
Where:
Kd = Soil-to-Water Distribution Coefficient (cm3/g) = 0.0083
p = Bulk Density (g/cm3) = 1.6

= 1.05

---

(4) Calculate: C(x,y,t) of Benzene at receptor location, varying t, k

t (d)	k (1/d)	C(x,y,t) (mg/L)
365	0	0.0E+00
1,825	0	8.4E-295
10,950	0	7.3E-47
36,500	0	1.3E-12
365	0.001	0.0E+00
1,825	0.001	1.4E-295
10,950	0.001	1.3E-51
36,500	0.001	1.8E-28

Spreadsheet B-3
Two-Dimensional Horizontal Flow Model Assuming a Slug Source (Wilson & Miller, 1978)
Source: TCE @ 440 ug/L in 78-GW23
Receptor: Supply Well HP-642

Model Assumptions:

1) Uniform steady regional groundwater flow in the X - direction.
2) There is no confining unit between the shallow and deep aquifers.
3) TCE concentration is assumed constant over the full saturated thickness.
4) Dimension of slug is estimated as rectangular in shape, with an average depth of 34.14 m.
4) y - Component = 0 throughout lateral spread of slug.
5) Contaminant decay is evaluated under two scenarios: decay occurrs and is first order aerobic (k = 0.0004/d); no decay occurs (k = 0/d).
6) Receptor location concentrations were estimated at t = 365 days (1 year), 1850 days (5 years), 10,950 days (30 years), and 36,500 days (100 years).

Equation:

$$C(x,y,t) = \frac{Co*Q}{b4*(pi)*P*t*(DxDy)\text{^}0.5} \ * \ \exp \ \{-kt - [(X*Rd - Vx*t)\text{^}2/(4Dx*t*Rd)] - [(y*Rd)\text{^}2/(4Dy*t*Rd)\}$$

Where:

Variable	Description	Value
Co	Initial Groundwater Concentration (mg/L)	0.44
Q	Volume of Slug Source (m3)	Derived (a)
b	Aquifer Thickness (m)	34.14
P	Porosity (Unitless)	0.28
t	Time (d)	Variable (b)
X	Longitudinal Distance to Receptor Location (m)	853.44
Dx	Longitudinal Dispersion Coefficient (m2/d)	Derived (a)
Dy	Lateral Dispersion Coefficient (m2/d)	Derived (a)
Vx	Seepage Velocity (m/d)	0.0021
k	First Order Decay Coefficient(1/d)	0, 0.0004
Rd	Retardation Coefficient (Unitless)	Derived (a)
y	Lateral Component (m)	0

Notes:
(a) Value derived below:
(b) Value is variable. See spreadsheet below for inputs.

---

(1) Calculate: Q for TCE slug

Q (m3) = L * W * D
Where:
L = Length of Slug Source (m) 121.92
W = Width of Slug Source (m) = 121.92
D = Depth of Slug Source (m) = 34.14

= $\boxed{507,474}$

---

(2) (a) Calculate: Dx for TCE slug

Dx (m2/d)= a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= $\boxed{0.2}$

(b) Calculate: Dy for TCE slug

Dy (m2/d)= 0.333 * a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= $\boxed{0.1}$

---

(3) Calculate: Rd for TCE slug

Rd = 1 + [(Kd *p)/P]
Where:
Kd = Soil-to-Water
Distribution Coefficient (cm3/g) = 0.126
p = Bulk Density (g/cm3) = 1.6

= $\boxed{1.72}$

---

(4) Calculate: C(x,y,t) of TCE at receptor location, varying t, k

t (d)	k (1/d)	C(x,y,t) (mg/L)
365	0	0.0E+00
1,825	0	0.0E+00
10,950	0	1.2E-67
36,500	0	1.0E-19
365	0.0004	0.0E+00
1,825	0.0004	0.0E+00
10,950	0.0004	1.5E-69
36,500	0.0004	4.7E-26

Spreadsheet B-4
Two-Dimensional Horizontal Flow Model Assuming a Slug Source (Wilson & Miller, 1978)
Source: Benzene @ 9200J ug/L in 78GW22-1
Receptor: Supply Well HP-642

Model Assumptions:

1) Uniform steady regional groundwater flow in the X - direction.
2) There is no confining unit between the shallow and deep aquifers.
3) Benzene concentration is assumed constant over the full saturated thickness.
4) Dimension of slug is estimated as rectangular in shape, with an average depth of 34.14 m.
4) y - Component = 0 throughout lateral spread of slug.
5) Contaminant decay is evaluated under two scenarios: decay occurrs and is first order aerobic (k = 0.001/d); no decay occurs (k = 0/d).
6) Receptor location concentrations were estimated at t = 365 days (1 year), 1850 days (5 years), 10,950 days (30 years), and 36,500 days (100 years).

Equation:

$$C(x,y,t) = \frac{Co*Q}{b4*(pi)*P*t*(DxDy)^{\wedge}0.5} \quad * \ \exp \quad \{-kt - [(X*Rd - Vx*t)^{\wedge}2/(4Dx*t*Rd)] - [(y*Rd)^{\wedge}2/(4Dy*t*Rd)$$

Where:

Variable	Description	Value
Co	Initial Groundwater Concentration (mg/L)	9.2
Q	Volume of Slug Source (m3)	Derived (a)
b	Aquifer Thickness (m)	34.14
P	Porosity (Unitless)	0.28
t	Time (d)	Variable (b)
X	Longitudinal Distance to Receptor Location (m)	853.44
Dx	Longitudinal Dispersion Coefficient (m2/d)	Derived (a)
Dy	Lateral Dispersion Coefficient (m2/d)	Derived (a)
Vx	Seepage Velocity (m/d)	0.0021
k	First Order Decay Coefficient (1/d)	0, 0.001
Rd	Retardation Coefficient (Unitless)	Derived (a)
y	Lateral Component (m)	0

Notes:
(a) Value derived below:
(b) Value is variable. See spreadsheet below for inputs.

---

(1) Calculate: Q for Benzene slug

Q (m3) = L * W * D
Where:
L = Length of Slug Source (m) 121.92
W = Width of Slug Source (m) = 121.92
D = Depth of Slug Source (m) = 34.14

= 507,474

---

(2) (a) Calculate: Dx for Benzene slug

Dx (m2/d)= a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= 0.2

(b) Calculate: Dy for Benzene slug

Dy (m2/d)= 0.333 * a * Vx
Where: a = Longitudinal Dispersivity (m) = 0.1*X

= 0.1

---

(3) Calculate: Rd for Benzene slug

Rd = 1 + [(Kd *p)/P]
Where:
Kd = Soil-to-Water Distribution Coefficient (cm3/g) = 0.0083
p = Bulk Density (g/cm3) = 1.6

= 1.05

---

(4) Calculate: C(x,y,t) of Benzene at receptor location, varying t, k

t (d)	k (1/d)	C(x,y,t) (mg/L)
365	0	0.0E+00
1,825	0	1.8E-249
10,950	0	3.0E-39
36,500	0	2.7E-10
365	0.001	0.0E+00
1,825	0.001	2.9E-250
10,950	0.001	5.3E-44
36,500	0.001	3.8E-26

TABLES

TABLE 1-1

PREVIOUS REPORTS
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Date	Report Title	Prepared By
1983	Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina	Water and Air Research, Inc.
1988	Characterization Step Report for HPIA, Confirmation Study to Determine Existence and Possible Migration of Specific Chemicals In-Situ	Environmental Science and Engineering, Inc.
1990	Site Summary Report	Environmental Science and Engineering, Inc.
1992	Remedial Investigation Report for HPIA Operable Unit Shallow Soils and Castle Hayne Aquifer, Characterization Study to Determine Existence and Possible Migration of Specific Chemicals In-Situ	Environmental Science and Engineering, Inc.
1992	Interim Remedial Action RI for the Shallow Aquifer at the HPIA Operable Unit	Baker Environmental, Inc.
1992	Interim Remedial Action FS for the Shallow Aquifer of the HPIA Operable Unit	Baker Environmental, Inc.
1993	Treatability Study Report for the Shallow Aquifer and the HPIA	Baker Environmental, Inc.
1993	Remedial Action Work Plan for the HPIA Shallow Aquifer	Baker Environmental, Inc.
June 1994	Design Construction Cost Estimate, and Remedial Design Expansion, HPIA	Baker Environmental, Inc.
June 1994	RI Report, OU No. 1 (Sites 21, 24, and 78)	Baker Environmental, Inc.
July 1994	FS Report for OU No. 1 (Sites 21, 24, and 78)	Baker Environmental, Inc.
Sept. 1994	Final Rod for OU No. 1	Baker Environmental, Inc.
Nov. 1994	Design for the Remediation of Pesticide and PCB-Contaminated Soil and Sites 21 at 78, OU No. 1	Baker Environmental, Inc

TALBE 1-2

INITIAL REMEDIAL ACTIONS
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Date	Remedial Action
1988	Supply wells HP-601, HP-602, HP-608, and HP-634 were inactivated.
1991	Product recovery and groundwater extraction/treatment system began operation.
September 1994	Construction of the IRA groundwater extraction/treatment system began.
December 1994	Construction of the IRA groundwater extraction/treatment system and its expansion (i.e., additional recovery wells) was completed. Operation of the system began.
1996	The plan to abandon all supply wells in the vicinity of OU No. 1, with the exception of HP-637 and HP-642, is being conducted.

