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FINAL CLOSE OUT REPORT

**OPERABLE UNIT NO. 7 - SITES 1 & 28
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA**

SEPTEMBER 2002

CONTRACT TASK ORDER 0120

Prepared for:

**DEPARTMENT OF THE NAVY
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NAVAL FACILITIES
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*Norfolk, Virginia***

Under the:

**LANTDIV CLEAN II Program
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QC Review Page

Final Close-Out Report
Operable Unit No. 7
MCB Camp Lejeune

Jacksonville, North Carolina

Contract Task Order Number - 0120
Contract Number N62470-95-D-6007
Navy CLEAN II Program

Prepared by

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September 2002

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A	Site 1 Final LTM Report
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C	Evaluation of Lead at Site 28 Report, March 1, 2001
D	Evaluation of Lead at Site 28 Report, November, 2001
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F	USEPA Region IV Approval Letter

ACRONYMS AND ABBREVIATIONS

Baker	Baker Environmental, Inc.
CERCLA CS	Comprehensive Environmental Response, Compensation, and Liability Act Confirmation Study
ESE	Environmental Science and Engineering, Inc.
FCOR FS	Final Close Out Report Feasibility Study
HPIA	Hadnot Point Industrial Area
IAS	Initial Assessment Study
LANTDIV LTM	Atlantic Division Naval Facilities Engineering Command Long Term Monitoring
MCAS MCB	Marine Corps Air Station Marine Corps Base
NC DENR NCP NCWQS NPW	North Carolina Department of Environment and Natural Resources National Oil and Hazardous Substances Pollution Contingency Plan North Carolina Water Quality Standard Net Present Worth
O&M OU	Operation and Maintenance Operable Unit
POL	Petroleum, Oil, Lubricants
RI ROD	Remedial Investigation Record of Decision
SARA	Superfund Amendments and Reauthorization Act
TCE	Trichloroethene
ug/L USEPA	Micrograms per liter United States Environmental Protection Agency
VOC	Volatile Organic Compound
WAR	Water and Air Research

1.0 INTRODUCTION

This Final Closeout Report (FCOR) documents all response actions for Operable Unit (OU) 7, Sites 1 and 28, have been completed in accordance with the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This OU close out decision is based on the results of a Remedial Investigation (RI) and completion of the necessary requirements for Long Term Monitoring (LTM) as stipulated in the Final Record of Decision (ROD).

This FCOR has been prepared by Baker Environmental, Inc. (Baker) under the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy Clean (CLEAN) II contract administered by the Naval Facilities Engineering Command, Atlantic Division (LANTDIV).

2.0 SUMMARY OF SITE CONDITIONS

2.1 Site Location and Description

In order to provide the reader with the entire framework of Sites 1 and 28, the following subsections discuss site locations and descriptions for both Marine Corps Base (MCB), Camp Lejeune and Sites 1 and 28.

2.1.1 MCB, Camp Lejeune

MCB, Camp Lejeune is located on the coastal plain of North Carolina in Onslow County. The facility is bisected by the New River and encompasses approximately 236 square miles (of which approximately 40 square miles is water made up by the New River and its tributaries). The New River flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The southeastern border of MCB, Camp Lejeune is the Atlantic Ocean shoreline. The western and northeastern boundaries of the Base are U.S. Route 17 and State Route 24, respectively. The city of Jacksonville borders MCB, Camp Lejeune to the north.

Construction of MCB, Camp Lejeune began in April 1941 at the Hadnot Point Industrial Area (HPIA), where major functions of the Base are still centered today. The facility was designed to be the "world's most complete amphibious training Base". The MCB, Camp Lejeune complex consists of six geographical and operational locations under the jurisdiction of the Base Command. These areas include Camp Geiger, Montford Point (which includes Camp Johnson), Courthouse Bay, Main Side, the Rifle Range Area, and the Greater Sandy Run Area. Marine Corps Air Station (MCAS) New River is operationally under the control of MCAS Cherry Point. MCB, Camp Lejeune, however, is responsible for the facilities and environmental management of MCAS New River.

OU 7 consists of three sites: Site 1, the French Creek Liquids Disposal Area; Site 28, the Hadnot Point Burn Dump; and Site 30, the Sneads Ferry Road Fuel Tank Sludge Area. Sites 1, 28, and 30 were grouped together because of their similar nature of the wastes that were reportedly disposed of at the sites and the geographic proximity of the sites. A No Further Action (NFA) remedy was recommended for Site 30 as part of the ROD and, therefore, will not be discussed in this report.

As shown on Figure 1, OU 7 is located on the eastern portion of the Base, situated between the New River and Sneads Ferry Road, south of the HPIA. The following paragraphs present brief descriptions of Sites 1 and 28.

2.1.2 Site 1

Site 1, the French Creek Liquids Disposal Area, is located approximately one mile east of the New River and one mile southeast of the HPIA (Figure 1). Site 1 is situated along both the north and south sides of Main Service Road near the western edge of the Gun Park Area and Force Troops Complex.

Site 1 consists of two suspected disposal areas: the northern disposal area and the southern disposal area. Figure 1-1 presents a map of Site 1 that identifies the approximate boundaries of the two suspected disposal areas at the site. The site had been used by several different mechanized, armored, and artillery units since the 1940s. Reportedly, liquid wastes (petroleum, oil, and lubricants [POL]) generated from vehicle maintenance were routinely poured onto the ground surface. During motor oil changes, vehicles were driven to a disposal point and drained of used oil. In addition, acid from spent batteries was reportedly hand carried from maintenance buildings to disposal points. At times, holes were reportedly dug for waste acid disposal and then immediately backfilled (Water and Air Research [WAR], 1983).

2.1.3 Site 28

Site 28, the Hadnot Point Burn Dump, is located along the eastern bank of the New River and is approximately one mile south of the HPIA on the Mainside portion of MCB, Camp Lejeune (Figure 1). Figure 28-1 presents a map of Site 28. As shown, Codgels Creek flows into the New River at Site 28 and forms a natural divide between the eastern and western portions of the site.

Site 28 operated from 1946 to 1971 as a burn area for a variety of solid wastes. Reportedly, industrial waste, trash, oil-based paint, and construction debris were burned then covered with soil. In 1971, the burn dump ceased operations, was graded, and seeded with grass. The total volume of fill covering Site 28 is estimated to be between 185,000 and 375,000 cubic yards, based upon a surface area of 23 acres and a depth ranging from five to ten feet (WAR, 1983). Currently, a majority of the estimated 23 acres that constitute Site 28 are used for recreation and physical training exercises. Picnic pavilions and playground equipment are located within this recreation area, primarily on the western portion of the site.

3.0 INVESTIGATIVE ACTIVITIES AND REMEDIAL GOALS

The following subsections provide a summary of the investigations conducted at Sites 1 and 28, and demonstration of ROD goals achieved. The final remedies recommended in the ROD for both Sites 1 and 28 included a LTM program. The LTM program for both Sites 1 and 28 consisted of field activities and data reporting. The field activities included sample collection and field observations, while the data reporting was comprised of data management and evaluation. Sampling activities were conducted and subsequent laboratory analyses were performed according to procedures and methods specified in the Long Term Monitoring Work Plans for OU 7 (Baker, 1996). The project work plans identify specific tasks associated with the monitoring activities conducted at Sites 1 and 28.

3.1 Site 1

The conditions at Site 1 have been evaluated through several separate investigative activities, including a LTM program. A chronological account of these investigative activities for Site 1 is presented on the Site 1 Activities Timeline in Figure 1-2. This timeline provides milestones reached during the seven years of activity conducted at Site 1. Relevant information associated with specific events are cross-referenced as data tables or graphs and are presented within this report. The following subsections provide a summary of the previous studies completed at the site along with the results of the LTM program.

Investigative activities for OU 7 began in 1983 with an Initial Assessment Study (IAS) conducted by Water and Air Research (WAR, April 1983) along with other areas on the Base. Site 1 was identified as one of the ten sites on Base that required further investigative studies. A two-part Confirmation Study (CS) was conducted by Environmental Science and Engineering, Inc. (ESE) from 1984 through 1986 (ESE, September 1990). The purpose of the CS was to investigate potential contaminant source areas identified in the IAS report. Site 1 was evaluated and consequently was determined to warrant further investigation.

In addition to the IAS, aerial photographic analysis addressed site operations between 1938 and 1990, and an interim report was completed in August 1992 (Figure 1-2, box 3 on the Timeline). A recent aerial photograph of Site 1 with superimposed site boundaries is provided on Figure 1-3.

3.1.2 Remedial Investigation

In 1994 a RI was completed by Baker (Baker, June 1995) for Site 1. As part of the RI at Site 1, soil and groundwater investigations were conducted. The information gathered during these investigations was intended to fill previously existing data gaps identified during the CS and to generate information for assessing human health and ecological risks. Remedial alternatives for groundwater were evaluated during preparation of the Feasibility Study (FS) (Baker, July 1995). Table 1-1 provides an abbreviated summary of the groundwater analytical results for contaminants at the completion of the RI in 1994 (Figure 1-2, box 4).

3.1.3 Record of Decision

As stipulated in the final ROD signed for OU 7 in 1995, the primary objective of the remedial action at Site 1 is to address trichloroethene (TCE) contamination in the shallow groundwater aquifer (Baker, May 1996). The ROD identifies the implementation of a LTM program as the selected remedy for groundwater. Volatile Organic Compound (VOC) analysis was required by the ROD with TCE being specifically mentioned with a 5.0 micrograms per liter ($\mu\text{g/L}$) remedial level goal. The ROD stated the 5.0 $\mu\text{g/L}$ as the North Carolina Water Quality Standard (NCWQS), however, the actual NCWQS is 2.8 $\mu\text{g/L}$ for TCE. Accordingly, the actual NCWQS of 2.8 $\mu\text{g/L}$ for TCE is considered the intended remediation level for this site.

3.1.4 Long Term Monitoring Program

The timeline on Figure 1-2 illustrates the evolution of the monitoring program over time. The LTM program began at Site 1 in July 1996 (Figure 1-2, box 6) and initially included the sampling of eight monitoring wells on a semi-annual basis. Monitoring reports have been prepared after each sampling event that track and document the progression of the LTM program over time (Baker, 1996 through 2001). Figure 1-1 shows all the LTM sampling locations at Site 1. The following section provides a summary of LTM at Site 1, and supporting evidence that the

remedial goals have been achieved. For a complete description of LTM activities refer to the Final LTM Report for Site 1 included in Attachment A.

In January 1998 Site 1 was removed from LTM and only confirmatory sampling continued to monitor wells 1-MW10 and 1-MW17 for VOCs. Confirmatory sampling at this OU was documented in the meeting minutes (November, 1997) for the Camp Lejeune Partnering Team that include representatives from the Base, United States Environmental Protection Agency (USEPA), North Carolina Department of Environmental Protection (NC DENR), and LANTDIV. Confirmatory sampling initiation is also documented in the LTM Report for OU 7 (Baker, July 1998). Confirmatory sampling was agreed upon by all members of the partnering team in order to monitor the levels in selected monitoring wells that were fluctuating, all other monitoring wells at the site were stable and LTM was no longer required. Confirmatory sampling has no set criteria for groundwater concentrations and can be discontinued by the agreement of all parties. The primary objective of the confirmatory sampling was to evaluate TCE levels after the LTM program concluded. Although levels for vinyl chloride were not stipulated in the ROD they have been monitored and are included on Table 1-2. Table 1-2 provides the concentrations of TCE and vinyl chloride detected in monitoring wells 1-MW10 and 1-MW17 from the beginning of LTM to the completion of LTM. This same data is also presented in a graphical format in Figures 1-4 and 1-5 for monitoring wells 1-MW17 and 1-MW10, respectively.

In April 2000 (Figure 1-2, box 17), LTM analytical data indicated a fourth consecutive round of non-detections of TCE and vinyl chloride at both monitoring well 1-MW10 and 1-MW17. Accordingly, Site 1 had achieved the ROD specified objectives and, therefore, the site was recommended for removal from the overall monitoring program at Camp Lejeune. Confirmatory sampling continued until approval by the regulatory agencies to discontinue monitoring activities was granted in January 2001.

3.2 Site 28

The conditions at Site 28 have been evaluated through several separate investigative activities, including a monitoring program. A chronological account of these investigative activities for Site 28 is presented on the Site Activities Timeline in Figure 28-2. This timeline provides milestones reached during the seven years of activity conducted at Site 28. Relevant information associated with specific events are cross-referenced as data tables or graphs and are presented with in this report. The following subsections provide a summary of the previous studies completed at the site along with the results of the LTM program.

Investigative activities for OU 7 began in 1983 with an IAS (WAR, April 1983) along with other areas on the Base. Site 28 was also identified as one of the ten sites on Base that required further investigative studies. A two-part CS was conducted by ESE from 1984 through 1987 (ESE, September 1990). The purpose of the CS was to investigate potential contaminant source areas identified in the IAS report. Site 28 was evaluated and consequently was determined to warrant further investigation.

In addition to the IAS, aerial photographic analysis addressed site operations between 1938 and 1990, and an interim report was completed in August 1992 (Figure 28-2, box 3 on the Timeline). A recent aerial photograph of Site 28 with superimposed site boundaries is provided on Figure 28-3.

3.2.1 Remedial Investigation

In 1994 a RI was completed (Baker, June 1995) for Site 28. As part of the RI at Site 28, soil, groundwater, surface water, sediment, and aquatic investigations were conducted. The information gathered during these investigations was intended to fill previously existing data gaps identified during the CS and to generate information for assessing human health and ecological risks. Remedial alternatives for groundwater were evaluated during preparation of the FS (Baker, July 1995). Table 28-1 provides an abbreviated summary of the groundwater analytical results for contaminants of concern at the completion of the RI in 1994 (Figure 28-2, box 4).

3.2.2 Record of Decision

As stipulated in the final ROD signed for OU 7 in 1995, the primary objective of the remedial action at Site 28 is to address lead and manganese contamination in the shallow groundwater aquifer (Baker, May 1996). The ROD identifies the implementation of a LTM program as the selected remedy for groundwater. VOC, lead and manganese analysis was required by the ROD with lead and manganese being specifically mentioned with a 15 µg/L and 50 µg/L remedial level goal, respectively. The ROD states that it does not expect the remediation level of manganese to be achieved due to the natural occurrence of high levels of this inorganic.

3.2.3 Long Term Monitoring Program

The timeline on Figure 28-2 illustrates the evolution of the monitoring program over time. The LTM program began at Site 28 in July 1996 (Figure 28-2, box 6) and initially included the sampling of seven monitoring wells on a semi-annual basis. Monitoring reports have been prepared after each sampling event that track and document the progression of the LTM program over time (Baker, 1996 through 2001). Figure 28-1 shows all the LTM sampling locations at Site 28. The following section provides a summary of LTM at Site 28, and supporting evidence that the remedial goals have been achieved. For a complete description of LTM activities refer to the Final LTM Report for Site 28 included in Attachment B.

In January 1998 Site 28 was removed from LTM and only confirmatory sampling continued at monitor wells 28-MW01, 28-MW02 and 28-MW07 for lead and manganese. Table 28-2 provides the concentrations of lead and manganese detected in these three monitoring wells from the beginning of LTM to the completion of LTM.

In July 1999 monitoring wells 28-MW01 and 28-MW02 were removed from the monitoring program. Both wells had detected lead under the ROD level of 15 µg/L since the beginning of the LTM program (ten consecutive quarters). Manganese was not stipulated under the ROD level of 50 µg/L, but as stated in the ROD manganese is naturally occurring on the coastal plane of North Carolina and was not expected to drop below 50 µg/L in any of the monitoring wells. Beginning in April 2000 monitoring well 28-MW07 was only sampled and analyzed for lead.

In April 2001 (box 21), LANTDIV directed that the site be further evaluated for lead and a monitoring well be installed. Monitoring well 28-MW09 was installed during late April 2001 and sampled during July 2001, and subsequently did not detect lead.

In October 2001 (box 23), Site 28 was recommended for removal from LTM and site closure after multiple rounds of data at 28-MW07 showed lead to increase and decrease seasonally. Figure 28-4 provides a graph of lead in monitoring well 28-MW07 since the beginning of the LTM program. Research into the soil and groundwater in this area indicate that monitoring well 28-MW07 is screened in peat, which is lowering the pH and is contributing to the leaching of

lead. It is believed that because the well is over two-thirds screened in peat, the organic material is keeping the pH in the groundwater at a level below neutral. Because lead solubility increases with decreasing pH, the lead is more inclined to dissolve into the groundwater in this acidic environment. The lead is leaching during periods of high groundwater elevations and it is believed that this cycle will continue indefinitely. Refer to Attachments C and D for evaluations of lead concentrations at Site 28.

4.0 SUMMARY OF OPERATION AND MAINTENANCE

There is no operation or maintenance associated with this OU. LTM was the selected remedy for this OU.

5.0 SUMMARY OF REMEDIATION COSTS

5.1 Site 1

Based on costs prepared in the FS and reported in the Final ROD for OU 7, the net present worth (NPW) for Site 1 was projected to be \$600,000 over a 30 year period. The total cost for the five years of LTM at Site 1 is approximately \$62,400 (Table 1-3). This cost deviation is a result of changes to the LTM program at Site 1 in terms of ending LTM activities after only five years, altering the sampling frequency during this time period, and reducing the number of actual monitoring wells sampled during each event. The ROD also projected an estimated annual operation and maintenance (O&M) costs of \$40,000. The average annual costs were approximately \$12,480.

5.2 Site 28

Based on costs prepared in the FS and reported in the Final ROD for OU 7, the NPW for Site 28 was projected to be \$500,000 over a 30 year period. The total cost for the six years of LTM at Site 28 is approximately \$159,900 (Table 28-3). This cost deviation is a result of changes to the LTM program at Site 28 in terms of ending LTM activities after only six years, altering the sampling frequency during this time period, and reducing of the number of actual monitoring wells sampled during each event. The ROD also projected an estimated annual O&M cost of \$30,000. The average annual costs were approximately \$26,650.

6.0 PROTECTIVENESS

Past investigations at Sites 1 and 28 focused on the evaluation of the extent as well as the cleanup of contamination. In addition to these efforts as mentioned above, the RI, FS, ROD and LTM reports were prepared to address the protectiveness of human health and the environment at Sites 1 and 28.

6.1 ROD

The ROD is a decision document that establishes an agreed upon and legally binding set of conditions that Sites 1 and 28 must achieve to acquire a site closure status. The ROD specifies restrictions on groundwater use within OU 7 and restricts the installation of water supply wells within a 1,000 foot radius of the OU.

6.2 Five Year Review

In 1999, the initial Five-Year Review was conducted for all sites at Camp Lejeune. The Five-Year Review is conducted in line with procedures detailed in the NCP and CERCLA. A Five-Year Review is required for a CERCLA site if: 1) a remedial action results in hazardous substances, pollutants, or contaminants remaining at a site; or 2) the ROD was signed on or after October 17, 1986. This document was submitted to, reviewed, and approved by the USEPA and NC DENR. The complete document can be referenced as part of the Administrative Record for Camp Lejeune.

6.3 Site 1 Closure

Site 1 has achieved the remedial goals as set forth in the previously mentioned documents and, through LTM, meets the requirements for site closure. Four consecutive rounds of data collection through LTM indicate non-detections of contaminants at the monitoring wells and in some instances greater than four consecutive rounds.

6.4 Site 28 Closure and Lead Investigations

In addition to the previously mentioned investigations including the RI and LTM, further research was conducted at Site 28 into the oscillating levels of lead detected during LTM. Refer to Attachments C and D for two evaluations of lead at Site 28 conducted by Baker. These evaluations explain the fluctuating lead concentrations in monitoring well 28-MW07. The lead fluctuations are due to a number of factors, mainly that monitoring well 28-MW07 is screened in peat. The peat is lowering the pH and is contributing to the leaching of lead. Organic matter such as peat tends to bind up the inorganics. The inorganics are leaching during periods of high groundwater elevations and it is believed that this cycle will continue indefinitely.

7.0 REGULATORY AGENCY

The USEPA and NC DENR have been actively involved with the investigation processes of Sites 1 and 28. These agencies are members of the Camp Lejeune Partnering Team, which review the monitoring reports, discuss the proposed recommended items, and provide direction for future activities.

8.0 REFERENCES

Baker Environmental, Inc. (Baker). June 1995. Remedial Investigation Report, Operable Unit No. 7 (Sites 1 and 28). Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). July 1995. Final Feasibility Study Report, Operable Unit Number 7 - Sites 1 and 28. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996. Work Plans for Long Term Monitoring OU No. 7. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). May 1996. Final Record of Decision, Operable Unit Number 7 - Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996 to 2001. Long Term Monitoring Report, Operable Unit Number 7 - Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Environmental Science and Engineering (ESE). September, 1990. Site Summary Report Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command. ESE Project No. 49-02036.

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

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TABLES

TABLE 1 - 1
REMEDIAL INVESTIGATION GROUNDWATER DATA SUMMARY - SITE 1
OPERABLE UNIT NO. 7 - SITE 1
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well/Volatile Compound	(Round 1) May 1994	(Round 2) December 1994
<i>1-MW10</i>		
Vinyl Chloride	2	4
1,2-Dichloroethene (Total)	10	21
1,1-Dichloroethene (Total)	ND	2
Trichloroethene	4	8
<i>1-MW11</i>		
Trichloroethene	1	ND
<i>1-MW12</i>		
Xylenes	3	9
<i>1-MW17</i>		
1,2-Dichloroethene (Total)	1	ND
Trichloroethene	27	18

Notes:

All concentrations are presented in micrograms per liter ($\mu\text{g/L}$)
 Two rounds of groundwater samples were collected during the RI
 ND = Not Detected

TABLE 1 - 2
TCE AND VINYL CHLORIDE IN GROUNDWATER - SITE 1
OPERABLE UNIT NO. 7 - SITE 1
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	Jan 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998	Oct 1998	Jan 1999	April 1999	July 1999	Four Rounds of ROD Levels Achieved			
		NCWQS	MCL	ROD										Oct 1999	Jan 2000	April 2000	Oct 2000
		1-MW10	Trichloroethene	2.8										5	2.8	ND	ND
	Vinyl Chloride	0.015	2	NE	ND	3 J	ND	ND	ND	2 J	ND	1 J	1 J	ND	ND	ND	ND

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	Jan 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998	Oct 1998	Jan 1999	April 1999	July 1999	Four Rounds of ROD Levels Achieved			
		NCWQS	MCL	ROD										Oct 1999	Jan 2000	April 2000	Oct 2000
		1-MW17	Trichloroethene	2.8										5	2.8	ND	3 J
	Vinyl Chloride	0.015	2	NE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

All concentrations are presented in micrograms per liter (µg/L)

(1) = Confirmatory Sampling Begins.

ND = Not Detected

NE = Not Established

J = Estimated Concentration

NCWQS = North Carolina Water Quality Standard 2L

MCL = United States Environmental Protection Agency, Maximum Contaminant Level.

ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).

 = Shading indicates that a concentration is above the screening criteria.

* = The detection of TCE at 12 (µg/L) in October 1999 is a result of laboratory contamination as evidenced by a TCE detection in the associated trip blank at the time of sampling. It is therefore considered a non-detection.

TABLE 1-3

**SUMMARY OF COSTS - SITE 1
OPERABLE UNIT NO. 7 - SITE 1
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA**

Activity	Costs
Groundwater LTM	\$62,400

Notes:

LTM = Long Term Monitoring

Costs include loabor, travel, other direct costs
(e.g., equipment), laboratory, and validation.

TABLE 28 - 1
REMEDIAL INVESTIGATION GROUNDWATER DATA SUMMARY - SITE 28
OPERABLE UNIT NO. 7 - SITE 28
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well/Inorganics	Round 1 (May 1994)	Round 2 (November 1994)
<i>28-MW01</i>		
Lead	114	ND
Manganese	186	225
<i>28-MW02</i>		
Lead	449	ND
Manganese	ND	185
<i>28-MW07</i>		
Lead	4810	8.2
Manganese	3330	694

Notes:

All concentrations are presented in micrograms per liter ($\mu\text{g/L}$)
 Two rounds of groundwater samples were collected during the RI
 ND = Not Detected

TABLE 28 - 2
LEAD AND MANGANESE IN GROUNDWATER - SITE 28
OPERABLE UNIT NO. 7 - SITE 28
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Lead Comparison Criteria			July 1996	Feb 1997	Aug 1997	Jan 1998	July 1998 (1)	Oct 1998	Jan 1999	April 1999	July 1999	Oct 1999 (2)	Jan 2000	April 2000	July 2000	Oct 2000	Jan 2001	April 2001	July 2001	Oct 2001			
	NCWQS	MCL	ROD																					
28-MW01	15	15	15	4.9	1.6	ND	ND	ND	2.9B	ND	2.6B	2.9B	NS	NS	NS	NS	NS	NS	NS	NS	NS			
28-MW02				4.9	ND	ND	ND	ND	ND	ND	ND	1.6B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
28-MW07				12.4	6.8	30.6	ND	65	32.5	1B	6.6	34.2	17	4.5	8.7	4.5	41.7	ND	8.3	47.8	131			
28-MW09				NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND

Monitoring Well ID	Manganese Comparison Criteria			July 1996	Feb 1997	Aug 1997	Jan 1998	July 1998 (1)	Oct 1998	Jan 1999	April 1999	July 1999	Oct 1999 (2)
	NCWQS	MCL	ROD										
28-MW01	50	NE	50	250	214	66.2	113	114	195	83.2	83.8	72.8	NA
28-MW02				174	185	196	197	204	181	184	169	179	NS
28-MW07				860	460	906	1270	798	787	497	706	740	NS

Notes:

All concentrations are presented in micrograms per liter (µg/L).

- (1) = Confirmatory Sampling Begins.
- (2) = Sampling was discontinued at monitoring wells 28-MW01 and 28-MW02, manganese was also discontinued for analyzation
- B = Reported value is < CRDL, but >IDL.
- NA = Not Applicable
- ND = Not Detected
- NS = Not Sampled
- NE = Not Established

NCWQS = North Carolina Water Quality Standard, 2L.

MCL = United States Environmental Protection Agency, Maximum Contaminant Level.

ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).

Shading indicates that a concentration is above the comparison criteria.

TABLE 28-3

SUMMARY OF COSTS - SITE 28
OPERABLE UNIT NO. 7 - SITE 28
FINAL CLOSE OUT REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Activity	Costs
Groundwater LTM	\$66,000
Surface Water LTM	\$76,800
Sediment LTM	\$15,600
Additional Monitoring Well Installation	\$1,500
Total for Site	\$159,900

Notes:

LTM = Long Term Monitoring
Costs include loabor, travel, other direct costs
(e.g., equipment), laboratory, and validation.

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FIGURES

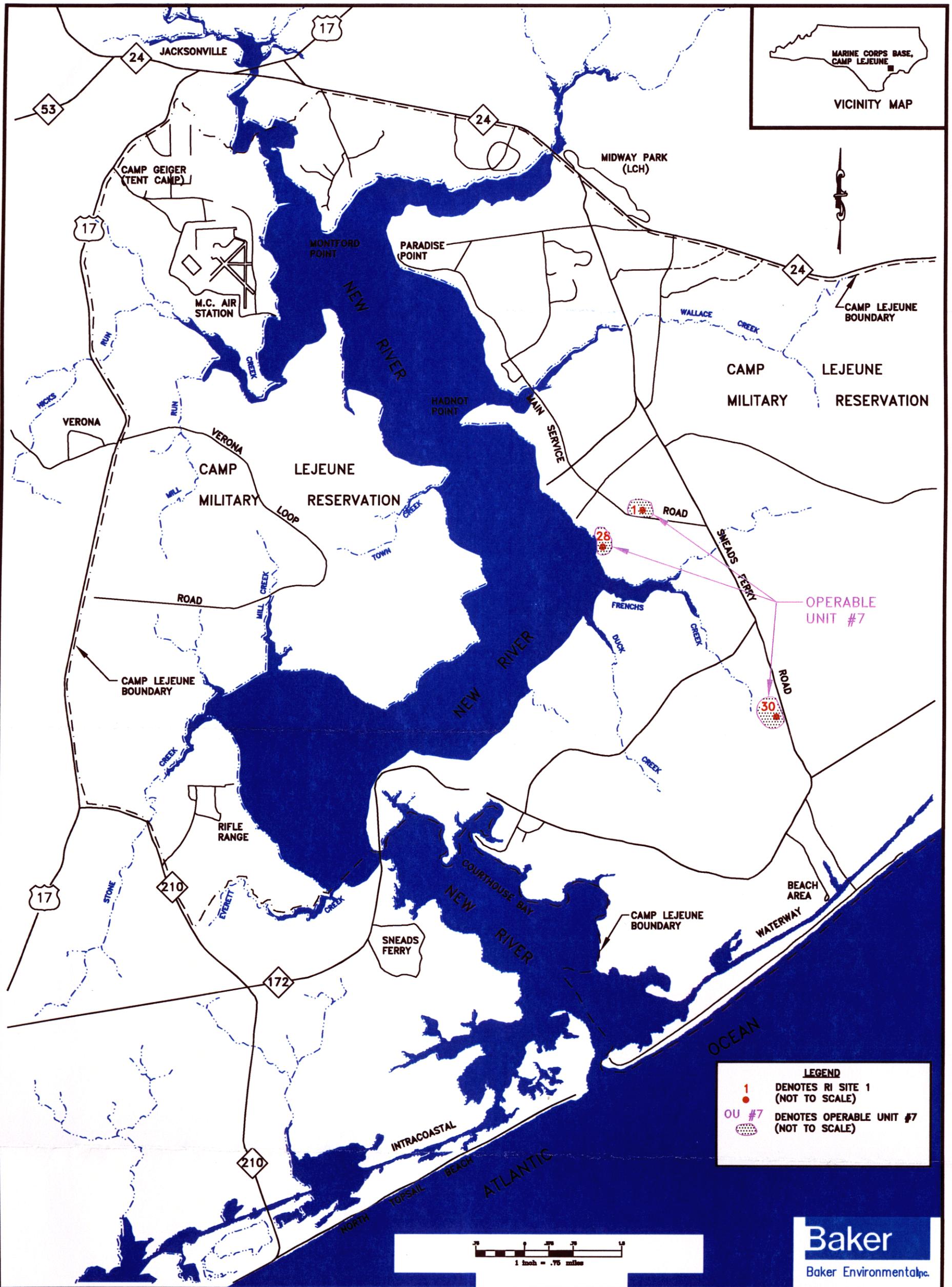
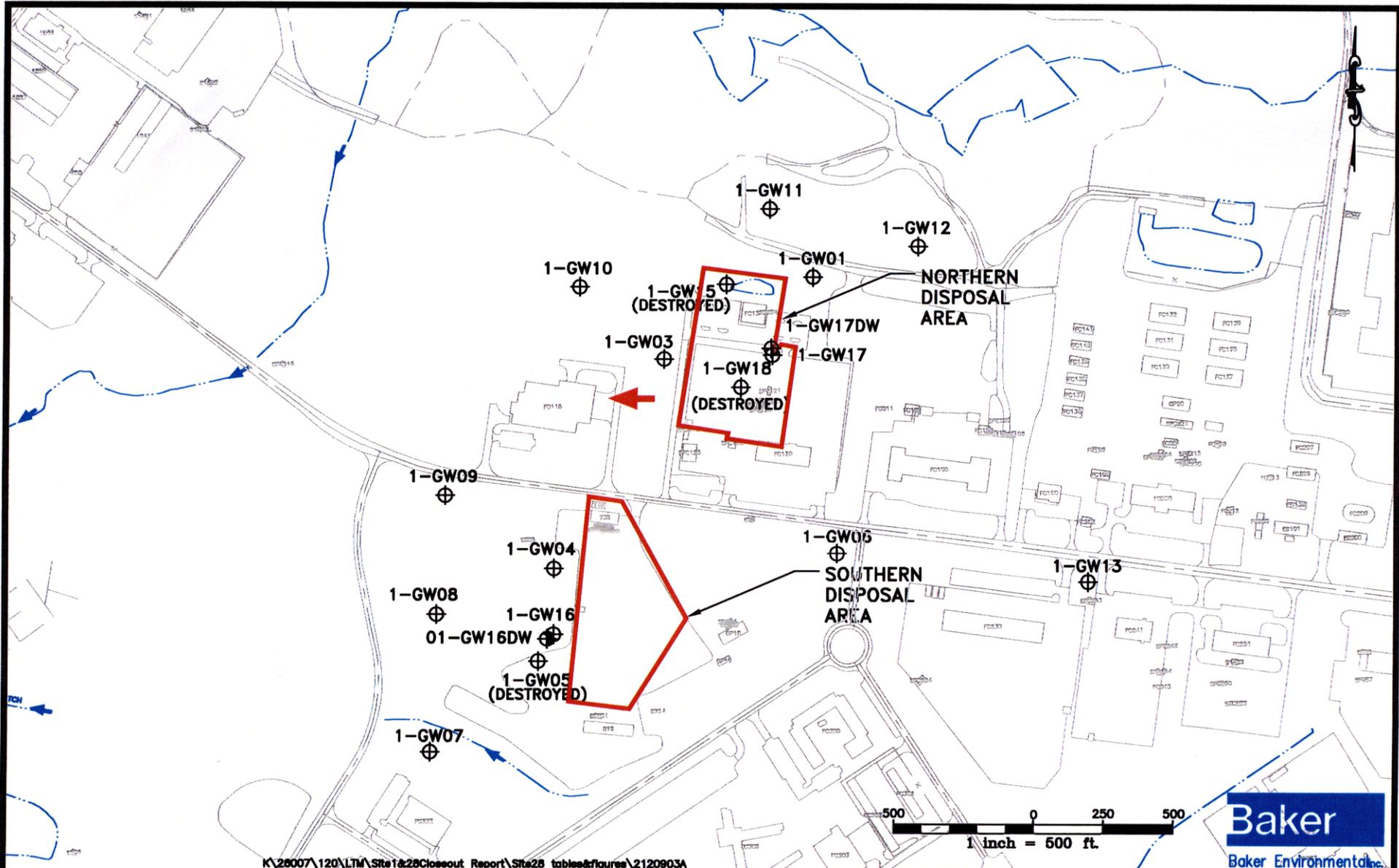


FIGURE 1
 OPERABLE UNIT AND SITE LOCATION MAP
 OPERABLE UNIT NO.7 -SITES 1, 28, AND 30
 FINAL CLOSE OUT REPORT, CTO-0120

MARINE CORPS BASE, CAMP LEJEUNE
 NORTH CAROLINA



kt:\26007\120phase\fm\offe1&28\offe1&28closeout report\2120906W



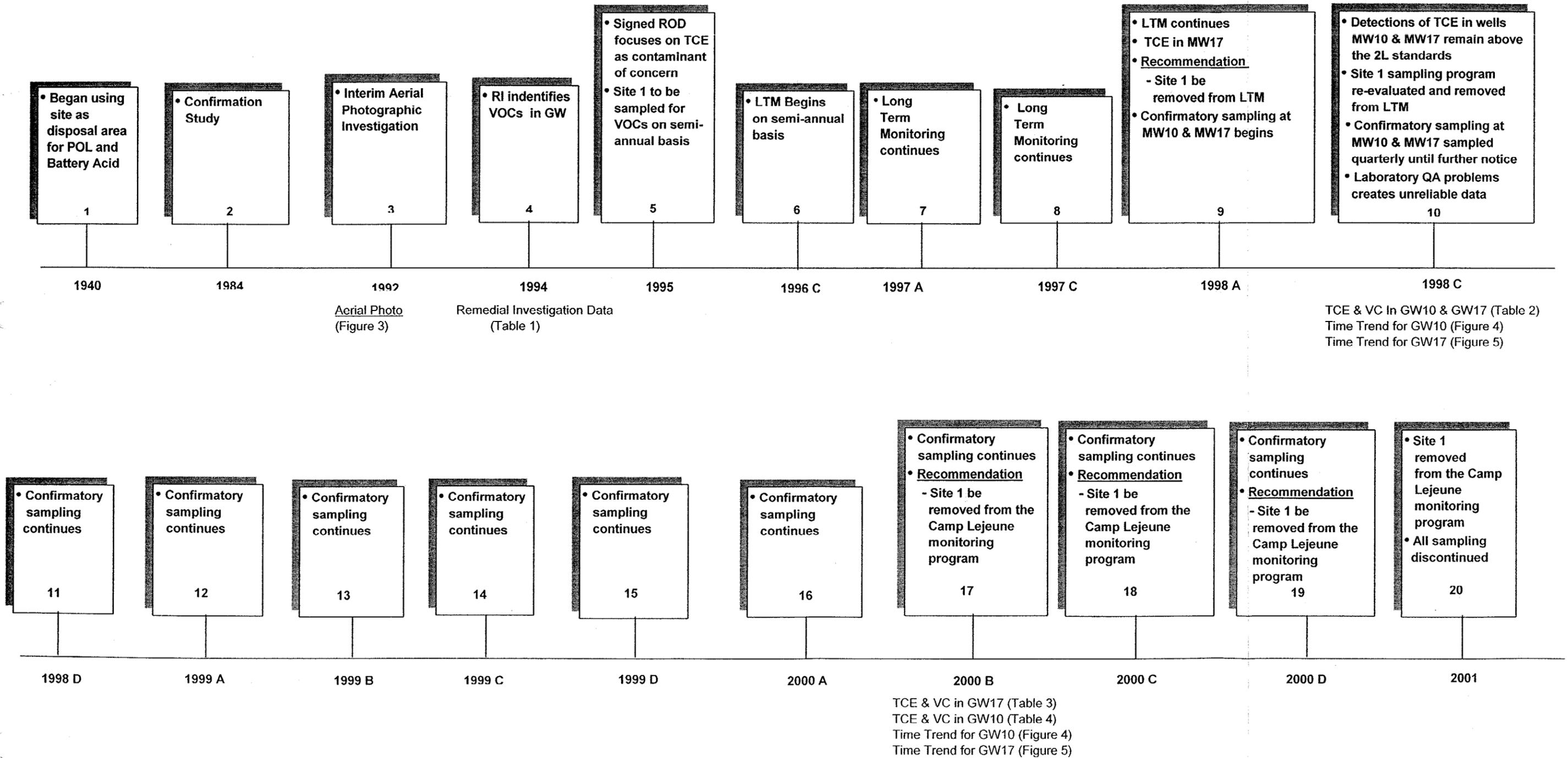
K:\28007\120\LTM\Site1&28Closeout Report\Site28 tables&figures\2120903A

LEGEND	
1-GW01 ⊕	- SHALLOW MONITORING WELL
1-GW16DW ⊕	- DEEP MONITORING WELL
➔	- SHALLOW GROUNDWATER FLOW DIRECTION

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

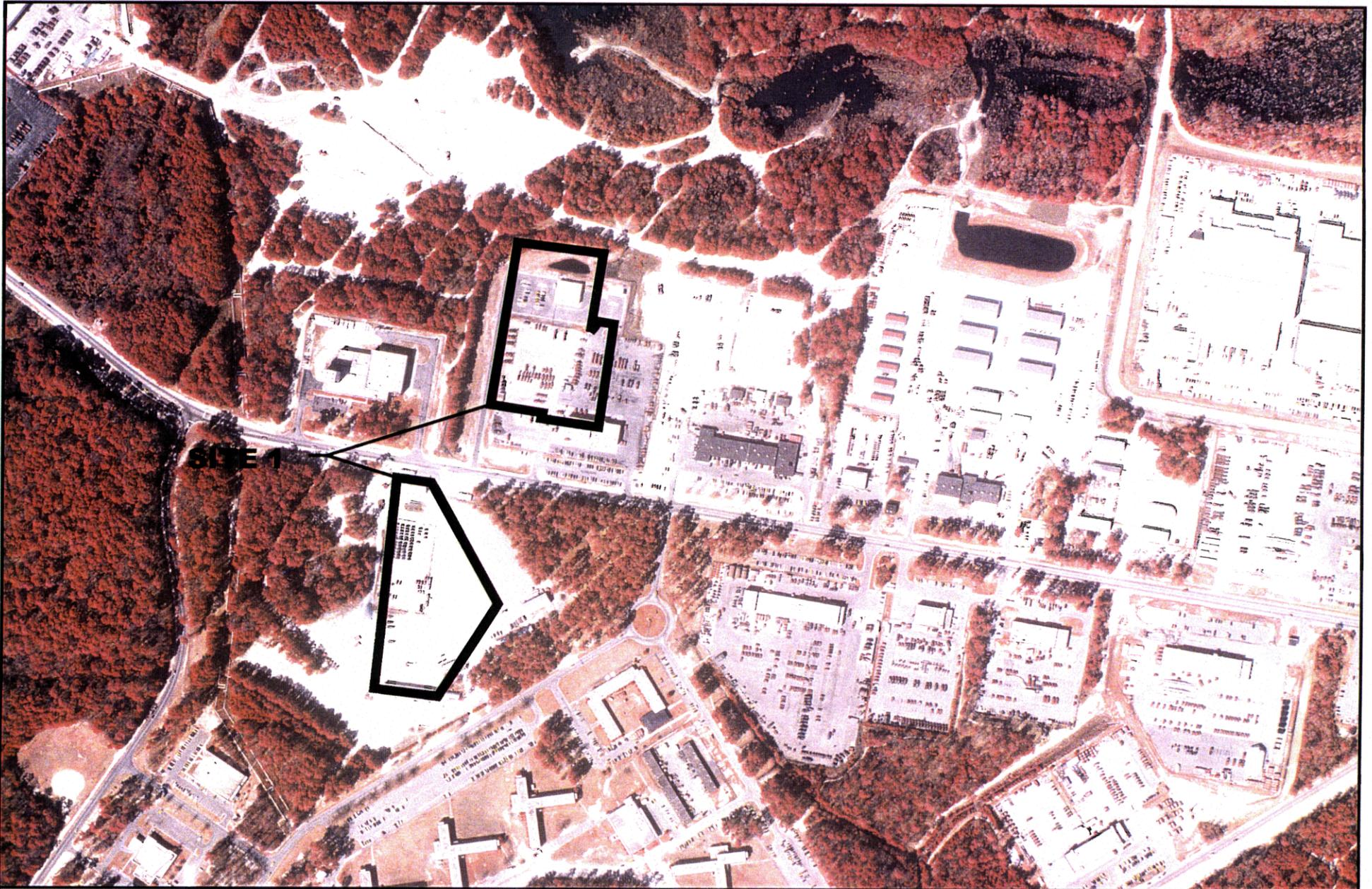
FIGURE 1-1
SITE 1 SAMPLING LOCATION MAP
OPERABLE UNIT NO. 7 - SITE 1
FINAL CLOSE OUT REPORT, CTO - 0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 1 - 2
 SITE 1 ACTIVITIES TIMELINE
 OPERABLE UNIT NO. 7 - SITE1
 FINAL CLOSE OUT REPORT, CTO-120
 MCB, CAMP LEJEUNE, NORTH CAROLINA



Notes:
 A = 1st quarter of calendar year
 B = 2nd quarter of calendar year
 C = 3rd quarter of calendar year
 D = 4th quarter of calendar year

03205B02Z



SITE 1

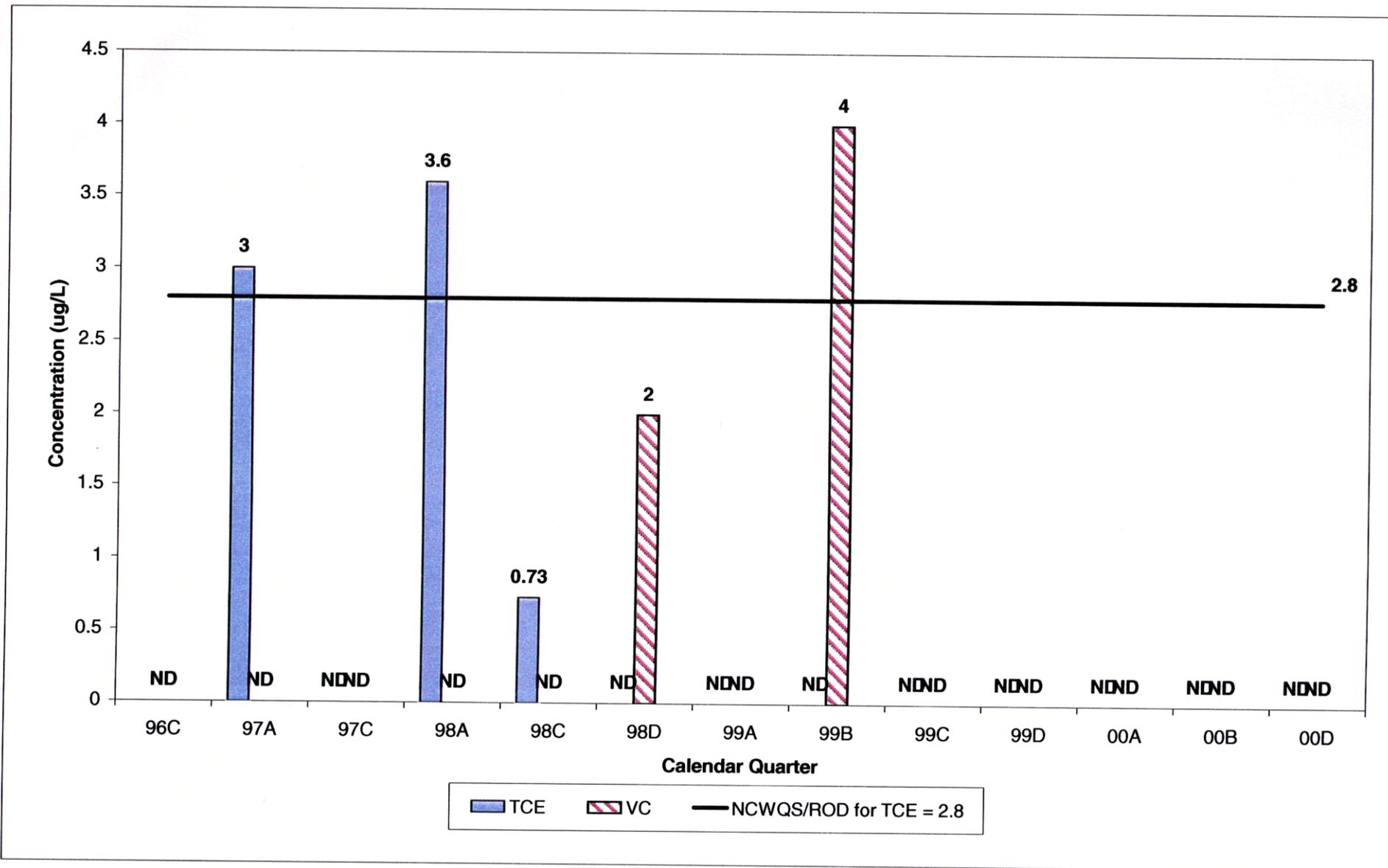
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SCALE: 1=150 DATE: MARCH 1996
S.O. NO.: 28007-120-0000-040DM FILE: aerial_1
DSN/DWN: CHK:
SOURCE: IGIR - DATA CATALOG



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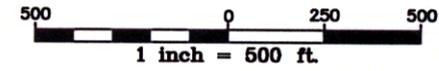
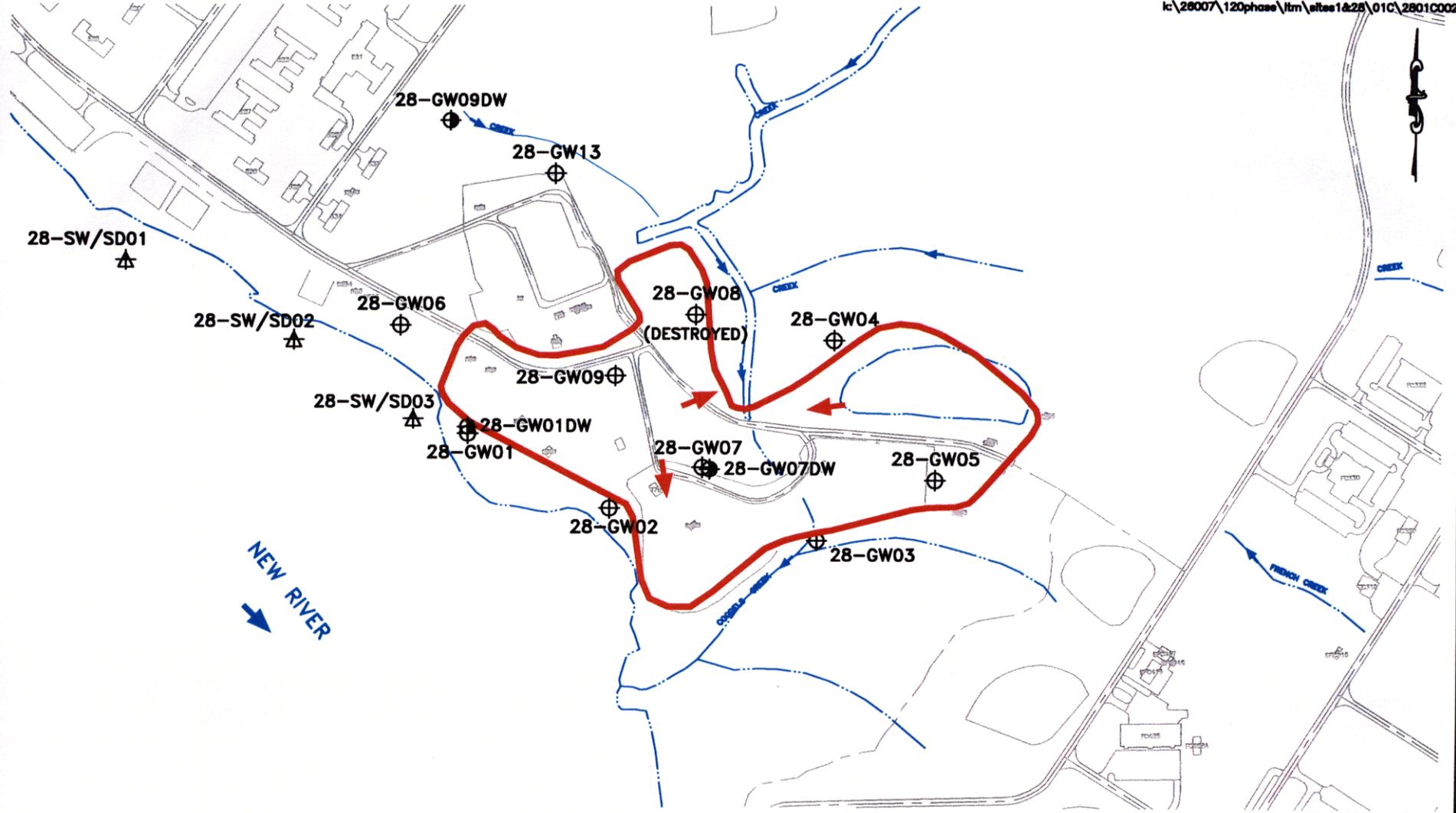
FIGURE 1-3
SITE 1 AERIAL PHOTOGRAPH
OPERABLE UNIT NO.7 - SITE 1
FINAL CLOSE OUT REPORT, CTO-0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

TIME TREND OF TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW17
 OPERABLE UNIT NO. 7 - SITE 1
 FINAL CLOSE OUT REPORT, CTO - 0120
 MCB, CAMP LEJEUNE, NORTH CAROLINA



Note:

NCWQS for Vinyl Chloride is 0.015 ug/L
 ND = Not Detected



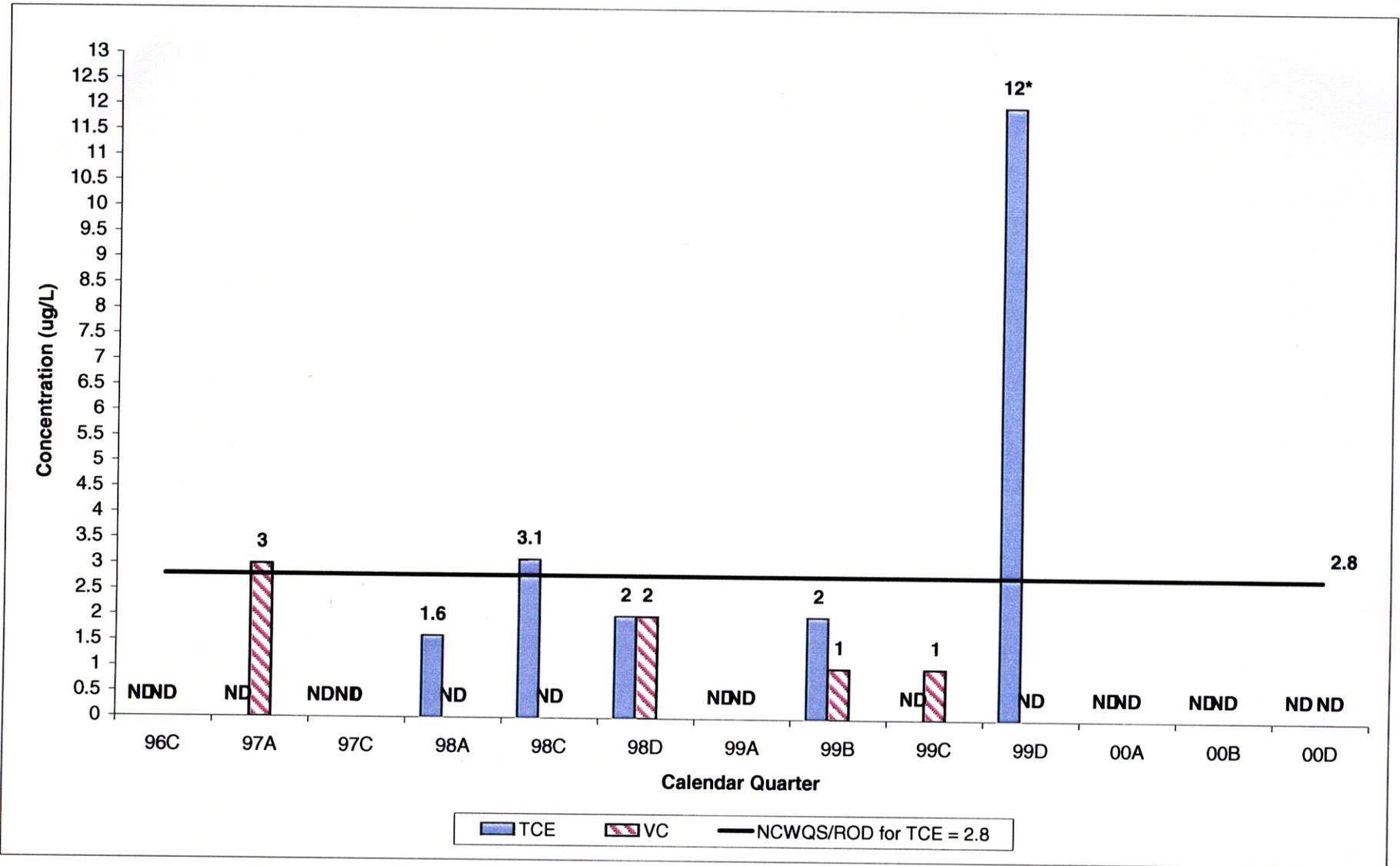
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LEGEND	
28-GW01 ⊕	- SHALLOW MONITORING WELL
28-GW01DW ⊙	- DEEP MONITORING WELL
28-SW/SD01 ▲	- SURFACE WATER/SEDIMENT SAMPLE
→ (blue)	- DIRECTION OF SURFACE WATER FLOW
→ (red)	- APPROXIMATE DIRECTION OF GROUNDWATER FLOW
— (red)	- SITE 28 BOUNDARY

FIGURE 28-1
SITE 28 SAMPLING LOCATION MAP
OPERABLE UNIT NO. 7 - SITE 28
FINAL CLOSE OUT REPORT, CTO - 0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE:
MCB, CAMP LEJEUNE MARCH 2000

TIME TREND OF TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW10
 OPERABLE UNIT NO. 7 - SITE 1
 FINAL CLOSE OUT REPORT, CTO - 0120
 MCB, CAMP LEJEUNE, NORTH CAROLINA



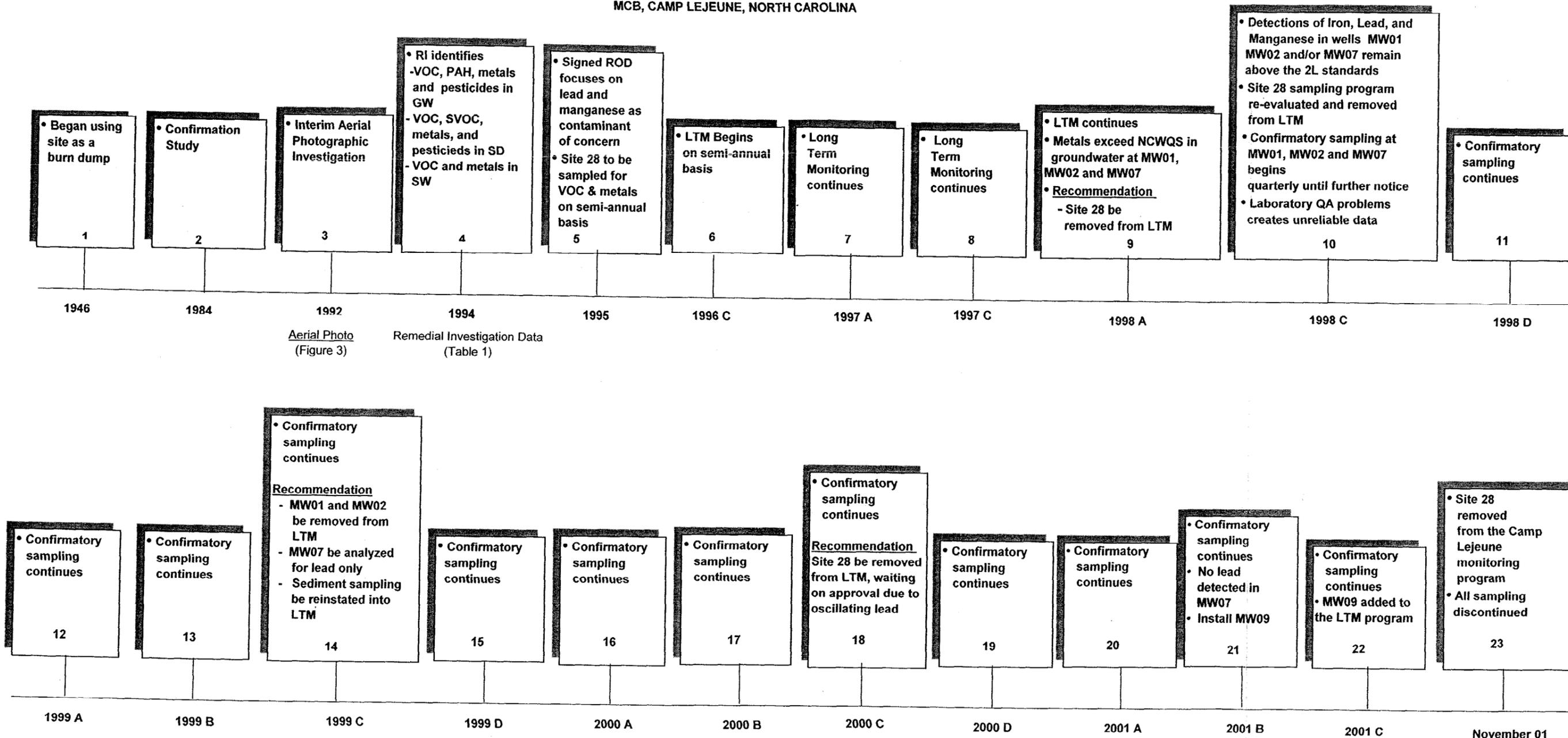
Note:

NCWQS for Vinyl Chloride is 0.015 ug/L

ND = Not Detected

* = The detection of TCE at 12 in October 1999 is a result of laboratory contamination as evidenced by a TCE detection in the associated trip blank at the time of sampling. It is therefore considered a non-detection.