TABLE 2-1

REMEDIATION LEVELS FOR CONTAMINANTS OF CONCERN
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminant of Potential Concern	Remediation Goal	Unit[1]
Groundwater	Benzene	1.0	µg/L
	1,2-Dichloroethene (total)	70	µg/L
	Ethylbenzene	29	µg/L
	Heptachlor Epoxide	0.2	µg/L
	Tetrachloroethene	0.7	µg/L
	Toluene	1,000	µg/L
	Trichloroethene	2.8	µg/L
	Vinyl Chloride	0.015	µg/L
	Xylenes (total)	400	µg/L
	Arsenic	50	µg/L
	Barium	1,000	µg/L
	Beryllium	4	µg/L
	Chromium	50	µg/L
	Manganese	50	µg/L
	Vanadium	110	µg/L
Soil	PCBs (total)	370	µg/kg
	4,4'-DDD	12,000	µg/kg
	4,4'-DDT	8,400	µg/kg
	Chlordane (total)	2,200	µg/kg

[1] µg/L = microgram per liter
µg/kg = microgram per kilogram

TABLE 3-1

SURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
CORRECTIVE ACTION PLAN 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

Note:

Concentrations expressed in microgram per kilogram (µg/kg)

TABLE 3-2

SURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE U NIT NO. 1 - SITE 21
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Surface Soil (0-6 inches)				
Inorganic	Average Base-Specific Background Concentration Range[1]	Twice the Average Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Twice the Average Background Concentration
Aluminum	729.65	1459.3	1,120 - 7,320	9/9	8
Arsenic	0.40	0.80	0.76 - 3.9	9/9	8
Barium	6.53	13.1	9.1 - 31.6	9/9	7
Beryllium	0.07	0.1	0.21 - 0.22	4/9	4
Cadmium	0.38	0.8	1	1/9	1
Calcium	2465.8	4931.6	14,000-183,000	9/9	9
Chromium	1.02	2.0	5.8 - 19.9	9/9	9
Cobalt	0.79	1.6	2.1 - 2.4	2/9	2
Copper	1.4	2.8	3.1 - 16.3	9/9	9
Iron	525.4	1050.8	2,030 - 6,730	9/9	9
Lead	22.68	45.4	10.9 - 252	9/9	2
Magnesium	73.15	146.3	344 - 2,700	9/9	9
Manganese	7.14	14.3	13.8 - 70	9/9	8
Mercury	0.04	0.1	0.54	1/9	1
Nickel	1.40	2.80	4.8 - 6	2/9	0
Potassium	52.23	104.5	121 - 451	9/9	9
Selenium	0.45	0.9	0.32 - 0.59	6/9	0
Silver	0.53	1.1	ND	0/9	0
Sodium	24.34	48.7	67.8 - 429	9/9	9
Vanadium	2.31	4.6	4.2 - 17.4	9/9	8
Zinc	11.47	22.9	14.5 - 67.7	9/9	4

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.

TABLE 3-3

SURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
CORRECTIVE ACTION PLAN 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

Note:

Concentrations expressed in microgram per kilogram (μg/kg)

TABLE 3-4

SURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Surface Soil (0-6 inches)				
	Average Base-Specific Background Concentration Range[(1)]	Twice the Average Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Twice the Average Background Concentration
Aluminum	729.65	1459.3	88.2 - 18,700	38/38	29
Arsenic	0.40	0.80	0.43 - 35.2	31/38	21
Barium	6.53	13.1	4.4 - 502	38/38	22
Beryllium	0.07	0.1	0.2 - 4	18/38	18
Cadmium	0.38	0.8	1.6 - 1.9	2/38	2
Calcium	2465.8	4931.6	73.2 - 356,000	37/38	8
Chromium	1.02	2.0	2 - 23	30/38	30
Cobalt	0.79	1.6	2 - 14.4	7/38	7
Copper	1.4	2.8	0.45 - 314	38/38	23
Iron	525.4	1050.8	249 - 13,900	38/38	22
Lead	22.68	45.4	1.5 - 393	38/38	2
Magnesium	73.15	146.3	22.7 - 3,330	38/38	22
Manganese	7.14	14.3	3 - 93.4	38/38	18
Mercury	0.04	0.1	0.15 - 1.2	7/38	7
Nickel	1.40	2.80	6 - 80.8	6/38	6
Potassium	52.23	104.5	24.8 - 1,890	36/38	22
Selenium	0.45	0.9	0.25 - 18	18/38	4
Silver	0.53	1.1	1.3	1/38	1
Sodium	24.34	48.7	16.5 - 373	36/38	24
Vanadium	2.31	4.6	1.3 - 634	38/38	29
Zinc	11.47	22.9	2.4 - 93.8	36/38	7

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.

TABLE 3-5

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
CORRECTIVE ACTION PLAN 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

Note:

Concentrations expressed in microgram per kilogram (µg/kg)

TABLE 3-6

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 21
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Subsurface Soil (6 inches and below)				
Inorganic	Average Base-Specific Background Concentration Range[1]	Twice the Average Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Twice the Average Background Concentration
Aluminum	4473.17	8946.3	1,150 - 14,500	15/15	3
Arsenic	0.28	0.6	0.48 - 5.2	15/15	13
Barium	5.94	11.9	2.1 - 15.6	15/15	5
Beryllium	0.10	0.20	0.23 - 0.26	8/15	8
Cadmium	0.52	1.0	1.5	1/15	1
Calcium	754.13	1508.3	44.6 - 37,200	14/15	2
Chromium	4.34	8.7	2.6 - 19.7	15/15	9
Cobalt	0.80	1.6	1.8 - 2.2	4/15	4
Copper	0.81	1.6	0.96 - 3.4	15/15	8
Iron	8.89	1778	791 - 9,720	15/15	15
Lead	4.57	9.1	2.6 - 24.8	15/15	3
Magnesium	115.6	231.2	33.3 - 926	15/15	12
Manganese	3.10	6.2	2.9 - 40.6	15/15	6
Mercury	0.04	0.1	ND	0/15	0
Nickel	1.98	4.0	4.6 - 5.8	2/15	2
Potassium	111.40	222.8	49.2 - 574	15/15	11
Selenium	0.41	0.8	0.23 - 0.46	11/15	0
Sodium	20.29	40.6	41.4 - 108	13/15	13
Vanadium	50.4	10.1	3.6 - 22.4	15/15	11
Zinc	2.81	5.6	2.5 - 18.1	15/15	8

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.

TABLE 3-7

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO.1 - SITE 24
CORRECTIVE ACTION PLAN 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

Note:

Concentrations expressed in microgram per kilogram (µg/kg)

TABLE 3-8

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 24
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Subsurface Soil (6 inches and below)				
	Average Base-Specific Background Concentration Range[1]	Twice the Average Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Twice the Average Background Concentration
Aluminum	4473.17	8946.3	964 - 19,800	59/59	14
Arsenic	0.28	0.6	0.46 - 15	39/59	31
Barium	5.94	11.9	3 - 628	59/59	17
Beryllium	0.10	0.20	0.2 - 3.8	29/59	29
Cadmium	0.52	1.0	ND	0/59	0
Calcium	754.13	1508.3	20.9 - 62,200	46/59	8
Chromium	4.34	8.7	2.1 - 32.8	57/59	22
Cobalt	0.80	1.6	1.8 - 13.8	12/59	12
Copper	0.81	1.6	0.44 - 55	59/59	19
Iron	889	1778	411 - 17,300	59/59	21
Lead	4.57	9.1	1.3 - 19.3	59/59	4
Magnesium	115.6	231.2	29.8 - 2,950	57/59	23
Manganese	3.1	6.2	1.6 - 113	52/59	13
Mercury	0.04	0.1	0.11 - 0.29	4/59	4
Nickel	1.98	4.0	8 - 96.2	4/59	4
Potassium	111.40	222.8	51.6 - 1,710	59/59	41
Selenium	0.41	0.8	0.25 - 11.9	19/59	5
Sodium	20.29	40.6	16.6 - 729	58/59	38
Vanadium	50.4	10.1	2 - 594	59/59	27
Zinc	2.81	5.6	1.3 - 20.1	46/59	17

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.

TABLE 3-9

SUBSURFACE SOIL ORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 78
CORRECTIVE ACTION PLAN CRO-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

Note:

Concentrations expressed in microgram per kilogram (µg;kg)

TABLE 3-10

SUBSURFACE SOIL INORGANIC DATA SUMMARY
OPERABLE UNIT NO. 1 - SITE 78
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Inorganic	Subsurface Soil (6 inches and below)				
	Average Base-Specific Background Concentration Range[(1)]	Twice the Average Base-Specific Maximum Concentration	Range of Positive Detections	No. of Positive Detects/ No. of Samples	No. of Times Exceeded Twice the Average Background Concentration
Aluminum	4473.17	8946.3	2,730 - 14,100	16/16	3
Arsenic	0.28	0.6	0.49 - 6.2	10/16	8
Barium	5.94	11.9	2.8 - 13	16/16	2
Beryllium	0.10	0.20	0.26	1/16	1
Cadmium	0.52	1.0	ND	0/16	0
Calcium	754.13	1508.3	29.1 - 297	16/16	0
Chromium	4.34	8.7	4.2 - 18.5	15/16	4
Cobalt	0.80	1.6	ND	0/16	0
Copper	0.81	1.6	0.51 - 3.4	16/16	3
Iron	889	1778	462 - 5,890	16/16	9
Lead	4.57	9.1	1 - 6.5	16/16	0
Magnesium	115.6	231.2	101 - 458	16/16	4
Manganese	3.1	6.2	1.6 - 9.2	16/16	2
Mercury	0.04	0.1	ND	0/16	0
Nickel	1.98	4.0	ND	0/16	0
Potassium	111.40	222.8	88 - 280	16/16	6
Selenium	0.41	0.8	0.26 - 1.2	5/16	1
Sodium	20.29	40.6	30.2 - 93	16/16	8
Vanadium	5.04	10.1	2.2 - 19.2	16/16	5
Zinc	2.81	5.6	1.4 - 7.9	16/16	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.

TABLE 3-11

ORGANIC PHYSICAL AND CHEMICAL PROPERTIES
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Chemical	Vapor Pressure (mm Hg)	Water Solubility (mg/l)	Octanol/Water Coefficient (log K_{ow})	Sediment Partition (log K_{oc})	Specific Gravity (g/cm^3)	Henry's Law Constant ($atm-m^3/mole$)	Mobility Index	Comments
Volatiles:								
Benzene	76	1780	2.13	1.92	0.879	5.55E-03	3.2	Very mobile
Bromodichloromethane	50	4500	2.10	1.79	--	2.41E-03	3.6	Very mobile
Chlorobenzene	8.8	500	2.84	2.64	1.1066	3.58E-03	1	Very mobile
1,1-Dichloroethene	500	400	1.48	2.26	1.218	1.90E-01	3.0	Very mobile
1,2-Dichloroethane	61	8700	1.48	1.52	1.25	8.14E-04	4.2	Very mobile
1,2-Dichloroethene	200	600	1.48	2.17	1.26	5.32E-03	2.9	Very mobile
Ethylbenzene	7	152	3.15	2.93	0.867	6.44E-03	0.1	Very mobile
Tetrachloroethene	14	150	2.6	2.6	1.626	2.87E-03	0.75	Very mobile
Toluene	22	515	2.69	2.54	0.867	5.90E-03	1.5	Very mobile
1,1,2-Trichloroethane	19	4500	2.17	1.75	1.44	7.42E-04	3.2	Very mobile
1,1,2,2-Trichloroethane	5	2900	2.56	1.92	1.60	3.83E-04	2.2	Very mobile
Trichloroethene	60	1100	2.29	2.09	1.46	1.17E-03	2.7	Very mobile
Vinyl chloride	2660	1100	0.6	1.91	0.9121	8.14E-02	4.6	Very mobile
Xylenes (total)	6	180	3.02	2.84	0.87	4.64E-03	0.19	Very mobile
Semivolatiles:								
Benzo(a)anthracene	5.0E-09	0.014	5.61	5.34	NA	1.0E-06	-15.5	Very Immobile
Benzo(b)fluoranthene	10E-06 to 10E-07	0.009	6.57	6.26	NA	1.22E-05	-14	Very Immobile
Benzo(k)fluoranthene	9.6E-11	0.0016	6.84	6.22	NA	3.87E-05	-19	Very Immobile
Benzo(a)pyrene	5.0E-09	0.0038	6.04	5.72	NA	4.9E-07	-16.4	Very Immobile

TABLE 3-11 (Continued)

ORGANIC PHYSICAL AND CHEMICAL PROPERTIES
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Chemical	Vapor Pressure (mm Hg)	Water Solubility (mg/l)	Octanol/Water Coefficient (log K_{ow})	Sediment Partition (log K_{oc})	Specific Gravity (g/cm^3)	Henry's Law Constant (atm-m^3/mole)	Mobility Index	Comments
Semivolatiles (continued):								
Chrysene	10E-06 to 10E-11	0.006	5.61	5.44	1.274	1.1E-06	-13.7	Very Immobile
1,4-Dichlorobenzene	6.0E-01	49	3.39	3.22	1.458	3.1E-03	-1.8	Slightly mobile
Fluoranthene	10E-06 to 10E-04	0.265	5.33	4.84	NA	6.5E-06	-9.4	Immobile
Ideno(1,2,3-cd)pyrene	1E-10	5.3E-04	6.51	6.20	1.070	6.95E-08	-19.5	Very Immobile
Pyrene	6.85	0.14	5.32	4.91	NA	5.1E-06	-11.9	Very Immobile
Pesticides/PCBs:								
Dieldren	1.87E-04	0.1	5.6	4.31	1.75	4.57E-10	-12	Very Immobile
4,4'-DDT	1.9E-07	0.0034	6.19	4.89	*NA	1.58E-05	-14	Very immobile
4,4'-DDD	10.2E-07	0.09	5.99	4.47	*NA	2.2E-08	-12	Very immobile
4,4'-DDE	6.5E-06	0.04	4.28	3.66	*NA	6.8E-05	-10	Immobile
Endrin	2.0E10-07	0.26	5.6	4.06	NA	4.0E-07	-11	Very Immobile
PCB-1254	7.7E-05	0.03	6.03	4.59	1.50	2.80E-03	-10	Immobile

Sources:
1. Verscheuren, K. 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York.
2. Lyman, et al. 1982. Handbook of Chemical Property Estimation Methods. Environmental Behavior of Organic Compounds.
3. USEPA. 1982. Aquatic Fate Process Data for Organic Priority Pollutants. Final Report.

TABLE 3-12

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Relative Mobility	Environmental Conditions			
	Oxidizing	Acidic	Neutral/Alkaline	Reducing
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg, Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:

Se = Selenium
Zn = Zinc
Cu = Copper
Ni = Nickel
Hg = Mercury
Ag = Silver
As = Arsenic

Cd = Cadmium
Ba = Barium
Pb = Lead
Fe = Iron
Cr = Chromium
Be = Beryllium

Source: Swartzbaugh, et al. "Remediating Sites Contaminated with Heavy Metals." Hazardous Materials Control, November/December 1992.

TABLE 3-13

TOTAL SITE RISK
OPERABLE UNIT NO. 1 - SITE 21
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Receptors	Soil		Groundwater		Surface Water		Sediment		Total	
	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Current Military Personnel	6E-06 (100)	0.19 (100)	NA	NA	NA	NA	NA	NA	6E-06	0.19
Future Child Resident	NA	NA	NA	NA	1E-06 (71)	0.08 (89)	4E-07 (29)	0.01 (11)	1E-06	0.09
Future Adult Resident	NA	NA	NA	NA	1E-06 (67)	0.02 (100)	5E-07 (34)	<0.01 (<1)	2E-06	0.02
Future Construction Worker	1E-07 (100)	0.01 (100)	NA	NA	NA	NA	NA	NA	1E-07	0.01

Notes:

ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
( ) = Approximate percent contribution to the total ICR or HI values
Total = Soil + Groundwater + Beaver Dam Creek Surface Water + Beaver Dam Creek Sediment
NA = Not Applicable

TABLE 3-14

TOTAL SITE RISK
OPERABLE UNIT NO. 1 - SITE 24
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

	Soil		Groundwater		Surface Water		Sediment		Total	
Receptors	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Current Military Personnel	8E-07 (100)	0.03 (100)	NA	NA	NA	NA	NA	NA	8E-07	0.03
Future Child Resident	1E-05 (1.4)	0.3 (1.0)	7E-04 (98)	29 (98)	4E-07 (<1)	0.01 (<1)	4E-07 (<1)	0.04 (<1)	7E-04	29.35
Future Adult Resident	4E-06 (<1)	0.03 (<1)	2E-03 (99)	13 (99)	6E-07 (<1)	0.01 (<1)	5E-07 (<1)	<0.01 (<1)	2E-03	13
Future Construction Worker	1E-09 (100)	0.02 (100)	NA	NA	NA	NA	NA	NA	1E-09	0.02

Notes:

ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
() = Approximate percent contribution to the total ICR or HI values
Groundwater = Risks for Operable Unit No. 1 generally, not limited to Site 24
Total = Soil + Groundwater + Beaver Dam Creek Surface Water + Beaver Dam Creek Sediment
NA = Not Applicable

Shading indicates an exceedence of the USEPA target risk range of 1E-06 to 1E-04 for ICRs, and 1.0 for HIs.

TABLE 4-1
GLOSSARY OF EVALUATION CRITERIA

- **Overall Protection of Human Health and Environment** - addresses whether or not an alternative provides adequate protection and describes how risks posed through each pathway are eliminated, reduced, or controlled through treatment engineering controls or institutional controls.

- **Compliance with ARARs** - addresses whether or not an alternative will meet all of the applicable or relevant and appropriate requirements (ARARs) or other Federal and State environmental statutes.