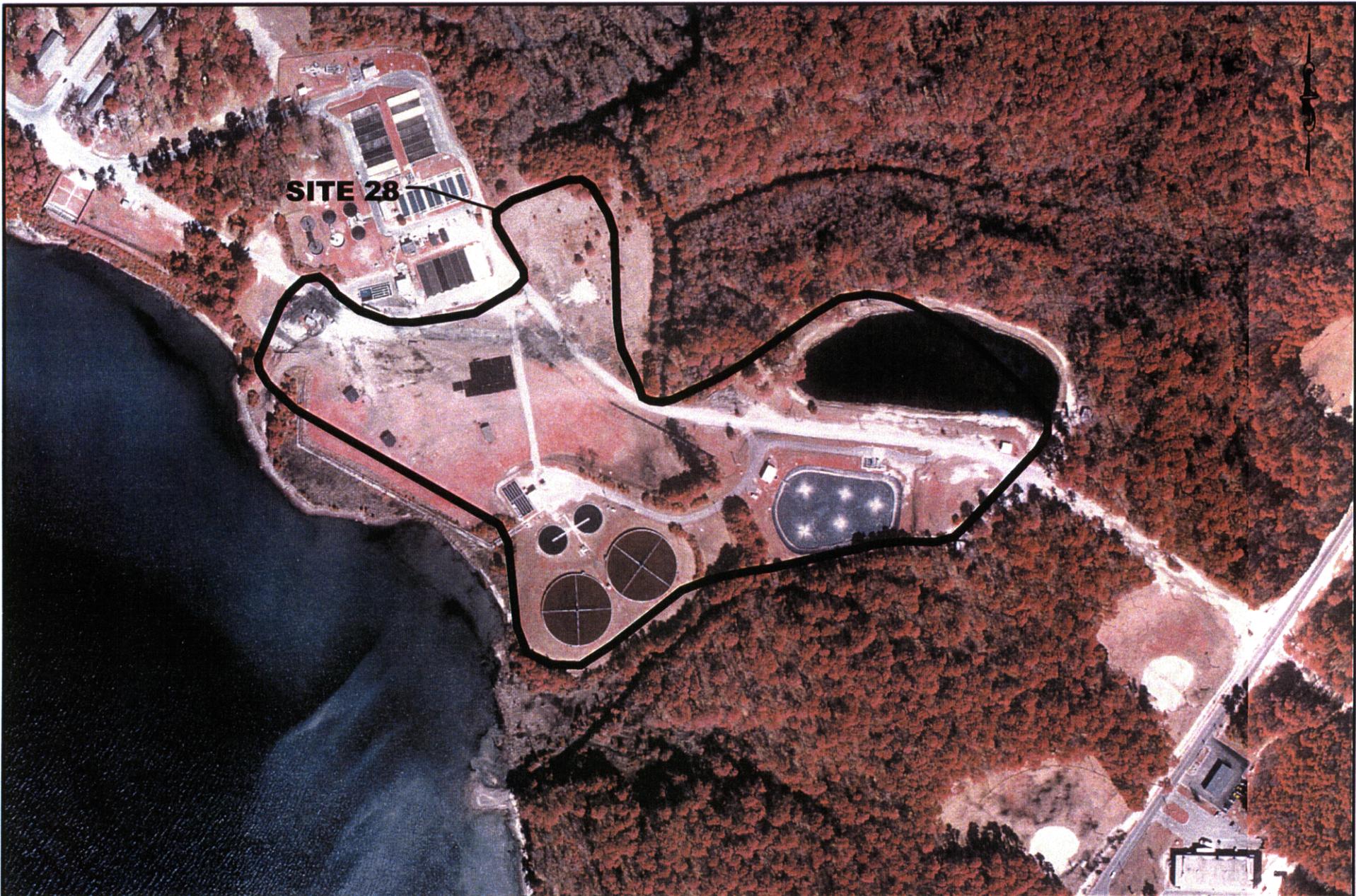
FIGURE 28-2
 SITE 28 ACTIVITIES TIMELINE
 OPERABLE UNIT NO. 7 - SITE 28
 FINAL CLOSE OUT REPORT, CTO-120
 MCB, CAMP LEJEUNE, NORTH CAROLINA



Notes:
 A = 1st quarter of calendar year
 B = 2nd quarter of calendar year
 C = 3rd quarter of calendar year
 D = 4th quarter of calendar year

Time Trend of ROD Contaminants of Concern in Groundwater (Table 2)
 Time Trend of Lead in Groundwater in Monitoring Well 28-MW07 (Figure 5)

03205 B042



SITE 28

k:\26007\120phase\itm\site1&28\sites1&28closeout report
SCALE: 1=100 DATE: 12/06/01
S.O. NO.: 26007-120-0000-RA100 FILE: 2120900A
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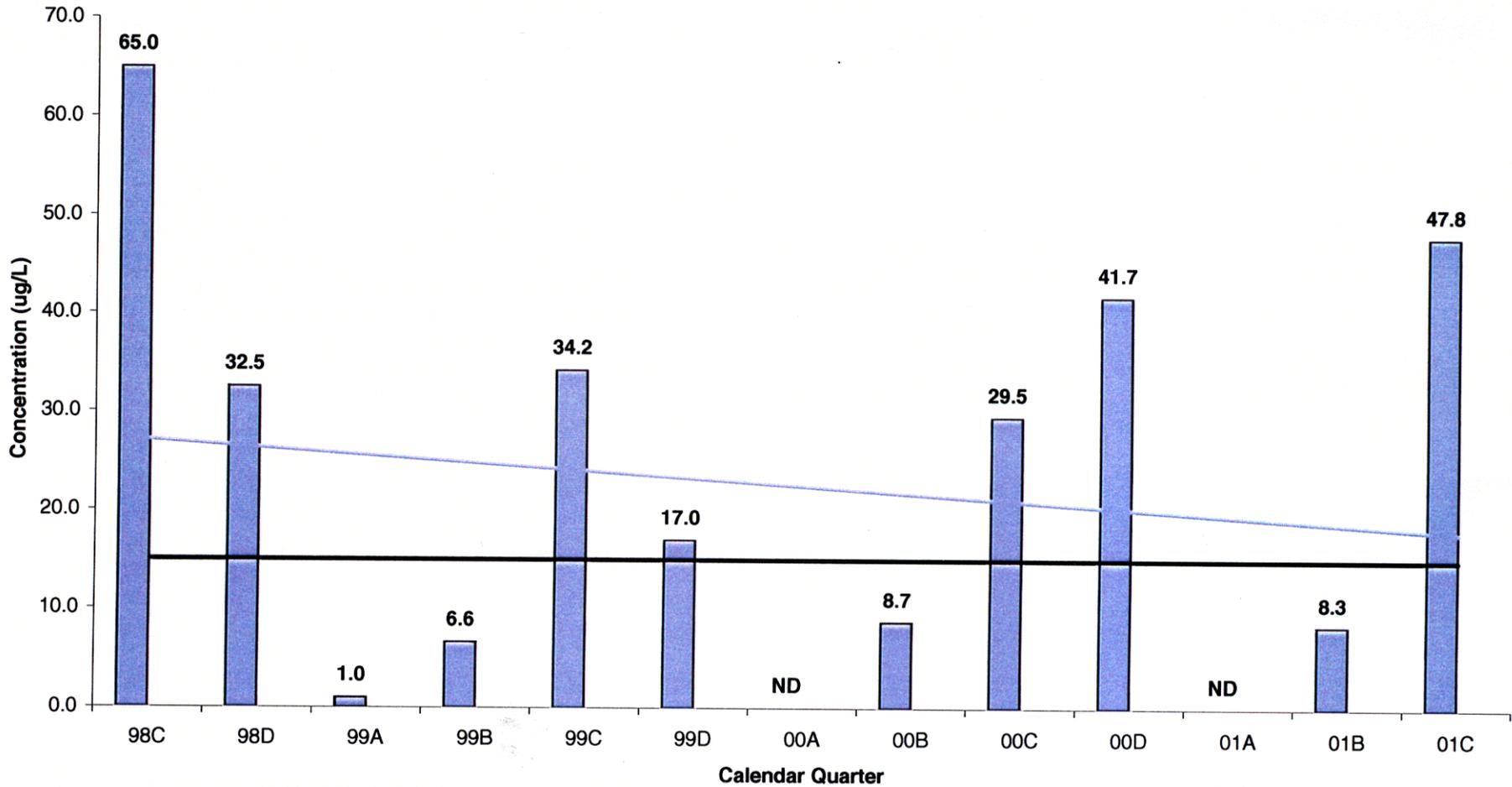


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FIGURE 28-3
SITE 28 AERIAL PHOTOGRAPH
OPERABLE UNIT NO.7 - SITES 1 AND 28
FINAL CLOSE OUT REPORT, CTO-0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 28-4

TIME TREND OF LEAD IN MONITORING WELL 28-MW07
OPERABLE UNIT NO. 7- SITE 28
FINAL CLOSE OUT REPORT, CTO-0120
MCB, CAMP LEJEUNE, NORTH CAROLINA



ND = Non-Detected



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ATTACHMENT A

Site 1 Final LTM Report

FINAL LONG TERM MONITORING REPORT

**OPERABLE UNIT NO. 7 – SITE 1
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA**

JANUARY 21, 2002

CONTRACT TASK ORDER 0120

Prepared for:

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

Under the:

**LANTDIV CLEAN II Program
Contract N62470-95-D-6007**

Prepared by:

**CH2M HILL FEDERAL GROUP, LTD.
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*Coraopolis, Pennsylvania***

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2	Sampling Location Map
3	Site Activities Timeline
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5	Time Trend of TCE and Vinyl Chloride in Monitoring Well 1-MW17
6	Time Trend of TCE and Vinyl Chloride in Monitoring Well 1-MW10

1.0 INTRODUCTION

This document provides the Final Long Term Monitoring (LTM) Report for Site 1, the French Creek Liquids Disposal Area. Site 1 has completed the necessary requirements for no further LTM actions as stipulated in the Final Record of Decision (ROD). This Final LTM Report is being prepared as an attachment to the Final Closeout Report (FCOR) for Operable Unit (OU) 7.

2.0 SUMMARY OF SITE CONDITIONS

Site 1, along with Sites 28 and 30, comprise OU 7 at Marine Corps Base (MCB) Camp Lejeune, North Carolina. The site is located on the eastern portion of the Base, situated between the New River and Sneads Ferry Road, south of Hadnot Point Industrial Area (HPIA) (Figure 1) and is the northern most site located within OU 7.

Site 1 consists of two suspected disposal areas: the northern disposal area and the southern disposal area. Figure 2 presents a map of Site 1 that identifies the approximate boundaries of the two suspected disposal areas at the site. The site had been used by several different mechanized, armored, and artillery units since the 1940s. Reportedly, liquid wastes (petroleum, oil, and lubricants [POL]) generated from vehicle maintenance were routinely poured onto the ground surface. During motor oil changes, vehicles were driven to a disposal point and drained of used oil. In addition, acid from spent batteries was reportedly hand carried from maintenance buildings to disposal points. At times, holes were reportedly dug for waste acid disposal and then immediately backfilled (Water and Air Research [WAR], 1983).

3.0 PROCEDURES

The LTM program for Site 1 consisted of field activities and data reporting. The field activities included sample collection and field observations, while the data reporting was comprised of data management and evaluation. Sampling activities were conducted and subsequent laboratory analyses were performed according to procedures and methods specified in the Long Term Monitoring Work Plans for OU 7 [Baker Environmental, Inc. (Baker, 1996)]. The project work plans identify specific tasks associated with the monitoring activities conducted at Site 1.

4.0 INVESTIGATIVE ACTIVITIES AND REMEDIAL GOALS

The conditions at Site 1 have been evaluated through several separate investigative activities, including a monitoring program. A chronological account of these investigative activities for Site 1 is presented on the Site Activities Timeline in Figure 3. This timeline provides milestones reached during the seven years of activity conducted at Site 1. Relevant information associated with specific events are cross-referenced as data tables or graphs and are presented in this report. The following subsections provide a summary of the previous studies completed at the site along with the results of the LTM program.

Investigative activities for OU 7 began in 1983 with an Initial Assessment Study (IAS) conducted by Water and Air Research (WAR, April 1983) along with other areas on the Base. Site 1 was identified as one of the ten sites on Base that required further investigative studies. A two-part Confirmation Study (CS) was conducted by Environmental Science and Engineering, Inc. (ESE) from 1984 through 1986 (ESE, September 1990). The purpose of the CS was to investigate potential contaminant source areas identified in the IAS report. Site 1 was evaluated and consequently determined to warrant further investigation.

In addition to the IAS, aerial photographic analysis addressed site operations between 1938 and 1990, and an interim report was completed in August 1992 (Figure 3, box 3). A recent aerial photograph of Site 1 with superimposed site boundaries is provided on Figure 4.

4.1 Remedial Investigation

In 1994 a Remedial Investigation (RI) was completed by Baker (Baker, June 1995) for Site 1. As part of the RI at Site 1, soil and groundwater investigations were conducted. The information gathered during these investigations was intended to fill previously existing data gaps identified during the CS and to generate information for assessing human health and ecological risks. Remedial alternatives for groundwater were evaluated during preparation of the Feasibility Study (FS) (Baker, July 1995). Table 1 provides an abbreviated summary of the groundwater analytical results for contaminants at the completion of the RI in 1994 (Figure 3, Box 4).

4.2 Record of Decision

As stipulated in the final signed ROD for OU 7 in 1995, the primary objective of the remedial action at Site 1 is to address trichloroethene (TCE) contamination in the shallow groundwater aquifer (Baker, May 1996). The ROD identifies the implementation of a LTM program as the selected remedy for groundwater. Volatile Organic Compound (VOC) analysis was required by the ROD with TCE being specifically mentioned with a 5.0 micrograms per liter ($\mu\text{g/L}$) remedial level goal. The ROD stated the 5.0 $\mu\text{g/L}$ as the North Carolina Water Quality Standard (NCWQS), however, the actual NCWQS is 2.8 $\mu\text{g/L}$ for TCE. Accordingly, the actual NCWQS of 2.8 $\mu\text{g/L}$ for TCE is considered the intended remediation level for this site.

4.3 Long Term Monitoring Program

The timeline on Figure 3 illustrates the evolution of the monitoring program over time. The LTM program began at Site 1 in July 1996 (Figure 3, box 6) and initially included the sampling of eight monitoring wells on a semi-annual basis. Monitoring reports have been prepared after each sampling event that track and document the progression of the LTM program over time (Baker, 1996 through 2001). Figure 1-1 shows all LTM sampling locations at Site 1. The following provides clarifications of the LTM sequence shown on Figure 3, and supporting evidence that the remedial goals have been achieved:

- Boxes 7 and 8 indicate that LTM sampling continued at Site 1 with no unusual changes in the site conditions or monitoring program activities.
- Box 10 indicates that Site 1 was removed from LTM, and only confirmatory sampling continued to monitor wells 1-MW10 and 1-MW17. Confirmatory sampling at this site was documented in the meeting minutes (November, 1997) for the Camp Lejeune Partnering Team that include representatives from the Base, United States Environmental Protection Agency (USEPA), North Carolina Department of Environmental Protection (NC DENR), and the Atlantic Division Naval Facilities Engineering Command (LANTDIV). Confirmatory sampling is also documented in the LTM Report for OU 7 (Baker, July 1998). Table 2 provides the concentrations of TCE and vinyl chloride that were detected during the first five quarters of LTM, up to the initiation of confirmatory sampling. This same data is also presented in a graphical format presented in Figures 5 and 6 for wells 1-MW17 and 1-MW10, respectively. The analytical results clearly indicate that monitoring wells 1-MW10 and 1-MW17 continued to have TCE concentrations above the NCWQS of 2.8 $\mu\text{g/L}$ and would require further evaluation.

Box 10 also states that there was a problem with the reliability of the laboratory data for this round (July 1998). Quality control samples related to VOC analyses indicated possible laboratory contamination of the data set. One trip blank, IR01-TB01-98C, was prepared prior to the sampling event and was kept with the groundwater samples from Site 1 during field collection, shipment, and laboratory analysis. The trip blank was analyzed for VOCs and had positive detections of 1,2-dichloroethene (Total) (2.4 µg/L), methylene chloride (1.9 µg/L), tetrachloroethene (39 µg/L), and TCE (14 µg/L). Because of the compounds found in the trip blank, detections of VOCs from this round were considered unreliable.

- Boxes 11 through 16 indicate that confirmatory sampling of monitoring wells 1-MW10 and 1-MW17 continued at Site 1 with no unusual changes in the site conditions or monitoring program activities. Box 15 indicates that a detection of TCE in well 1-MW10 is not considered reliable due to a detection of TCE in the associated trip blank during the October 1999 sampling event.
- In April 2000 (Figure 3, box 17), LTM analytical data indicated a fourth consecutive round of non-detections of TCE and vinyl chloride at both monitoring wells 1-MW10 and 1-MW17. Accordingly, Site 1 had achieved the ROD specified objectives and, therefore, the site was recommended for removal from the overall monitoring program at Camp Lejeune. Confirmatory sampling continued until approval by the regulatory agencies to discontinue monitoring activities at Site 1 was granted in January 2001.

Table 3 provides analytical results through October 2000 for the confirmatory sampling at monitoring well 1-MW17. The same data is presented in a graphical format on Figure 5 for well 1-MW17. As shown, four consecutive rounds of non-detections of VOCs at 1-MW17 has been achieved and, therefore, supports the recommendation for removal of Site 1 from LTM.

Table 4 provides analytical results through October 2000 for the confirmatory sampling for monitoring well 1-MW10. The same data is presented in a graphical format on Figure 6 for well 1-MW10. As mentioned earlier, the detection of TCE at 12 µg/L in October 1999 is a result of laboratory contamination as evidenced by a TCE detection in the associated trip blank at the time of sampling. It is therefore considered a non-detection.

5.0 PROTECTIVENESS

Past investigations at Site 1 focused on the evaluation of the extent as well as the cleanup of contamination at Site 1. In addition to these efforts as mentioned above, the RI, FS, ROD, and LTM Reports were prepared to address the protectiveness of human health and the environment at Site 1.

5.1 ROD

The ROD is a decision document that establishes an agreed upon and legally binding set of conditions that Site 1 must achieve to acquire a site closure status. The ROD specifies restrictions on groundwater use within OU 7 and restricts the installation of water supply wells within a 1,000 foot radius of the OU.

5.2 Five Year Review

In 1999, the initial Five-Year Review was conducted for all sites at Camp Lejeune. The Five-Year Review is conducted in line with procedures detailed in the National Contingency Plan (NCP) and the Comprehensive Environmental Response, Compensation, and Liability Act

(CERCLA) of 1980. A Five -Year Review is required for a CERCLA site if: 1) a remedial action results in hazardous substances, pollutants, or contaminants remaining at a site; or 2) the ROD was signed on or after October 17, 1986. This document was submitted to, reviewed, and approved by the USEPA and NC DENR. The Final Five-Year Review can be referenced as part of the Administrative Record for Camp Lejeune.

5.3 Site 1 Closure

Site 1 has achieved the remedial goals as set forth in the previously mentioned documents and, through LTM, meets the requirements for site closure. Four consecutive rounds of data collection through LTM indicate non-detections of contaminants at the monitoring wells and in some instances, greater than four consecutive rounds.

6.0 REGULATORY AGENCY

The USEPA and NC DENR have been actively involved with the investigation processes of Site 1. These agencies are members of the Camp Lejeune Partnering Team, which review the monitoring reports, discuss the proposed recommended items, and provide direction for future activities.

7.0 CONCLUSION

Serving as the final LTM report for Site 1, there will be no future activities associated with this site.

8.0 REFERENCES

Baker Environmental, Inc. (Baker). June 1995. Remedial Investigation Report, Operable Unit No. 7 (Sites 1 and 28). Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). July 1995. Final Feasibility Study Report, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996. Work Plans for Long Term Monitoring OU No. 7. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). May 1996. Final Record of Decision, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996 to 2001. Long Term Monitoring Report, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Environmental Science and Engineering (ESE). September, 1990. Site Summary Report Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command. ESE Project No. 49-02036.

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

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TABLES

TABLE 1
REMEDIAL INVESTIGATION GROUNDWATER DATA SUMMARY
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well/Volatile Compound	(Round 1) May 1994	(Round 2) December 1994
<i>1-GW10</i>		
Vinyl Chloride	2	4
1,2-Dichloroethene (Total)	10	21
1,1-Dichloroethene (Total)	ND	2
Trichloroethene	4	8
<i>1-GW11</i>		
Trichloroethene	1	ND
<i>1-GW12</i>		
Xylenes	3	9
<i>1-GW17</i>		
1,2-Dichloroethene (Total)	1	ND
Trichloroethene	27	18

Notes:

All concentrations are presented in micrograms per liter ($\mu\text{g/L}$)
 Two rounds of groundwater samples were collected during the RI
 ND = Not Detected

TABLE 2
TCE AND VINYL CHLORIDE IN GROUNDWATER
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	Jan 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998
		NCWQS	MCL	ROD					
1-MW10	Trichloroethene	2.8	5	2.8	ND	ND	ND	1.6 J	3.1 J
	Vinyl Chloride	0.015	2	NE	ND	3 J	ND	ND	ND

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	Jan 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998
		NCWQS	MCL	ROD					
1-MW17	Trichloroethene	2.8	5	2.8	ND	3 J	ND	3.6 J	0.73 J
	Vinyl Chloride	0.015	2	NE	ND	ND	ND	ND	ND

Notes:

All concentrations are presented in micrograms per liter (µg/L)

(1) = Confirmatory Sampling Begins.

ND = Not Detected

NE = Not Established

J = Estimated Concentration

NCWQS = North Carolina Water Quality Standard 2L

MCL = United States Environmental Protection Agency, Maximum Contaminant Level.

ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).

 = Shading indicates that a concentration is above the screening criteria.

TABLE 3
TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW17
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	January 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998	Oct 1998	Jan 1999	Apr 1999	Four Rounds of ROD Levels Achieved				
		NCWQS	MCL	ROD									July 1999	Oct 1999	Jan 2000	April 2000	October 2000
1-MW17	Trichloroethene	2.8	5	2.8	ND	3 J	ND	3.6 J	0.73 J	2	ND	4 J	ND	ND	ND	ND	ND
	Vinyl Chloride	0.015	2	NE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

All concentrations are presented in micrograms per liter (µg/L)

- (1) = Confirmatory Sampling Begins.
- ND = Not Detected
- NE = Not Established
- J = Estimated Concentration
- NCWQS = North Carolina Water Quality Standard 2L
- MCL = United States Environmental Protection Agency, Maximum Contaminant Level.
- ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).
- = Shading indicates that a concentration is above the screening criteria.

TABLE 4
TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW10
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Volatile	Comparison Criteria			July 1996	January 1997	July 1997	Jan ⁽¹⁾ 1998	July 1998	Oct 1998	Jan 1999	Apr 1999	July 1999	Four Rounds of ROD Levels Achieved			
		NCWQS	MCL	ROD										Oct 1999	Jan 2000	April 2000	October 2000
1-MW10	Trichloroethene	2.8	5	2.8	ND	ND	ND	1.6 J	3.1 J	2 J	ND	2 J	ND	12*	ND	ND	ND
	Vinyl Chloride	0.015	2	NE	ND	3 J	ND	ND	ND	2 J	ND	1 J	1 J	ND	ND	ND	ND

Notes:

All concentrations are presented in micrograms per liter ($\mu\text{g/L}$)

(1) = Confirmatory Sampling Begins.

ND = Not Detected

NE = Not Established

J = Estimated Concentration

NCWQS = North Carolina Water Quality Standard 2L

MCL = United States Environmental Protection Agency, Maximum Contaminant Level.

ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).

 = Shading indicates that a concentration is above the screening criteria.

* = The detection of TCE at 12 $\mu\text{g/L}$ in October 1999 is a result of laboratory contamination as evidenced by a vinyl chloride detection in the associated trip blank at the time of sampling. It is therefore considered a non-detection.

Baker

Baker Environmental, Inc.

FIGURES

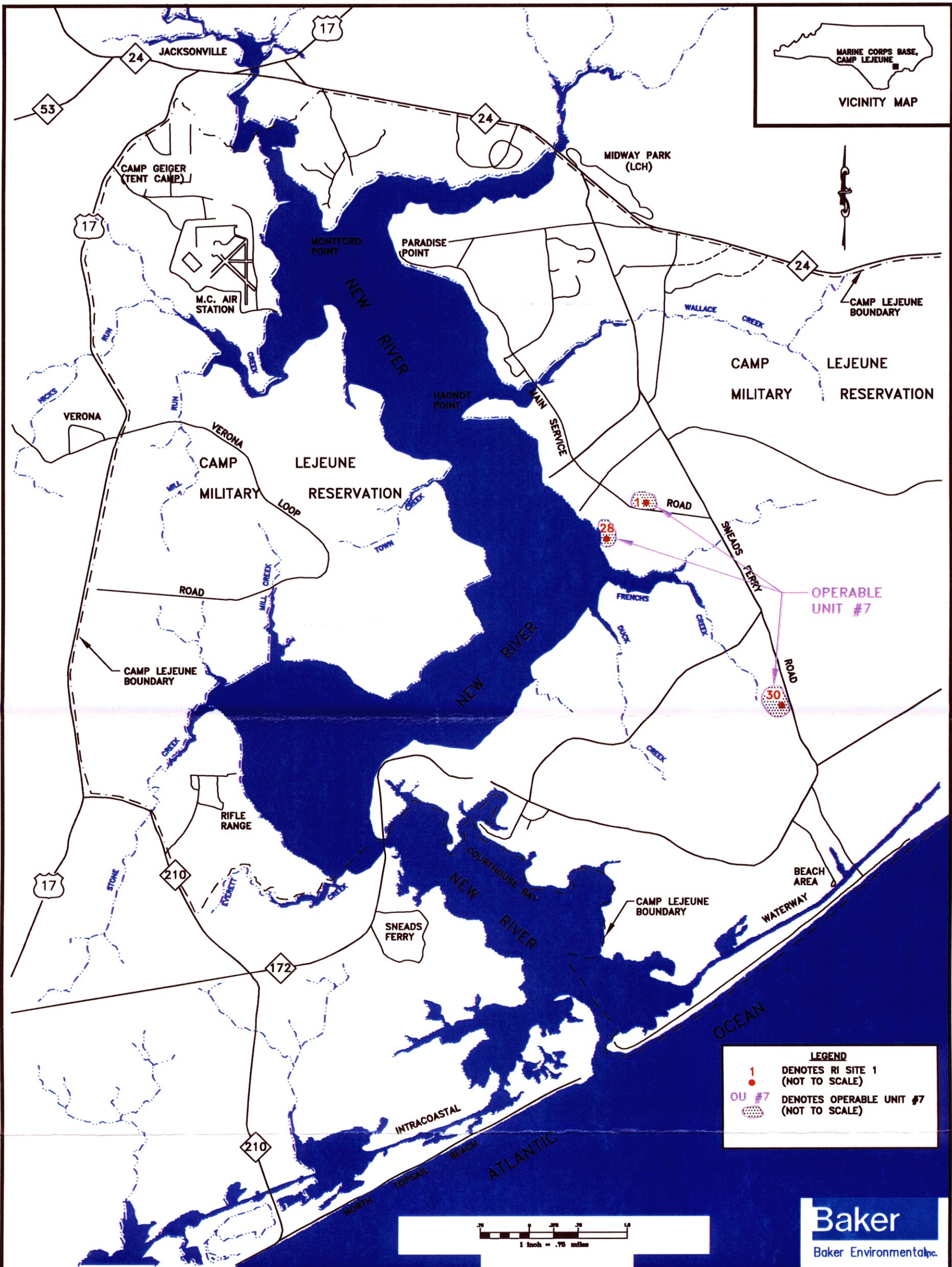
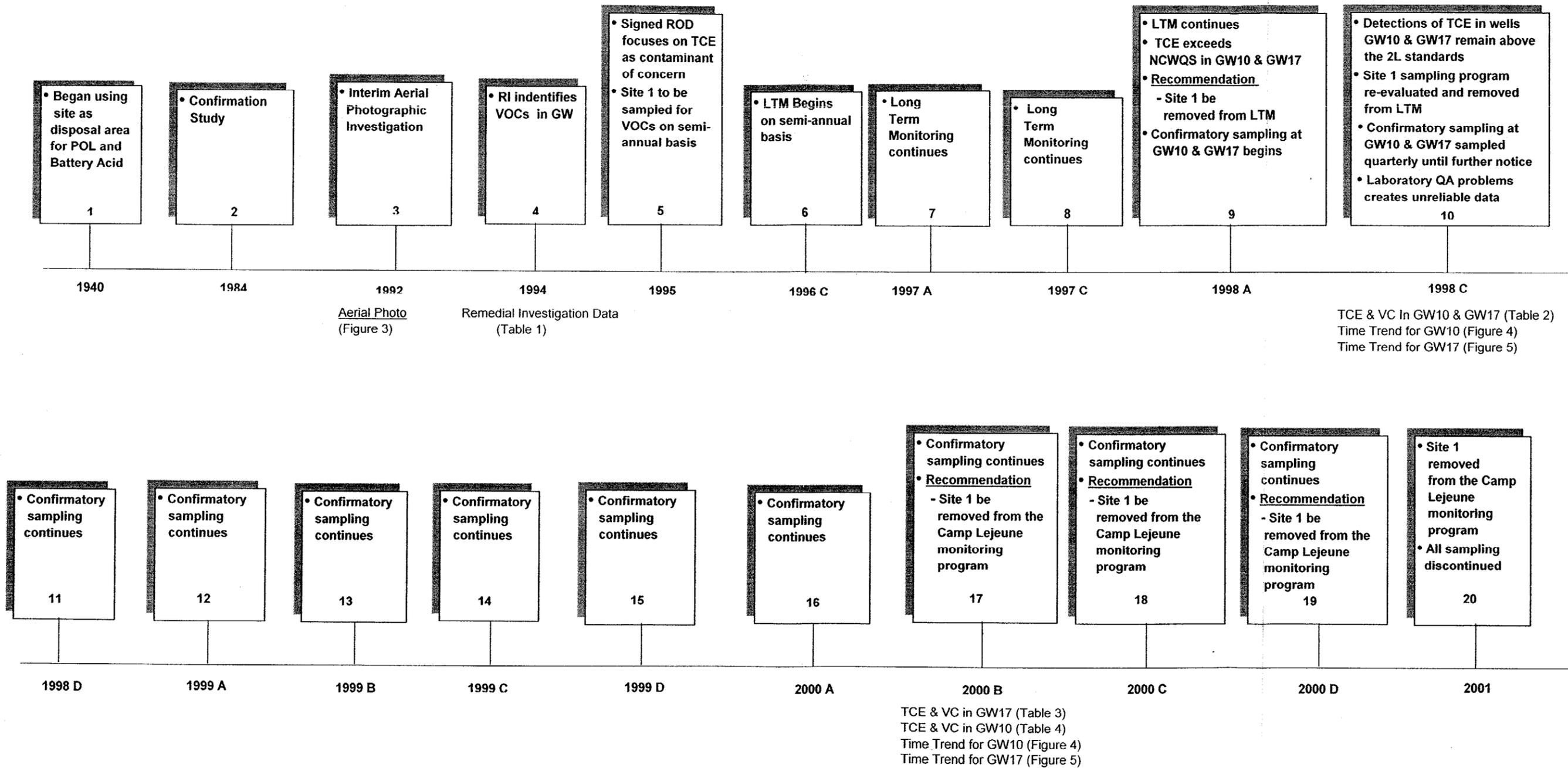


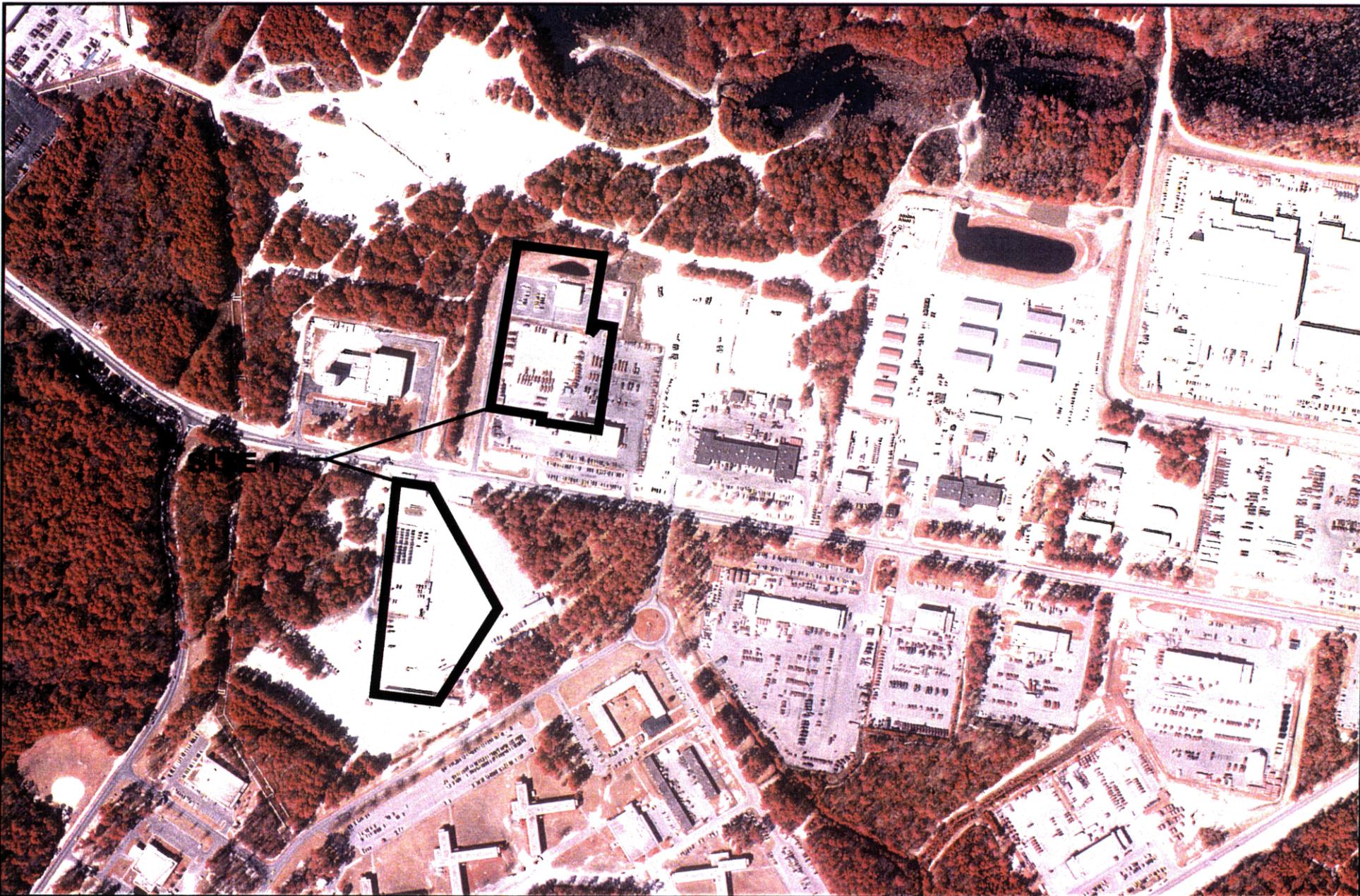
FIGURE 1
 OPERABLE UNIT AND SITE LOCATION MAP
 OPERABLE UNIT NO.7 -SITES 1, 28, AND 30
 FINAL LTM REPORT, CTO-0120