- **Long-term Effectiveness and Permanence** - refers to the magnitude of residual risk and the ability of an alternative to maintain reliable protection of human health and the environment over time once cleanup goals have been met.

- **Reduction of Toxicity, Mobility, or Volume through Treatment** - entails the anticipated performance of the treatment options that may be employed in an alternative.

- **Short-term Effectiveness** - refers to the speed with which the alternative achieves protection, as well as the remedy's potential to create adverse impacts on human health and the environment that may result during the construction and implementation period.

- **Implementability** - entails the technical and administrative feasibility of an alternative, including the availability of materials and services needed to implement the chosen solution.

- Cost - includes capital and operation and maintenance costs. For comparative purposes, presents present worth values.

- **USEPA/State Acceptance** - Evaluates the technical and administrative issues and concerns the USEPA and State have regarding each of the alternatives. This criterion is addressed in the ROD once comments on the RI/FS report and PRAP have been received.

- **Community Acceptance** - Evaluates the issues and concerns the public may have regarding each of the alternatives. This criterion is addressed in the ROD once the comments on the RI/FS reports and the PRAP have been received.

TABLE 4-2

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
CORRECTIVE ACTION PLAN 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.	Since organics and total metals above State and Federal standards will remain untreated in some portions of the operable unit, a Corrective Action Plan will need to be prepared in accordance with Title 15A NCAC 2L.0106(k) and (l). These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	Since organics and total metals above State and Federal standards will remain untreated in some portions of the operable unit, a Corrective Action Plan will need to be prepared in accordance with Title 15A NCAC 2L.0106(k) and (l). These portions are outside of the primary VOC plumes. All other chemical-specific ARARs will be met over time.	Since organics and total metals above State and Federal standards will remain untreated in some portions of the operable unit, a Corrective Action Plan will need to be prepared in accordance with Title 15A NCAC 2L.0106(k) and (l). 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 4-2 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
CORRECTIVE ACTION PLAN 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 4-2 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
CORRECTIVE ACTION PLAN 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.

TABLE 4-2 (Continued)

SUMMARY OF DETAILED ANALYSIS - GROUNDWATER RAAs
CORRECTIVE ACTION PLAN 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
• 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.
IMPLEMENT-ABILITY • 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.	• Will require a pilot study. 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 4-3

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
CORRECTIVE ACTION PLAN 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 unless the treatment process last longer than five years.	Review not needed since contaminated soil removed.

TABLE 4-3 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
CORRECTIVE ACTION PLAN 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.	Contaminated soil is capped.	Residuals remaining on site 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.
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.

TABLE 4-3 (Continued)

SUMMARY OF DETAILED ANALYSIS - SOIL RAAs
CORRECTIVE ACTION PLAN 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
• 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)

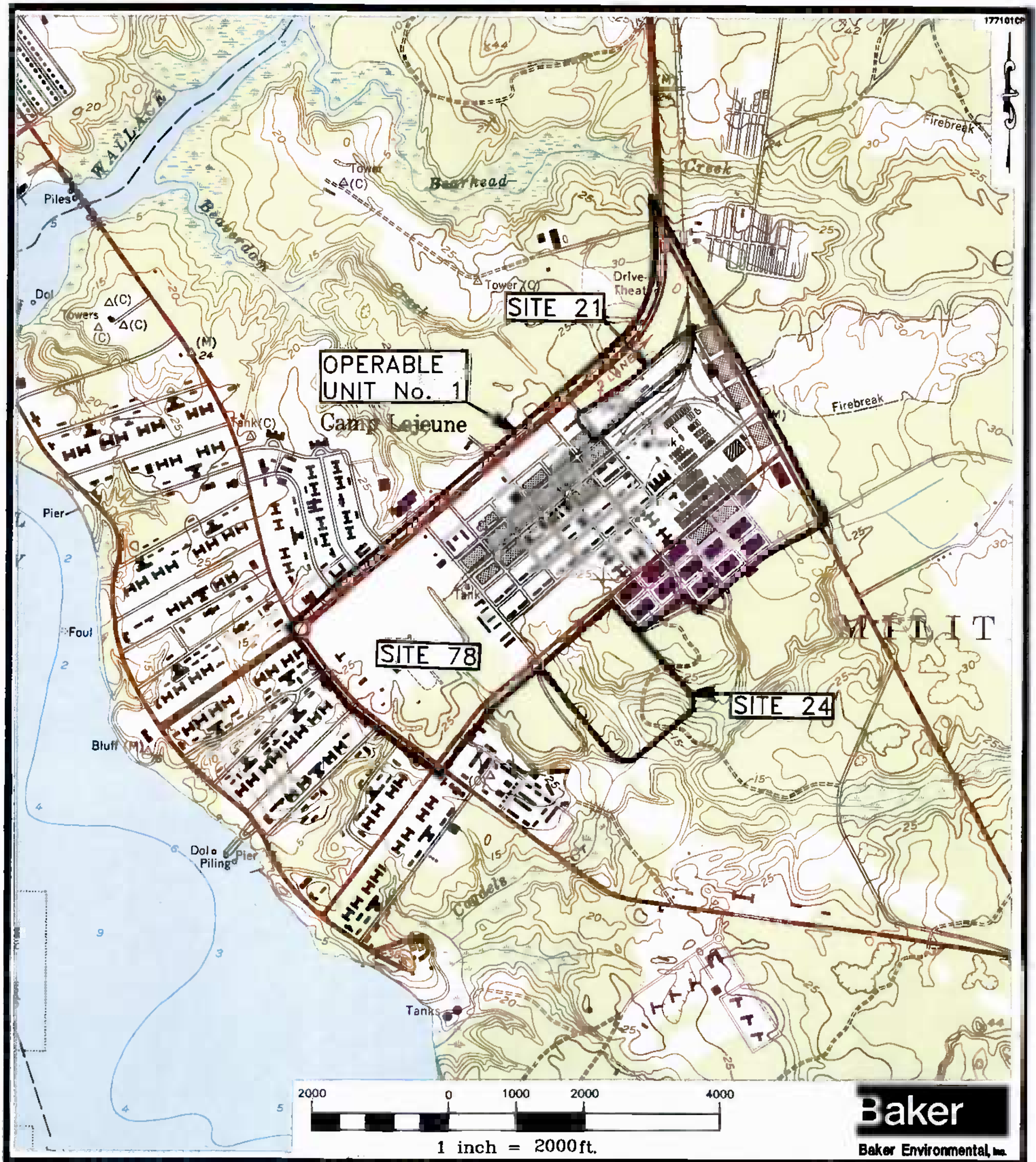
TABLE 4-4

ESTIMATED COST SUMMARY FOR THE SELECTED REMEDY
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA

Cost Component	Estimated Cost
<u>**Capital Costs:**</u>	
• **Groundwater Remediation**	
Mobilization	$25,000
Extraction Well System	89,000
Treatment System*	0
Discharge System*	0
Demobilization	17,000
Pilot Studies	7,000
	138,000
Engineering and Contingencies	39,000
	$177,000
• **Soil Remediation**	
Site Preparation	$75,000
Off-Site Landfilling	260,000
Site Restoration	22,000
Demobilization	15,000
	$372,000
Engineering and Contingencies	110,000
	$482,000
<u>**Operation and Maintenance Costs**</u>**:**	
• **Groundwater Remediation**	
Groundwater Monitoring [Years 1 through 5]	$30,000
Groundwater Monitoring [Years 6 through 30]	15,000
TOTAL CAPITAL COST	$659,000
TOTAL OPERATION AND MAINTENANCE COSTS	$30,000 (Years 1-5) $15,000 (Years 6-30)
TOTAL NET PRESENT WORTH (Using 5% discount rate)	$1.0 million

* Costs for the groundwater treatment and discharge systems are included in the Interim Remedial Action for OU No. 1.

FIGURES



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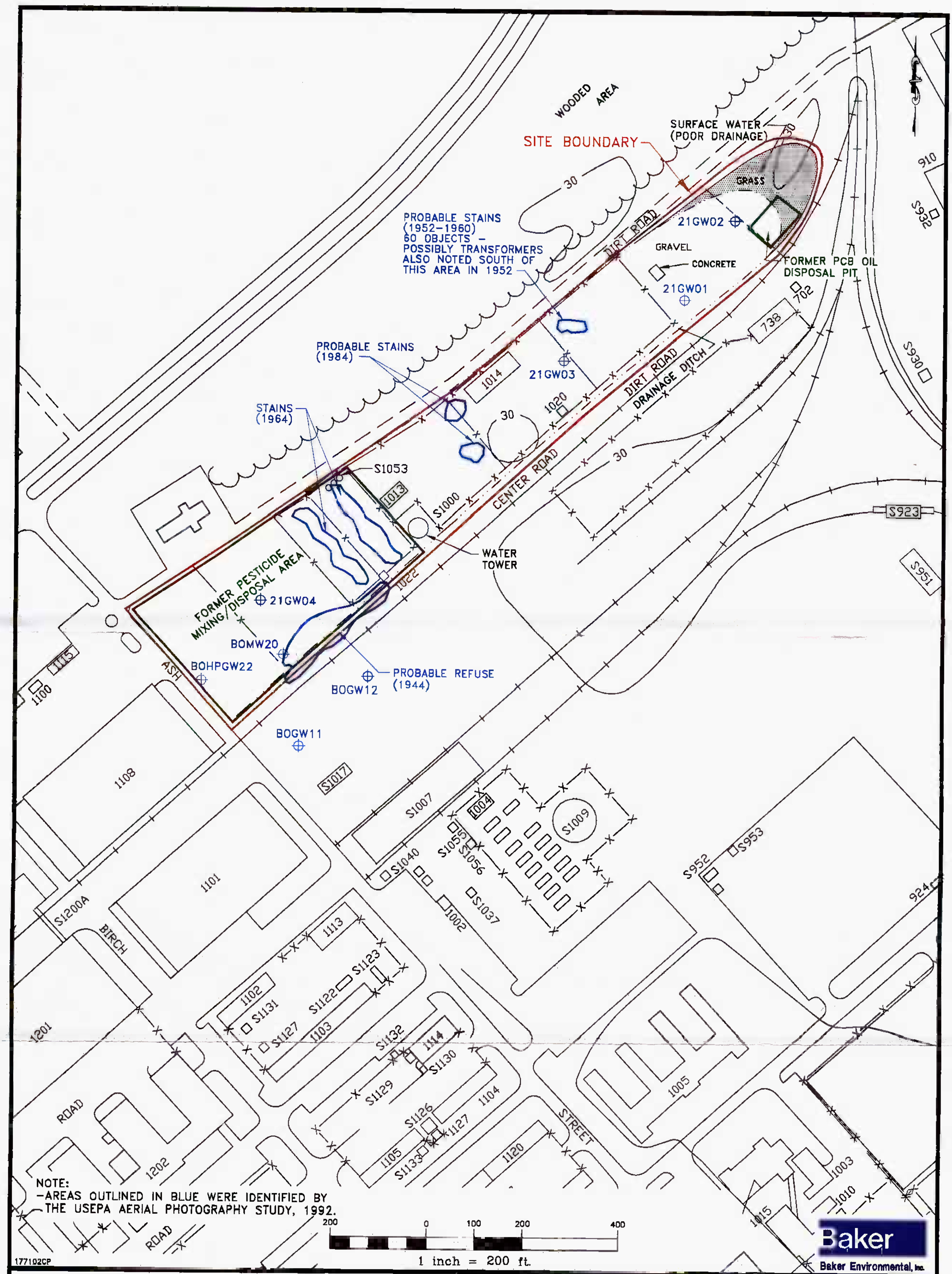
SOURCE: CAMP LEJEUNE QUADRANGLE,
7.5 MINUTE TOPOGRAPHIC MAP,
1952, PHOTOREVISED 1971

FIGURE 1-1
LOCATION MAP-OPERABLE UNIT No. 1
SITES 21, 24, AND 78
CORRECTIVE ACTION PLAN CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01991DDB2Y



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

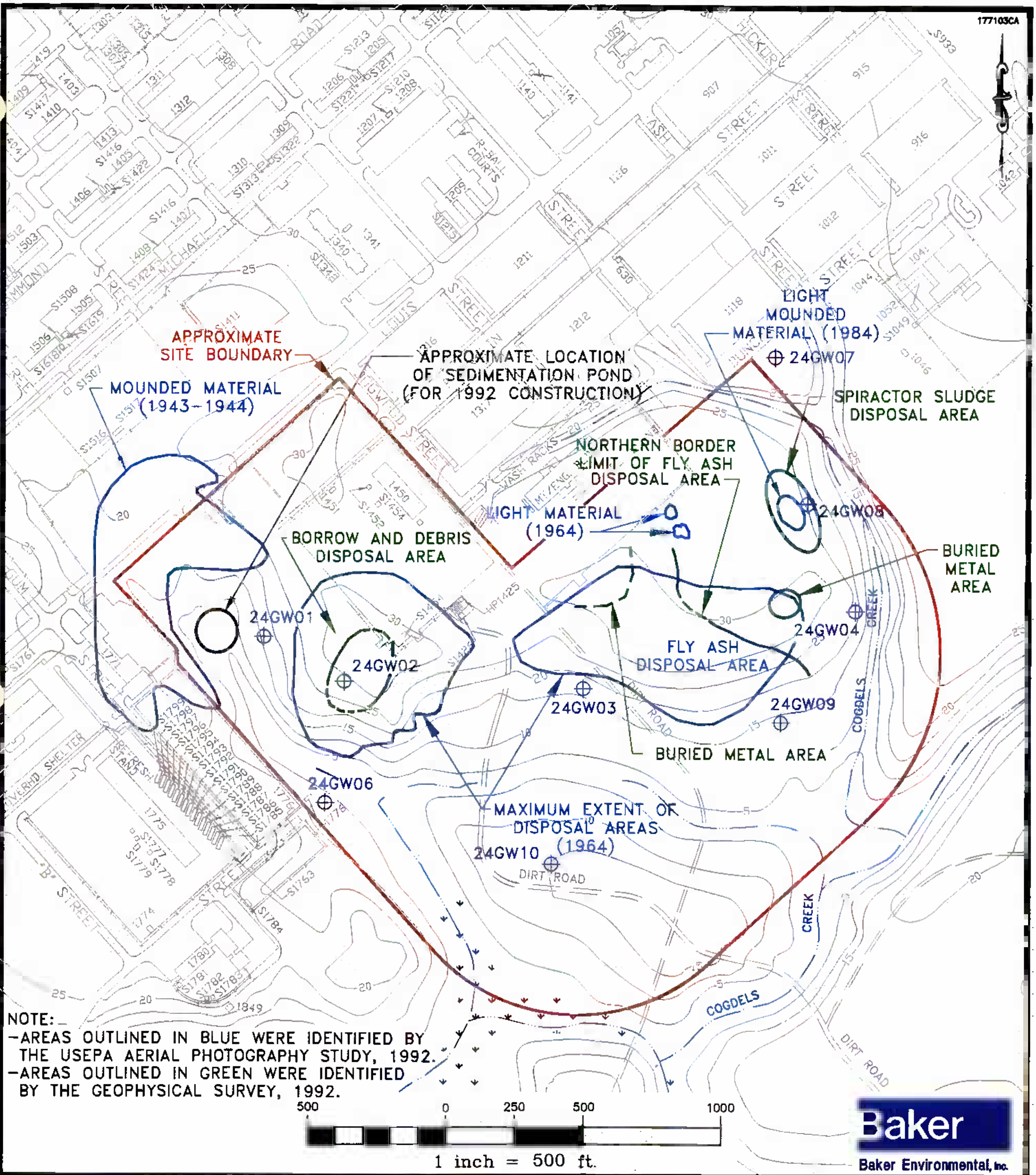
LEGEND

21GW01 ⊕ SHALLOW MONITORING WELL

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 1-2
SITE MAP
SITE 21: TRANSFORMER STORAGE LOT 140
CORRECTIVE ACTION PLAN CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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