MARINE CORPS BASE, CAMP LEJEUNE
 NORTH CAROLINA

**FIGURE 3
SITE ACTIVITIES TIMELINE
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO-120
MCB, CAMP LEJEUNE, NORTH CAROLINA**



Notes:
A = 1st quarter of calendar year
B = 2nd quarter of calendar year
C = 3rd quarter of calendar year
D = 4th quarter of calendar year

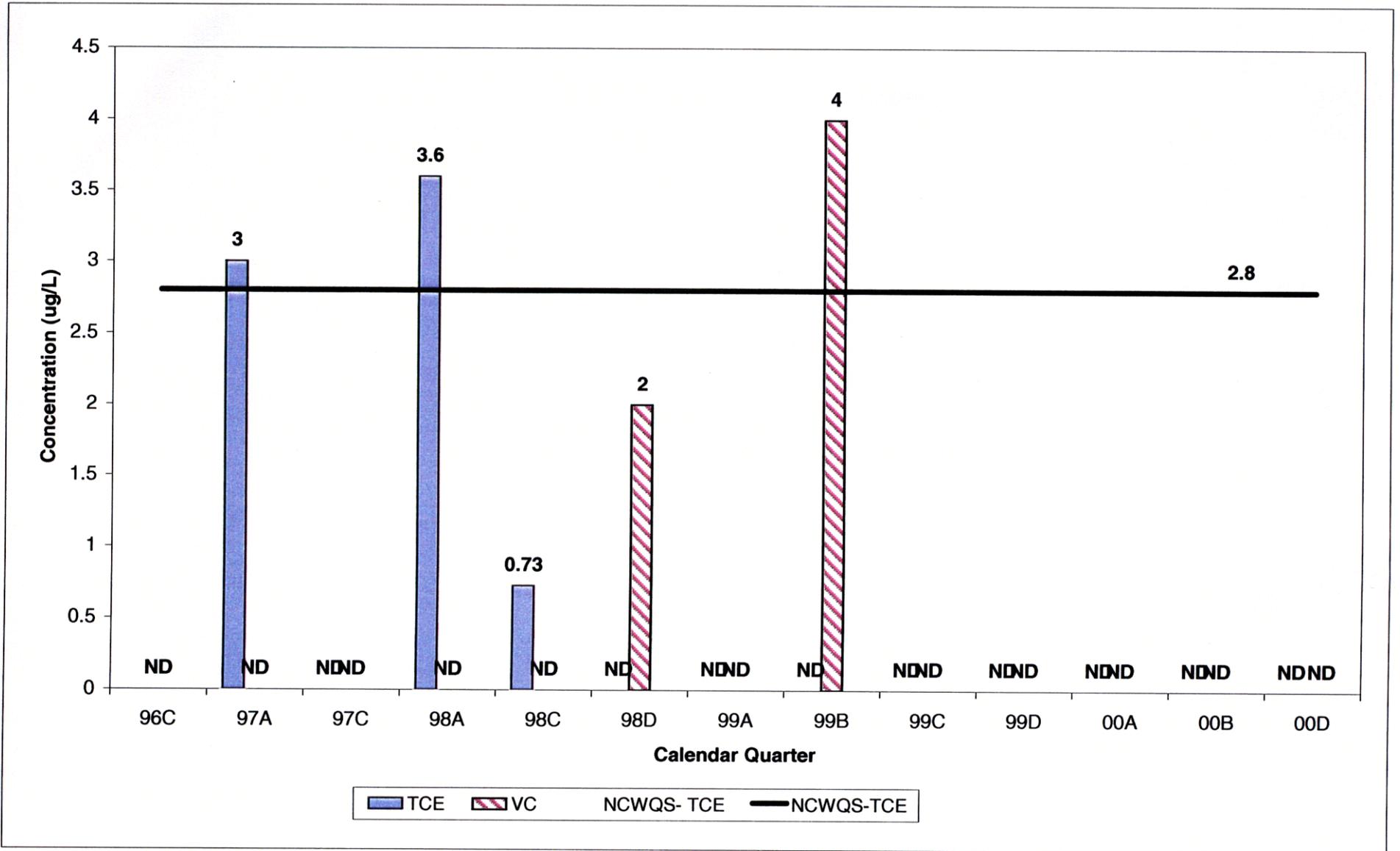


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DSN/DWN: CHK:
SOURCE: IGIR - DATA CATALOG

site 1\
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Baker Environmental
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CORAOPOLIS, PENNSYLVANIA

FIGURE 4
AERIAL PHOTOGRAPH
OPERABLE UNIT NO.7 - SITE 1
FINAL CLOSE OUT REPORT, CTO-0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

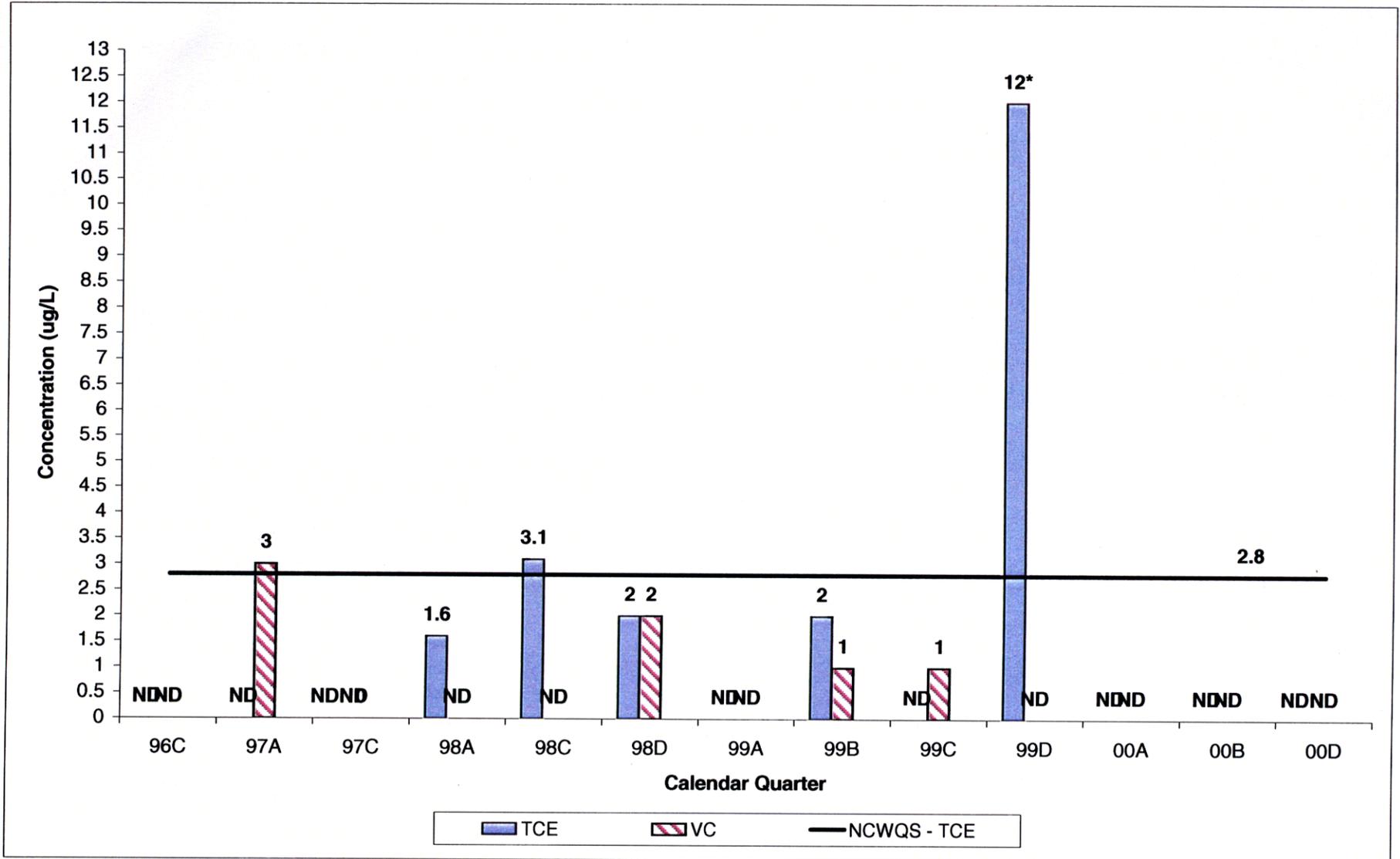
FIG 5
TIME TREND OF TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW17
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA



Note:

NCWQS for Vinyl Chloride is 0.015 ug/L
 ND = Not Detected

FIG. 6
TIME TREND OF TCE AND VINYL CHLORIDE IN MONITORING WELL 1-MW10
OPERABLE UNIT NO. 7 - SITE 1
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA



Note:

NCWQS for Vinyl Chloride is 0.015 ug/L

ND = Not Detected

* = The detection of TCE at 12 ug/L in October 1999 is a result of laboratory contamination as evidenced by a TCE detection in the associated trip blank at the time of sampling. It is therefore considered a non-detection.

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ATTACHMENT B

Site 28 Final LTM Report

FINAL LONG TERM MONITORING REPORT

**OPERABLE UNIT NO. 7 – SITE 28
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA**

JANUARY 21, 2002

CONTRACT TASK ORDER 0120

Prepared for:

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

Under the:

**LANTDIV CLEAN II Program
Contract N62470-95-D-6007**

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*Coraopolis, Pennsylvania***

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ATTACHMENTS

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D	Evaluation of Lead at Site 28 Report, November, 2001

1.0 INTRODUCTION

This document provides the Final Long Term Monitoring (LTM) Report for Site 28, the Hadnot Point Burn Dump. Site 28 has completed the necessary requirements for no further LTM actions as stipulated in the Final Record of Decision (ROD). This Final LTM Report is being prepared as an attachment to the Final Closeout Report (FCOR) for Operable Unit (OU) 7.

2.0 SUMMARY OF SITE CONDITIONS

Site 28, along with Sites 1 and 30, comprise OU 7 at Marine Corps Base (MCB) Camp Lejeune, North Carolina. The site is located on the eastern bank of the New River. This site is within the Hadnot Point development area, approximately one mile south of Hadnot Point Industrial Area (HPIA) on the Mainside portion of MCB, Camp Lejeune (Figure 1). Figure 2 presents a map of Site 28. As shown, Codgels Creek flows into the New River at Site 28 and forms a natural divide between the eastern and western portions of the site.

Site 28 operated from 1946 to 1971 as a burn area for a variety of solid wastes. Reportedly, industrial waste, trash, oil-based paint, and construction debris were burned then covered with soil. In 1971, the burn dump ceased operations, was graded, and seeded with grass. The total volume of fill covering Site 28 is estimated to be between 185,000 and 375,000 cubic yards, based upon a surface area of 23 acres and a depth ranging from five to ten feet [Water and Air Research (WAR), 1983]. Currently, a majority of the estimated 23 acres that constitute Site 28 are used for recreation and physical training exercises. Picnic pavilions and playground equipment are located within this recreation area, primarily on the western portion of the site.

3.0 PROCEDURES

The LTM program for Site 28 consisted of field activities and data reporting. The field activities included sample collection and field observations, while the data reporting was comprised of data management and evaluation. Sampling activities were conducted and subsequent laboratory analyses were performed according to procedures and methods specified in the Long Term Monitoring Work Plans for OU 7 [Baker Environmental, Inc. (Baker, 1996)]. The project work plans identify specific tasks associated with the monitoring activities conducted at Site 28.

4.0 INVESTIGATIVE ACTIVITIES AND REMEDIAL GOALS

The conditions at Site 28 have been evaluated through several separate investigative activities, including a monitoring program. A chronological account of these investigative activities for Site 28 is presented on the Site Activities Timeline in Figure 3. This timeline provides milestones reached during the seven years of activity conducted at Site 28. Relevant information associated with specific events are cross-referenced as data tables or graphs and are presented with this report. The following subsections provide a summary of the previous studies completed at the site along with the results of the LTM program.

Investigative activities for OU 7 began in 1983 with an Initial Assessment Study (IAS) conducted by WAR (WAR, April 1983) along with other areas on the Base. Site 28 was identified as one of the ten sites on Base that required further investigative studies. A two-part Confirmation Study (CS) was conducted by Environmental Science and Engineering, Inc. (ESE) from 1984 through 1987 (ESE, September 1990). The purpose of the CS was to investigate potential contaminant source areas identified in the IAS report. Site 28 was evaluated and consequently was determined to warrant further investigation.

In addition to the IAS, aerial photographic analysis addressed site operations between 1938 and 1990, and an interim report was completed in August 1992 (Figure 3, box 3 on the Timeline). A recent aerial photograph of Site 28 with superimposed site boundaries is provided on Figure 4.

4.1 Remedial Investigation

In 1994 a Remedial Investigation (RI) was completed by Baker (Baker, June 1995) for Site 28. As part of the RI at Site 28, soil, groundwater, surface water, sediment, and aquatic investigations were conducted. The information gathered during these investigations was intended to fill previously existing data gaps identified during the CS and to generate information for assessing human health and ecological risks. Remedial alternatives for groundwater were evaluated during preparation of the Feasibility Study (FS) (Baker, July 1995). Table 1 provides an abbreviated summary of the groundwater analytical results for contaminants of concern at the completion of the RI in 1994 (Figure 3, box 4).

4.2 Record of Decision

As stipulated in the final ROD signed for OU 7 in 1995, the primary objective of the remedial action at Site 28 is to address lead and manganese contamination in the shallow groundwater aquifer (Baker, May 1996). The ROD identifies the implementation of a LTM program as the selected remedy for groundwater. VOC, lead and manganese analysis was required by the ROD with lead and manganese being specifically mentioned with a 15 micrograms per liter ($\mu\text{g/L}$) and 50 $\mu\text{g/L}$ remedial level goal, respectively. The ROD states that it does not expect the remediation level of manganese to be achieved due to the natural occurrence of high levels of this inorganic.

4.3 Long Term Monitoring Program

The timeline on Figure 3 illustrates the evolution of the monitoring program over time. The LTM program began at Site 28 in July 1996 (Figure 3, box 6) and initially included the sampling of seven monitoring wells on a semi-annual basis. Monitoring reports have been prepared after each sampling event that track and document the progression of the LTM program over time (Baker, 1996 through 2001). Figure 2 shows all LTM sampling locations at Site 28. Table 2 provides a time trend of lead and manganese data since the beginning of the LTM program for three monitoring wells at Site 28. The following provides clarifications of the LTM sequence shown on Figure 3, and supporting evidence that the remedial goals have been achieved:

- Boxes 7 and 8 indicate that LTM sampling continued at Site 28 with no unusual changes in the site conditions or monitoring program activities.
- Box 9 indicates that LTM sampling continues and metals concentrations remain high in three of the original seven monitoring included in the monitoring program. These high detections are infrequent and the possibility that they are naturally occurring is introduced for the first time as a rationale that the ROD metals requirements may never be achieved. Based on this assumption, it is recommended that Site 28 be removed from LTM.
- Box 10 indicates that Site 28 was re-evaluated and removed from LTM, but that three monitoring wells, 28-MW01, 28-MW02 and 28-MW07, should be further monitored for confirmatory purposes. Confirmatory sampling at this site was documented in the meeting minutes (November, 1997) for the Camp Lejeune Partnering Team that include representatives from the Base, United States Environmental Protection Agency (USEPA),

North Carolina Department of Environmental Protection (NC DENR), and the Atlantic Division Naval Facilities Engineering Command (LANTIDV). Confirmatory sampling is also documented in the LTM Report for OU 7 (Baker, July 1998).

- Boxes 11 through 13 indicate that quarterly confirmatory sampling of monitoring wells 28-MW01, 28-MW02 and 28-MW07 continued at Site 28 with no unusual changes in the site conditions or monitoring program activities.
- Box 14 indicates that monitoring wells 28-MW01 and 28-MW02 were removed from the monitoring program. Both wells had detected lead under the ROD level of 15 µg/L since the beginning of the LTM program (ten consecutive quarters). Manganese was not under the ROD level of 50 µg/L, but as stated in the ROD manganese is naturally occurring on the coastal plane of North Carolina and was not expected to drop below 50 µg/L in any of the monitoring wells. Monitoring well 28-MW07 will only be sampled and analyzed for lead. Table 2 provides a time trend of lead and manganese data since the beginning of the LTM program in the three monitoring wells at Site 28.
- Boxes 15 through 17 indicate that quarterly confirmatory sampling of monitoring well 28-MW07 for lead continued.
- In July 2000 (Box 18), LTM analytical data suggested that Site 28 oscillating lead concentrations were due to seasonal and groundwater fluctuations and has met the ROD specified and therefore, the site was recommended for removal from the overall monitoring program at Camp Lejeune. Refer to Attachment C of the FCOR for an evaluation of lead at Site 28. With an official directive pending, confirmatory sampling continued until an approval by the regulators to discontinue monitoring activities at Site 28.
- Boxes 19 and 20 indicate that quarterly confirmatory sampling of monitoring well 28-MW07 for lead continued.
- In April 2001 (box 21), LANTDIV directed that the site be further evaluated for lead and a monitoring well be installed. Monitoring well 28-MW09 was installed during late April 2001 and sampled during July 2001, and subsequently did not detect lead.
- In October 2001 (box 23), Site 28 was recommended for removal from LTM and site closure after multiple rounds of data at 28-MW07 showed lead to increase and decrease seasonally. Research into the soil and groundwater in this area indicate that monitoring well 28-MW07 is screened in peat, which is lowering the pH and is contributing to the leaching of lead. It is believed that because the well is over two-thirds screened in peat, the organic material is keeping the pH in the groundwater at a level below neutral. Because lead solubility increases with decreasing pH, the lead is more inclined to dissolve into the groundwater in this acidic environment. The lead is leaching during periods of high groundwater elevations and it is believed that this cycle will continue indefinitely. Refer to Attachments C and D of the FCOR for evaluations of lead performed at Site 28. Refer to Table 2 and Figure 5 for a time trend of lead data at monitoring well 28-MW07 since the inception of the LTM program. Monitoring well 28-MW09 did not detect lead during the three quarters it was sampled.

5.0 PROTECTIVENESS

Past investigations at Site 28 focused on the evaluation of the extent as well as the cleanup of contamination. In addition to these efforts as mentioned above the RI, FS, ROD and LTM reports were prepared to address the protectiveness of human health and the environment at Site 28.

5.1 ROD

The ROD is a decision document that establishes an agreed upon and legally binding set of conditions that Site 28 must achieve to acquire a "site closure" status. The ROD specifies restrictions on groundwater use within OU 7 and restricts the installation of water supply wells within a 1,000 foot radius of the OU.

5.2 Five Year Review

In 1999, the initial Five -Year Review was conducted for all sites at Camp Lejeune. The Five -Year Review is conducted in line with procedures detailed in the National Contingency Plan (NCP) and the Compliance Environmental Responsibility Compensation Liabilities Act (CERCLA). A Five -Year Review is required for a CERCLA site if: 1) a remedial action results in hazardous substances, pollutants, or contaminants remaining at a site; or 2) the ROD was signed on or after October 17, 1986. This document was submitted to, reviewed, and approved by the USEPA and NC DENR. The Five -Year Review Report can be referenced as part of the Administrative Record for Camp Lejeune.

5.3 Site 28 Closure and Lead Investigations

In addition to the previously mentioned investigations including the RI and LTM, further research was conducted at Site 28 into the oscillating levels of lead detected during LTM. Refer to Attachments C and D of the FCOR for two evaluations of lead at Site 28 conducted by Baker. These evaluations explain the fluctuating lead concentrations in monitoring well 28-MW07. The lead fluctuations are due to a number of factors, mainly that monitoring well 28-MW07 is screened in peat. The peat is lowering the pH and is contributing to the leaching of lead. Organic matter such as peat tends to bind up the inorganics. The inorganics are leaching during periods of high groundwater elevations and it is believed that this cycle will continue indefinitely.

6.0 REGULATORY AGENCY

The USEPA and NC DENR have been actively involved with the investigation processes of Site 28. These agencies are members of the Camp Lejeune Partnering Team, which review the monitoring reports, discuss the proposed recommended items, and provide direction for future activities.

7.0 REFERENCES

Baker Environmental, Inc. (Baker). June 1995. Remedial Investigation Report, Operable Unit No. 7 (Sites 1 and 28). Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). July 1995. Final Feasibility Study Report, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the

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

Baker Environmental, Inc. (Baker). May 1996. Final Record of Decision, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996 to 2001. Long Term Monitoring Report, Operable Unit Number 7 – Sites 1 and 28. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Baker Environmental, Inc. (Baker). 1996. Work Plans for Long Term Monitoring OU No. 7. Marine Corps Base, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Environmental Science and Engineering (ESE). September, 1990. Site Summary Report Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy Atlantic Division, Naval Facilities Engineering Command. ESE Project No. 49-02036.

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

Baker

Baker Environmental, Inc.
TABLES

TABLE 1
REMEDIAL INVESTIGATION GROUNDWATER DATA SUMMARY
OPERABLE UNIT NO. 7 - SITE 28
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well/Inorganic	Round 1 (May 1994)	Round 2 (November 1994)
<i>28-MW01</i>		
Lead	114	ND
Manganese	186	225
<i>28-MW02</i>		
Lead	449	ND
Manganese	ND	185
<i>28-MW07</i>		
Lead	4810	8.2
Manganese	3330	694

Notes:

All concentrations are presented in micrograms per liter ($\mu\text{g/L}$)

Two rounds of groundwater samples were collected during the RI

ND = Not Detected

TABLE 2
LEAD AND MANGANESE IN GROUNDWATER
OPERABLE UNIT NO. 7 - SITE 28
FINAL LTM REPORT, CTO - 0120
MCB, CAMP LEJEUNE, NORTH CAROLINA

Monitoring Well ID	Lead Comparison Criteria			July 1996	Feb 1997	Aug 1997	Jan 1998	July 1998 (1)	Oct 1998	Jan 1999	April 1999	July 1999	Oct 1999 (2)	Jan 2000	April 2000	July 2000	Oct 2000	Jan 2001	April 2001	July 2001	Oct 2001		
	NCWQS	MCL	ROD																				
28-GW01	15	15	15	4.9	1.6	ND	ND	ND	2.9B	ND	2.6B	2.9B	NS	NS	NS	NS	NS	NS	NS	NS	NS		
28-GW02				4.9	ND	ND	ND	ND	ND	ND	ND	ND	1.6B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
28-GW07				12.4	6.8	30.6	ND	65	32.5	1B	6.6	34.2	17	4.5	8.7	4.5	41.7	ND	8.3	47.8	131		
28-GW09				NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND

Monitoring Well ID	Manganese Comparison Criteria			July 1996	Feb 1997	Aug 1997	Jan 1998	July 1998 (1)	Oct 1998	Jan 1999	April 1999	July 1999	Oct 1999 (2)
	NCWQS	MCL	ROD										
28-GW01	50	NE	50	250	214	66.2	113	114	195	83.2	83.8	72.8	NA
28-GW02				174	185	196	197	204	181	184	169	179	NS
28-GW07				860	460	906	1270	798	787	497	706	740	NS

Notes:

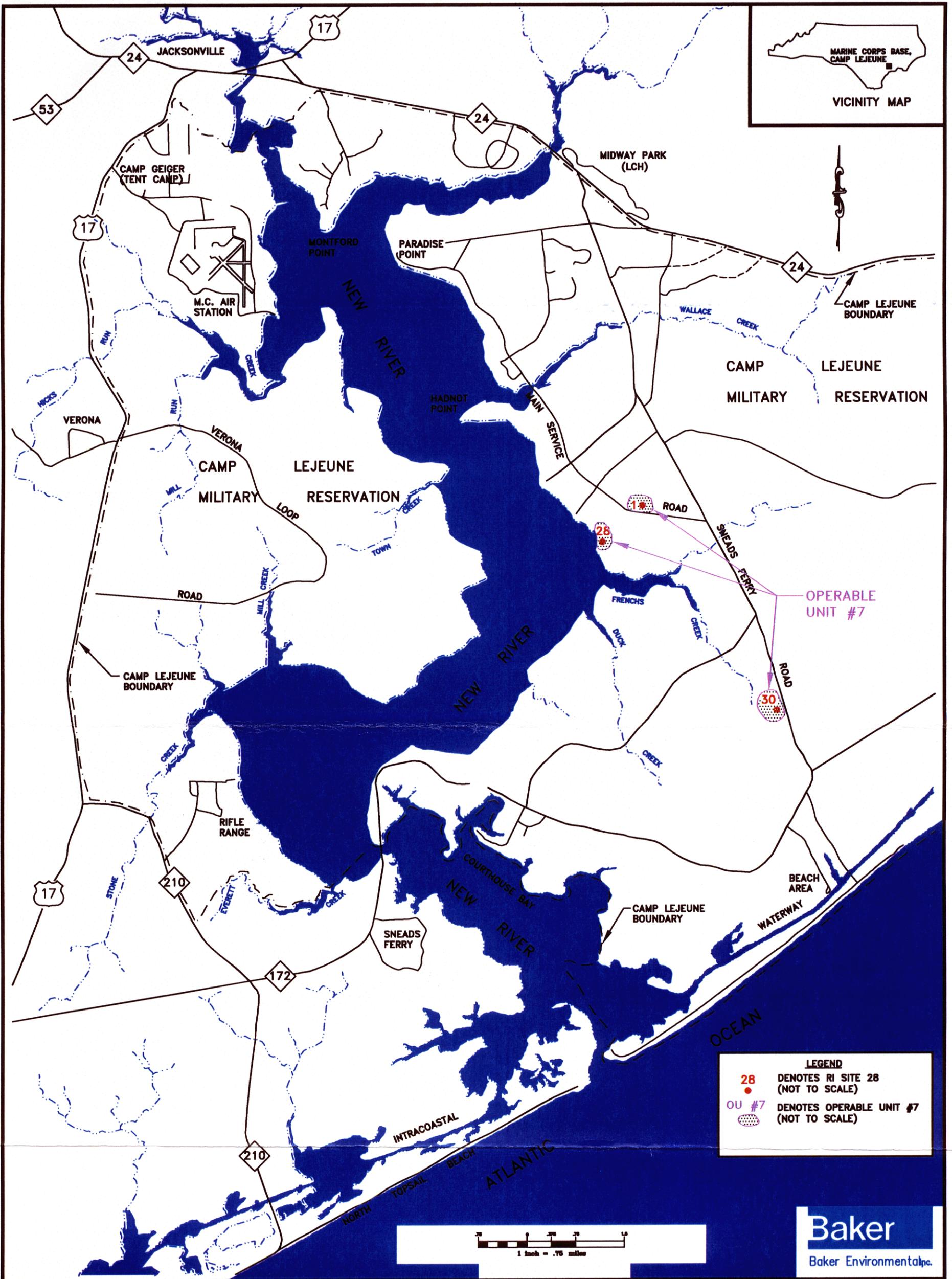
All concentrations are presented in micrograms per liter ($\mu\text{g/L}$).

- (1) = Confirmatory Sampling Begins.
- (2) = Sampling was discontinued at monitoring wells 28-GW01 and 28-GW02, manganese was also discontinued for analyzation
- B = Reported value is < CRDL, but >IDL.
- NA = Not Applicable
- ND = Not Detected
- NS = Not Sampled
- NE = Not Established
- NCWQS = North Carolina Water Quality Standard, 2L.
- MCL = United States Environmental Protection Agency, Maximum Contaminant Level.
- ROD = Record of Decision for Operable Unit No. 7 - Sites 1 and 28 (Baker, May 1996).
- = Shading indicates that a concentration is above the comparison criteria.

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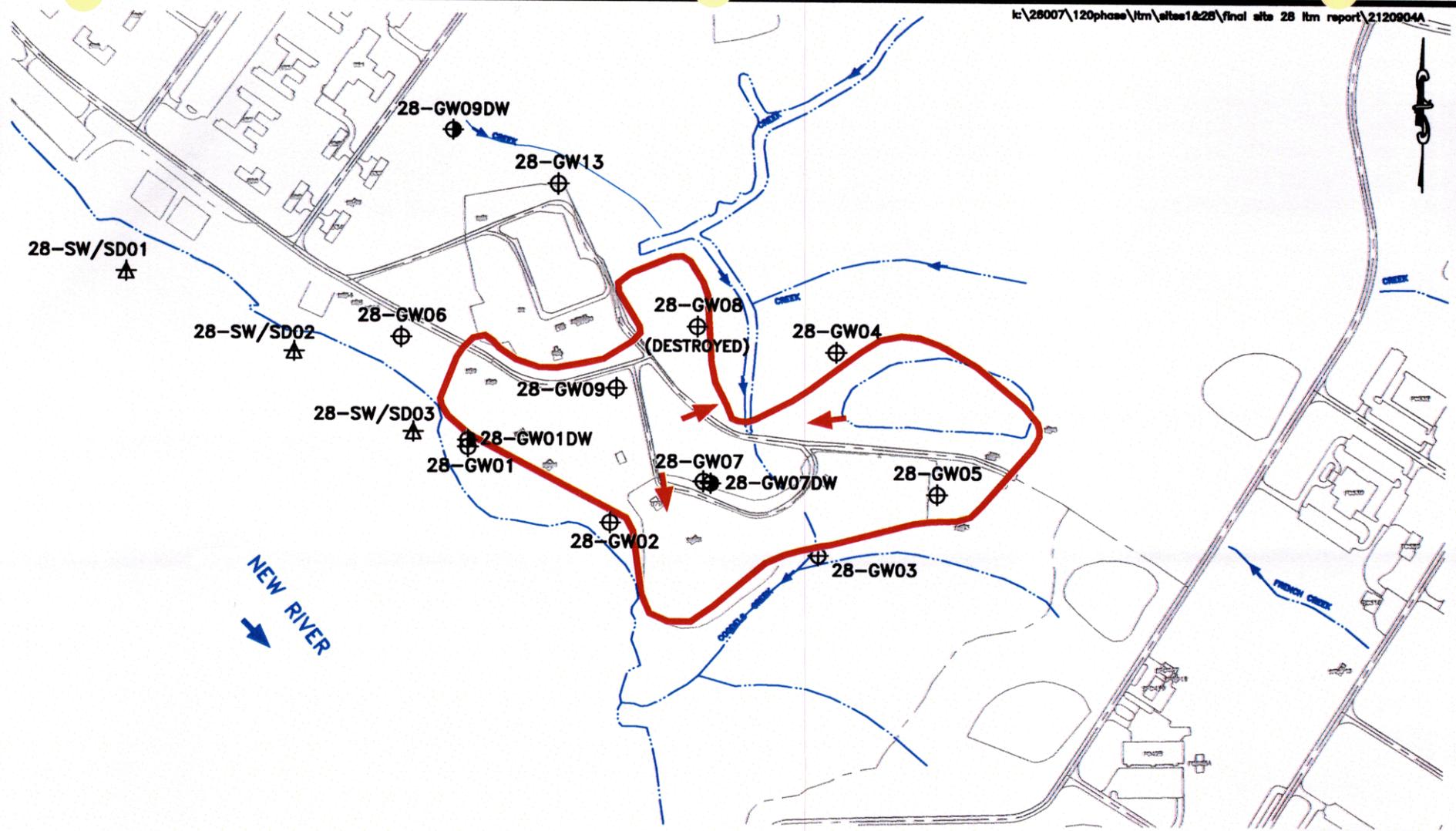
Baker Environmental, Inc.