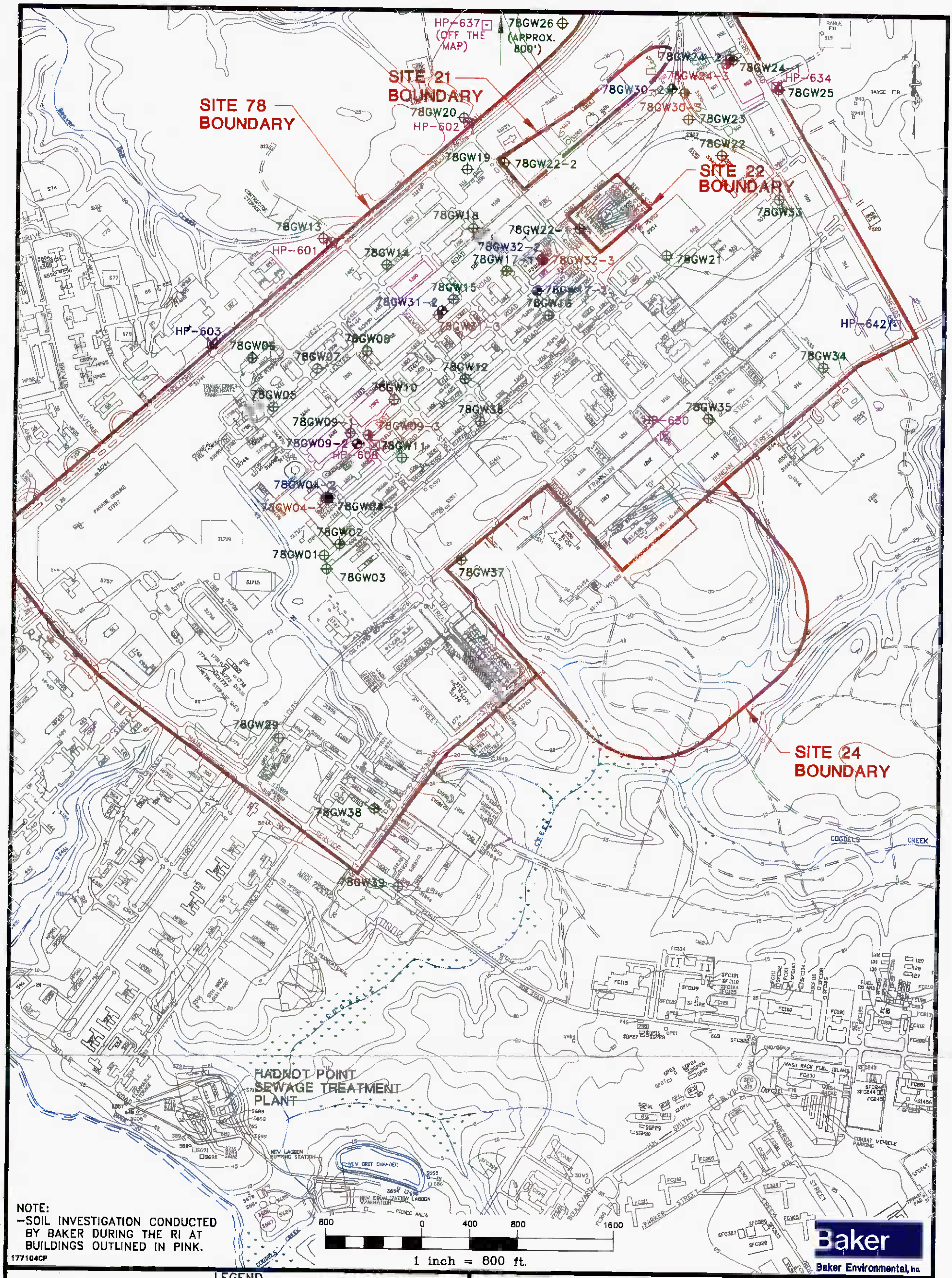
LEGEND

⊕ 24GW01 SHALLOW MONITORING WELL

SOURCE: LANTDIV, FEB. 1992

FIGURE 1-3
SITE MAP
SITE 24: INDUSTRIAL FLY ASH DUMP
CORRECTIVE ACTION PLAN CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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

Baker Environmental, Inc.

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		

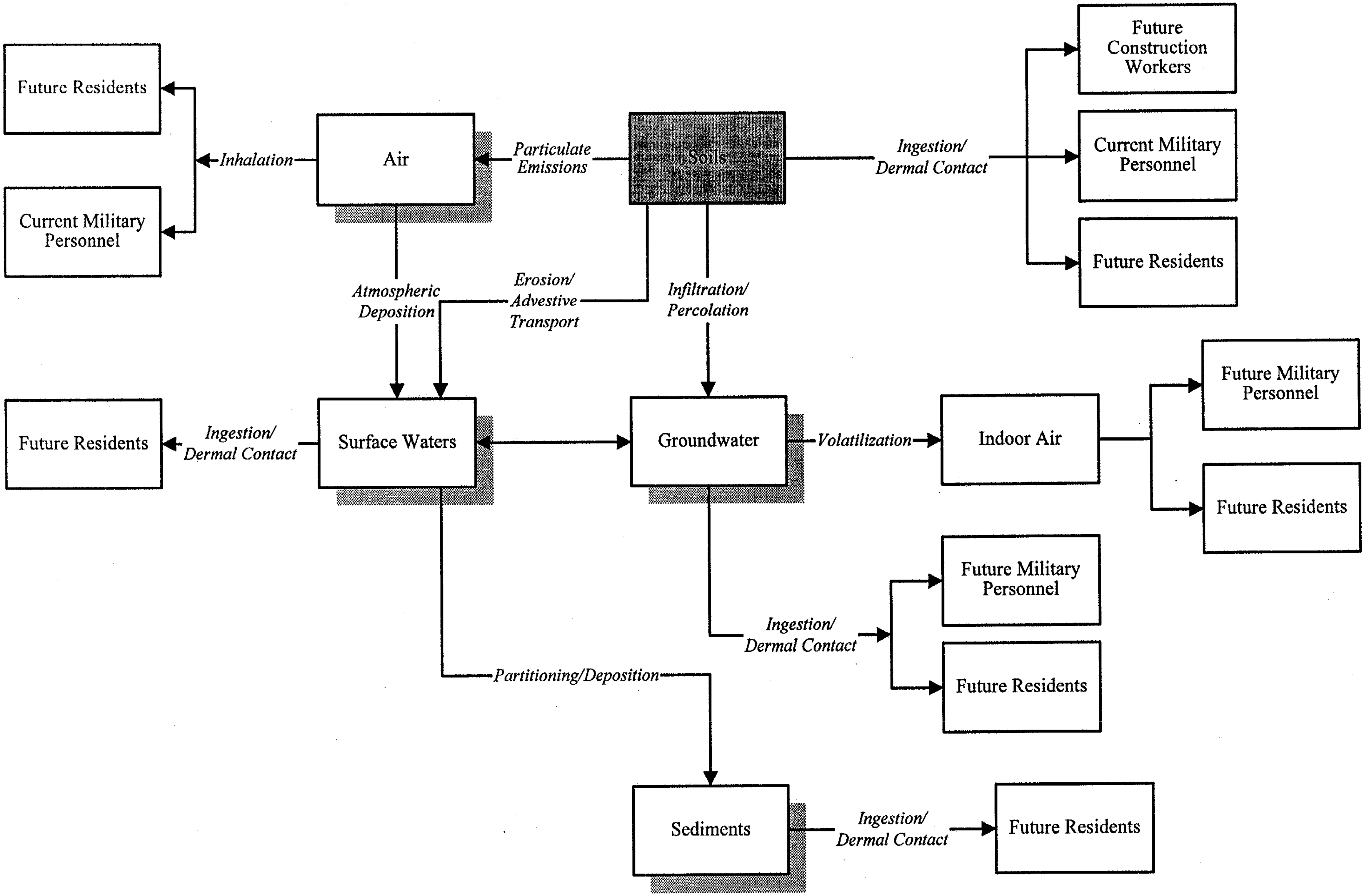
SOURCE: LANTDIV, FEBRUARY 1992

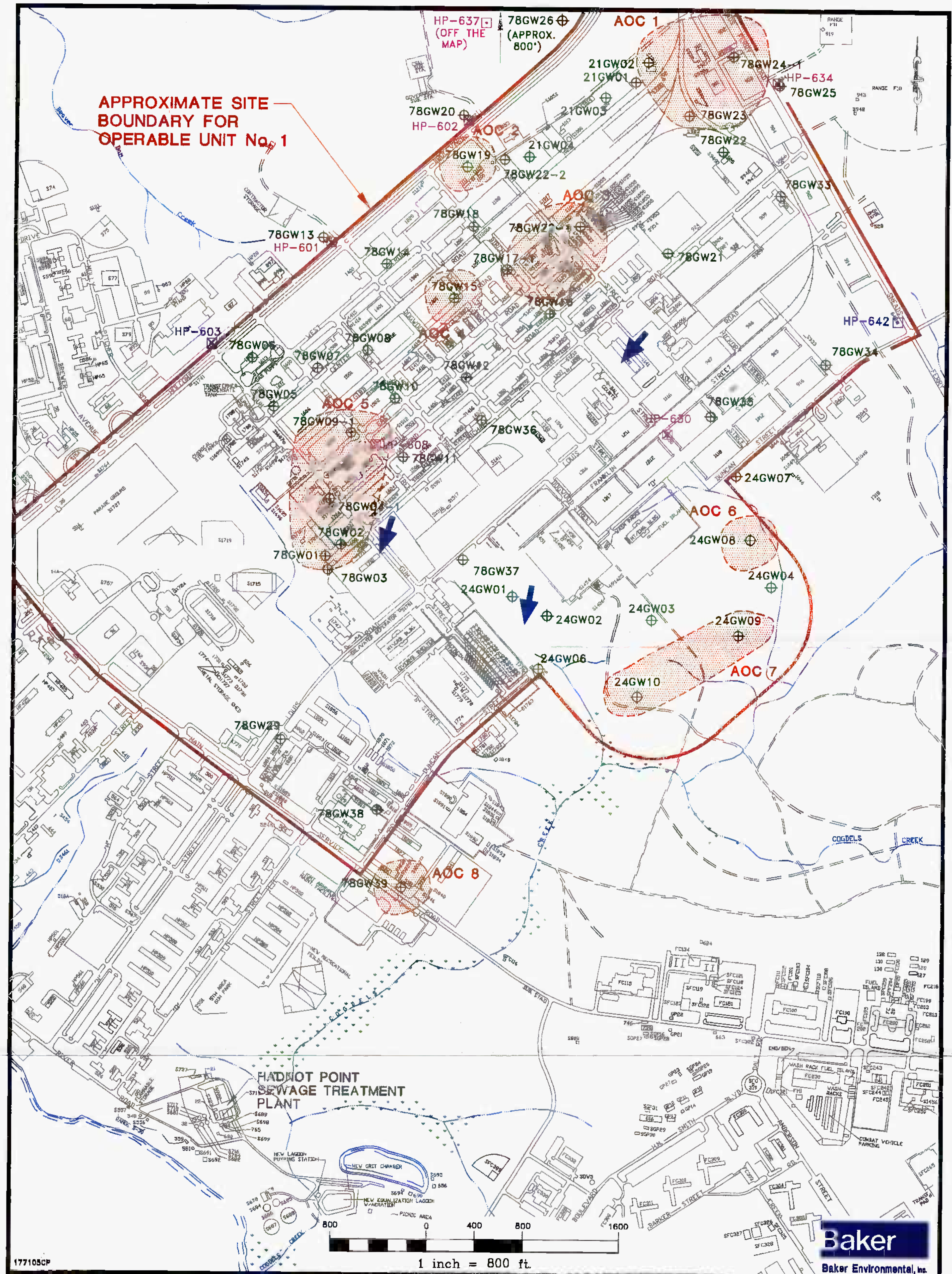
FIGURE 1-4
SITE MAP
SITE 78: HPIA
CORRECTIVE ACTION PLAN CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 3-1

CONCEPTUAL SITE MODEL
OPERABLE UNIT NO. 1
CORRECTIVE ACTION PLAN CTO-0177
MCB CAMP LEJEUNE, NORTH CAROLINA





LEGEND

⊕ 78GW02 SHALLOW MONITORING WELL

➜ ESTIMATED DIRECTION OF GROUDWATER FLOW

▨ APPROXIMATE AREA OF GROUNDWATER CONTAMINATION EXCEEDING REMEDIATION LEVELS FOR ORGANICS (SHALLOW MONITORING WELLS)

AOC 8 AREA OF CONCERN

HP-603 ⊡ WATER SUPPLY WELL (ACTIVE)

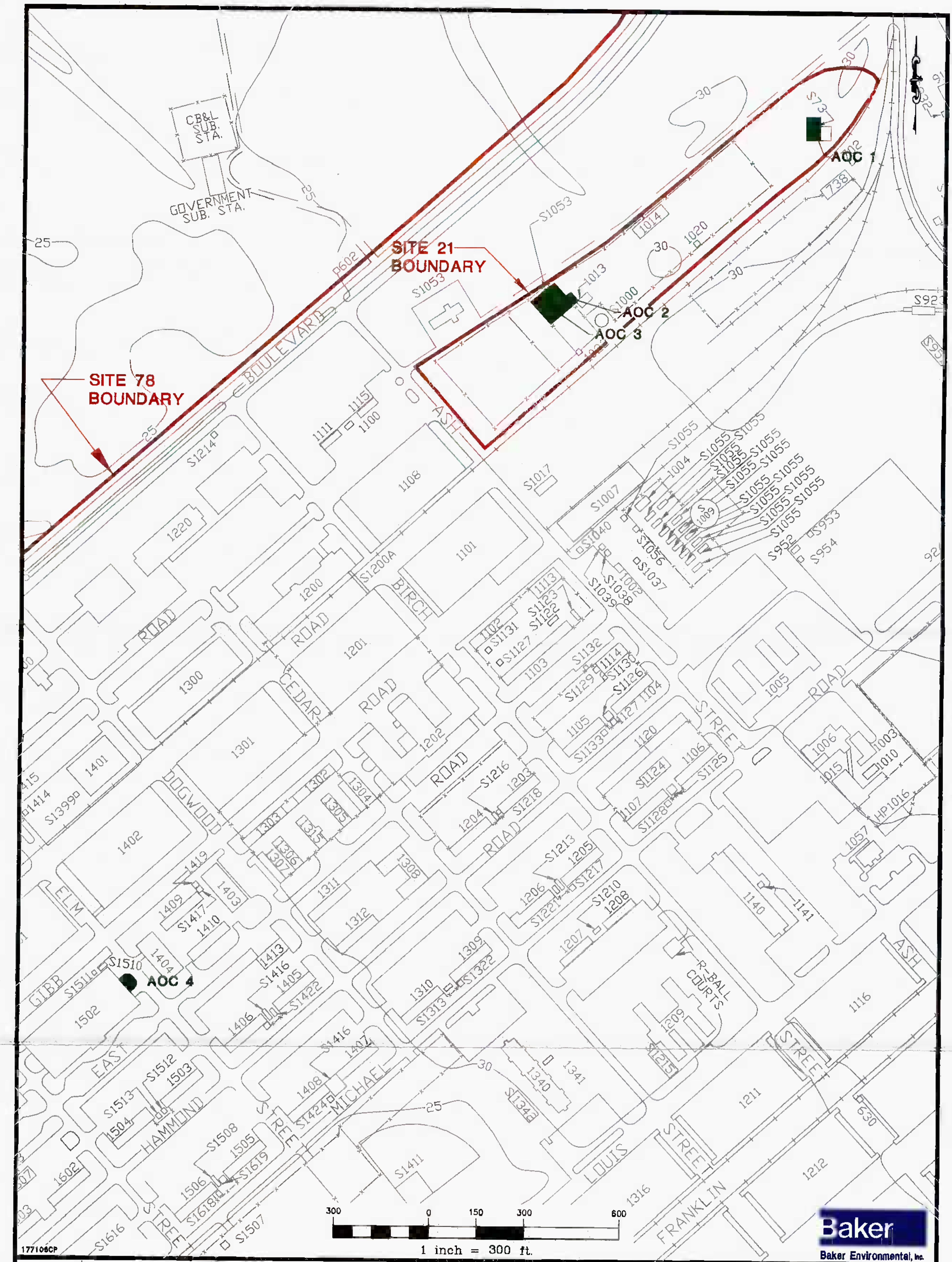
HP-601 ☒ WATER SUPPLY WELL (INACTIVE)

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 4-1
GROUNDWATER AREAS OF CONCERN
OPERABLE UNIT No. 1
CORRECTIVE ACTION PLAN CTO-0177

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01991DDB3Y



177106CP

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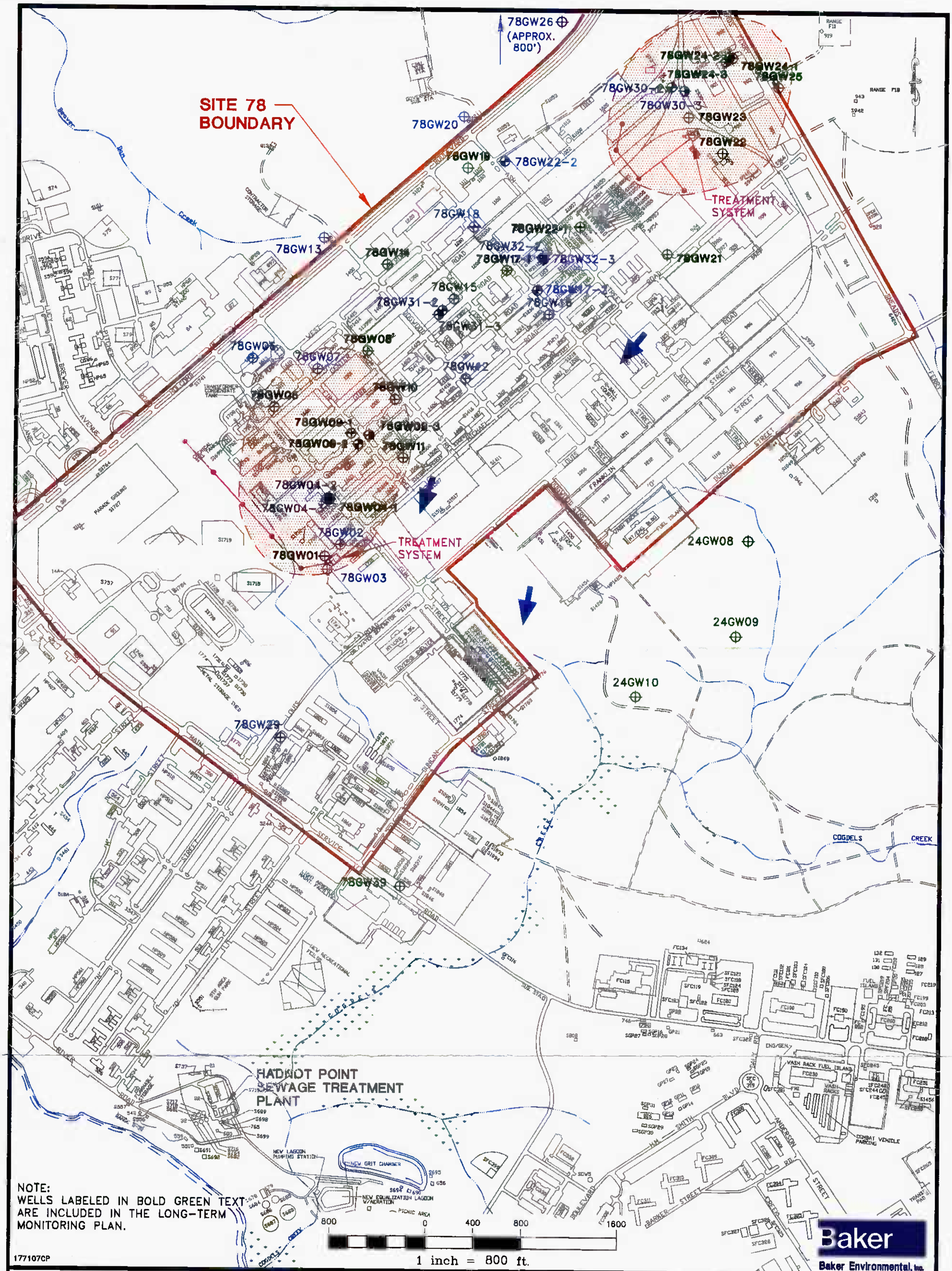
LEGEND

● AOC 1 APPROXIMATE LOCATION OF SOIL EXCEEDING REMEDIATION LEVELS.