FIGURES



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FIGURE 1
 OPERABLE UNIT AND SITE LOCATION MAP
 OPERABLE UNIT NO.7 -SITES 1, 28, AND 30
 FINAL LTM REPORT, CTO-0120
 MARINE CORPS BASE, CAMP LEJEUNE
 NORTH CAROLINA

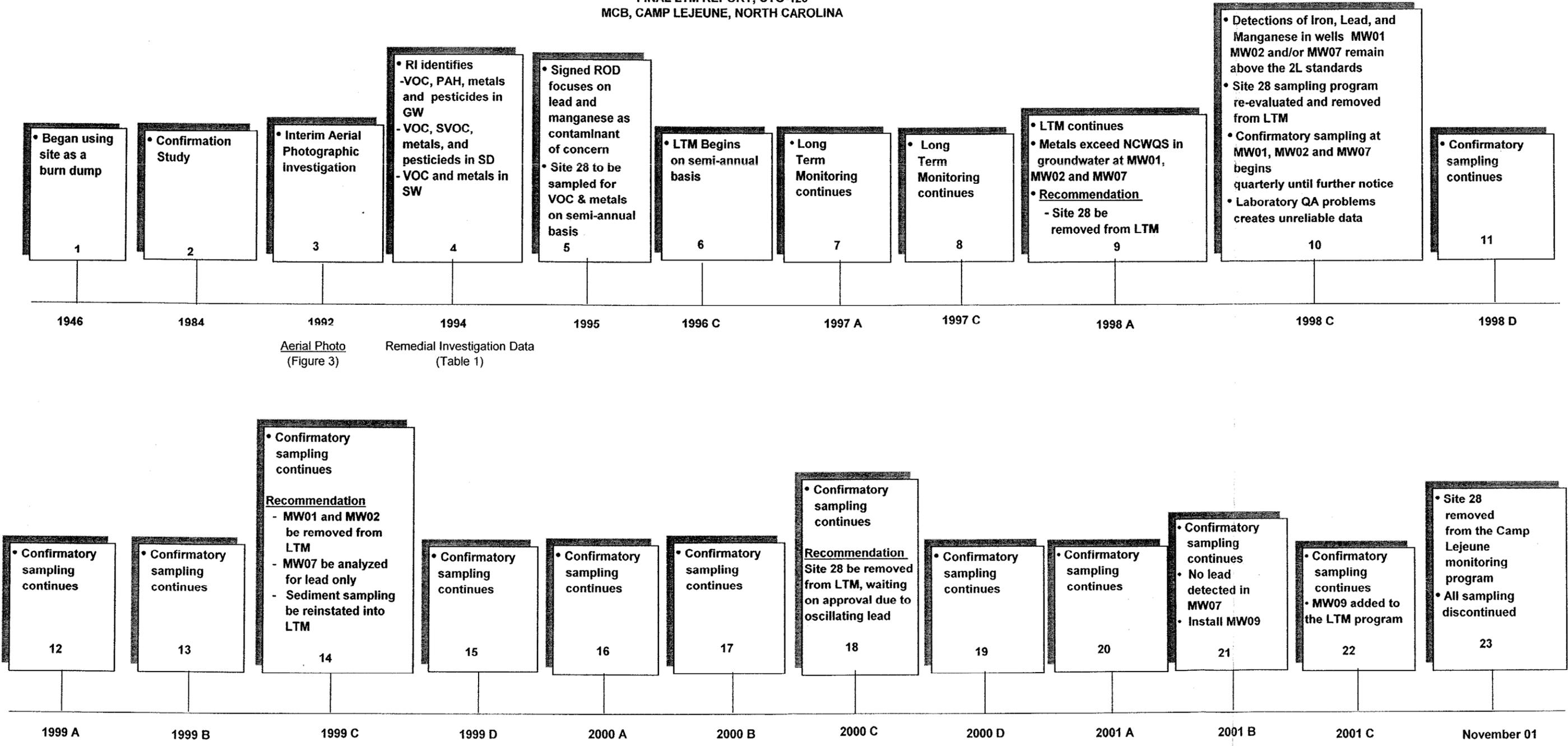


LEGEND	
28-GW01 ⊕	- SHALLOW MONITORING WELL
28-GW01DW ⊗	- DEEP MONITORING WELL
28-SW/SD01 ▲	- SURFACE WATER/SEDIMENT SAMPLE
→ (blue)	- DIRECTION OF SURFACE WATER FLOW
→ (red)	- APPROXIMATE DIRECTION OF GROUNDWATER FLOW
— (red)	- SITE 28 BOUNDARY

FIGURE 2
SITE 28 SAMPLING LOCATION MAP
OPERABLE UNIT NO. 7 – SITE 28
FINAL LTM REPORT, CTO – 0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE:
MCB, CAMP LEJEUNE MARCH 2000

**FIGURE 3
SITE ACTIVITIES TIMELINE
OPERABLE UNIT NO. 7 - SITE 28
FINAL LTM REPORT, CTO-120
MCB, CAMP LEJEUNE, NORTH CAROLINA**



Notes:
A = 1st quarter of calendar year
B = 2nd quarter of calendar year
C = 3rd quarter of calendar year
D = 4th quarter of calendar year

November 01
Time Trend of ROD Contaminants of Concern in Groundwater (Table 2)
Time Trend of Lead in Groundwater in Monitoring Well 28-MW07 (Figure 5)

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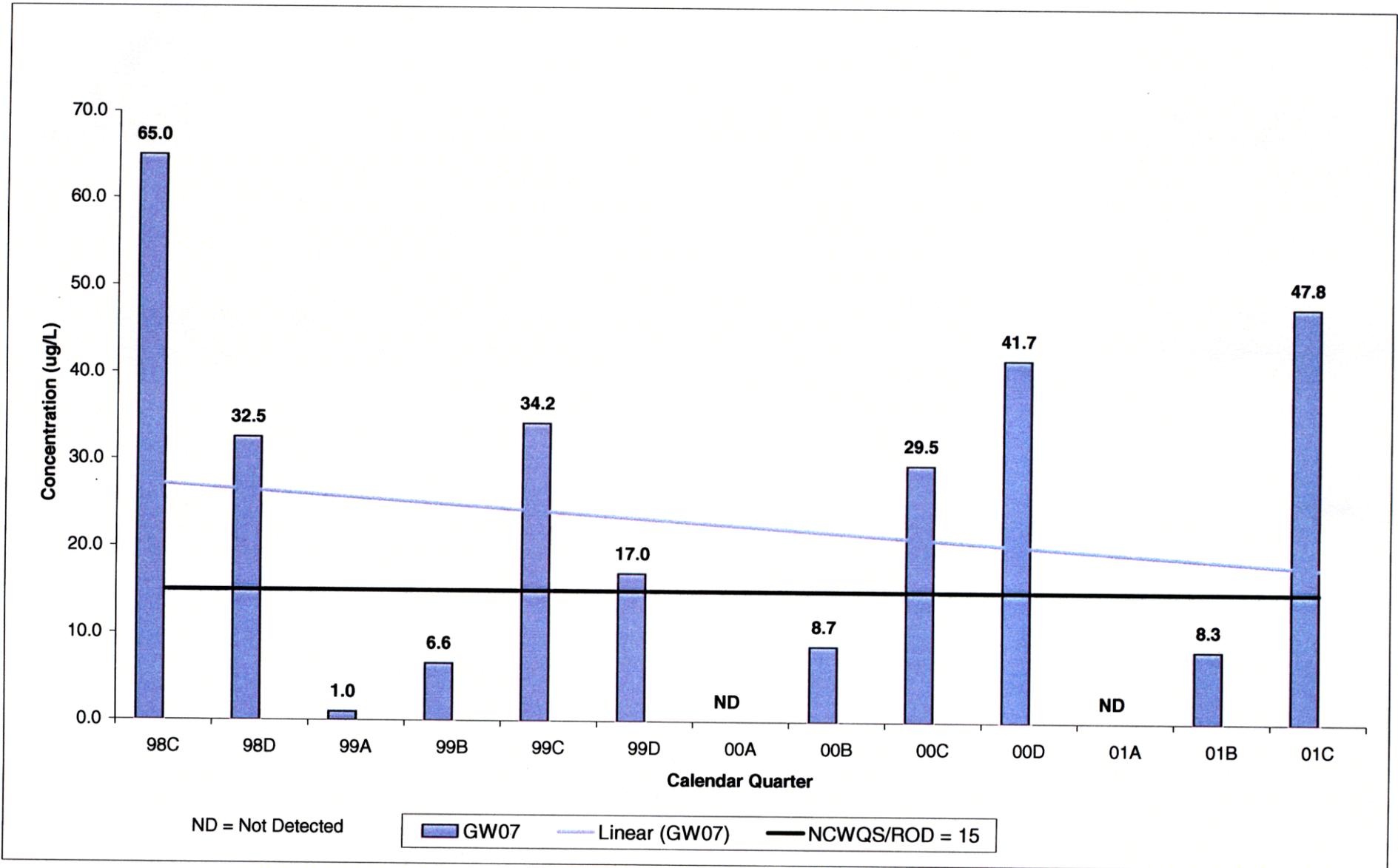
Baker
Baker Environmental

BAKER ENVIRONMENTAL, INC.
CORAOPOLIS, PENNSYLVANIA

FIGURE 4
AERIAL PHOTOGRAPH
OPERABLE UNIT NO. 7 - SITE 28
FINAL LTM REPORT, CTO-0120
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 5

TIME TREND OF LEAD IN MONITORING WELL 28-MW07
OPERABLE UNIT NO. 7- SITE 28
FINAL LTM REPORT, CTO-0120
MCB, CAMP LEJEUNE, NORTH CAROLINA



Baker

Baker Environmental, Inc.
ATTACHMENT C

Evaluation of Lead at Site 28 Report
March, 1 2001

EVALUATION OF LEAD AT SITE 28
MCB, CAMP LEJEUNE
MARCH 1, 2001
PREPARED BY BAKER ENVIRONMENTAL, INC.

1.0 INTRODUCTION

At the January 2001 Partnering Meeting, Baker Environmental, Inc. (Baker) proposed to discontinue the Long Term Monitoring (LTM) Program at Site 28 and close out the site from further Remedial Actions. This recommendation was made since only one well was actively sampled at Site 28 and the data suggested that the oscillating lead concentrations were the result of natural conditions. USEPA suggested that Baker further evaluate the lead by comparing the soil data from the RI to the LTM groundwater data to determine if a potential source of lead is contributing to the detection of lead in the groundwater. This report provides a data assessment and summary of the findings.

Operable Unit 7 (See Figure 1) at MCB, Camp Lejeune is comprised of Sites 1, 28, and 30. It is located on the eastern portion of the Base, situated between the New River and Sneads Ferry Road, south of the Hadnot Point Industrial Area. This report focuses on Site 28, also known as the Hadnot Point Burn Dump.

Since the Record of Decision (ROD) (Baker, 1996) specifying institutional controls as the remedy for Site 28, the site has fallen under the LTM Program at MCB, Camp Lejeune. There have been consistent detections of lead and manganese at the site, with lead levels appearing to fluctuate seasonally. Manganese levels are typically high at MCB, Camp Lejeune, and are not discussed here. Because the lead concentrations consistently fluctuate above the North Carolina Groundwater Protection Standard (2L) of 15 ug/L, this report was written to assess the lead issue at the site.

The report is written in six sections, including the introduction. A brief site description and history are given in Section 2. Sections 3 and 4 summarize the concentrations of the lead in the soil and in the groundwater at the site. These results were obtained from the Remedial Investigation (RI) Report (Baker, 1995), and the LTM reports (Baker, 1996 et seq.). The results

of the unsaturated and saturated groundwater flow models for future lead movement are given in Section 5, and the report is concluded in Section 6.

2.0 SITE DESCRIPTION AND HISTORY

2.1 Site Description

Site 28, the Hadnot Point Burn Dump, is located along the eastern bank of the New River. The 23-acre site is bordered to the north by an open field (formerly the Hadnot Point Sewage Treatment Plant [STP]), to the east and south by wooded areas, and to the west by the New River. Cogdels Creek flows into the New River at Site 28 and forms a natural divide between the eastern and western portions of the site. Site 28 is predominantly comprised of two lawn and recreation areas, known collectively as the Orde Pond Recreation Area, separated by Cogdels Creek. An improved gravel road serves the eastern and western portions of the site. Picnic pavilions, playground equipment, and the stocked fishpond, Orde Pond, located at the site, are regularly used by Base personnel and their families. In addition, field exercises and physical training activities frequently take place at the recreation area. Figure 2 depicts the surface features and surrounding conditions at Site 28.

2.2 Site History

Site 28 operated from 1946 to 1971 as a burn area for a variety of solid waste generated on the Base. Industrial waste, trash, oil-based paint, and construction debris were reportedly burned and subsequently covered with soil. In 1971 the burn dump ceased operations and the area was graded and seeded with grass. The total volume of fill is estimated to be between 185,000 and 375,000 cubic yards, based upon a surface area of 23 acres and a depth ranging from three to twenty-two feet (Baker, 1995). Figure 2 also depicts the locations of the two (termed "east fill area" and "west fill area") suspected burn dump areas.

In 1995 Baker conducted a RI to evaluate the nature and extent of impacted media, and to determine the threat to public health and the environment. The RI was intended to provide information to support a Feasibility Study (FS) and ROD for a final remedial action at the site. Conclusions from this report regarding Site 28 include:

- In surface and subsurface soils, copper, lead, manganese, and zinc were observed at maximum concentrations greater than two orders of magnitude above Base-specific

background levels (note that at the time of the RI, Base-specific background levels were determined through calculating averages of data collected at various IR sites);

- Metals were the most prevalent and widely distributed contaminants in groundwater at the site. Concentrations of total metals were generally higher in shallow groundwater samples than in samples collected from the underlying deeper aquifer. Lead, iron, and manganese were the most prevalent metals detected; and
- The risk assessment done using the USEPA's Uptake/Biokinetic (UBK) lead model indicated that exposure to surface soil, subsurface soil and groundwater at this site generated acceptable blood lead levels in children.

The RI also reported concentrations of lead in the surface waters and sediment in the New River adjacent to Site 28.

2.3 Geology and Hydrogeology

The shallow soils (less than 30 feet) underlying Site 28 consist of predominantly charred fill material/debris, sand, and silty-sand, with minor amounts of silt and clay. Geologic cross sections depicting the shallow and deep soil conditions across Site 28 are available in the RI Report (Baker, 1995).

The hydrogeologic setting in the vicinity of Site 28 consists of several aquifer systems; however, only the two uppermost systems are discussed here. The upper surficial aquifer lies within the "undifferentiated" deposits of sand, silt, and clay. The thickness of the upper surficial aquifer is approximately 40 feet. The underlying Castle Hayne aquifer consists of sand, silty clay, and shell hash. There does not appear to be a significant hydraulic separation of the aquifers at Site 28. During the RI, the apparent hydraulic gradient of 0.004 in the upper surficial aquifer was toward Cogdels Creek. The hydraulic gradient in the Castle Hayne formation was 0.0013 in the direction of the New River.

Groundwater flow velocity within the surficial aquifer was estimated to be 4.1×10^{-2} feet/day or 15 feet/year using Darcy's equation. An average hydraulic conductivity of 3.1 ft/day (Baker, 1992), porosity of 0.3 and the 0.004 hydraulic gradient value were used in this calculation.

3.0 LEAD IN SURFACE AND SUBSURFACE SOILS

During the RI, a total of 47 borings were advanced to assess suspected disposal practices at Site 28. Seven of those borings were converted to monitoring wells. Twenty-seven of the boring locations were advanced on the western portion of the site, including the monitoring well test borings. A total of eighteen soil borings and monitoring well test borings were advanced on the eastern portion of the site. The remaining two borings were advanced off the site for background analyses. Seven of the borings were used to further evaluate the fill material and debris in order to collect soils for identification purposes only. No samples from these seven borings were submitted for chemical analysis. The location of the borings is shown in Figure 3.

Tables 1 and 2 contain a summary of the lead concentrations in the surface and subsurface soils during the RI. Lead concentrations in the surface soils ranged from 3.9 mg/kg to 551 mg/kg. It is helpful to look at the west fill area and the east fill area separately. The west fill area contains lead concentrations an order of magnitude higher than the east fill area in the surface soils.

Lead concentrations in the subsurface soils ranged from 1.9 mg/kg to 2060 mg/kg. Again, the average concentration in the west area fill subsoil is much higher than in the east fill area subsoil, in this case, two orders of magnitude. Figure 4 depicts an isoconcentration map of the lead in the subsurface soils for the west fill area.

As part of the RI, two background locations (BB-SB37 and BB-SB38) were sampled for metals to determine the baseline magnitude of these constituents in the soil. The average concentrations of lead in the surface soil and subsurface soil at these two locations were 2.25 mg/kg and 3.2 mg/kg, respectively (Baker, 1995). These numbers are slightly lower than the average background lead concentrations over the entire OU (including Site 1) during this time. The average background lead concentration in the surface soil at OU 7 was 12.06 mg/kg, and the average background lead concentration in the subsurface soil at OU 7 was 3.64 mg/kg. In July 2000, another background study was conducted at MCB, Camp Lejeune as part of the Base and Area of Concern (AOC) Background Investigations under the RCRA Program. During this investigation, the soil types were differentiated and the average constituent concentrations were found for each soil type. For a fine sand, typical of the upper formation at Site 28, the average lead concentration across the Base is 5.24 mg/kg (Baker, 2000).

4.0 LEAD IN THE GROUNDWATER

In the post-ROD phase of the remedial action at Site 28, long-term monitoring of seven groundwater-monitoring wells was implemented on a semi-annual basis, beginning in July 1996. The wells that were monitored were GW01, GW01DW, GW02, GW04, GW07, GW07DW, and GW08. They were sampled for lead and manganese. After the July 1998 sampling event, quarterly monitoring of the remaining wells was implemented. Because of consistently low or non-detect levels of lead, all but one of the wells has been dropped from the monitoring program at this point. Only GW07 has had consistent detections of lead at levels above the North Carolina Groundwater Quality Standard (2L) of 15 ug/L. Table 3 contains a summary of the lead concentration results at Site 28 through the LTM Program.

The solubility of lead in water is the lowest in neutral or slightly basic conditions (Blowes, 2000). As can be seen on Table 3, most of the average pH values at each well are in the neutral 7.0 range. Only at GW07 is the pH seen to indicate slightly acidic conditions. This would seem to indicate that something is causing the pH to remain acidic in the vicinity of GW07, and thereby allowing more lead to dissolve into the groundwater at this location. Figure 5 also depicts the concentrations of lead in all the groundwater samples versus the pH of the groundwater. Note the inverse relationship between lead concentration and pH at Site 28, mostly due to the detections at GW07.

5.0 LEAD MODELING

5.1 Vadose Zone Leaching

The finite-difference model VLEACH (Ravi and Johnson, 1996) was used to predict one-dimensional, transient leaching of lead through the vadose zone to the water table of the upper surficial aquifer. This model was specifically written to estimate the mobilization and migration to the water table of a sorbed, organic contaminant in the vadose zone. Since lead is not an organic contaminant, the model was "tricked" into working for a metal by manipulating the input parameters. Recharge to the soil via precipitation is the driving force behind the vertical contaminant movement. Some amount of contaminant is assumed to be in the dissolved state, based on the distribution coefficient and initial soil concentrations, at the beginning of each time step. In the geometrical portion of the model, a representative area surrounding a soil boring location is defined (contaminant concentration information in the soil is available at that location). A vertical prism is projected downward from this area, and the contaminant is allowed to move through the prism to the water table.

At Site 28, the lead concentrations in the east fill area are only slightly above the average values and, therefore, they were ignored in the modeling effort. Four soil boring locations from the west fill area were modeled based on their soil concentrations and their proximity to Cogdels Creek. The four locations were SB17, SB18, SB19, and SB20. The depth to the water table was assumed to be twenty feet based on the findings in the RI. (It should be noted that SB16 is also close to Cogdels Creek but the lead concentrations were insignificant at that location). The following paragraphs describe the input parameters for the VLEACH model.

As noted above, the recharge to the soil is the driving parameter behind the solute movement to the water table. At MCB, Camp Lejeune the average precipitation per year is approximately 53 inches. A conservative assumption of the amount of precipitation that reaches the water table is about half of the total. It may be much less, but based on the soil cover and topography at Site 28, taking half the total seems reasonable. Therefore, 2.2 feet of recharge per year was assumed for the VLEACH model.

The other important parameter used in the VLEACH model is the soil-water distribution coefficient, K_d , assumed for the lead. In the actual program, K_d is calculated as the product of the

K_{oc} , or organic carbon partition coefficient, and f_{oc} , fraction organic carbon. Because the model is being manipulated for a metal, the K_{oc} is set equal to the K_d , and the fraction organic carbon is set equal to unity. In this case, the K_d determines how much lead is in the water and how much the soil is holding in each time step. As may be expected, K_d is high for a metal that is not very soluble. The value given for K_d in the North Carolina Hazardous Waste Section Soil Screening Levels (rev 9/05/00) document is 900 L/kg (Appendix A). Another excellent reference for K_d values for lead is found in the USEPA (1999) document, "Understanding Variation in Partition Coefficients, K_d , Values." Appendix F of the USEPA document gives several values for K_d for lead for many different soil types and for different pH values. It is attached as Appendix B to this document. The average (log-based) of all the K_d values for lead in Table F.1 is 2123 L/kg. Because there is an order of magnitude difference in these two values cited, both were used in the modeling effort.

The model was allowed to run for a simulated time of 100 years. During that time there was little variation in the amount of lead reaching the water table. In other words, based on the amount of lead available to go to the water table, the flux to the water table was nearly constant over the 100-year period. The results of the VLEACH model and the input parameters are given in Table 4. The mass flux produced by the VLEACH model was converted to concentration at the water table. Using the North Carolina value for K_d , the concentration at the water table was higher than the groundwater standard (15 ug/L) at all four soil boring locations. Using the average USEPA K_d value, the compliance lead concentration is met or exceeded at three soil boring locations, but is not exceeded at one location.

Based on the results of the vadose zone model, the lead concentrations in the groundwater that are possible from lead leaching from the soil to the groundwater are representative of the concentrations observed in the vicinity of GW07. These concentrations have not been diluted in any way by the water in the aquifer. However, if the lead leaching is steady state, it may be assumed that the concentration at the water table is representative of the concentration below the water table.

5.2 Groundwater Contaminant Transport

In order to determine the lead movement from the surficial aquifer toward Cogdels Creek, the Domenico (1987) model was used (Appendix C). This Excel spreadsheet model solves the

analytical equation for contaminant movement in groundwater in three dimensions for a horizontally flowing, homogenous, isotropic aquifer. The model has the option for incorporating decay and adsorption, but these mechanisms were not incorporated into this simulation. The steady state contaminant source is assumed to be a vertical plane of constant concentration in the aquifer. It should be noted that if the contaminant movement is primarily in the horizontal plane, with the exception of dispersion in the vertical direction, it might be likely that the resulting groundwater concentrations are located below the creek bed, depending on if the creek is feeding the groundwater or if the groundwater is feeding the creek.

The Domenico model was evaluated eight times, and the results of the model are shown in Table 4. The source concentrations are given in column 4 of Table 4, and a thirty-year time frame was used. The hydraulic gradient and hydraulic conductivity used were those described in Section 2.3. All hydraulic and soil parameters are assumed to be averages. (See Appendix C for model outputs.)

The resulting modeled lead concentrations at Cogdels Creek are above the North Carolina Water Quality Standard of 25 ug/L in surface water when the lower K_d value concentrations are used, but below the North Carolina Water Quality Standard when the higher K_d value concentrations are used.

6.0 CONCLUSIONS

The lead concentrations in the surface and subsurface soils at Site 28 were evaluated to determine if the soil concentrations were sufficient to account for the groundwater lead concentrations observed. The groundwater results from the LTM Program were summarized at the site. Two computer models were used to evaluate lead movement from the soil to the water table, and from the source area in the groundwater to Cogdels Creek.

The findings of this assessment are as follows:

- The west fill area of Site 28 has significantly more lead in the surface and subsurface soils than the east fill area. Both fill areas have lead levels above the Base background levels for lead in soil;
- Only one monitoring well at Site 28, GW07, has had sporadic lead detections above the North Carolina Groundwater Quality Standard for lead. This assessment suggests that the reason that lead is detected at that location is because the pH at that location is lower, causing more lead to dissolve from the soil;
- A leaching model of lead from the soil to the groundwater table indicates that there is sufficient lead in the subsurface to impact the groundwater. The levels indicated by the model are similar to those observed during the LTM Program; and
- Depending on which value of K_d is used, groundwater movement of lead to Cogdels Creek indicates that the movement of the lead in the aquifer can impact the surface water at values above the North Carolina Surface Water Quality Standard if the creek is fed by the groundwater.

7.0 REFERENCES

- Blowes, David W., "Natural Attenuation of Inorganic Contaminants in the Sub-surface," Waterloo In-Situ Course, June 2000.
- Domenico, P.A., "An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species," Journal of Hydrology, 91, 1987.
- Long-Term Monitoring Reports, MCB Camp Lejeune, North Carolina, CTO 0120, Department of the Navy, LANTDIV, Naval Facilities Engineering Command, Baker Environmental, Inc., July 1996 - current.
- North Carolina Hazardous Waste Section Soil Screening Levels, Table 1, Facility Management Branch, revision 1/20/00.
- Ravi, V., and Johnson, J.A., "VLEACH, A One-Dimensional Finite Difference Vadose Zone Leaching Model, Version 2.2a," Center for Subsurface Modeling Support, USEPA RSKERL, Ada, Oklahoma, 1996.
- Remedial Investigation Report, OU No. 7 (Sites 1, 28, 30), MCB Camp Lejeune, North Carolina, CTO 0231, Department of the Navy, LANTDIV, Naval Facilities Engineering Command, Baker Environmental, Inc., June 29, 1995.
- Record of Decision, OU No. 7, Sites 1, 28, 30, MCB Camp Lejeune, North Carolina, CTO 0231, Department of the Navy, LANTDIV, Naval Facilities Engineering Command, Baker Environmental, Inc., December 14, 1995.
- USEPA , "Understanding Variation in Partition Coefficients, K_d , Values," Volume II, Appendix F, EPA 402/R-99-004B, August, 1999.

TABLES

Table 1
Lead Concentrations in Soil
Site 28, MCB Camp Lejeune
Hadnot Point Burn Dump, West Side
Remedial Investigation, 3/26/94

Boring	Surface Soil	Subsurface Soil
SB01	4.4	2.5 *
SB02	46.4	2.2 *
SB03	16.2	414.0 *
SB04	13.9	6.5 *
SB05	30.2	NA
SB06	19.8	1700.0
SB07	29.1	NA
SB08	514.0	299.0
SB09	44.1	1670.0
SB10	112.0	2060.0 *
SB11	276.0	146.0
SB12	128.0	1670.0
SB13	9.9	25.1
SB14	13.4	234.0
SB15	281.0	1300.0
SB16	15.1	18.9
SB17	78.3	1150.0
SB18	551.0	1670.0
SB19	99.9	697.0
SB20	157.0	572.0
GW01	512.0	162.0
GW01DW	316.0	92.1
GW06	59.4	9.8 *
GW07	3.9	105.0
GW07DW	5.1	27.2
GW08	73.2	122.0
Average	131.13	589.80

All values are mg/kg

* Highest value if more than one result

Highest value reported

Table 2
Lead Concentrations in Soil
Site 28, MCB Camp Lejeune
Hadnot Point Burn Dump, East Side
Remedial Investigation, 3/26/94

Boring	Surface Soil	Subsurface Soil
SB21	15.0	6.8
SB22	10.8	13.4
SB23	5.0	6.1
SB24	8.2	7.6
SB25	14.3	10.2
SB26	30.9	10.2
SB27	5.5	14.3
SB28	94.3	10.9
SB29	6.9	4.8
SB30	7.7	6.3 *
SB31	4.7	8.8
SB32	18.8	7.1 *
SB33	18.5	5.4 *
SB34	47.8	4.6 *
SB35	6.8	5.7
SB36	19.4	23.4
GW05	11.4	6.1
Average	19.18	8.92

All values are mg/kg

* Highest value if more than one result

Highest value reported

Table 3
Lead Concentrations in Groundwater (ug/L)
Site 28, MCB Camp Lejeune
Hadnot Point Burn Dump, West Side

Date	Location	Concentration (ug/L)	pH
7/26/96	28-GW01-96C	4.9	7.46
2/6/97	28-GW01-97A	1.6	8.09
8/6/97	28-GW01-97C	ND	7.23
1/20/98	28-GW01-98A	ND	7.74
7/23/98	IR28-GW01-98C	ND	7.28
10/25/98	IR28-GW01-98D	2.9	B 7.22
1/18/99	IR28-GW01-99A	ND	7.59
4/17/99	IR28-GW01-99B	2.6	B 7.68
7/30/99	IR28-GW01-99C	2.9	B 7.65
AVERAGE		2.98	7.55
7/26/96	28-GW02-96C	4.9	8.05
2/6/97	28-GW02-97A	ND	7.9
8/6/97	28-GW02-97C	ND	7.07
1/20/98	28-GW02-98A	ND	8.06
7/23/98	IR28-GW02-98C	ND	NA
10/25/98	IR28-GW02-98D	ND	7.42
1/18/99	IR28-GW02-99A	ND	7.75
4/17/99	IR28-GW02-99B	ND	7.77
7/30/99	IR28-GW02-99C	1.6	B 7.69
AVERAGE		3.25	7.71
7/26/96	28-GW07-96C	12.4	6.37
2/6/97	28-GW07-97A	6.8	6.78
8/6/97	28-GW07-97C	30.6	6.55
1/20/98	28-GW07-98A	ND	7.22
7/23/98	IR28-GW07-98C	65	NA
10/25/98	IR28-GW07-98D	32.5	6.37
1/18/99	IR28-GW07-99A	1	B 6.68
4/17/99	IR28-GW07-99B	6.6	6.74
7/30/99	IR28-GW07-99C	34.2	6.4
10/23/99	IR28-GW07-99D	17	6.51
01/12/00	IR28-GW07-00A	4.5	6.77
04/13/00	IR28-GW07-00B	8.7	6.37
7/15/00	IR28-GW07-00C	29.5	6.43
10/21/00	IR28-GW07-00D	41.7	6.38
AVERAGE		22.35	6.58

Table 3, continued
Lead Concentrations in Groundwater (ug/L)
Site 28, MCB Camp Lejeune
Hadnot Point Burn Dump, West Side

Date	Location	Concentration (ug/L)	pH
7/26/96	28-GW01DW-96C	ND	7.73
2/6/97	28-GW01DW-97A	1.4	8.12
8/6/97	28-GW01DW-97C	ND	8.25
1/20/98	28-GW01DW-98A	ND	7.97
AVERAGE		1.40	8.02
7/26/96	28-GW04-96C	ND	6.88
2/6/97	28-GW04-97A	ND	6.97
8/6/97	28-GW04-97C	ND	7.07
1/20/98	28-GW04-98A	ND	7.34
AVERAGE		ND	7.07
7/26/96	28-GW07DW-96C	ND	9.09
2/6/97	28-GW07DW-97A	ND	9.29
8/6/97	28-GW07DW-97C	ND	7.45
1/20/98	28-GW07DW-98A	ND	9.26
AVERAGE		ND	8.77
7/26/96	28-GW08-96C	9.8	7.36
2/6/97	28-GW08-97A	2	8.31
8/6/97	28-GW08-97C	5.2	7.27
AVERAGE		5.67	7.65

Table 4
Modeling Summary
Average Concentrations of Lead at the Water Table and Codgels Creek
Hadnot Point Burn Dump, West Side
Site 28, MCB Camp Lejeune

Kd = 900 L/kg, the value given in the NC Hazardous Waste Section soil screening levels TABLE 1, rev09/05/00

Boring ID	Area sq.ft.^	Mass flux g/yr *	Lead concentration at water table mg/L **	Lead concentration at Codgels Creek mg/L***
SB17	21,600	97.00	0.072	0.040
SB18	27,000	168.73	0.100	0.049
SB19	18,000	44.00	0.039	0.035
SB20	18,000	37.00	0.033	0.024

Kd = 2123 L/kg, the log average of the values given in EPA/402/R-99/004B, August 1999, Appendix F

Boring ID	Area sq.ft.^	Mass flux g/yr *	Lead concentration at water table mg/L **	Lead concentration at Codgels Creek mg/L***
SB17	21,600	41.16	0.031	0.017
SB18	27,000	71.56	0.043	0.021
SB19	18,000	16.68	0.015	0.013
SB20	18,000	15.70	0.014	0.010

^ Representative area around boring

* Values obtained from VLEACH using surface and subsurface lead concentrations

** Concentration = [Mass flux / (recharge*area)] * conversion factor

***Obtained from Domenico model for groundwater transport based on aquifer conditions and distance to Codgels Creek

recharge : 2.2 ft/yr conversion factor (mg-ft³/g-L)= 35.315

FIGURES

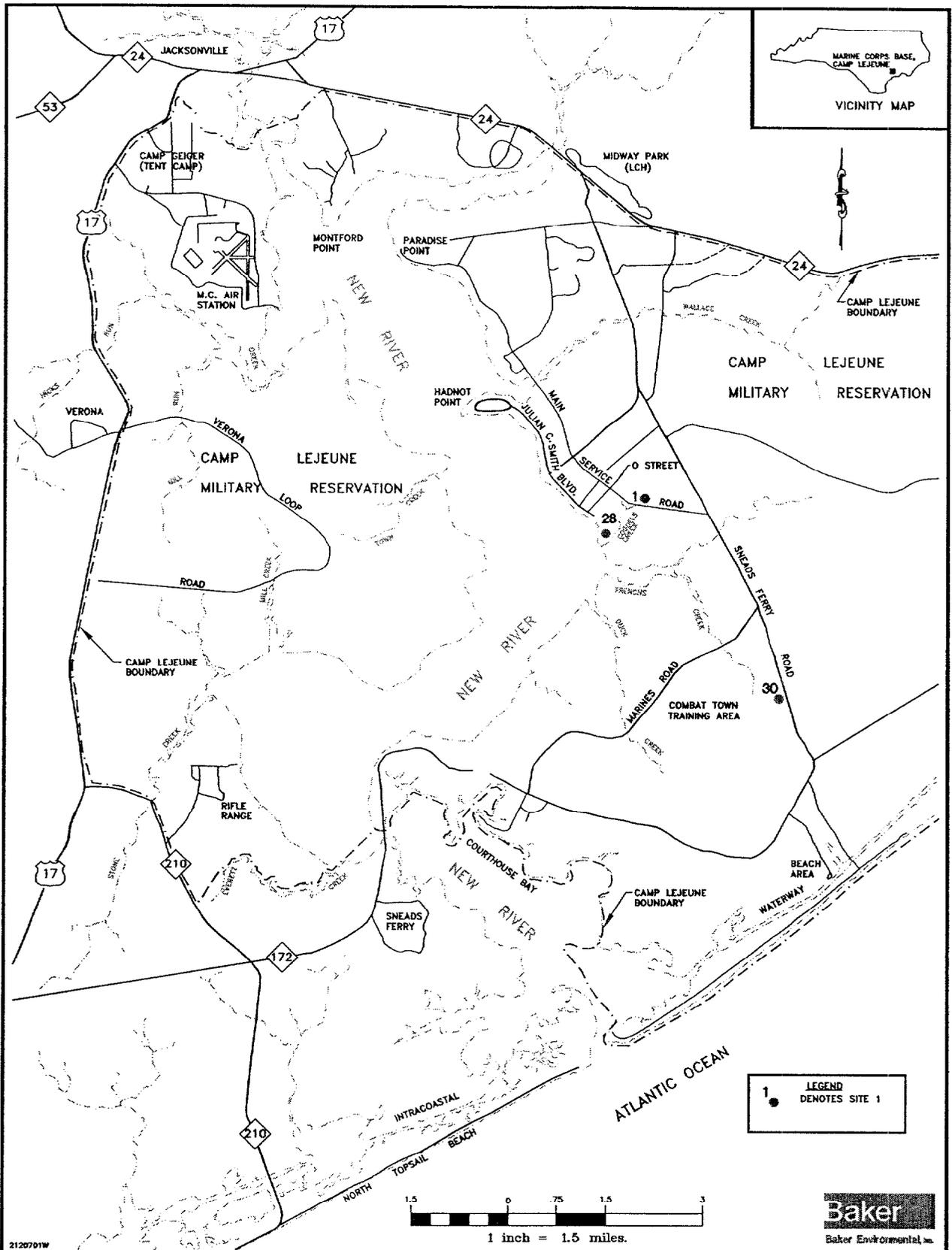
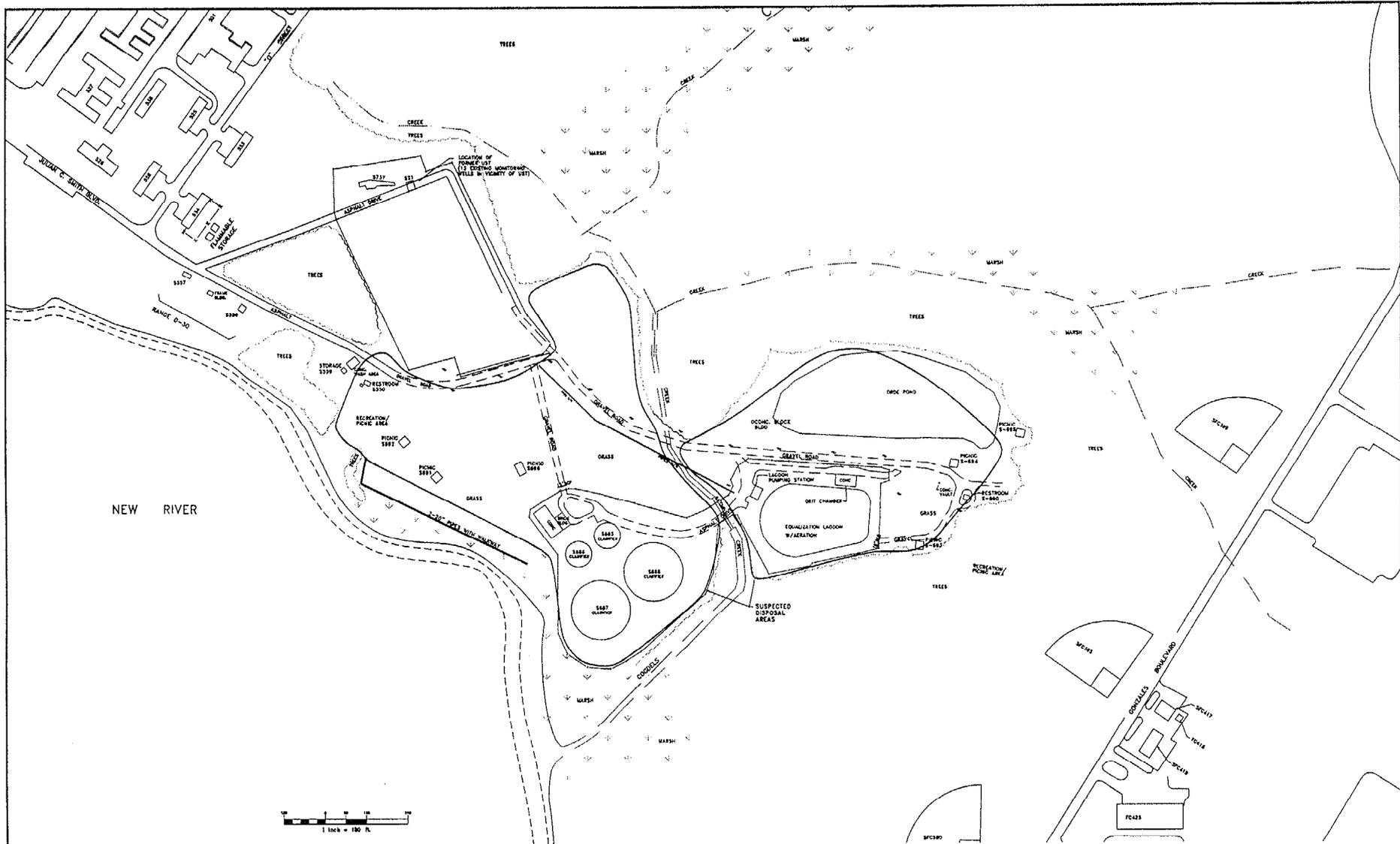


FIGURE 1
 OPERABLE UNIT No. 7 - SITES 1, 28, AND 30
 MARINE CORPS BASE CAMP LEJEUNE
 REMEDIAL INVESTIGATION CTO-0231
 MARINE CORPS BASE, CAMP LEJEUNE
 NORTH CAROLINA

2120701W

Baker
 Baker Environmental, Inc.

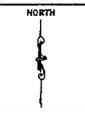


LEGEND

VEGETATION
 FENCE
 CREEK/DRAINAGE
 MARSH
 ESTIMATED EXTENT OF FILL

SOURCE: LANTOY, FEBRUARY 1992

DATE NOVEMBER 1994
 SCALE 1" = 120'
 DRAWN REL
 REVIEWED TTT
 S.O.# 26007-120
 CADD# 2120702W



REMEDIAL INVESTIGATION CTO-0231
 MARINE CORPS BASE, CAMP LEJEUNE
 NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
 Coraopolis, Pennsylvania

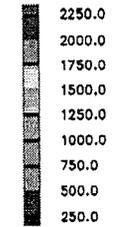


SITE MAP
 SITE 28 - HADNOT POINT BURN DUMP

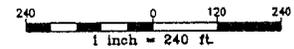
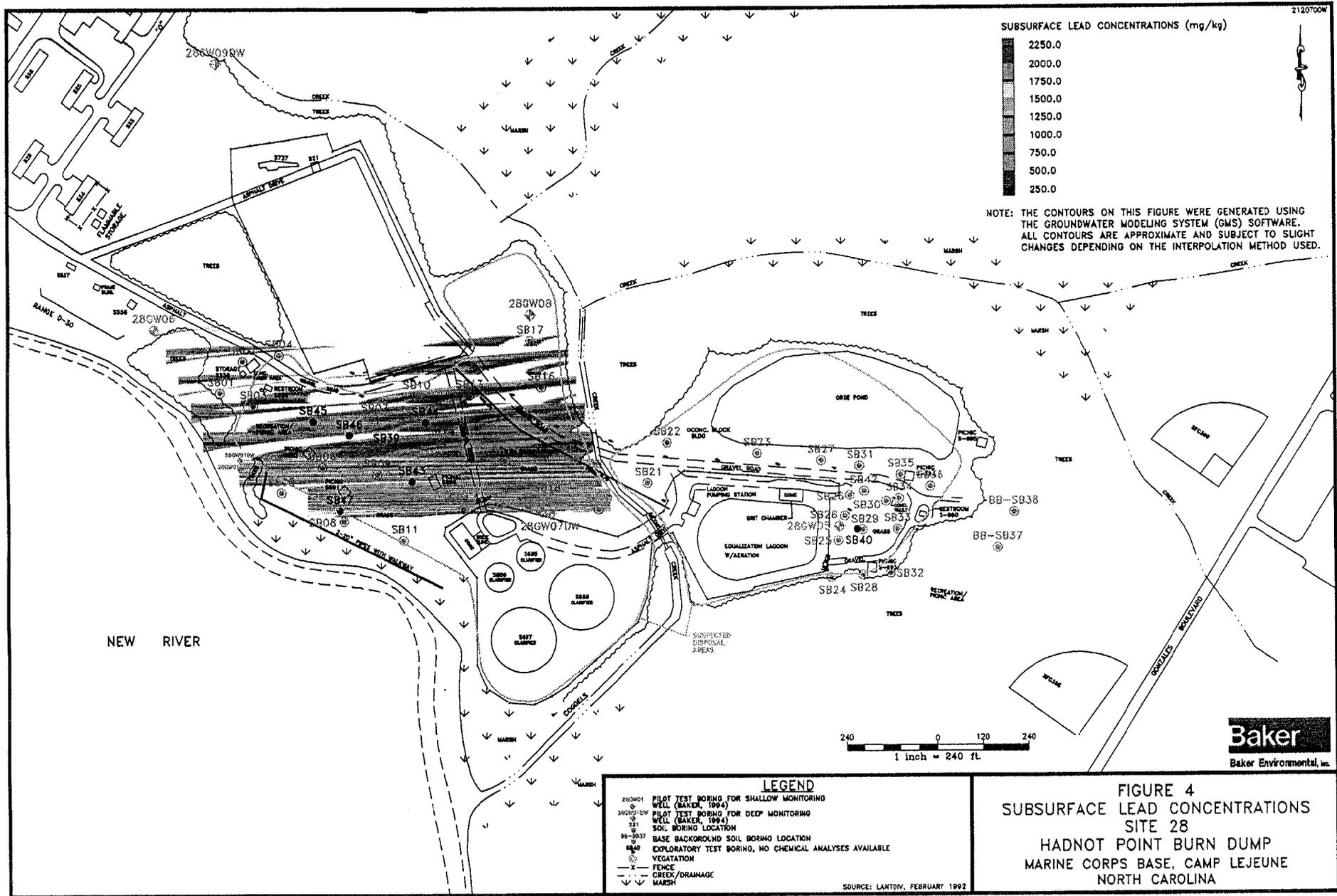
SCALE 1" = 120' DATE NOVEMBER 1994

FIGURE No.
 2

SUBSURFACE LEAD CONCENTRATIONS (mg/kg)



NOTE: THE CONTOURS ON THIS FIGURE WERE GENERATED USING THE GROUNDWATER MODELING SYSTEM (GMS) SOFTWARE. ALL CONTOURS ARE APPROXIMATE AND SUBJECT TO SLIGHT CHANGES DEPENDING ON THE INTERPOLATION METHOD USED.



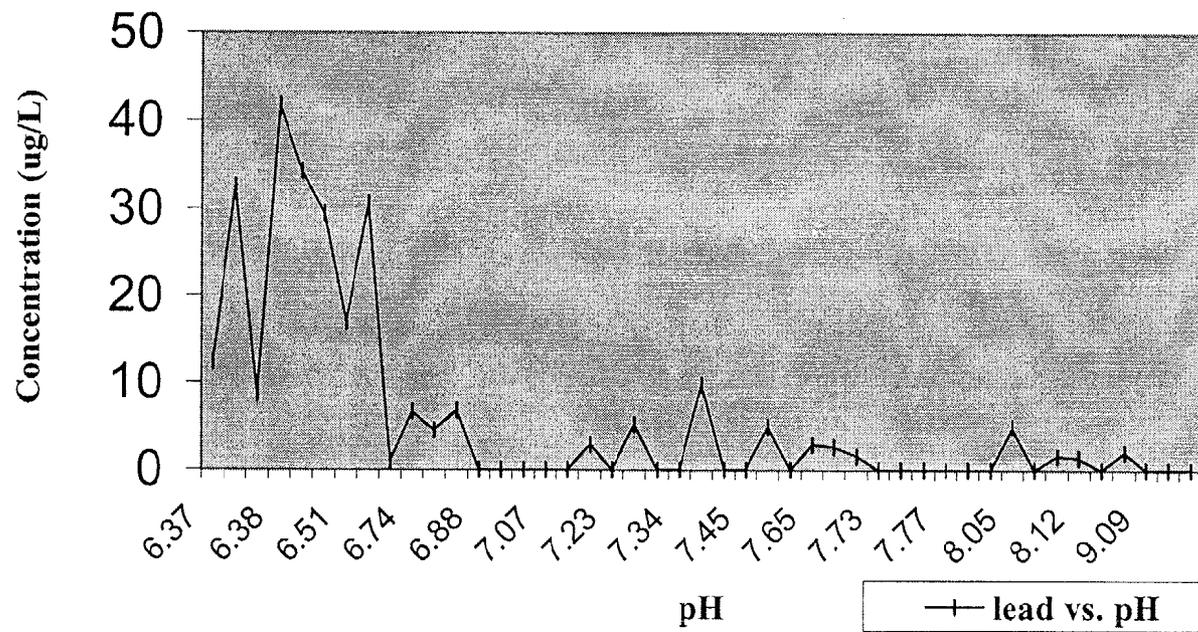
LEGEND

28GW01	PILOT TEST BORING FOR SHALLOW MONITORING WELL (BAKER, 1994)
28GW02-10	PILOT TEST BORING FOR DEEP MONITORING WELL (BAKER, 1994)
SB1	SOIL BORING LOCATION
SB-2037	BASE BACKGROUND SOIL BORING LOCATION
SB40	EXPLORATORY TEST BORING, NO CHEMICAL ANALYSES AVAILABLE
(Symbol)	VEGETATION
(Symbol)	FENCE
(Symbol)	CREEK/DRAINAGE
(Symbol)	MARSH

FIGURE 4
SUBSURFACE LEAD CONCENTRATIONS
SITE 28
HADNOT POINT BURN DUMP
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE: LANTOV, FEBRUARY 1992

Figure 5
Groundwater Lead Concentration vs. pH



APPENDIX A

TA. 1
 NORTH CAROLINA HAZARDOUS WASTE SECTION (HWS) SOIL SCREENING LEVELS
 Protective of Groundwater Used for Drinking

DRAFT: Values in Table are subject to change. Contact the NC Hazardous Waste Section, Facility Management Branch for the most recent version.

COMPOUNDS	CAS #	Kd (L/kg)	Ref.	Koc (L/kg)	Ref.	HENRY'S LAW CONSTANT (unitless)	Ref.	See Footnotes	TARGET GROUNDWATER CONCENTRATION (2L, Interim 2L Recommended 2L, or MCLG) (mg/L)	NC HWS SSL CONCENTRATIONS (mg/kg)
ACENAPHTHENE	83329			4900	a	0.00636	a	1	0.08	8.16
ACENAPHTHYLENE	208968			2500	c	0.05945	c	1	0.21	11.4
ACETONE	67641			0.575	a	0.00159	a		0.7	2.81
ACETONITRILE	75058			2.88	e	0.0012	e	2	0.0420	0.17
ACRYLAMIDE (PROPENAMIDE)	79061			0	e	1.2423E-07	e		0.000010	0.000040
ANTHRACENE	120127			23500	a	0.00267	a	1	2.1	995
ANTIMONY	7440360	45	d					3	0.006	5.42
ARSENIC	7440382	26	a						0.05000	26.2
ATRAZINE	1912249			200	f	0.000000086	j	1	0.003	0.024
BARIUM	7440393	21	a						2	848
BENZENE	71432			61.7	a	0.2255	c		0.001	0.00562
BENZOIC ACID	65850			1.94	a	0.0000631	a	1	28	113
BENZO (A) ANTHRACENE	56553			358000	a	0.000137	a	1	0.00005	0.358
BENZO (A) PYRENE	50328			969000	a	0.0000463	a	1	0.0000047	0.0911
BENZO (G,H,I) PERYLENE	191242			1600000	c	0.000005904	c	1	0.21	6720
BERYLLIUM	7440417	42	a					3	0.004	3.38
BIS (2-CHLOROETHYL) ETHER	111444			75.9	a	0.000738	a	1	0.000031	0.000171
BIS (2-CHLOROISO-PROPYL) ETHER	396383329			61	c	0.004633	c			
BORON	7440428	3	d						0.32	20.5
BROMODICHLOROMETHANE	75274			55	a	0.0656	a	1	0.0006	0.00313
BROMOFORM (TRIBROMOMETHANE)	75252			126	a	0.0219	a		0.00019	0.00125
BROMOMETHANE	74839			5.9	c	8.077	c			
BUTYL BENZYL PHTHALATE	85687			13700	a	0.0000517	a		0.1	27.8
CADMIUM	7440439	27	a						0.005	2.72
CAPROLACTAM	105602				cd		cd	1	3.5	
CARBOFURAN	1563662			158	e	1.5908E-06	e		0.036	0.258
CARBON DISULFIDE	75150			45.7	a	1.24	a	1	0.7	4.94
CARBON TETRACHLORIDE	56235			152	a	1.2013	c		0.00030	0.0027

1 - Interim 2L Standard
 2 - Recommended 2L Standards per 4/15/98, 12/14/98, 5/18/99 or 7/7/99 OES Memorandum
 3 - No 2L Std or interim standard; MCLG/proposed MCLG used instead

TABLE 1
NORTH CAROLINA HAZARDOUS WASTE SECTION (HWS) SOIL SCREENING LEVELS
Protective of Groundwater Used for Drinking

DRAFT: Values in Table are subject to change. Contact the NC Hazardous Waste Section, Facility Management Branch for the most recent version.

COMPOUNDS	CAS #	Kd (L/kg)	Ref.	Koc (L/kg)	Ref.	HENRY'S LAW CONSTANT (unitless)	Ref.	See Footnotes	TARGET GROUNDWATER CONCENTRATION (2L, Interim 2L Recommended 2L, or MCLG) (mg/L)	NC HWS SSL CONCENTRATIONS (mg/kg)
CHLORDANE	57749			51300	a	0.00199	a		0.0000270	0.0278
CHLOROBENZENE	108907			224	a	0.16113	c		0.05	0.438
CHLOROETHANE	124481			3.24	e	0.4551	e	1	2.8	13.6
CHLOROFORM (TRICHLOROMETHANE)	75003			52.5	a	0.13899	c		0.00019	0.00101
CHLOROPHENOL 2-	95578			397	a	0.016	a		0.0001	0.00120
CHROMIUM	7440473	27	a						0.05000	27.200
CHRYSENE	218019			398000	a	0.00388	a	1	0.005	39.8
COPPER	7440508	35	d						1.0	704
CYANIDE	57125	9.9	a						0.154	31.1
4,4' - DDD	72548			4.58E+04	a	1.64E-04	a	1	0.00014	0.129
4,4' - DDT	50293			6.78E+05	a	3.32E-04	a	1	0.0001	1.36
DIBENZ (A,H) ANTHRACENE	53703			1.79E+06	a	6.03E-07	a	1	0.0000047	0.168
DI (OR BIS) 2-ETHYLHEXYL PHTHALATE (DEHP)	117817			111000	c	0.0000418	c		0.0030	6.67
DI-N-BUTYL (OR DIBUTYL) PHTHALATE (DBP)	84742			1570	a	3.85E-08	a		0.7	24.8
DI-N-OCTYL PHTHALATE	117840			83200000	a	0.00274	a,sat		0.14	10,000
DIBROMOCHLOROMETHANE (CHLORODIBROMOMETHANE)	124481			6.31E+01	a	0.03210	a	1	0.00041	0.00171
DIBROMO-3-CHLOROPROPANE 1,2-	96128			98	b	0.01275	b		0.000025	0.00015
DICHLOROBENZENE 1,2 (O-DCB)	95501			379	a	0.07954	c		0.062	7.270
DICHLOROBENZENE 1,3 (M-DCB)	541731			1700	c	0.10783	c		0.62	23.7
DICHLOROBENZENE 1,4 (P-DCB)	106467			616	a	0.11152	c		0.075	1.24
DICHLORODIFLUOROMETHANE (FREON-12; HALON)	75718			58	b	123	e		1.4	306
DICHLOROETHANE 1,1	75343			53.4	a	0.22345	c		0.70	3.820
DICHLOROETHANE 1,2 (ETHYLENE DICHLORIDE)	107062			38	a	0.0451	c		0.00038	0.00184
DICHLOROETHENE 1,2 (CIS)	156592			35.5	a	0.167	a		0.07	0.350
DICHLOROETHENE 1,2 (TRANS)	156605			38	a	0.385	a		0.07	0.380
DICHLOROETHYLENE 1,1 (VINYLIDENE CHLORIDE)	75354			65	c	0.6109	c		0.007	0.0445
DICHLOROPHENOXY ACETIC ACID 2,4 (2,4-D)	94757			20	b	0.007708	b		0.07	0.309
DICHLOROPROPANE 1,2-	78875			47	a	0.11562	c		0.00056	0.00288

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NORTH CAROLINA HAZARDOUS WASTE SECTION (HWS) SOIL SCREENING LEVELS
Protective of Groundwater Used for Drinking

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COMPOUNDS	CAS #	Kd (L/kg)	Ref.	Koc (L/kg)	Ref.	HENRY'S LAW CONSTANT (unitless)	Ref.	See Footnotes	TARGET GROUNDWATER CONCENTRATION (2L, Interim 2L Recommended 2L, or MCLG) (mg/L)	NC HWS SSL CONCENTRATIONS (mg/kg)
DICHLOROPROPENE 1,3 (CIS AND TRANS)	542756			27.1	a	0.1435	c	1	0.0002	0.000958
DIELDRIN				25500	a	0.000619	a	1	0.0000022	0.00113
DIETHYLPHTHALATE (DEP)	84662			82.2	a	0.0000185	a		5	28.2
DINOSEB (DNBP) (2-SEC-BUTYL-4,6-DINITROPHENOL)								3	0.007	
2,4-DIMETHYLPHENOL	105679			209	a	0.000082	a	1	0.140	1.15
DIOXANE 1,4	123911			3.47	e	0.00020008	e		0.00700	0.0285
DIOXIN: 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD)	1746016			3300000	b	0.1476	b		0.00000000022	0.0000145
DIPHENYL (BIPHENYL)	92524			1072	e	0.007913	e	1	0.35	8.91
DIUNDECYL PHTHALATE (SANTICIZER 711)	3648202				cd		cd		0.14	
ENDRIN	72208			10800	a	0.000308	a	1	0.002	0.440
EPICHLOROHYDRIN (1-CHLORO-2,3-EPOXYPROPANE)	106898			10	b	0.0013079	b		0.00354	0.0149
ETHYLBENZENE	100414			204	a	0.14063	c		0.029	0.241
ETHYLENE DIBROMIDE (EDB, 1,2-DIBROMOETHANE)	106934			44	c	0.027593	c		0.0000004	0.00000197
ETHYLENE GLYCOL	107211			0.0127	g	9.594E-09	k		7	28.0
FLUORANTHENE	206440			49100	a	0.00066	a	1	0.28	276
FLUORENE	86737			7710	a	0.00261	a		0.28	44.3
FLUORIDE	7782414		cd						2	
HEPTACHLOR	76448			9530	a	60.7	a		0.000008	0.00240
HEPTACHLOR EPOXIDE	1024573			83200	a	0.00039	a		0.0000040	0.00667
HEPTANE	142825			5870	h	83.435	e		2.1	559
HEXACHLOROBENZENE (PERCHLOROBENZENE)	118741			80000	a	0.0541	a		0.00002	0.0321
HEXACHLOROCYCLOPENTADIENE	77474			200000	a	1.1	a	3	0.05	200
IRON	7439896	25	d						0.3	151
INDENO (1,2,3-CD) PYRENE	193395			3.47E+06	a	6.56E-05	a	1	0.000047	3.26
ISOPHORONE	78591			46.8	a	0.000272	a	1	0.0368	0.182
ISOPROPYL ETHER (DIISOPOROPYL ETHER)	108203			31.22	g	0.40877	e	1	0.07	0.373
LEAD	7439921	900	d						0.015	270
LINDANE (GAMMA-BHC)	58899			1350	a	0.000574	a		0.0002	0.00620

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TABLE 1
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Protective of Groundwater Used for Drinking

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COMPOUNDS	CAS #	Kd (L/kg)	Ref.	Koc (L/kg)	Ref.	HENRY'S LAW CONSTANT (unitless)	Ref.	See Footnotes	TARGET GROUNDWATER CONCENTRATION (2L, Interim 2L Recommended 2L, or MCLG) (mg/L)	NC HWS SSL CONCENTRATIONS (mg/kg)
MANGANESE	7439965	65	d						0.05	65.2
MERCURY	7439976	0.46	a			0.467	a		0.00110	0.0154
METHANOL	67561			2.75	e	0.00018204	e	1	3.5	14.2
METHOXYCHLOR	72435			80000	a	0.000648	a		0.035	56.1
METHYL ETHYL KETONE (MEK; 2-BUTANONE)	78933			3.5	c	0.0011234	c		0.170	0.692
METHYL ISOBUTYL KETONE (MIBK)	108101			3.1	c	0.005658	c	2	0.56000	2.28
METHYLPHENOL 2-	95487			91.2	a	0.0000492	a	2	0.035	0.204
METHYLPHENOL 4-	106445			49	e	0.0000325	e	1	0.0035	0.0174
METHYL TERT-BUTYL ETHER	1634044			27	c	0.024231	c		0.20	0.916
METHYLENE CHLORIDE (DICHLOROMETHANE)	75092			10	a	0.13079	c		0.0050	0.0220
N-HEXANE	110543			1468	h	31.488	e		0.42	36.9
NAPHTHALENE	91203			1190	a	0.0198	a		0.021	0.585
NICKEL	7440020	28	a						0.1	56.4
NITRATE (AS N)	14797558		cd						10	
NITRITE (AS N)	14797650		cd						1	
OXAMYL	23135220			2.24	l	0.0000902	l		0.175	0.708
PENTACHLOROPHENOL	87865			3650	a	0.000001	a		0.0003	0.0231
PHENANTHRENE	85018			14000	c	0.0016113	c		0.21	59.6
PHENOL	108952			91	c	0.0000163	a		0.3	1.75
POLYCHLORINATED BIPHENYLS; PCBs										
PYRENE	129000			68000	a	0.000451	a	1	0.21	286
SELENIUM	7782492	12	a						0.05	12.2
SILVER	7440224	0.42	a						0.0180	0.223
SILVEX (2,4,5-TP)	93721			2570	i	3.444E-09	i		0.05	2.77
SIMAZINE	122349			138	l	1.394E-07	l	1	0.0035	0.0237
STYRENE (ETHENYLBENZENE)	100425			912	a	0.10701	c		0.1	2.24
SULFATE	4808798		cd						250	
TETRACHLOROETHANE 1,1,1,2-	630206			54	c	0.451	c			

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COMPOUNDS	CAS #	Kd (L/kg)	Ref.	Koc (L/kg)	Ref.	HENRY'S LAW CONSTANT (unitless)	Ref.	See Footnotes	TARGET GROUNDWATER CONCENTRATION (2L, Interim 2L Recommended 2L, or MCLG) (mg/L)	NC HWS SSL CONCENTRATIONS (mg/kg)
TETRACHLOROETHANE 1,1,2,2-	79345			79	a	0.0141	a	1	0.00017	0.000953
TETRACHLOROETHYLENE (PERCHLOROETHYLENE; PCE)	127184			265	a	0.754	a		0.0007	0.00742
TETRAHYDROFURAN	109999			23.4	e	0.00289	e	2	0.0046	0.0206
THALLIUM	7440280	51	a					3	0.0005	0.512
TOLUENE (METHYLBENZENE)	108883			140	a	0.27388	c		1	7.27
TOXAPHENE	8001352			95800	a	0.000246	a		0.000031	0.0595
TRICHLOROBENZENE 1,2,4-	120821			1660	a	0.05822	c	1	0.07	2.61
TRICHLOROETHANE 1,1,1 (METHYL CHLOROFORM)	71556			135	a	0.9471	c		0.2	1.67
TRICHLOROETHANE 1,1,2-	79005			75	a	0.03731	c	2	0.0006	0.00334
TRICHLOROETHYLENE (TCE)	79016			94.3	a	0.37392	c		0.0028	0.0183
TRICHLOROFLUORO-METHANE	75694			158	e	4.51	e		2.1	31.5
TRICHLOROPHENOL 2,4,5-	95954			363	e	0.000178	a	2	0.350	3.94
VINYL ACETATE	108054			5.25	a	0.0210	a	2	0.088	0.364
VINYL CHLORIDE (CHLOROETHYLENE)	75014			18.6	a	1.1398	c		0.000015	0.0000952
XYLENES (O-, M-, AND P-)	1330207			249	a	0.21607	c		0.53	4.96
ZINC	7440666	26	a						2.10	1100

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TABLE 1
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- a USEPA, 1996, Soil screening guidance: Technical background document: EPA/540/R95/128
 - b USEPA, 1986, Superfund public health evaluation manual: Office of Emergency and Remedial Response
 - c Massachusetts Department of Environmental Protection, 1994, Background documentation for the development of the MCP numerical standards
 - d Baes, C.F., III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor, 1984, A review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture: Oak Ridge National Laboratory
 - e Montgomery, J.H., 1996, Groundwater chemicals desk reference: CRC Press, Inc.
 - f Lyman, W.J., W.F. Reehl, D.H. Rosenblat, 1990, Handbook of chemical property estimation methods: American Chemical Society
 - g Calculated using equation (70) in reference (a)
 - h Calculated using equation (71) in reference (a)
 - i Sims, R.C., J.L. Sims, and S.G. Hansen, 1991, Soil transport and fate database, version 2.0: USEPA Robert S. Kerr Environmental Research Laboratory
 - j Calculated using equation (63) in reference (a)
 - k ABDR Toxicity Profile, 1993
 - l Montgomery, J.H., 1993, Agrochemical desk reference environmental data: Lewis Publishers, Chelsea, MI
- sat Per EPA Region 9 guidance, the soil saturation concentration, which corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached, was used as the target remedial concentration for some chemicals.



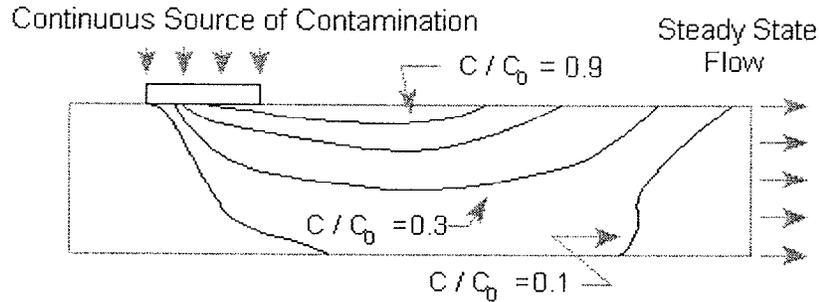
UNDERSTANDING VARIATION IN PARTITION COEFFICIENT, K_d , VALUES



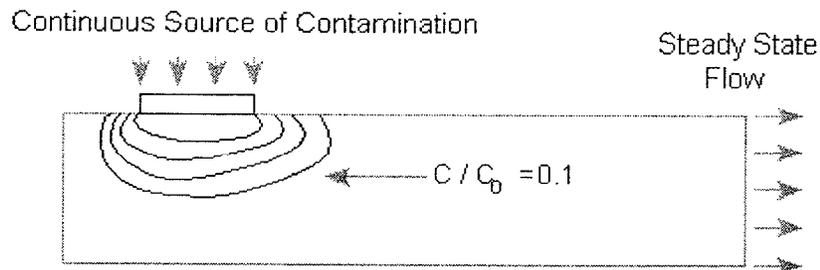
Volume II:

Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (^3H), and Uranium

Case I: $K_d = 1 \text{ ml/g}$



Case II: $K_d = 10 \text{ ml/g}$



soils indicate that soil organic matter has a higher affinity for lead adsorption as compared soil minerals.

A number of lead adsorption studies on bulk soils indicate that the adsorption is strongly correlated with pH and the CEC values of soils (Zimdahl and Hassett, 1977). A multiple regression analysis by Hassett (1974) of lead adsorption data indicated that properties that affect CEC of soils, such as organic matter content, clay content, and surface area, have a greater effect on lead adsorption than soil pH. The results of a number of studies of lead adsorption on a variety of soil and mineral surfaces were summarized by McLean and Bledsoe (1992). These data show that lead has very strong adsorption affinity as compared to a number of first row transition metals (cobalt, nickel, copper, and zinc). According to a recent study (Peters and Shem, 1992), the presence of very strong chelating organic ligands dissolved in solution will reduce adsorption of lead onto soils. These data show that the adsorption of lead in the environment is influenced by a number of factors such as the type and properties of adsorbing substrate, pH, the concentrations of lead, and the type and concentrations of other competing cations and complex forming inorganic and organic ligands.

5.5.6 Partition Coefficient, K_d , Values

5.5.6.1 General Availability of K_d Data

The review of lead K_d data reported in the literature for a number of soils (Appendix F) led to the following important conclusions regarding the factors which influence lead adsorption on minerals and soils.¹ These principles were used to evaluate available quantitative data and generate a look-up table. These conclusions are:

- Lead may precipitate in soils if soluble concentrations exceed about 4 mg/l at pH 4 and about 0.2 mg/l at pH 8. In the presence of phosphate and chloride, these solubility limits may be as low as 0.3 mg/l at pH 4 and 0.001 mg/l at pH 8. Therefore, in experiments in which concentrations of lead exceed these values, the calculated K_d values may reflect precipitation reactions rather than adsorption reactions.
- Anionic constituents such as phosphate, chloride, and carbonate are known to influence lead reactions in soils either by precipitation of minerals of limited solubility or by reducing adsorption through complex formation.
- A number of adsorption studies indicate that within the pH range of soils (4 to 11), lead adsorption increases (as does precipitation) with increasing pH.

¹ Since the completion of our review and analysis of K_d data for the selected contaminants and radionuclides, the studies by Azizian and Nelson (1998) and Yong and MacDonald (1998) were identified and may be of interest to the reader.

- Adsorption of lead increases with increasing organic matter content of soils.
- Increasing equilibrium solution concentrations correlates with decreasing lead adsorption (decrease in K_d).

The factors which influence lead adsorption were identified from the following sources of data. A description and assessment of these data are provided in Appendix F. Lead adsorption behavior on soils and soil constituents (clays, oxides, hydroxides, oxyhydroxides, and organic matter) has been studied extensively. However, calculations by Rickard and Nriagu (1978) show that the solution lead concentrations used in a number of adsorption studies may be high enough to induce precipitation. For instance, their calculations show that lead may precipitate in soils if soluble concentrations exceed about 4 mg/l at pH 4 and about 0.2 mg/l at pH 8. In the presence of phosphate and chloride, these solubility limits may be as low as 0.3 mg/l at pH 4 and 0.001 mg/l at pH 8. Therefore, in experiments in which concentrations of lead exceed these values, the calculated K_d values may reflect precipitation reactions rather than adsorption reactions.

Lead adsorption studies on manganese and iron oxides and oxyhydroxides indicate irreversible adsorption which was attributed to the formation of solid solution phases (*i.e.*, coprecipitation) (Forbes *et al.*, 1976; Grasselly and Hetenyi, 1971; Rickard and Nriagu, 1978). No correlations however have been established between the type and content of oxides in soil and the lead adsorption characteristics of soil.

Anionic constituents such as phosphate, chloride, and carbonate are known to influence lead reactions in soils either by precipitation of minerals of limited solubility or by reducing adsorption through complex formation (Rickard and Nriagu, 1978). Presence of synthetic chelating ligands, such as EDTA, has been shown to reduce lead adsorption on soils (Peters and Shem, 1992). These investigators showed that the presence of strongly chelating EDTA in concentrations as low as 0.01 M reduced K_d for lead by about 3 orders of magnitude. By comparison quantitative data is lacking on the effects of more common inorganic ligands (phosphate, chloride, and carbonate) on lead adsorption on soils.

A number of adsorption studies indicate that within the pH range of soils (4 to 11), lead adsorption increases with increasing pH (Braids *et al.*, 1972; Bittel and Miller, 1974; Griffin and Shimp, 1976; Haji-Djafari *et al.*, 1981; Hildebrand and Blum, 1974; Overstreet and Krishamurthy, 1950; Scudato and Estes, 1975; Zimdahl and Hassett, 1977). Griffin and Shimp (1976) also noted that clay minerals adsorbing increasing amounts of lead with increasing pH may also be attributed to the formation of lead carbonate precipitates which was observed when the solution pH values exceeded 5 or 6.

Solid organic matter such as humic material in soils is known to adsorb lead (Rickard and Nriagu, 1978; Zimdahl and Hassett, 1977). Additionally, soluble organic matter such as fulvates and amino acids are known to chelate soluble lead and affect its adsorption on soils (Rickard and Nriagu, 1978). Correlative relationships between the organic matter content of soils and its

effect on lead adsorption have been established by Gerritse *et al.* (1982) and Soldatini *et al.* (1976).

Lead adsorption by a subsurface soil sample from Hanford, Washington was investigated by Rhoads *et al.* (1992). Adsorption data from these experiments showed that K_d values increased with decreasing lead concentrations in solution (from 0.2 mg/l to 0.0062 mg/l).

5.5.6.2 K_d Look-Up Tables

Among all available data, Gerritse *et al.* (1982) obtained adsorption data at lead concentrations (0.0001 - 0.01 mg/l) which apparently precluded precipitation reactions. Also, these concentrations are within the range of lead concentrations most frequently encountered in ground waters (Chow, 1978). Additionally, data obtained by Rhoads *et al.* (1992) indicated that K_d values vary log-linearly as a function of equilibrium lead concentrations within the range of 0.00001 to 0.2 mg/l. The data generated by Gerritse *et al.* (1982) and Rhoads *et al.* (1992) were used to develop a look-up table (Table 5.9) of K_d as a function of soil pH and equilibrium lead concentrations.

5.5.6.2.1 Limits of K_d Values with Respect to pH

The pH ranges in the look-up table (Table 5.9) were selected from the rate of change that we noted in the K_d data as a function of pH. The K_d values within this pH range increase with increasing pH, and are greatest at the maximum pH limit (pH 11) of soils.

Table 5.9. Estimated range of K_d values for lead as a function of soil pH, and equilibrium lead concentrations.

Equilibrium Lead Concentration ($\mu\text{g/l}$)	K_d (ml/g)	Soil pH		
		4.0 - 6.3	6.4 - 8.7	8.8 - 11.0
0.1 - 0.9	Minimum	940	4,360	11,520
	Maximum	8,650	23,270	44,580
1.0 - 9.9	Minimum	420	1,950	5,160
	Maximum	4,000	10,760	20,620
10 - 99.9	Minimum	190	900	2,380
	Maximum	1,850	4,970	9,530
100 - 200	Minimum	150	710	1,880
	Maximum	860	2,300	4,410

5.5.6.2.2 Limits of K_d Values with Respect to Equilibrium Lead Concentrations

The limits of equilibrium lead concentrations (0.0001 mg/l to about 0.2 mg/l) were selected based on the experimental data generated by Gerritse *et al.* (1982) and Rhoads *et al.* (1992). These investigators showed that within the range of initial lead concentrations used in their experiments the principal lead removal reaction from solution was adsorption and not precipitation. Four concentration ranges were selected to develop the K_d values.

5.6 Plutonium Geochemistry and K_d Values

5.6.1 Overview: Important Aqueous- and Solid-Phase Parameters Controlling Retardation

In the ranges of pH and conditions typically encountered in the environment, plutonium can exist in all 4 oxidation states, namely +3, 4, +5, and +6. Under oxidizing conditions, Pu(IV), Pu(V), and Pu(VI) are common, whereas, under reducing conditions, Pu(III) and Pu(IV) would exist. Dissolved plutonium forms very strong hydroxy-carbonate mixed ligand complexes, therefore, its adsorption and mobility is strongly affected by these complex species. Under conditions of low pH and high concentrations of dissolved organic carbon, it appears that plutonium-organic complexes may be control adsorption and mobility of plutonium in the environment.

If plutonium is present as a distinct solid phase (amorphous or partly crystalline $\text{PuO}_2 \cdot x\text{H}_2\text{O}$) or as a solid solution, the upper limits of aqueous plutonium concentrations would be in the 10^{-12} to 10^{-9} M range. Dissolved plutonium in the environment is typically present at $\leq 10^{-15}$ M levels indicating that adsorption may be the principal phenomenon that regulates the mobility of this actinide.

Plutonium can adsorb on geologic material from low to extremely high affinities with K_d values ranging from 11 to 300,000 ml/g. Plutonium in the higher oxidation state adsorbed on iron oxide surfaces may be reduced to the tetravalent state by Fe(II) present in the iron oxides.

Two factors that influence the mobilization of adsorbed plutonium under environmental pH conditions (>7) are the concentrations of dissolved carbonate and hydroxyl ions. Both these ligands form very strong mixed ligand complexes with plutonium, resulting in desorption and increased mobility in the environment.

5.6.2 General Geochemistry

Plutonium is produced by fissioning uranium fuel and is used in the construction of nuclear weapons. Plutonium has entered the environment either through accidental releases or through disposal of wastes generated during fuel processing and the production and detonation of nuclear weapons. Plutonium has 15 isotopes, but only 4 of these isotopes namely, ^{238}Pu [$t_{1/2}$ (half life) =

APPENDIX F

Partition Coefficients For Lead

Appendix F

Partition Coefficients For Lead

F.1.0 Background

The review of lead K_d data reported in the literature for a number of soils led to the following important conclusions regarding the factors which influence lead adsorption on minerals, soils, and sediments. These principles were used to evaluate available quantitative data and generate a look-up table. These conclusions are:

- Lead may precipitate in soils if soluble concentrations exceed about 4 mg/l at pH 4 and about 0.2 mg/l at pH 8. In the presence of phosphate and chloride, these solubility limits may be as low as 0.3 mg/l at pH 4 and 0.001 mg/l at pH 8. Therefore, in experiments in which concentrations of lead exceed these values, the calculated K_d values may reflect precipitation reactions rather than adsorption reactions.
- Anionic constituents such as phosphate, chloride, and carbonate are known to influence lead reactions in soils either by precipitation of minerals of limited solubility or by reducing adsorption through complex formation.
- A number of adsorption studies indicate that within the pH range of soils (4 to 11), lead adsorption increases with increasing pH.
- Adsorption of lead increases with increasing organic matter content of soils.
- Increasing equilibrium solution concentrations correlates with decreasing lead adsorption (decrease in K_d).

Lead adsorption behavior on soils and soil constituents (clays, oxides, hydroxides, oxyhydroxides, and organic matter) has been studied extensively. However, calculations by Rickard and Nriagu (1978) show that the solution lead concentrations used in a number of adsorption studies may be high enough to induce precipitation. For instance, their calculations show that lead may precipitate in soils if soluble concentrations exceed about 4 mg/l at pH 4 and about 0.2 mg/l at pH 8. In the presence of phosphate and chloride, these solubility limits may be as low as 0.3 mg/l at pH 4 and 0.001 mg/l at pH 8. Therefore, in experiments in which concentrations of lead exceed these values, the calculated K_d values may reflect precipitation reactions rather than adsorption reactions.

Based on lead adsorption behavior of 12 soils from Italy, Soldatini *et al.* (1976) concluded that soil organic matter and clay content were 2 major factors which influence lead adsorption. In these experiments, the maximum adsorption appeared to exceed the cation exchange capacity

(CEC) of the soils. Such an anomaly may have resulted from precipitation reactions brought about by high initial lead concentrations used in these experiments (20 to 830 mg/l).

Lead adsorption characteristics of 7 alkaline soils from India were determined by Singh and Sekhon (1977). The authors concluded that soil clay, organic matter, and the calcium carbonate influenced lead adsorption by these soils. However, the initial lead concentrations used in these experiments ranged from 5 to 100 mg/l, indicating that in these alkaline soils the dominant lead removal mechanism was quite possibly precipitation.

In another adsorption study, Abd-Elfattah and Wada (1981) measured the lead adsorption behavior of 7 Japanese soils. They concluded that soil mineral components which influenced lead adsorption ranged in the order: iron oxides>halloysite>imogolite, allophane>humus, kaolinite>montmorillonite. These data may not be reliable because high lead concentrations (up to 2,900 mg/l) used in these experiments may have resulted in precipitation reactions dominating the experimental system.

Anionic constituents, such as phosphate, chloride, and carbonate, are known to influence lead reactions in soils either by precipitation of minerals of limited solubility or by reducing adsorption through complex formation (Rickard and Nriagu, 1978). A recent study by Bargar *et al.* (1998) showed that chloride solutions could induce precipitation of lead as solid $PbOHCl$. Presence of synthetic chelating ligands such as ethylenediaminetetraacetic acid (EDTA) has been shown to reduce lead adsorption on soils (Peters and Shem, 1992). These investigators showed that the presence of strongly chelating EDTA in concentrations as low as 0.01 M reduced K_d for lead by about 3 orders of magnitude. By comparison quantitative data is lacking on the effects of more common inorganic ligands (phosphate, chloride, and carbonate) on lead adsorption on soils.

A number of adsorption studies indicate that within the pH range of soils (4 to 11), lead adsorption increases with increasing pH (Bittel and Miller, 1974; Braids *et al.*, 1972; Griffin and Shimp, 1976; Haji-Djafari *et al.*, 1981; Hildebrand and Blum, 1974; Overstreet and Krishnamurthy, 1950; Scudato and Estes, 1975; Zimdahl and Hassett, 1977). Griffin and Shimp (1976) also noted that clay minerals adsorbing increasing amounts of lead with increasing pH may also be attributed to the formation of lead carbonate precipitates which was observed when the solution pH values exceeded 5 or 6.

Solid organic matter such as humic material in soils and sediments are known to adsorb lead (Rickard and Nriagu, 1978; Zimdahl and Hassett, 1977). Additionally, soluble organic matter such as fulvates and amino acids are known to chelate soluble lead and affect its adsorption on soils (Rickard and Nriagu, 1978). Gerritse *et al.* (1982) examined the lead adsorption properties of soils as a function of organic matter content of soils. Initial lead concentrations used in these experiments ranged from 0.001 to 0.1 mg/l. Based on adsorption data, the investigators expressed K_d value for a soil as a function of organic matter content (as wt.%) and the distribution coefficient of the organic matter. The data also indicated that irrespective of soil organic matter content, lead adsorption increased with increasing soil pH (from 4 to 8). In certain soils, lead is

also known to form methyl-lead complexes (Rickard and Nriagu, 1978). However, quantitative relationship between the redox status of soils and its effect on overall lead adsorption due to methylation of lead species is not known.

Tso (1970), and Sheppard *et al.* (1989) studied the retention of ^{210}Pb in soils and its uptake by plants. These investigators found that lead in trace concentrations was strongly retained on soils (high K_d values). Lead adsorption by a subsurface soil sample from Hanford, Washington was investigated by Rhoads *et al.* (1992). Adsorption data from these experiments showed that K_d values increased with decreasing lead concentrations in solution (from 0.2 mg/l to 0.0062 mg/l). At a fixed pH of 8.35, the authors found that K_d values were log-linearly correlated with equilibrium concentrations of lead in solution. Calculations showed that if lead concentrations exceeded about 0.207 mg/l, lead-hydroxycarbonate (hydrocerussite) would probably precipitate in this soil.

The K_d data described above are listed in Table F.1.

F.2.0 Approach

The initial step in developing a look-up table consisted of identifying the key parameters which were correlated with lead adsorption (K_d values) on soils and sediments. Data sets developed by Gerritse *et al.* (1982) and Rhoads *et al.* (1992) containing both soil pH and equilibrium lead concentrations as independent variables were selected to develop regression relationships with K_d as the dependent variable. From these data it was found that a polynomial relationship existed between K_d values and soil pH measurements. This relationship (Figure F.1) with a correlation coefficient of 0.971 (r^2) could be expressed as:

$$K_d \text{ (ml/g)} = 1639 - 902.4(\text{pH}) + 150.4(\text{pH})^2 \quad (\text{F.1})$$

The relationship between equilibrium concentrations of lead and K_d values for a Hanford soil at a fixed pH was expressed by Rhoads *et al.* (1992) as:

$$K_d \text{ (ml/g)} = 9,550 C^{-0.335} \quad (\text{F.2})$$

where C is the equilibrium concentration of lead in $\mu\text{g/l}$. The look-up table (Table F.2) was developed from using the relationships F.1 and F.2. Four equilibrium concentration and 3 pH categories were used to estimate the maximum and minimum K_d values in each category. The relationship between the K_d values and the 2 independent variables (pH and the equilibrium concentration) is shown as a 3-dimensional surface (Figure F.2). This graph illustrates that the highest K_d values are encountered under conditions of high pH values and very low equilibrium lead concentrations and in contrast, the lowest K_d values are encountered under lower pH and higher lead concentrations. The K_d values listed in the look-up table encompasses the ranges of pH and lead concentrations normally encountered in surface and subsurface soils and sediments.

Table F.1. Summary of K_d values for lead adsorption on soils.

Soil Description	Clay Content (wt.%)	Organic Carbon (wt.%)	Iron Oxide content (wt.%)	pH	CEC (meq/100g)	K_d (ml/g)	Experimental Parameters	Reference
Sediment, Split Rock Formation, Wyoming	--	--	--	2.0	--	20	--	Haji-Djafari <i>et al.</i> , 1981
	--	--	--	4.5	--	100	--	
	--	--	--	5.75	--	1,500	--	
	--	--	--	7.0	--	4,000	--	
Sand (Soil C)	0	--	--	4.5	22	280	Batch Experiment	Gerritse <i>et al.</i> (1982)
Sand (Soil C)	0	--	--	5.0	22	1295	Batch Experiment	
Sandy Loam (Soil D)	2	--	--	7.5	16	3,000	Batch Experiment	
Sandy Loam (Soil D)	2	--	--	8.0	16	4,000	Batch Experiment	
Loam (Soil 2)	15	--	--	7.3	17	21,000	Batch Experiment	Sheppard <i>et al.</i> (1989)
Medium Sand (Soil 3)	2	--	--	4.9	5.8	19	Batch Experiment	
Organic soil (Soil 4)	<1	--	--	5.5	120	30,000	Batch Experiment	
Fine Sandy Loam (Soil 6)	11	--	--	7.4	8.7	59,000	Batch Experiment	
Sand (Hanford)	0.06	<0.01	0.41	8.35	5.27	13,000 - 79,000	Batch tracer studies (Initial activities 2.38 - 23.4 μ Ci/l)	Rhoads <i>et al.</i> (1992)

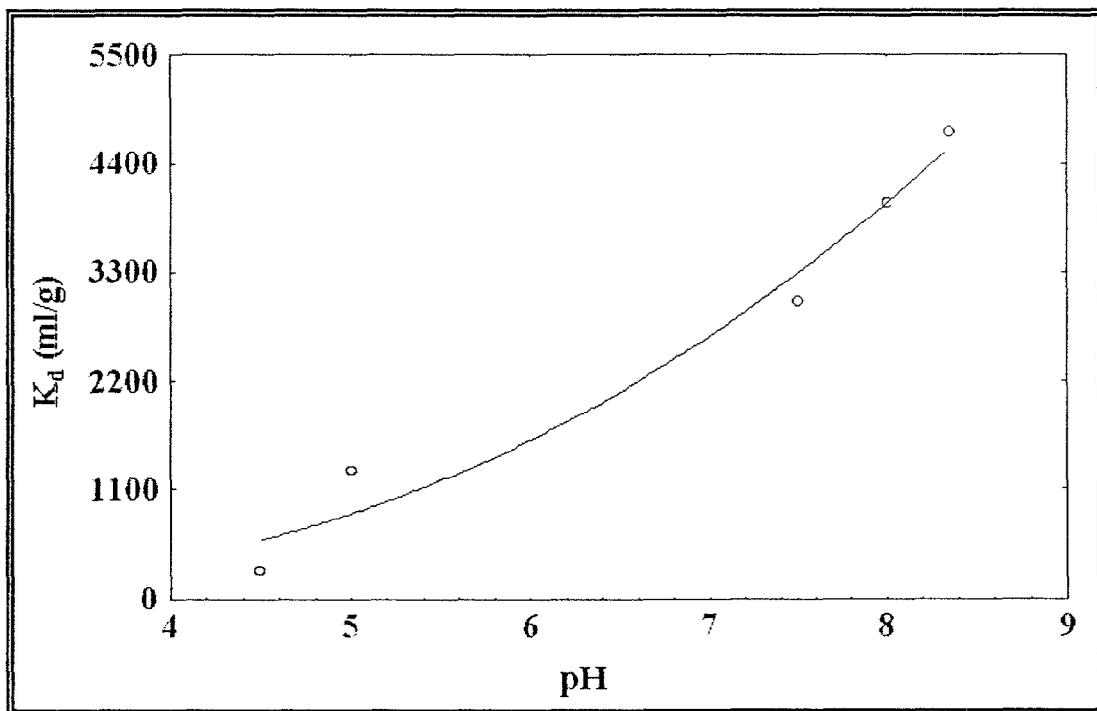


Figure F.1. Correlative relationship between K_d and pH.

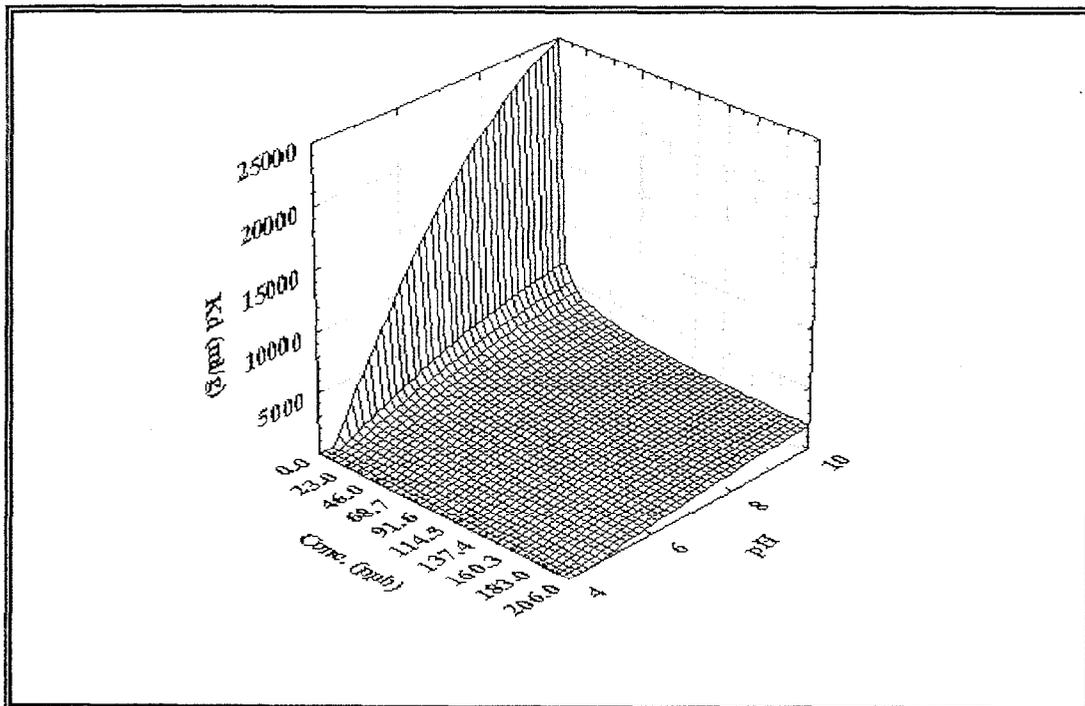


Figure F.2. Variation of K_d as a function of pH and the equilibrium lead concentrations.

F.3.0 Data Set for Soils

The data sets developed by Gerritse *et al.* (1982) and Rhoads *et al.* (1992) were used to develop the look-up table (Table F.2). Gerritse *et al.* (1982) developed adsorption data for 2 well-characterized soils using a range of lead concentrations (0.001 to 0.1 mg/l) which precluded the possibility of precipitation reactions. Similarly, adsorption data developed by Rhoads *et al.* (1992) encompassed a range of lead concentrations from 0.0001 to 0.2 mg/l at a fixed pH value. Both these data sets were used for estimating the range of K_d values for the range of pH and lead concentration values found in soils.

Table F.2. Estimated range of K_d values for lead as a function of soil pH, and equilibrium lead concentrations.

Equilibrium Lead Concentration ($\mu\text{g/l}$)	K_d (ml/g)	Soil pH		
		4.0 - 6.3	6.4 - 8.7	8.8 - 11.0
0.1 - 0.9	Minimum	940	4,360	11,520
	Maximum	8,650	23,270	44,580
1.0 - 9.9	Minimum	420	1,950	5,160
	Maximum	4,000	10,760	20,620
10 - 99.9	Minimum	190	900	2,380
	Maximum	1,850	4,970	9,530
100 - 200	Minimum	150	710	1,880
	Maximum	860	2,300	4,410

F.4.0 References

- Abd-Elfattah, A., and K. Wada. 1981. "Adsorption of Lead, Copper, Zinc, Cobalt, and Cadmium by Soils that Differ in Cation-Exchange Material." *Journal of Soil Science*, 32:71-283.
- Bargar, J. R., G. E. Brown, Jr., and G. A. Parks. 1998. "Surface Complexation of Pb(II) at Oxide-Water Interface: III. XAFS Determination of Pb(II) and Pb(II)-Chloro Adsorption Complexes on Goethite and Alumina." *Geochimica et Cosmochimica Acta*, 62(2):193-207.
- Bittel, J. R., and R. J. Miller. 1974. "Lead, Cadmium, and Calcium Selectivity Coefficients on Montmorillonite, Illite, and Kaolinite." *Journal of Environmental Quality*, 3:250-253.
- Braids, O. C., F. J. Drone, R. Gadde, H. A. Laitinen, and J. E. Bittel. 1972. "Movement of Lead in Soil-Water System." In *Environmental Pollution of Lead and Other Metals*. pp 164-238, University of Illinois, Urbana, Illinois.
- Chow, T. J. 1978. "Lead in Natural Waters." In *The Biogeochemistry of Lead in the Environment. Part A. Ecological Cycles.*, J. O. Nriagu (ed.), pp. 185-218, Elsevier/North Holland, New York, New York.
- Forbes, E. A., A. M. Posner, and J. P. Quirk. 1976. "The Specific Adsorption of Cd, Co, Cu, Pb, and Zn on Goethite." *Journal of Soil Science*, 27:154-166.
- Gerritse, R. G., R. Vriesema, J. W. Dalenberg, and H. P. De Roos. 1982. "Effect of Sewage Sludge on Trace Element Mobility in Soils." *Journal of Environmental Quality*, 11:359-364.
- Grasselly, G., and M. Hetenyi. 1971. "The Role of Manganese Minerals in the Migration of Elements." *Society of Mining Geology of Japan*, Special Issue 3:474-477.
- Griffin, R. A., and N. F. Shimp. 1976. "Effect of pH on Exchange-Adsorption or Precipitation of Lead from Landfill Leachates by Clay Minerals." *Environmental Science and Technology*, 10:1256-1261.
- Haji-Djafari, S., P. E. Antommara, and H. L. Crouse. 1981. "Attenuation of Radionuclides and Toxic Elements by In Situ Soils at a Uranium Tailings Pond in central Wyoming." In *Permeability and Groundwater Contaminant Transport*, T. F. Zimmie, and C. O. Riggs (eds.), pp 221-242. ASTM STP 746. American Society of Testing Materials. Washington, D.C.
- Hildebrand, E. E., and W. E. Blum. 1974. "Lead Fixation by Clay Minerals." *Naturewissenschaften*, 61:169-170.

- Leckie, J. O., M. M. Benjamin, K. Hayes, G. Kaufman, and S. Altman. 1980. *Adsorption/Coprecipitation of Trace Elements from Water with Iron Oxyhydroxides*. EPRI-RP-910, Electric Power Research Institute, Palo Alto, California.
- Overstreet, R., and C. Krishnamurthy. 1950. "An Experimental Evaluation of Ion-exchange Relationships." *Soil Science*, 69:41-50.
- Peters, R. W., and L. Shem. 1992. "Adsorption/Desorption Characteristics of Lead on Various Types of Soil." *Environmental Progress*, 11:234-240.
- Rhoads, K., B. N. Bjornstad, R. E. Lewis, S. S. Teel, K. J. Cantrell, R. J. Serne, J. L. Smoot, C. T. Kincaid, and S. K. Wurster. 1992. *Estimation of the Release and Migration of Lead Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground. Volume 1: Final Report*. PNL-8356 Volume 1, Pacific Northwest Laboratory, Richland, Washington.
- Rhoades, J. D. 1996. "Salinity: electrical Conductivity and Total Dissolved Solids." In *Methods of Soil Analysis, Part 3, Chemical Methods*, J. M. Bigham (ed.), pp. 417-436. Soil Science Society of America Inc., Madison, Wisconsin.
- Richards, L. A. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. Agricultural Handbook 60, U. S. Department of Agriculture, Washington, D.C.
- Rickard, D. T., and J. E. Nriagu. 1978. "Aqueous Environmental Chemistry of Lead." In *The Biogeochemistry of Lead in the Environment. Part A. Ecological Cycles*, J. O. Nriagu (ed.), pp. 291-284, Elsevier/North Holland, New York, New York.
- Scudato, R. J., and E. L. Estes. 1975. "Clay-Lead Sorption Studies." *Environmental Geology*, 1:167-170.
- Sheppard, S. C., W. G. Evenden, and R. J. Pollock. 1989. "Uptake of Natural Radionuclides by Field and Garden Crops." *Canadian Journal of Soil Science*, 69:751-767.
- Singh, B, and G. S. Sekhon. 1977. "Adsorption, Desorption and Solubility Relationships of Lead and Cadmium in Some Alkaline Soils." *Journal of Soil Science*, 28:271-275.
- Soldatini, G. F., R. Riffaldi, and R. Levi-Minzi. 1976. "Lead adsorption by Soils." *Water, Air and Soil Pollution*, 6:111-128.
- Tso, T.C. 1970. "Limited Removal of ^{210}Po and ^{210}Pb from Soil and Fertilizer Leaching." *Agronomy Journal*, 62:663-664.
- Zimdahl, R. L., and J. J. Hassett. 1977. "Lead in Soil." In *Lead in the Environment*. W. R. Boggess and B. G. Wixson (eds.), pp. 93-98. NSF/RA-770214. National Science Foundation, Washington, D.C.

APPENDIX C

INTRODUCTION

Quick Domenico.xls (QD) is a Microsoft Excel spreadsheet application of "An Analytical Model For Multidimensional Transport of a Decaying Contaminant Species", by P.A. Domenico, Journal of Hydrology, 91 (1987), pp 49-58. QD solves the following equation with two modifications to be discussed below:

$$C(x,y,z,t) = \left(\frac{C_0}{8}\right) \exp\left\{\frac{x}{2\alpha_x} \left[1 - \left(1 + \frac{4\lambda\alpha_x}{v}\right)^{\frac{1}{2}}\right]\right\} \operatorname{erfc}\left[\frac{x - vt(\sqrt{1 + 4\lambda\alpha_x/v})}{2\sqrt{\alpha_x vt}}\right] \\ \left\{\operatorname{erf}\left[\frac{(y + Y/2)}{2\sqrt{\alpha_y x}}\right] - \operatorname{erf}\left[\frac{(y - Y/2)}{2\sqrt{\alpha_y x}}\right]\right\} \left\{\operatorname{erf}\left[\frac{(z + Z/2)}{2\sqrt{\alpha_z x}}\right] - \operatorname{erf}\left[\frac{(z - Z/2)}{2\sqrt{\alpha_z x}}\right]\right\}$$

where:

x = distance from planar source to the location of concern (i.e. property line) along the center line of the plume.

C(x,y,z,t) = the concentration of the contaminant at location x, y, z from the source at time t.

C₀ = source concentration - the highest concentration of the contaminant in the groundwater at the source.

α_x = dispersivity in the x direction.

α_y = dispersivity in the y direction .

α_z = dispersivity in the z direction.

k = hydraulic conductivity.

i = hydraulic gradient

n = porosity (entered as a decimal fraction - (i.e. .25)

v = specific discharge. (ki/n)

λ = 1st order decay constant.

S_w = width of source area.

S_z = depth of source area.

x,y,z - these are the spatial coordinates in the horizontal, transverse and vertical directions that define the point or points where concentration information is desired.

t - this is time since the plume source started moving

In QD this equation has been modified in two ways.

First, "v" has been modified to include a retardation factor defined as $1 + (KOC \cdot f_{oc} \cdot p_b/n)$.

where:

KOC = the organic carbon partition coefficient

f_{oc} = fraction of organic carbon expressed as a decimal percent

and p_b = the dry bulk density of the aquifer matrix.

Secondly, the term “Z/2” in the last two error function terms of the equation have been replaced by “Z” as described by Domenico (1987), page 53, to account for dispersion in the vertical axis in only the downward direction, as would occur with contaminants at the water table in a thick uniform aquifer and the source geometry for which this application is designed.

SYSTEM REQUIREMENTS

IBM Compatible PC

Windows 3.1 or later

Microsoft Excel 5.0 or later - with Analysis Tool Pack running. (On menu bar, click Tools, AddIns, Analysis ToolPak)

Intel 486 or better processor recommended.

GENERAL APPLICATION INFORMATION

Overview

Quick Domenico(QD) calculates the concentration of contaminant species at any point and time downgradient of a source area of known size and strength. The kinds of contaminants for which QD is intended are dissolved organic contaminants whose fate and transport are can be described or influenced by first order decay and reaction with organic carbon in the soil. The model allows for first order decay, retardation and three dimensional dispersion, which will be discussed below. In addition, QD calculates the concentrations in a two dimensional 5x10 grid whose length and width are set by the user. The output of the grid is plotted on an Excel chart each time any element of the input data is changed. This allows users to see almost immediately the effects of changes in input data.

Upon selection and input of the final input parameters, the output can be printed on any Windows compatible printer using a pre-set print area.

Limitations

QD is based on the Domenico analytical model referenced above. Only a single value of any one of the 20 or so flow and transport parameters required by the model are allowed at any one time. Therefore the model should not be used where any of these parameters vary significantly in direction or magnitude over the model domain. Further, QD uses physical properties of the soil such as dry bulk density and fraction organic carbon which are difficult to relate to or determine for fractured bedrock aquifers. Therefore QD should be used with caution in these environments. QD is primarily intended for use in unconsolidated (soil) aquifers with reasonably uniform physical and hydrogeologic properties.

QD is primarily intended for use with dissolved organic compounds and radioactive compounds that may react with organic carbon in the soil and/or may be subject to biodegradation or reaction that can be described by 1st order decay. The first order decay constant (λ) should be set to zero where the biodegradability of the compound or its decay rate is questionable. (e.g. MTBE). QD is not appropriate for use with organic compounds that are undergoing transformation to daughter compounds (e.g. TCE to DCE). QD considers compounds individually and assumes no reaction between compounds.

Despite these many limitation, the Domenico model has been successfully applied to actual data from contaminated sites. In addition, QD has application as a “conceptual” model where hypothetical or “worst case” conditions are investigated. By using conservative input assumptions, QD may be useful in Pennsylvania’s Land Recycling Program in providing quantitative support to qualitative fate and transport analyses based solely on professional experience or opinion at sites which do appear to justify the time, expense and data requirements associated with more rigorous numerical modeling efforts.

Color Scheme

The cells in the spreadsheet have been color coded to assist in use and understanding.

Light Green - these cells allow the user to enter data.

Light Yellow - these cells are locked and calculated by the spreadsheet.

Other Colors - these cells are used for labels and other information not critical to use of the application.

Units

Where input requires a certain unit of measurement, it has been indicated. Because the spreadsheet contains internal formulas that depend on the units of the input data, use of improper units will result in spurious results.

Cell By Cell Description - Input Data

The following section discusses the information that is input cell by cell. The discussion will emphasize conservative selection of parameters where appropriate.

B2:D2 Enter project name

B3 Enter the date that application was prepared.

D3 Enter name of person or firm preparing application.

D4 Enter name of contaminant.

A9 Source Concentration in mg/l - QD allows one source concentration which is applied to the entire width and thickness dimensions of the source. The source is presumed to be continuous, which makes QD inherently conservative for use at sites where sources have been removed or remediated. For conservative use, enter the highest concentration in the groundwater determined from the site characterization.

B9 Distance to Location of Concern (x) (in feet) - this is the distance measured from the source, perpendicular to the hydraulic gradient, to the point where a concentration is desired.

C9 Longitudinal Dispersivity - (A_x) - dispersion parallel to the direction of groundwater flow and water table.

D9 Transverse Dispersivity - (A_y) - dispersion perpendicular to the direction of groundwater flow and parallel to the water table.

E9 Vertical Dispersivity - (A_z) - dispersion perpendicular to the direction of groundwater flow and water table. In QD, only vertical dispersion downward below the water table is considered.

These parameters are dispersion terms which describe the extent to which contaminants spread out from the source into areas that cannot be accounted for by advective transport alone. Initially these parameters are often estimated and then adjusted in order to calibrate a model to better fit actual field conditions. Several relationships have been proposed for initial estimates of A_x , A_y , and A_z .

These are:

$A_x = X/10$ where X is the distance a contaminant has traveled by advective transport (i.e. velocity x time)

$A_y = A_x/10$

$Az = Ax/20$ to $Ax/100$. In general, it is recommended for conservative use of QD to use a very small vertical dispersion of .001, unless vertical monitoring can reliably justify a larger number. Because of the way QD is set up, a vertical dispersion of zero cannot be used. A value of about .001 is suggested for initial uncalibrated or conceptual applications.

- F9** Lambda (days^{-1}) - this is the first order decay constant. It is determined by dividing .693 by the half-life of the compound (in days). The value is determined from literature or by calibration to existing data. Dispersivity values and lambda are the two most important calibration terms available in this application. QD is very sensitive to the lambda term. For conservative use of QD, use the lowest lambda from the range of values listed in literature references. For compounds that are not biodegradable or at sites where biodegradation is not occurring use a lambda of zero.

For initial estimates of lambda, see Appendix A, Table 5 of the Act 2 regulations. Values in Appendix A are in years^{-1} . Divide these values by 365 to get lambda in days^{-1} for use in QD.

- G9** Source Width (ft) - enter the maximum width of the area of contaminated soils that have been impacted, or the maximum width of free product or smear zone of contamination measured perpendicular to the direction of groundwater flow. Data should be based on and justified by site characterization data. Because one concentration rarely characterizes the entire source width of a plume, source width can be adjusted somewhat and serve as a calibration parameter.
- H9** Source Thickness - typically this is the thickness of contaminated soils that contribute contamination to the water table plus the water table fluctuation that creates a smear zone.
- A14** Hydraulic Conductivity (k)(ft/day) - the hydraulic conductivity of a geologic material is a measure of its ability to transmit water. The hydraulic conductivity is determined from pumping or slug tests or, sometimes, laboratory tests using standard ASTM or other methods described in numerous hydrogeology text books. QD allows only one hydraulic conductivity measurement to be input. For conservative use, use the highest conductivity value measured at the site.
- B14** Hydraulic Gradient (ft/ft)- this is the slope of the water table in the direction of ground water flow. QD assumes horizontal flow and a uniform hydraulic gradient. Hydraulic gradient of the water table should be measured at each site. A minimum of three wells drilled to the same depth into the geologic formation is required to measure the hydraulic gradient.
- C14** Porosity - (decimal fraction- e.g. .25) - porosity is the ratio of volume of void space in a geologic material to the total volume of material. Porosity can be determined by sending soil samples to a laboratory or, if the texture of the material is well described, by estimating the value of text books. The lower the porosity, the faster groundwater moves through the void space for a given value of 'k' and hydraulic gradient. For conservative use of QD use a reasonably low value of porosity from the range of measured or estimated values.
- D14** Soil Bulk Density - (ρ_b) (g/cm^3) - this is the dry weight of a sample divided by its total volume in an undisturbed state. QD is not particularly sensitive to this parameter. Samples can be sent to a lab for measurement or a value of 1.8 is often estimated.
- E14** KOC - this is the organic carbon partition coefficient and is chemical specific. During formulation of the Act 2 regulations, the Department went to considerable time and expense, using outside expertise, to develop the most up-to-date KOC values. These are provided in Appendix A, Table 5, of the Act 2 regulations. Use these KOC values unless the KOC value is determined for the specific site.
- F14** Fraction Organic Carbon (foe) - (decimal fraction) - this is the organic carbon content of the soil. This value can be determined by a soil laboratory using ASTM methods. Samples for organic carbon should be taken from the same soil horizon in which the contaminant occurs, but from an

area that has not been impacted. For conservative use of QD, use the lowest of the range of values determined or estimated. One-half of one per cent (.005) is a commonly estimated value.

Note: QD may be used for metals where a KD is known by inputting a Koc and foc term such that $Koc * foc = KD$.

- G14** Retardation - the spreadsheet calculates this value automatically. It is defined as $1 + (KOC * foc * p_p / n)$.
- H14** Velocity (V) - (ft/day) - the is rate of groundwater flow. The spreadsheet calculates this value automatically from the previous inputs.
- A18** This cell is automatically filled by transfer of the 'X' coordinate in B7. The value is repeated here simply to facilitate the view of the x, y and z coordinates for which the spreadsheet calculates a solution.
- B18** 'y' (ft) This is the 'y' coordinate for which a solution is desired. For a solution on the centerline of the plume downgradient from the source, y would be set equal to zero. Both positive or negative values may be entered, however, because QD provides a symmetrical solution, there is no difference in the values obtained.
- C18** 'z' (ft) This is the 'z' coordinate in the vertical axis. For most applications this should be left at zero since this value will yield the highest concentration which is at the water table.
- D18** 't' - (days) - this is the time (in days), after a contaminant began moving in the groundwater, for which a solution is desired. By adjusting the spreadsheet with the scroll bars so that both the grid, graphic chart and time can be seen at the same time on the screen, adjusting the time progressively upward provides a graphical way to determine at what time steady state is reached for the particular set of input conditions represented by the input data.
- C26:C27** These cells are where the user sets the grid dimensions for the 5 by 10 grid that appears in cells **C29::K33**. By setting length at 500 ft and width at 50 feet, for example, the grid would cover a length of 500 feet and a width of 50 feet on either side of the source origin. Concentrations in the plume are calculated increments of length/10 or 50 feet, and for width/ 2 or 25 feet. By changing grid sizes, the user will very quickly see how grid dimensions are affected.

Output Data

A22:B22 These cells contain the source concentration calculated for the specific location and time defined in **A18 through D18**.

B29:K33 These cells contain the output for the grid defined by the grid dimension input in C26 and C27. For the grid output, z is fixed at zero by the spreadsheet.

The output from the grid is automatically displayed in a Microsoft Excel chart located above the grid.

Baker

Baker Environmental, Inc.

ATTACHMENT D

Evaluation of Lead at Site 28 Report

November, 2001

EVALUATION OF LEAD CONCENTRATIONS

AT SITE 28, WELL NO. 28-GW07

MCB, CAMP LEJEUNE

NOVEMBER 13, 2001

1.0 INTRODUCTION

An additional study into the lead concentrations at well 28-GW07 at the Hadnot Point Burn Dump, Site 28, MCB Camp Lejeune, was conducted to determine which, if any, mechanisms are responsible for the fluctuating lead concentrations in this well. This brief document supplements the initial report on lead evaluation at the Hadnot Point Burn Dump, Site 28, presented at the March 2001 Partnering Meeting.

In the initial report, the lead concentrations in the soil and groundwater at this site were examined and the following conclusions were forwarded:

- The west fill area of Site 28 has significantly more lead in the surface and subsurface soils than the east fill area. Both fill areas have lead levels above the Base background levels for lead in soil;
- Only one monitoring well at Site 28, 28-GW07, has had sporadic lead detections above the North Carolina Groundwater Quality Standard for lead. This assessment suggests that the reason that lead is detected at that location is because the pH at that location is lower, causing more lead to dissolve from the soil;
- A leaching model of lead from the soil to the groundwater table indicates that there is sufficient lead in the subsurface to impact the groundwater. The levels indicated by the model are similar to those observed during the LTM Program; and
- Depending on which value of K_d is used, groundwater movement of lead to Cogdels Creek indicates that the movement of the lead in the aquifer can impact the surface water at values above the North Carolina Surface Water Quality Standard if the creek is fed by the groundwater.

This report will focus on particularities of well 28-GW07, and draw some reasonable conclusions for the fluctuating lead concentrations at this well during the time frame of 1996 through 2001. When appropriate, comparisons with other wells will be noted. A summary of the data from 28-GW07 can be found in Attachment A.

2.0 BORING LOG INFORMATION

2.1 Summary

An examination of the available boring logs and well construction diagrams was made for the wells at Site 28. Several locations were logged as having fill and/or debris at depths close to the surface. This is not unexpected since this site is a former burn dump. It was also noted that there are some locations where organic material or peat is found in the subsurface. In particular, 28-GW07 was constructed with the lower 10.5 feet of its 15-foot screen in peat (see Attachment B). No other well was screened in this much peat. It was also noted that another well, 28-GW08, has approximately two feet of peat near the bottom of its screen.

2.2 Implications

It was observed and documented in the first report that depressed pH values were consistently found in the groundwater from 28-GW07. It is believed that because the well is over two-thirds screened in peat, the organic material is keeping the pH in the groundwater at a level below neutral. Because lead solubility increases with decreasing pH, the lead is more inclined to dissolve into the groundwater in this acidic environment.

It is also noted that the distribution coefficient, K_d , for lead increases with increasing organic matter (USEPA, 1999). If this is the case, more lead adsorbs to the organic material than to, for example, a sandy material. Combined with the lower pH, this adsorbed lead would also be more available to be dissolved into the groundwater.

2.3 Further Notes

As noted in Section 2.1, well 28-GW08 had a small amount of peat on its well construction diagram. This well also had low concentrations of lead during the 1996-1997 time period. Another well, 28-GW01, also had low sporadic detections of lead from 1996-1999. This well

does not have any peat located around its screen, but some "organic silt" is listed on the boring log. It is also screened through approximately two feet of debris, including metal debris, most likely causing the low lead concentrations.

It is believed that the high pH reading of 8.94 at 28-GW07 for the January 2001 sampling event (see Attachment A) is inaccurate. The pH meter may have been faulty or not calibrated correctly.

3.0 GROUNDWATER ELEVATION INFORMATION

3.1 Summary

In Figure 1 lead concentrations are plotted along with pH levels and static groundwater table elevations at 28-GW07. It can be seen that in most cases the groundwater elevations are high when lead concentrations are low and vice versa. This observation was studied further and the results are presented here.

Table 1 shows the results of the sampling events at 28-GW07 placed in order of highest groundwater elevation to lowest groundwater elevation. Most of the higher lead concentrations are at the bottom of the table where the groundwater elevations are lowest.

Table 2 depicts the same results in a slightly different order, sorting the concentrations by sampling event. Similar quarters of sampling events are listed together and the average lead concentration for each quarter is found. The months where the groundwater elevations are the highest, in effect, quarters A and B (January through June), show much lower lead concentrations (2 - 10 ug/L) than those months where the groundwater elevations are lower, July through December, or quarters C and D (30 - 33 ug/L).

In order to test the theory that these two groups of data, quarters A and B concentrations and quarters C and D concentrations, are, in fact, statistically different, the Mann-Whitney U test or Wilcoxon rank-sum test, was performed on the two groups of concentration data. The results are given in Table 3. The conclusion from this test is that the concentrations from the July through December sampling events are statistically different from the concentrations from the January through June sampling events. That is, these two groups of data have statistically different means or averages.

3.2 Implications

It is believed that, as a result of the lower water table during the dry season months, July through December, lead concentrations increase due to lack of dilution from recharge. The lead desorbs from the organic material surrounding the 28-GW07 screen into the groundwater and becomes concentrated in the groundwater until the rainy season occurs to dilute the lead. The statistical evidence for this theory is clearly noted in Table 3.

4.0 K_d CALCULATIONS

In order to evaluate the equilibrium conditions of lead around the well 28-GW07, a few calculations were performed to determine if the lead concentrations noted in the field during the LTM program are consistent with predicted values using the distribution coefficient, K_d . K_d is defined as the ratio of soil concentration to groundwater concentration:

$$K_d = \frac{\text{Soil concentration}}{\text{Groundwater concentration}}$$

If the K_d is assumed and the soil concentration is known, the equation can be rearranged to estimate the resulting groundwater concentration in equilibrium conditions.

The North Carolina Hazardous Waste Section Soil Screening Levels Table 1 lists the K_d for lead as 900 L/kg, most likely assuming a sandy soil. Appendix F of the USEPA (1999) document on partition coefficients gives an equation for calculating K_d if the pH of the soil is known (see Baker, 2001a, Appendix B). The pH of the soil (in this case organic matter) was conservatively assumed to be the same as the surrounding groundwater and assigned a value of 6.5. The equation from this document results in a K_d of 2128 L/kg.

Using the soil concentration of 105,000 ug/kg of lead found at 28-GW07, and the North Carolina K_d value, a groundwater concentration of 116 ug/L of lead is calculated. This value is higher than the concentrations observed. Using the estimated K_d value found with the USEPA equation, a groundwater concentration of 49 ug/L is calculated. This value is in the same order of magnitude of the concentrations observed in this well. The USEPA estimated K_d value is

believed to be more valid at this location because it accounts for the lower pH in the soil around the well due to the organic matter.

5.0 CONCLUSIONS

The following conclusions regarding the lead concentration fluctuation at 28-GW07 are forwarded:

- The large amount of organic matter in the soil around 28-GW07 adsorbs lead to a higher degree than a typical sandy soil. This lead is more available to dissolve in a lower pH groundwater resulting from the organic material surrounding the well.
- The lack of surficial recharge during the dryer seasons at MCB Camp Lejeune results in equilibrium concentrations of lead in the groundwater during these seasons. The lead concentrations in 28-GW07 are consistently higher during the dryer months than they are during the rainy months.
- It is believed that this cycle will continue indefinitely. Based on distribution coefficient calculations and assuming that the measured soil concentrations are representative of the subsurface, the concentrations of lead in 28-GW07 will be in the 5 to 100 ug/L range during the dryer months when equilibrium conditions are more likely.

6.0 REFERENCES

Baker Environmental, Inc., Evaluation of Lead at Site 28, presented at Partnering, March 2001a.

Baker Environmental, Inc., Long-Term Monitoring Reports, OU No. 7, (Sites 1 and 28), MCB Camp Lejeune, North Carolina, CTO 0120, Department of the Navy, LANTDIV, Naval Facilities Engineering Command, 2001, et al.

Baker Environmental, Inc., Remedial Investigation Report, OU No. 7 (Sites 1, 28, 30), MCB Camp Lejeune, North Carolina, CTO 0231, Department of the Navy, LANTDIV, Naval Facilities Engineering Command, June 29, 1995.

Hines, W.W., and Montgomery, D.C., *Probability and Statistics in Engineering and Management Science*, 2nd Edition, John Wiley and Sons, New York, 1980.

USEPA, "Understanding Variation in Partition Coefficients, K_d , Values," Volume II, Appendix F, EPA 402/R-99-004B, August, 1999.

TABLE 1
STATIC GROUNDWATER ELEVATIONS AND LEAD CONCENTRATIONS
WELL 28-GW07, SITE 28
MCB CAMP LEJEUNE, NORTH CAROLINA

Static Water Elevation (feet above msl)	Quarter Sampled	Lead Concentration (ug/L)
3.79	99A	1
3.75	98A	ND
3.60	99D	17
3.24	96C	12.4
3.00	01B	8.3
2.97	01A	ND
2.66	00A	4.5
2.62	99B	6.6
2.41	97A	6.8
2.17	00B	15
1.91	98C	65
1.82	00D	41.7
1.68	98D	32.5
1.55	01C	47.8
1.25	97C	30.6
1.22	99C	34.2
0.93	00C	4.5

TABLE 2
AVERAGE LEAD CONCENTRATION PER QUARTER
WELL 28-GW07, SITE 28
MCB CAMP LEJEUNE, NORTH CAROLINA

Quarter Sampled	Lead Concentration (ug/L)	Average Concentration in Quarter (ug/L)
97A	6.8	
98A	0.7 ND*	
99A	1	2.74
00A	4.5	
01A	0.7 ND*	
99B	6.6	
00B	15	9.97
01B	8.3	
96C	12.4	
97C	30.6	
98C	65	
99C	34.2	32.42
00C	4.5	
01C	47.8	
99D	17	
00D	41.7	30.40
98D	32.5	
Total Average =		19.37

* Half Non-Detect value (0.7 ug/L) used in calculations

TABLE 3
MANN-WHITNEY U TEST
WELL 28-GW07, SITE 28
MCB CAMP LEJEUNE, NORTH CAROLINA

Hypothesis: Mean (Group 1) is not equal to Mean (Group 2)
 Group 1 = samples from January through June, A and B
 Group 2 = samples from July through December, C and D

Sampling Event	Lead Concentration (ug/L) in ascending order	Group	Rank
01A	0.7	1	1
98A	0.7	1	2
99A	1	1	3
00A	4.5	1	4
00C	4.5	2	5
99B	6.6	1	6
97A	6.8	1	7
01B	8.3	1	8
96C	12.4	2	9
00B	15	1	10
99D	17	2	11
97C	30.6	2	12
98D	32.5	2	13
99C	34.2	2	14
00D	41.7	2	15
01C	47.8	2	16
98C	65	2	17

R_1 (sum of ranks of Group 1) = 41
 R_2 (sum of ranks of Group 2) = 112

Critical value

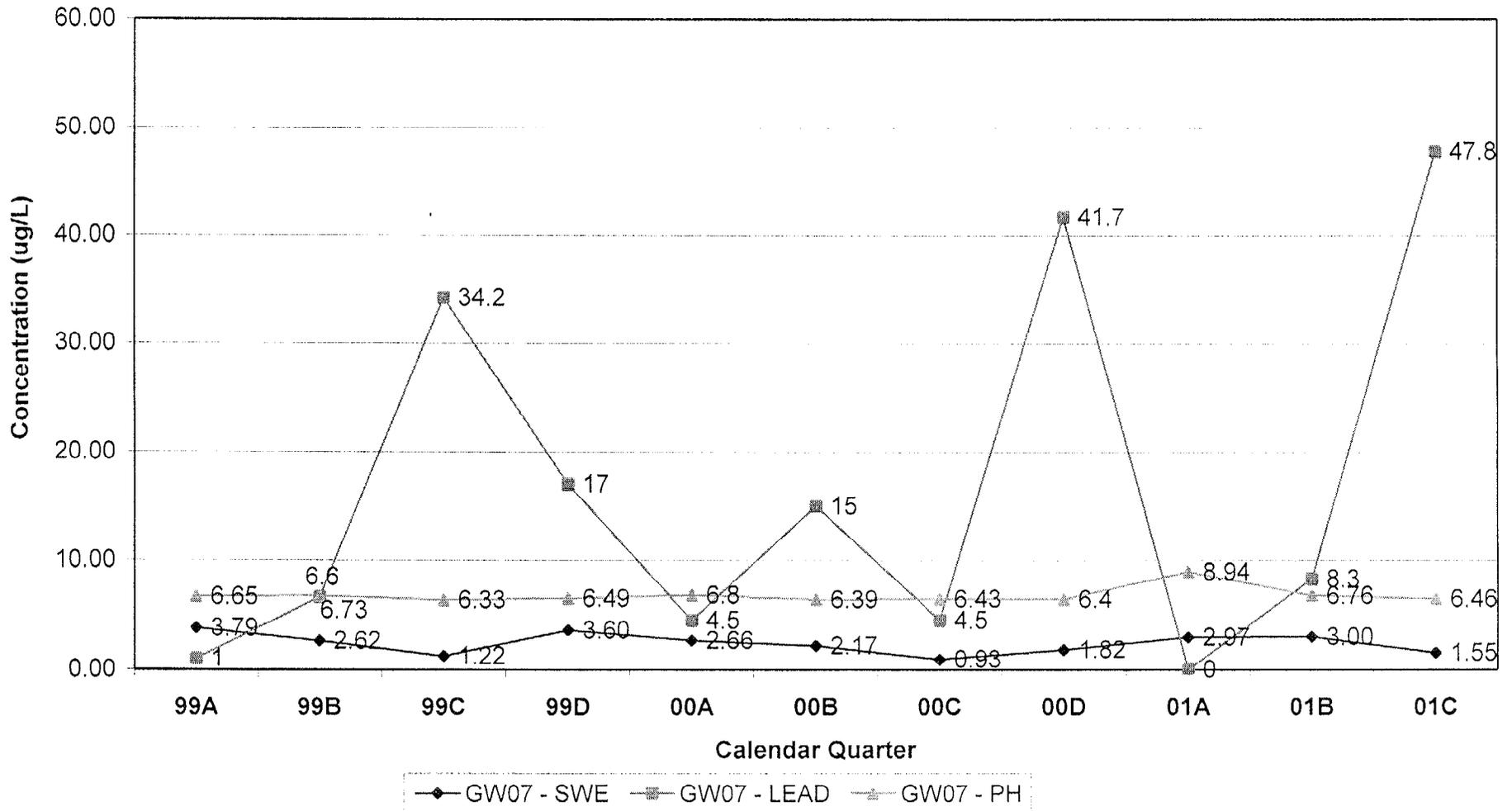
$R = 51$ (Table IX in Hines and Montgomery) ($n_1=8, n_2=9$).

Since R_1 is less than 51, we accept the hypothesis that these two populations are statistically different.

note: tiebreaker option would not yield different results

FIGURE 1

TIME TREND OF LEAD, Ph AND GROUNDWATER ELEVATIONS TRENDS
IN GROUNDWATER MONITORING WELL 28-GW07
OPERABLE UNIT NO. 7- SITE 28
MONITORING AND O&M SUPPORT, CTO-0120
MCB, CAMP LEJEUNE, NORTH CAROLINA



ATTACHMENT A
WELL 28-GW07 DATA
SITE 28
MCB CAMP LEJEUNE, NORTH CAROLINA

Sampling Event	Lead Concentration (ug/L)	pH	Static Water Elevation (feet above msl)
96C	12.4	6.37	3.24
97A	6.8	6.78	2.41
97C	30.6	6.55	1.25
98A	ND	7.22	3.75
98C	65	NA	1.91
98D	32.5	6.37	1.68
99A	1 B	6.68	3.79
99B	6.6	6.74	2.62
99C	34.2	6.4	1.22
99D	17	6.51	3.60
00A	4.5	6.77	2.66
00B	8.7	6.37	2.17
00C	29.5	6.43	0.93
00D	41.7	6.38	1.82
01A	ND	8.94	2.97
01B	8.3	6.76	3.00
01C	47.8	6.46	1.55

msl = mean sea level

B --below reporting limit but above method detection limit

Baker

Baker Environmental, Inc.
ATTACHMENT E

State of North Carolina Approval Letter

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ATTACHMENT F

USEPA Region IV Approval Letter

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