SOURCE: LANTDIV, OCT. 1991

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



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

177107CP

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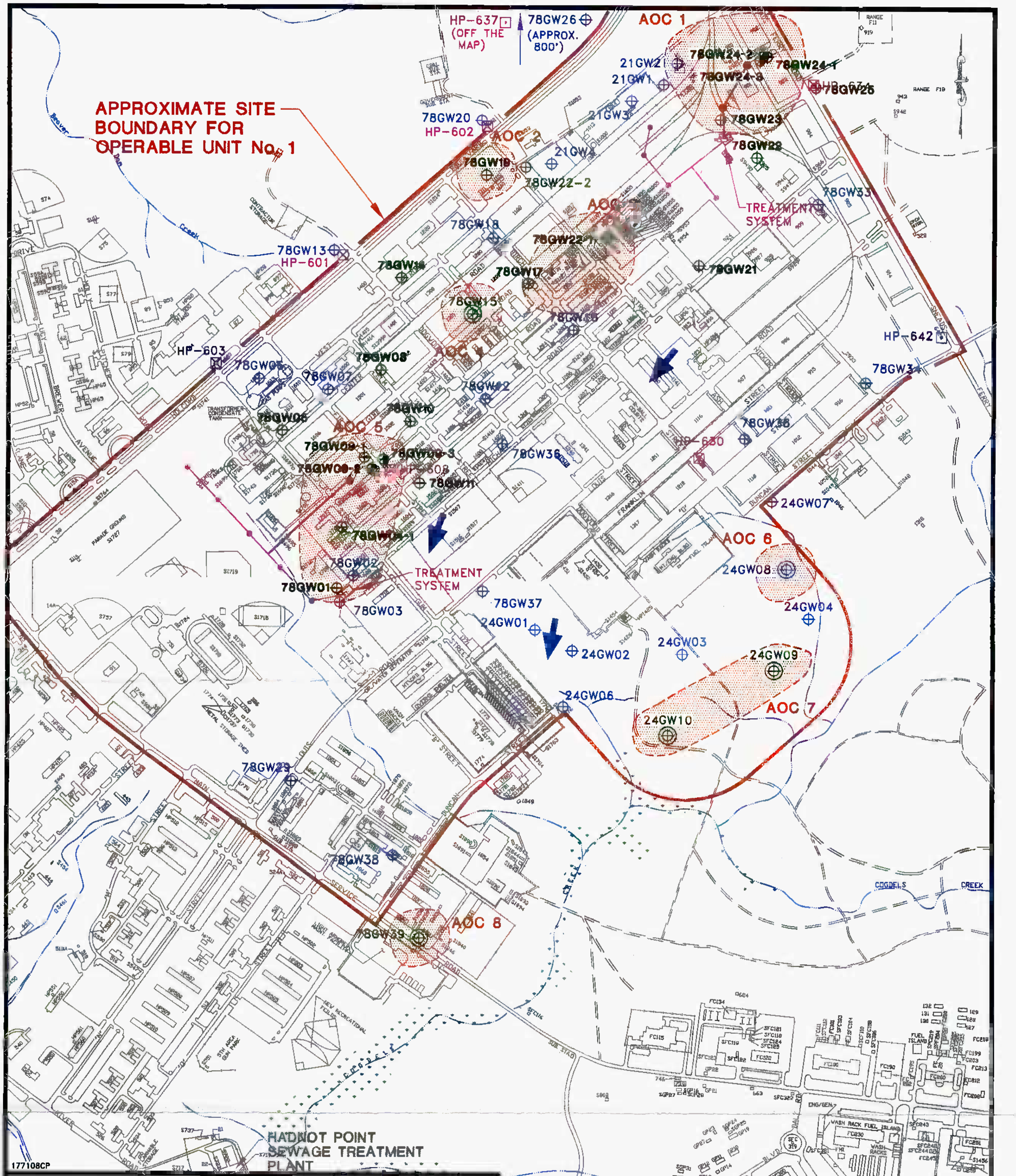
LEGEND

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

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 4-3
INTERIM REMEDIAL ACTION
FOR THE SURFICIAL AQUIFER
SITE 78: HPIA
CORRECTIVE ACTION PLAN CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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

800 0 400 800 1600

1 inch = 800 ft.

Baker

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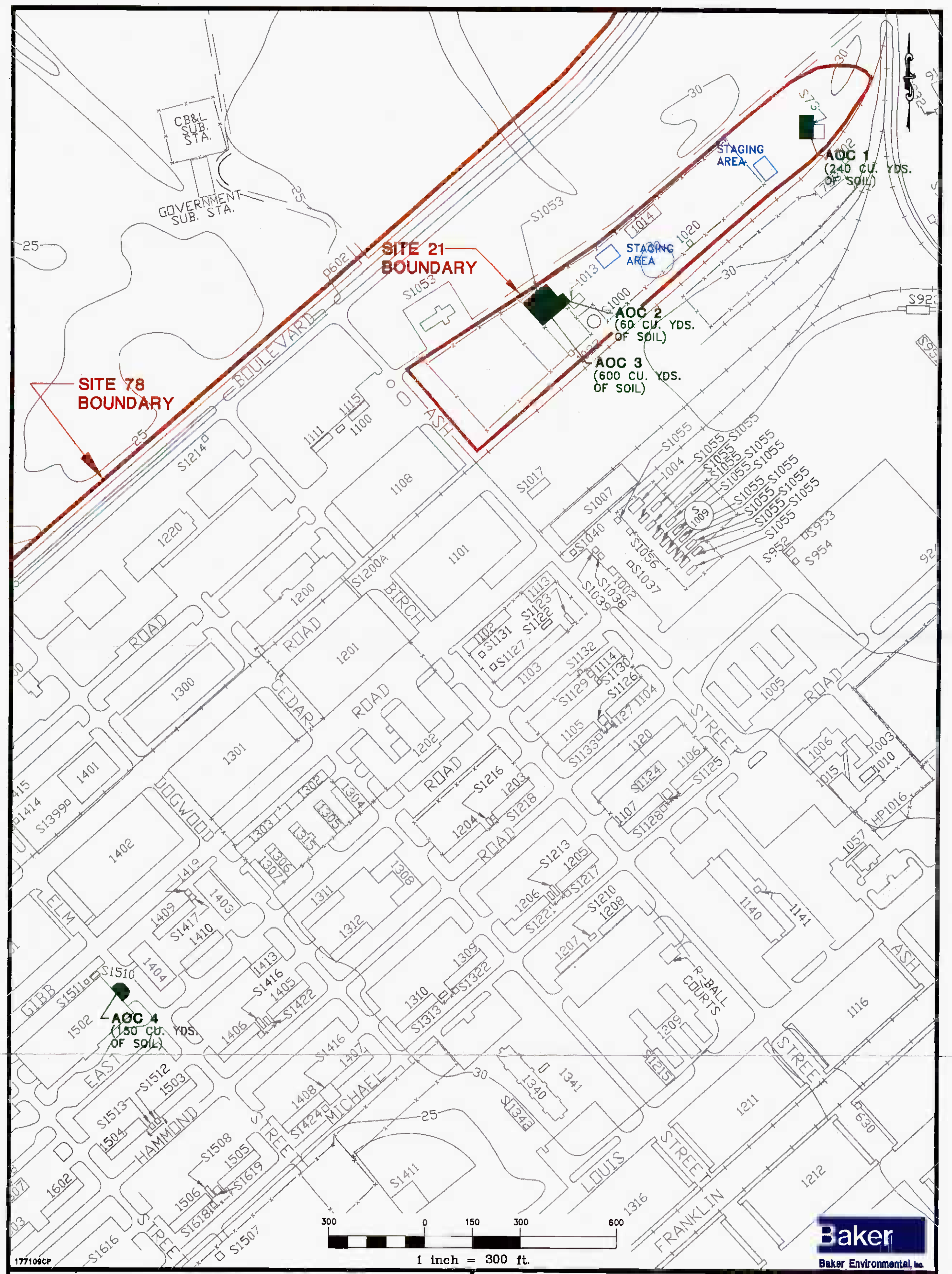
FIGURE 4-4
GROUNDWATER RAA: SOURCE CONTROL
(INTERIM TREATMENT SYSTEM EXTENSION)
OPERABLE UNIT No. 1
CORRECTIVE ACTION PLAN CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

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

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-5
PREFFERED SOIL RAA : OFF-SITE TREATMENT/DISPOSAL
OPERABLE UNIT NO. 1
CORRECTIVE ACTION PLAN CTO-0177
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA