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DRAFT SUPPLEMENTAL SITE INVESTIGATION REPORT OPERABLE UNIT 15 (OU 15) SITE 88 BUILDING 25 BASE DRY CLEANERS MCB CAMP LEJEUNE NC (DRAFT ACTING AS FINAL)

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CH2M HILL

DRAFT

Supplemental Site Investigation Report
Operable Unit No. 15 (Site 88)
Building 25, Base Dry Cleaners
Marine Corps Base
Camp Lejeune, North Carolina

Prepared for

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Prepared by

CH2MHILL

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Executive Summary

Marine Corps Base (MCB), Camp Lejeune is a training base for the United States Marine Corps located in Onslow County, North Carolina.

Site Description

Operable Unit No. 15, Site 88 consists of the Base Dry Cleaning facility (Building 25). See **Figures 1-1** and **1-2**. Beginning in the 1940s, Varsol™ was stored in underground storage tanks (USTs) located on the north side of the building, and later replaced by tetrachloroethene (PCE) in the 1970s. The PCE was stored in an above ground storage tank (AST). PCE was reportedly stored in the AST from the 1970's until the mid-1980's. Facility employees have reported that spent PCE was disposed of in floor drains. In March, 1995, two self-contained dry cleaning machines were installed in Building 25, eliminating the need for bulk storage of PCE.

Previous Investigations

Previous groundwater investigations at Site 88 were performed by Baker Environmental in 1997 (and reported in the Focused Remedial Investigation Report in 1998), and included installation of both temporary and permanent monitoring wells, soil and groundwater sampling and analysis, and aquifer parameter testing.

A total of 38 temporary monitoring wells and 21 permanent monitoring wells were installed during April/May 1997. **Figure 2-1** illustrates the locations of all permanent wells. All temporary wells were abandoned at the completion of the 1997 investigation.

Pilot Testing

Two separate remedial technology pilot tests have been conducted at Site 88 since the completion of the focused RI: 1) Surfactant-Enhanced Aquifer Remediation (SEAR), and 2) Reductive Anaerobic In-situ Treatment Technology (RABITT).

A 1999 SEAR demonstration involved the injection and subsequent extraction of a surfactant solution from a treatment cell located on the north side of Building 25 (**Figure 2-2)**. The treatment cell was equipped with injection wells, extraction wells, and hydraulic control wells, installed within the surficial aquifer.

Continuous surfactant injection was performed for a duration of 143 days. Extracted fluids were treated prior to disposal and the surfactant recycled. A total of 76 gallons of PCE were removed during the SEAR demonstration. A post-SEAR investigation estimated the volume of dense non-aqueous phase liquid (DNAPL) remaining in the treatment cell to be approximately 29 gallons.

RABITT treatability testing was performed in the northwestern portion of Site 88 during 2001, to investigate if "microbially-catalyzed reductive dechlorination of chloroethenes could be stimulated in-situ."

A treatment cell consisting of 12 intermediate-depth wells was constructed to the west of 88-MW05 (**Figure 2-3**). PCE-contaminated groundwater was pumped from 88-MW05IW, amended with electron donor solution, and then injected into RABITT well MW-5. Groundwater samples were collected and analyzed over a period of 30 weeks. The RABITT study concluded that native subsurface microbial populations were capable of sequentially reducing PCE to ethene.

Site Characteristics

The geology of the study area consists of Atlantic Coastal Plain sediments; which are predominantly comprised of fine sand, silt, and clay. Figure 3-1 presents the stratigraphic framework of the Atlantic Coastal Plain of North Carolina.

The uppermost undifferentiated formation consists of mostly fine sand with a lesser amount of silt. Thin discontinuous layers of silt and clay are found within the undifferentiated formation, including a silty unit ranging in thickness from 4 to 10 feet. At Site 88, the undifferentiated formation overlies the Oligocene age River Bend Fm., which is encountered at elevations of -10 to -30 ft msl (40 to 60 ft. bgs) at Site 88.

During the July 2002 well gauging event, the surficial aquifer at Site 88 was found to occur at elevations ranging from 8.9 to 19.2 ft. msl, while the static water level elevation within the upper Castle Hayne aquifer was found to range from 7.7 to 8.9 ft. msl. Groundwater flow within the surficial aquifer is generally toward the southwest.

Seepage velocities calculated from slug tests ranged from 0.1 to 4.5 ft/day in the shallow wells, 1.2 to 2.1 ft/day in the intermediate depth wells, and 5.0 ft/day in the deep wells.

The maximum depth of investigation at Site 88 has been limited to approximately 100 ft. bgs, without encountering sediments of the Castle Hayne Formation.

Nature and Extent of Contamination

In July 2002, CH2M HILL collected groundwater samples from 22 monitoring wells (see **Table 4-1**). Samples were analyzed for total TAL metals, VOCs, and natural attenuation indicator parameters.

Numerous chlorinated hydrocarbons exceeded their respective North Carolina Groundwater Quality Standard (NCGWQS). **Table 4-1** summarizes contaminant detections and exceedances of the NCGWQS. **Figures 4-1** through **4-6** illustrate the dissolved-phase contaminant detections and exceedances resulting from the July 2002 sampling event.

The highest contaminant concentrations were found in former SEAR injection well, IN-01, located in the source area (**Figure 4-1**). The available data indicates a general northwest migration of contaminants at all three screened intervals, but especially in the shallow and intermediate wells.

The presence of elevated concentrations of VOCs in the intermediate-depth wells suggests that although appreciable volumes of DNAPL are observed to accumulate upon the shallow silt layer discussed in **Section 3.3**, this layer is allowing dissolved-phase VOCs to migrate vertically to the intermediate depth wells.

The NAIP data indicates the presence of methanogenic conditions in the source area (north of Building 25) and former RABITT study area. Radiating from the source area, the redox conditions change to ferrogenic conditions at 88-GW03. These indicators coupled with the complete degradation pathway from PCE to ethene provide confirmation of the successful natural attenuation of PCE at Site 88.

Data Limitations

Site Characteristics

The primary data gaps include lithology and stratigraphic control, groundwater hydrology, and aquifer properties. Past investigations have identified two important geologic horizons that appear to inhibit the vertical migration of dissolved-phase contaminants. The first occurs within the undifferentiated Formation (Fm.), and is represented by an apparently discontinuous silt/clay layer, first encountered at an elevation of approximately 10 ft msl.

The second geologic horizon observed to retard vertical contaminant migration at Site 88 was identified by Baker at an elevation of approximately –30 ft. msl. Dissolved-phase VOC concentrations show a significant decrease across this zone, as indicated by the intermediate and deep wells. The lateral continuity of these features has not been determined beyond the immediate source area.

There are very few monitoring wells with which to accurately predict the groundwater flow regime. The current monitoring well network provides only a rudimentary understanding of the potential contaminant flow paths.

No attempt has been made to investigate the degree of hydraulic connection and fluid interaction between the surficial aquifer and the underlying upper Castle Hayne aquifer.

Extent of Contamination

The inter-well spacing of the current monitoring well network is too great to accurately delineate the horizontal extent of groundwater contaminants. Similarly, the vertical extent and distribution of contaminants is not well defined. A limited soil investigation was conducted during the focused RI in 1997. However, given the organic nature of the site contaminants, the 1997 information is likely no longer representative of site conditions.

Recommendations

1. Additional investigation is required to assess the areal extent and continuity of the lithologies (silt/clay layer and high density silty sand zone) that appear to be significantly influencing vertical contaminant migration. This will require the installation of several deep wells within the source area and at the periphery of the site. It is recommended that continuous soil samples be collected from these well borings, and that representative undisturbed samples from each lithology be submitted for laboratory testing to evaluate physical properties.

2. The current understanding of the local groundwater flow regime is very limited. Additional shallow and intermediate depth wells are required in order to better resolve groundwater flow patterns.

3. It is important to quantify the properties of the two aquifers and aquitards identified at Site 88. Consequently, it is recommended that two 72-hr aquifer pumping tests be conducted using intermediate and deep pumping wells. These wells should be located in such a manner so as to minimize contaminant migration. It may be necessary to install additional monitoring wells to serve as observation wells for these tests.

4. In order to complete the delineation of the VOC plumes in shallow, intermediate and deep zones, additional monitoring wells will be required. However, it is likely that wells cited in the preceding recommendations will accomplish the goal of plume delineation.

5. Given the historical practice of disposing spent PCE into the sewer system and the northwesterly propagation of the dissolved-phase VOC groundwater plume, it is recommended that a soil contamination investigation be conducted using direct push technology along the alignment of the buried utility lines to west and northwest of Site 88. The goal of this investigation should be to identify secondary source material that may be contributing to the northwesterly expansion of the VOC plume.

1. Introduction

Marine Corps Base (MCB), Camp Lejeune is located in Onslow County, North Carolina. In 1997, Baker Environmental was tasked by the Atlantic Division of the Naval Facilities Engineering Command (LANTDIV) to perform a focused Remedial Investigation (RI) at Operable Unit No. 15, Site 88. Due to the discovery of dense non-aqueous phase liquids (DNAPLs) and elevated concentrations of dissolved-phase chlorinated hydrocarbons during the focused RI, CH2M HILL is now tasked to perform a comprehensive RI of Site 88.

1.1 Purpose of Report

The purpose of this supplemental report is to present a summary of the data acquired during the past 6 years of RI, recent remediation pilot testing, and the July 2002 Baseline groundwater monitoring event, and to provide recommendations for the RI. The report provides an interpretation of these data, and discusses the estimated nature and extent of groundwater contamination. The report also provides a preliminary assessment of subsurface contaminant migration pathways and transport mechanisms. Finally, this report offers recommendations for focused study to be incorporated into the RI Work Plan.

1.2 Facility Description

Site 88 consists of Building 25 the Base Dry Cleaning facility, and the surrounding paved and grassy areas. See **Figures 1-1** and **1-2**. The approximate dimensions of Building 25 are 180 feet by 50 feet. North of Building 25 are several vaulted steam conveyance pipe lines, below grade concrete vaults, and shallow drainage channels. Steam condensate is directed away from Building 25 by shallow drainage channels that discharge into storm drains on the north side of the building. Wastewater is also discharged to the Base wastewater collection system located on the north side of the building. **Figure 1-3** shows that each subsurface conveyance system trends to the west or northwest upon leaving Building 25.

1.3 Report Organization

This Supplemental Investigation report is divided into six sections, as follows:

1.0 Introduction

2.0 Facility History

3.0 Site Characteristics

4.0 Nature and Extent of Contamination

5.0 Data Limitations

6.0 Recommendations

2. Facility History

2.1 Facility Development and Operational History

2.1.1 Sources of Historical Information on Site 88 Operations

In preparing this document, CH2MHILL has relied upon information presented in the 1998 Focused Remedial Investigation Report, produced by Baker Environmental that documents their 1997 investigation activities. No additional historical research was conducted in support of this report.

2.1.2 Summary of Operations and Chemicals used at Site 88

Building 25 has reportedly been utilized as a dry cleaning facility since the 1940's. Five underground storage tanks (USTs) were installed on the north side of the building to store dry cleaning fluids (**Table 2-1**). Initially, Varsol™ was used in dry cleaning operations at Building 25, although the use of Varsol™ was discontinued during the 1970's due to concerns about it's flammability.

TABLE 2-1
Summary of Product Usage and Waste Disposal
OU No. 15, Site 88, MCB Camp Lejeune, NC

Product	Dates Used	Storage	Disposal
Varsol™	1940's-1970's	Underground Storage Tanks	N/A
PCE	1970's- March, 1995	Above Ground Storage Tanks	Floor Drains
PCE	March, 1995-Present	Self-contained dry cleaning units	Off site

Varsol™ was replaced by tetrachloroethene (synonyms: tetrachloroethylene, perchloroethene, perchloroethylene, perc, and PCE). The PCE was stored in one 150-gallon above ground storage tank (AST) adjacent to the north wall of Building 25 in the same vicinity as the USTs. PCE was reportedly stored in the AST from the 1970's until the mid-1980's. During this time, facility employees have reported that spent PCE was disposed of in floor drains. In March 1995, self-contained dry cleaning machines were installed in Building 25, eliminating the need for bulk storage of PCE, and the USTs and AST were removed. There are currently two self-contained PCE dry cleaning units in operation at the site.

2.2 Past Groundwater Investigations

Baker conducted a RI in 1997. This work included: installation of both temporary and permanent monitoring wells, monitoring well development, groundwater sample acquisition, groundwater elevation measurements, on-site laboratory analysis, fixed-based laboratory analysis, and slug tests to evaluate hydraulic conductivity.

Focused RI – Phase I (April 1997)

A total of 38 temporary monitoring wells were installed during Baker's April 1997 Phase I Investigation. Of the wells installed during this phase of investigation, 24 were shallow wells (15 to 20 feet below ground surface (bgs)), and 14 were intermediate depth wells (~50 ft bgs). These wells were used to characterize the nature and extent of contamination as well as provide information used to determine the placement of permanent wells. After the investigation was completed, all temporary wells were abandoned.

Focused RI – Phase II (April/May 1997)

A total of 21 permanent groundwater monitoring wells were installed during Baker's Phase II study. Nine shallow wells were screened at the top of the surficial aquifer bracketing the water table (15 to 25 ft. bgs). Eight intermediate depth wells (39 to 50 ft. bgs; defined by the "IW" suffix in the well identification) were screened at the top of the Castle Hayne aquifer, and four deep wells (85 to 97 ft. bgs; defined by the "DW" suffix in the well identification) were installed. **Table 2-2** presents well construction details for the permanent monitoring wells. The locations of these wells are shown in **Figure 2-1**.

Samples collected from the temporary monitoring wells were analyzed for volatile organic compounds (VOCs) in an on-site laboratory. Samples collected from the permanent monitoring wells were shipped to a fixed-base laboratory for analysis of TCL VOCs, engineering parameters, and natural attenuation indicator parameters (NAIPs).

Slug tests were used to characterize the hydraulic conductivity of the Surficial and upper Castle Hayne Aquifers. Rising and falling head tests were conducted in the intermediate and deep permanent monitoring wells, and rising head tests were conducted on the shallow monitoring wells. **Table 2-3** summarizes the results of these slug tests.

TABLE 2-3
Summary of Aquifer Testing Data
OU No. 15, Site 88, MCB Camp Lejeune, NC

	Well ID	Hydraulic Conductivity			Horizontal Gradient	Porosity (assumed)	Seepage Velocity (ft./day)
		Falling Head (ft./day)	Rising Head (ft./day)	Geometric Mean (ft./day)			
Shallow	88-MW02	NA	9.2	NA	0.03	0.2	1.4
Shallow	88-MW04	NA	15.7	NA	0.04	0.2	3.1
Shallow	88-MW04*	NA	7.3	NA	0.04	0.2	1.5
Shallow	88-MW05	NA	0.8	NA	0.03	0.2	0.1
Shallow	88-MW06*	NA	4.7	NA	0.03	0.2	0.7
Shallow	88-MW07	NA	29.7	NA	0.03	0.2	4.5
Shallow	88-MW09	NA	0.4	NA	0.03	0.2	0.1
Shallow	Geometric Mean	NA	11.2	NA	0.03	0.2	1.7
Intermediate	88-MW03IW	170.3	6.8	34.0	0.007	0.2	1.2
Intermediate	88-MW04IW	59.4	64.7	62.0	0.005	0.2	1.5
Intermediate	88-MW07IW	51.9	60.9	56.2	0.006	0.2	1.7
Intermediate	88-MW09IW	84.0	86.9	85.4	0.005	0.2	2.1
Intermediate	Geometric Mean	81.5	39.1	56.4	0.006	0.2	1.7
Deep	88-MW03DW	6.2	4.0	5.0	0.004	0.2	0.1

* - Slug test performed by CH2M HILL, all others performed by Baker

2.3 Pilot Testing

Two remedial technology pilot tests have been conducted at Site 88 since the completion of the focused RI in 1998.

2.3.1 Surfactant-Enhanced Aquifer Remediation (SEAR)

In 1999, Duke Engineering and Services in cooperation with Baker Environmental, Inc., completed a focused demonstration of surfactant-enhanced aquifer remediation (SEAR) at Site 88.

The demonstration involved the injection and subsequent extraction of a surfactant solution from a treatment cell measuring approximately 20 feet x 30 feet, located on the north side of Building 25 (USDoD, 2001). It was estimated that the treatment cell encompassed approximately 25% of the DNAPL zone at Site 88. **Figure 2-2** shows the location of the treatment cell. The treatment cell was equipped with three injection wells (designated IN01 through IN03) and six extraction wells (designated EX01 through EX06) arranged in a 3 x 3 x 3 array with the injection wells in the center of the array. Hydraulic control wells (designated HC01 and HC02) were installed at each end of the injection wells. All wells were installed within the surficial aquifer, to a depth of approximately 20 feet below ground surface (bgs). **Table 2-4** presents a summary of the SEAR well construction details.

Continuous surfactant injection was performed for a duration of 143 days, beginning on March 15, 1999, and ending on August 30, 1999. The surfactant used was Alfoterra 145-4-PO Sulfate™. The injected surfactant solution contained 4% surfactant, 16% isopropyl alcohol (IPA), 0.16 to 0.19% Calcium chloride, with the remainder of the solution consisting of groundwater from the treatment cell. **Table 2-5** summarizes the mass of surfactant formulation chemicals injected.

TABLE 2-5
Summary of Surfactant Formulation Chemicals Injected
OU No. 15, Site 88, MCB Camp Lejeune, NC

Constituent	Mass Injected
Alfoterra 145-4-PO Sulfate™	9,718 lbs.[(a)]
Isopropyl alcohol	38,637 lbs.
Calcium chloride	1,806 lbs.

(a) This includes 1,806 lbs. of recovered surfactant that was re-injected during the latter 20 days of surfactant flooding

During the period from March 29 until August 19, 1999, 268,000 gallons of total fluids (consisting of a mixture of surfactant, DNAPL, and groundwater) were extracted from the treatment cell. Following extraction, 101,000 gallons were pretreated using pervaporation and ultrafiltration, the remaining volume was transported to the wastewater treatment plant located at Lot 203. The pervaporation was found to be 95% effective for the removal of PCE and 33 to 57% effective for the removal of Varsol™. A total of 76 gallons of PCE were removed during the SEAR demonstration. A post-SEAR investigation estimated the volume of DNAPL remaining in the treatment cell to be approximately 29 gallons.

2.3.2 Reductive Anaerobic In-Situ Treatment Technology (RABITT)

Reductive Anaerobic In-situ Treatment Technology (RABITT) treatability testing was performed by Battelle Memorial Institute (BMI) in the northwestern portion of Site 88 during the spring and early summer of 2001. The stated goal of the study was to investigate if "microbially-catalyzed reductive dechlorination of chloroethenes could be stimulated in-situ."

A treatment cell consisting of a total of 12 intermediate-depth wells was constructed to the west of 88-MW05. These wells were installed with screened intervals ranging from 45 to 48 ft. bgs. Three of the wells were initially designated as injection wells (IW-1 through IW-3), with the remainder being designated as monitoring wells (MW-1 through MW-9). **Figure 2-3** illustrates the configuration of the RABITT well array. **Table 2-6** summarizes the RABITT well construction details. Two existing wells were also used during the RABITT study. Well 88-MW05IW was used to supply PCE-contaminated ground water for injection, and well 88-MW03IW was used for background sampling.

In preparation for the study, a sodium bromide tracer test was conducted to evaluate the direction of groundwater flow through the treatment cell. The initial test yielded unexpected results, suggesting that groundwater injected into IW-1 through IW-3 may be flowing to the northeast, away from the treatment cell. Consequently, the tracer test was re-configured to use MW-5, located centrally, to act as the injection well. The revised test indicated essentially radial groundwater flow from the injection well.

During the RABITT test, PCE-contaminated groundwater was pumped from 88-MW05IW, amended with electron donor solution (3,000 µM butyric acid and yeast extract), and then injected into MW-5. Groundwater samples were collected and analyzed over a period of 30 weeks.

The RABITT study concluded that native subsurface microbial populations were capable of sequentially reducing PCE to ethene. Also, BMI observed that PCE and TCE concentrations were reduced to below detectable levels in almost all wells after 14 weeks and remained depressed throughout the remainder of the demonstration. It was reported that the degradation of PCE and TCE occurred so rapidly that the injected PCE-contaminated groundwater was free of both PCE and TCE by the time it reached the first monitoring well only 5.4 feet away.

2.4 DNAPL Recovery

Shallow monitoring wells and former SEAR wells adjacent to Building 25 are gauged weekly to monitor the accumulation of DNAPL. When detected, the Base Remedial Action Contractor (RAC) removes the DNAPL by vacuum extraction and transports it to Lot 203 for disposal. **Figure 2-4** illustrates the distribution of DNAPL as measured in site wells on July 22, 2002.

Table 2-2
Summary of Well Permanent Monitoring Well
Construction Details
OU 15, Site 88
MCB Camp Lejeune, NC

Well ID	Date Installed	Casing Diameter (in)	Elevation (feet above msl)		Boring Depth (feet bgs)	Well Depth (feet bgs)	Screen Intervals (feet above msl)		Sand Pack Interval (feet bgs)	Bentonite Interval (feet bgs)	Well Completion
			Top of PVC Casing	Ground Surface			Lower	Upper			
88-MW02DW	04/20/97	2.0	25.10	26.5	100.0	97.0	92.0	97.0	87.0 - 97.0	82.0 - 87.0	Flush Mount
88-MW03DW	04/30/97	2.0	25.32	25.890	85.0	85.0	80.0	85.0	75.0 - 85.0	70.0 - 75.0	Flush Mount
88-MW04DW	04/18/97	2.0	24.61	24.950	85.0	85.0	80.0	85.0	76.0 - 85.0	73.0 - 76.0	Flush Mount
88-MW05DW	04/22/97	2.0	24.33	24.740	87.0	85.0	80.0	85.0	75.0 - 85.0	70.0 - 75.0	Flush Mount
88-MW02IW	05/03/97	2.0	25.14	26.500	50.0	50.0	45.0	50.0	40.0 - 50.0	34.5 - 40.0	Flush Mount
88-MW03IW	05/01/97	2.0	25.62	25.890	50.5	50.0	45.0	50.0	40.0 - 50.0	35.0 - 40.0	Flush Mount
88-MW04IW	05/02/97	2.0	24.60	24.980	50.0	50.0	45.0	50.0	39.5 - 50.0	34.0 - 39.5	Flush Mount
88-MW05IW	05/03/97	2.0	24.33	24.700	50.0	49.2	45.0	50.0	40.0 - 50.0	35.0 - 40.0	Flush Mount
88-MW06IW	05/04/97	2.0	23.04	24.590	50.0	50.0	45.0	50.0	32.5 - 50.0	26.0 - 32.5	Flush Mount
88-MW07IW	05/05/97	2.0	23.38	23.600	50.0	50.0	45.0	50.0	40.0 - 50.0	35.0 - 40.0	Flush Mount
88-MW08IW	05/07/97	2.0	22.91	23.050	50.0	50.0	45.0	50.0	39.5 - 50.0	34.0 - 39.5	Flush Mount
88-MW09IW	05/05/97	2.0	21.74	22.000	50.0	49.3	45.0	50.0	40.0 - 50.0	34.0 - 40.0	Flush Mount
MW10IW		1/4" tube	25.5 *	25.8*	40.0	39.0	(12.9) - (8.4)	None	(6.1) - 13.34	8.2 - 6.1	Flush Mount
88-MW01	05/01/97	2.0	26.07	26.5	22.0	22.0	7.0	22.0	2.0 - 22.0	2.0 - 5.0	Flush Mount
88-MW02	05/02/97	2.0	25.11	26.6	23.0	23.0	8.0	23.0	6.0 - 23.0	3.5 - 6.0	Flush Mount
88-MW03	05/01/97	2.0	25.38	25.88	16.0	15.0	5.0	15.0	4.0 - 15.0	2.0 - 4.0	Flush Mount
88-MW04	05/02/97	2.0	24.54	23.00	25.0	25.0	10.0	25.0	8.0 - 25.0	5.0 - 8.0	Flush Mount
88-MW05	05/03/97	2.0	23.97	24.50	23.0	23.0	8.0	23.0	6.0 - 23.0	3.0 - 6.0	Flush Mount
88-MW06	05/04/97	2.0	23.13	24.60	23.0	23.0	8.0	23.0	6.0 - 23.0	3.0 - 6.0	Flush Mount
88-MW07	05/06/97	2.0	23.37	23.63	22.0	22.0	7.0	22.0	5.0 - 7.0	2.0 - 5.0	Flush Mount
88-MW08	05/07/97	2.0	22.98	23.21	20.0	20.0	5.0	20.0	4.0 - 20.0	2.0 - 4.0	Flush Mount
88-MW09	05/05/97	2.0	21.83	22.13	21.0	21.0	6.0	21.0	4.0 - 21.0	2.0 - 4.0	Flush Mount
EX01	NA	4.0	25.63	25.59	NA	20.0	6.1 - 10.6	None	12.8 - 5.6	16.8 - 12.8	Flush Mount
EX02	NA	4.0	25.56	25.66	NA	21.2	4.9 - 9.5	None	11.8 - 4.2	14.7 - 11.8	Flush Mount
EX03	NA	4.0	25.64	25.98	NA	19.9	6.5 - 11.0	None	12.9 - 6.0	15.9 - 12.9	Flush Mount
EX04	NA	4.0	25.65	25.59	NA	21.1	4.9 - 9.5	None	11.8 - 4.6	14.1 - 11.8	Flush Mount
EX04R	NA	4.0	25.65	25.59	NA	19.7	6.3 - 10.9	None	13.1 - 5.6	16.9 - 13.1	Flush Mount
EX05	NA	4.0	25.22	25.42	NA	21.8	4.1 - 8.7	None	11.2 - 4.4	13.9 - 11.2	Flush Mount
EX06	NA	4.0	25.45	25.73	NA	20.4	5.7 - 10.3	None	12.5 - 5.2	15.5 - 12.5	Flush Mount
HC01	NA	2.0	26.42	26.85	NA	22.7	4.5 - 9.1	5.9 - 15	11.9 - 4.9	13.9 - 11.9	Flush Mount
HC02	NA	2.0	25.87	26.17	NA	20.4	6.1 - 10.8	13.9 - 18.4	11.8 - 6.1	12.8 - 11.8	Flush Mount
IN01	NA	4.0	25.71	25.54	NA	22.6	3.5 - 8.0	14.0 - 18.0	10.1 - 3.0	12.1 - 10.1	Flush Mount
IN02	NA	4.0	25.27	25.52	NA	19.7	6.5 - 11.0	14.5 - 18.5	11.6 - 5.5	12.6 - 11.6	Flush Mount
IN03	NA	4.0	25.34	25.80	NA	20.0	6.4 - 10.9	14.4 - 18.4	11.9 - 5.8	12.9 - 11.9	Flush Mount
RW01	NA	4.0	25.49	25.24	NA	20.0	6.2 - 10.4	None	13.2 - 5.2	16.2 - 13.2	Flush Mount
RW02	NA	4.0	25.54	25.35	NA	20.0	6.4 - 10.9	None	13.4 - 5.4	16.4 - 13.4	Flush Mount
RW03	NA	2.0	26.49	26.84	NA	22.0	5.2 - 9.9	15.8 - 19.7	12.0 - 5.0	14.0 - 12.0	Flush Mount
RW04	NA	4.0	25.78	26.07	NA	23.4	3.3 - 7.8	13.7 - 18.2	11.2 - 4.1	13.2 - 11.2	Flush Mount
RW06	NA	2.0	26.46	26.86	NA	21.1	6.1 - 10.8	14.2 - 18.7	12.4 - 6.4	13.9 - 12.4	Flush Mount
IW01	NA	2.0	25.61	25.24	NA	18.5	6.9 - 11.4	None	17.7 - 6.2	20.7 - 17.7	Flush Mount
WP01AQT	NA	1/4" tube	25.6*	NA	NA	23.0	2.6 - 3.6	None	4.0 - 2.2	10.6 - 4.0	NA
WP02AQT	NA	2.0	25.6*	NA	NA	25.0	0.6 - 1.6	None	2.6 - 0.2	10.6 - 2.6	NA

Notes:

Highlighted wells were not found during the July 2002 monitoring event

PVC - Polyvinyl Chloride

msl - Mean sea level

bgs - Below ground surface

* - Estimated from nearby wells

Table 2-4
'SEAR' Well Construction Details
OU 15, Site 88
MCB Camp Lejeune, NC

Well ID	Casing Diameter (in)	Elevation		Well Depth (ft bgs)	Screen Intervals (ft		Bentonite Seal Interval (ft msl)	Sand Pack Interval
		Top of Casing	Ground Surface		Lower	Upper		
EX01	4	25.63	25.59	19.96	6.1-10.6	None	16.8-12.8	12.8-5.6
EX02	4	25.56	25.66	21.20	5.9-9.5	None	14.7-11.8	11.8-4.2
EX03	4	25.64	25.98	19.94	6.5-11.0	None	15.9-12.9	12.9-6.0
EX04	4	25.65	25.59	21.09	4.9-9.5	None	14.0-11.8	11.8-4.6
EX04R	4	25.65	25.59	19.70	6.3-10.9	None	16.9-13.1	13.1-5.6
EX05	4	25.22	25.42	21.75	4.1-8.7	None	13.9-11.2	11.2-4.4
EX06	4	25.45	25.73	20.41	5.7-10.3	None	15.5-12.5	12.5-5.2
HC01	2	26.42	26.85	22.71	4.5-9.1	4.9-15	13.9-11.9	11.9-4.9
HC02	2	25.87	26.17	20.40	6.1-10.8	13.9-18.4	12.8-11.8	11.8-6.1
IN01	4	25.71	25.54	22.58	3.5-8	14.0-18.0	12.1-10.1	10.1-3.0
IN02	4	25.27	25.52	19.65	6.5-11	14.5-18.5	12.6-11.6	11.6-5.5
IN03	4	25.34	25.8	19.96	6.4-10.9	14.4-18.4	12.9-11.9	11.9-5.8
RW01	4	25.49	25.24	20.00	6.2-10.4	None	16.2-13.2	13.2-5.2
RW02	4	25.54	25.35	20.00	6.4-10.9	None	16.4-13.4	13.4-5.4
RW03	2	26.49	26.84	21.97	5.2-9.9	15.8-19.7	14.0-12.0	12.0-5.0
RW04	4	25.78	26.07	23.39	3.3-7.8	13.7-18.2	13.2-11.2	11.2-4.1
RW06	2	26.46	26.86	21.07	6.1-10.8	14.2-18.7	13.9-12.4	12.4-6.4
IW01	2	25.61	25.24	18.50	6.9-11.4	None	20.7-17.7	17.7-6.2
WP01AQT	0.25	25.6(1)	NA	23.00	2.6-3.6	None	10.6-4.0	4.0-2.2
WP02AQT	2	25.6(1)	NA	25.00	0.6-1.6	None	10.6-2.6	2.6-0.2

Note: (1)Estimated from nearby wells

TABLE 2.6
RABITT WELL CONSTRUCTION DETAILS
OPERABLE UNIT NO. 15 - SITE 88
MCB CAMP LEJEUNE, NORTH CAROLINA
CTO-026

Well ID	Diameter (in.)	Screened Interval (ft bgs)	Slot Size (in)	Material
IW01	0.75	45-48	0.01	Sch 80 PVC
IW02	0.75	45-48	0.01	Sch 80 PVC
IW03	0.75	45-48	0.01	Sch 80 PVC
MW-1	1	45.75-47.25	0.01	Sch 80 PVC
MW-2	1	45.75-47.25	0.01	Sch 80 PVC
MW-3	1	45.75-47.25	0.01	Sch 80 PVC
MW-4	1	45.75-47.25	0.01	Sch 80 PVC
MW-5	1	45.75-47.25	0.01	Sch 80 PVC
MW-6	1	45.75-47.25	0.01	Sch 80 PVC
MW-7	1	45.75-47.25	0.01	Sch 80 PVC
MW-8	1	45.75-47.25	0.01	Sch 80 PVC
MW-9	1	45.75-47.25	0.01	Sch 80 PVC

3. Site Characteristics

3.1 Surface Features

The topography of MCB Camp Lejeune is generally flat with the majority of the Base ranging in elevation from 20 to 40 ft msl (Baker, 1998). Lower elevations represent stream channels and the upper elevations are flat interstream areas. The regional grade is ~0.5%, sloping to the west toward the New River. The Site 88 area has only slight surface relief.

Site 88 is a developed area of MCB Camp Lejeune and is surrounded by buildings, parking lots, streets, and sidewalks. Buildings surrounding Building 25 include: the Chaplain's Office immediately to the north, Marine Personnel Headquarters to the east, printing shop across Post Lane Road to the south, former snack shop across Post Lane Road to the southwest, and Post Marshall Headquarters and cobbler shop to the west.

Natural surface drainage is poor at Site 88. Storm runoff is collected by storm sewers, but water pools in grassy areas because of the topography. There are no surface water features located on Site 88. Beaverdam Creek is the closest surface water, located roughly 1500 ft. to the northeast, and the New River is approximately 3000 ft. to the west.

3.2 Subsurface Structures

North of Building 25 are several steam lines, below grade concrete vaults, and shallow drainage channels. **Figure 1-3** shows the locations of all subsurface utilities in the vicinity of Site 88. The concrete vaults contain a portion of the steam lines. The condensate from the steam lines is directed away from Building 25 by shallow drainage channels and discharges to the stormwater sewer. In late 1995 and early 1996, OHM Remediation Services Corporation removed several UST's that were located on the northern side of Building 25.

3.3 Site Geology

The regional stratigraphic framework of the Lower Coastal Plain in North Carolina is shown by **Figure 3-1**. According to Cardinell, et al. (1993), three of the upper Tertiary Formations (Yorktown, Eastover, and Pungo River) shown on **Figure 3-1** are not found at MCB Camp Lejeune. Based upon Baker's findings, the Lower Miocene Belgrade Formation (Fm.) is also absent at Site 88. Cardinell (1993) postulated that the New River may have eroded the Belgrade Fm. locally at MCB Camp Lejeune.

The uppermost undifferentiated formation of Quaternary age sediments consists of mostly fine sand with a lesser amount of silt. Thin discontinuous layers of silt and clay are found within the undifferentiated formation, including a silty unit ranging in thickness from 4 to 10 feet. However, this unit was not identified at 88-MW08IW on the western periphery of the site. The undifferentiated formation overlies the Oligocene age River Bend Fm., which is encountered at elevations of -10 to -30 ft msl (40 to 60 ft. bgs) at Site 88. This contact is indicated by a significant increase in formation density, although the logs suggest that the general lithologic character remains similar.

Within the River Bend Fm. sediments, sand is dominant with minor amounts of silt and shell fragments. The River Bend Fm. overlies the Eocene Castle Hayne Fm., although the maximum depth of investigation at Site 88 has thus far been limited to approximately 100 ft. bgs, without encountering sediments of the Castle Hayne Fm.

The locations of three geologic cross-sections are shown on **Figure 2-1**. The following paragraphs describe these cross-sections.

Cross-section A-A′ (**Figure 3-2**) trends north-south and passes through Building 25. The section includes the stratigraphic sequence of the undifferentiated and River Bend Formations described above.

At the north end of the A-A′ section the lithology alternates between sand and silt. The southern end of the section (in the vicinity of 88-MW04DW) contains mostly fine sand with the silt layer thinning. A continuous silt and clay layer, approximately 5 to 10 feet thick, was encountered at elevations of 10 to 14 ft. msl (depths of 13 to 18 ft. bgs) throughout the A-A′ section. In the middle portion of the section (near 88-MW02DW), a thin fossil layer was described at -62 to -60 ft. msl (roughly 88 to 90 ft. bgs). The fossil layer is an identifying characteristic of the River Bend Formation (Cardinell, 1993).

Cross-section B-B′ (**Figure 3-3**) trends west-east and passes just to the south of Building 25. Moving further west, the level of detail recorded on the Baker boring logs appears to decrease, resulting in the apparent presence of a large homogeneous sandy unit, and no clear distinction between the undifferentiated formation and the River Bend Fm. In the middle of the section, the log from 88-MW06IW shows a thin clay layer, extending from 8 to 10 ft. msl (approximately 15 to 17 ft. bgs). Three wells shown in this figure (88-MW06IW, 88-MW08, and 88-MW08IW) could not be located during the July 2002 field event and are presumed destroyed.

Cross-section A-B′ (**Figure 3-4**) trends north-south and passes through Building 25, including two wells (88-MW05DW and 88-MW02DW) used in the previous cross sections. This section shows a continuous silt and clay layer, approximately 4 to 10 feet thick, which was encountered at elevations of 9 to 11 ft. msl (depths of 14 to 18 ft. bgs).

3.4 Site Hydrogeology

Figure 3-1 provides the hydrostratigraphic framework for the North Carolina Coastal Plain. As previously mentioned, several of the upper Tertiary Formations (Yorktown, Eastover, Pungo River, and Belgrade Formations) are absent at Site 88. The current site investigation activities have been limited to the surficial aquifer which occurs within the Undifferentiated Fm., and the upper Castle Hayne aquifer which occurs within the River Bend Fm.

During the July 2002 well gauging event, the upper surface of the unconfined surficial aquifer at Site 88 was found to occur at an elevation of 8.9 to 19.2 ft. msl. The semi-continuous silty unit of the Undifferentiated Fm. provides local confinement of the Castle Hayne aquifer (see **Figures 3-2** through **3-4**). During the July 2002 well gauging event (**Table**

3-1), the static water level elevation within the upper Castle Hayne aquifer was found to range from 7.7 to 8.9 ft. msl (above the base of the silty confining unit).

The silty unit serves to inhibit downward groundwater movement and has also been observed to impede the vertical migration of DNAPL. Laboratory testing of samples collected from this unit, in the vicinity of 88-MW02, yielded vertical hydraulic conductivity values of 1.3 x 10^{-4} feet per day (ft/day) (**Table 3-2**). However, this unit varies in thickness across the study area, and does not appear to be present to the west of 88-MW06. Consequently, the Surficial and Castle Hayne aquifers may be in direct hydraulic communication in the western portion of the site.

3.4.1 Groundwater Flow Patterns

Groundwater potentiometric surface maps for Site 88 were produced for the shallow, intermediate and deep monitoring wells. The water level elevations used to produce the maps were measured on July 22, 2002 from the permanent monitoring wells at Site 88.

The water level elevation data show a significant difference in hydrostatic heads between the shallow and intermediate wells, with the higher heads being measured in the shallow wells. This suggests the potential for downward flow of water between the two well depths. However, the difference in heads also shows that the silt/clay layer is acting as an aquitard, significantly inhibiting the flow of water or other fluids vertically downward.

Significant downward flow is typical of a recharge area. Cardinell et al. (1993) stated that the interstream areas within MCB Camp Lejeune are groundwater recharge areas. Between the intermediate and deep wells there is little difference in water elevation, which suggests that there is little potential for vertical flow between the two well depths.

Figure 3-5 shows the potentiometric surface of the surficial aquifer, as represented by the shallow monitoring wells. This figure shows a general southwesterly groundwater flow component. The shallow wells show a much steeper horizontal hydraulic gradient than the intermediate and deep aquifers at 0.03 feet/foot (ft/ft).

Figure 3-6 shows the potentiometric surface of the upper portion of the upper Castle Hayne aquifer, as represented by the intermediate-depth wells. The groundwater flow pattern for this aquifer is more complex than that of the surficial aquifer. Groundwater flow is generally to the west under Building 25 with an approximate horizontal hydraulic gradient of 0.007 ft/ft. In the northern portion of Site 88, groundwater flows to the southwest with an approximate horizontal hydraulic gradient of 0.006 ft/ft. While in the southern portion of Site 88, groundwater flows to the northwest with an approximate horizontal hydraulic gradient of 0.005 ft/ft.

Figure 3-7 shows the potentiometric surface of the upper Castle Hayne aquifer, as represented by the deep wells. Groundwater flow patterns within this portion of the upper Castle Hayne aquifer are similar to those depicted in **Figure 3-6** with an approximate horizontal hydraulic gradient of 0.005 ft/ft. Beneath Building 25, groundwater flow is generally toward the west, while in the southern portion of the study area groundwater flow is to the northwest, and in the northern portion of the site groundwater flow is to the southwest.

3.4.2 Aquifer Testing

Aquifer testing was performed by Baker through the use of slug tests on five shallow wells, four intermediate-depth wells, and one deep well. The resulting data from these tests are shown in **Table 2-3**. Hydraulic conductivities were calculated using the Bouwer and Rice method. With the exception of 88-MW08IW, the hydraulic conductivity values calculated by Baker were generally consistent.

Baker also conducted limited studies on the vertical hydraulic conductivity of selected units through laboratory analysis of undisturbed soil samples. Results of these studies are reported in **Table 3-2**. Baker collected two Shelby tube samples (88-MW04IW at 16 to 18 ft bgs, and 88-SB04 at 20 to 22 ft bgs) from the previously referenced silt/clay layer that lies within the Undifferentiated Fm. One Shelby tube sample (88-MW02 at 2 to 4 ft bgs) was also collected from silty sands within the vadose zone. The silt/clay layer was determined to possess measured vertical hydraulic conductivities ranging from 1.28×10^{-4} ft/day to 1.79×10^{-4} ft/day. While the vertical hydraulic conductivity of the vadose zone sample was measured to be 1.76 ft day.

Groundwater flow velocities can be calculated using the hydraulic conductivity data along with the hydraulic gradient and an estimated porosity. Velocities were calculated using Darcy's equation. **Table 2-3** gives the calculated seepage velocities. Hydraulic gradients were estimated from the potentiometric surface maps prepared using July 22, 2002 data from the shallow, intermediate, and deep wells. Porosity was assumed to be 0.2 (20%) which is a typical value for coastal plain sediments.

Seepage velocities calculated for the shallow wells (Surficial aquifer) ranged from 0.1 to 4.5 ft/day. The range of seepage velocities represents spatial variations in hydraulic conductivity rather than differences in hydraulic gradient, which is relatively constant across the site. Hydraulic conductivity values calculated from slug tests are strongly influenced by well construction and near-well subsurface conditions. The lowest conductivities were found in wells 88-MW05 and 88-MW09. **Figure 3-2** shows that approximately 50% of the screened interval of well 88-MW05 is within a silty unit at the base of the Surficial aquifer, and therefore would be expected to exhibit a much lower conductivity than those wells screened in predominantly sandy units, such as 88-MW04.

In the intermediate depth wells (upper Castle Hayne aquifer), seepage velocities ranged from 1.2 to 2.1 ft/day with a geometric mean value of 1.7 ft/day.

To date, only one deep well (88-MW03DW) has been used to calculate hydraulic conductivity. Slug testing of this well yielded a geometric mean hydraulic conductivity of 5.0 ft/day.

Table 3-1
Well Gauging Summary, July 22, 2002
OU 15, SIte 88
MCB Camp Lejeune, NC

Well ID	Aquifer	Depth to Water (ft)	Depth to Product (ft)	Total Depth of Well (ft)	Product thickness	Well Elevation (ft msl)	GW Elevation
88-MW01	Shallow	6.88	--	21.41	0.00	26.07	19.19
88-MW02	Shallow	7.40	--	22.83	0.00	25.11	17.71
88-MW02DW	Deep	17.48	--	97.31	0.00	25.10	7.62
88-MW02IW	Intermediate	17.46	--	48.81	0.00	25.14	7.68
88-MW03	Shallow	6.89	--	14.92	0.00	25.38	18.49
88-MW03DW	Deep	17.08	--	84.12	0.00	25.32	8.24
88-MW03IW	Intermediate	16.75	--	48.69	0.00	25.62	8.87
88-MW04	Shallow	15.62	--	24.08	0.00	24.54	8.92
88-MW04DW	Deep	15.85	--	85.15	0.00	24.61	8.76
88-MW04IW	Intermediate	15.84	--	48.04	0.00	24.60	8.76
88-MW05	Shallow	7.52	--	21.77	0.00	23.97	16.45
88-MW05DW	Deep	15.85	--	80.60	0.00	24.33	8.48
88-MW05IW	Intermediate	15.85	--	48.52	0.00	24.33	8.48
88-MW06	Shallow	14.23	--	22.50	0.00	23.13	8.90
88-MW07	Shallow	10.86	--	22.05	0.00	23.37	12.51
88-MW07IW	Intermediate	15.39	--	50.05	0.00	23.38	7.99
88-MW09	Shallow	10.27	--	20.81	0.00	21.83	11.56
88-MW09IW	Intermediate	13.32	--	49.25	0.00	21.74	8.42
88-MW10IW	Intermediate	17.04	--	38.32	0.00	25.5 *	8.46*
EX01	Shallow	7.17	--	19.97	0.00	NS	NS
EX02	Shallow	7.06	--	21.07	0.00	NS	NS
EX04	Shallow	6.90	19.49	21.15	1.66	NS	NS
EX04R	Shallow	6.75	19.18	19.72	0.54	NS	NS
EX05	Shallow	6.44	--	21.53	0.00	NS	NS
EX06	Shallow	6.71	--	20.11	0.00	NS	NS
HC02	Shallow	7.13	--	19.98	0.00	NS	NS
IN01	Shallow	6.99	--	22.71	0.00	NS	NS
IN02	Shallow	6.75	--	19.04	0.00	NS	NS
IN03	Shallow	6.71	--	19.28	0.00	NS	NS
IW01	Shallow	6.50	--	17.34	0.00	NS	NS
RABITTIW1	Intermediate	15.31	--	47.25	0.00	NS	NS
RABITTIW2	Intermediate	15.25	--	47.03	0.00	NS	NS
RABITTIW3	Intermediate	15.20	--	47.10	0.00	NS	NS
RABITTMW1	Intermediate	15.28	--	46.79	0.00	NS	NS
RABITTMW2	Intermediate	15.25	--	46.68	0.00	NS	NS
RABITTMW3	Intermediate	15.22	--	46.72	0.00	NS	NS
RABITTMW4	Intermediate	15.06	--	46.85	0.00	NS	NS
RABITTMW5	Intermediate	15.25	--	47.05	0.00	NS	NS
RABITTMW6	Intermediate	15.11	--	46.78	0.00	NS	NS
RABITTMW7	Intermediate	14.88	--	46.84	0.00	NS	NS
RABITTMW8	Intermediate	14.95	--	46.28	0.00	NS	NS
RABITTMW9	Intermediate	15.00	--	46.97	0.00	NS	NS
RW01	Shallow	6.87	19.27	19.68	0.41	NS	NS
RW02	Shallow	6.68	19.54	19.60	0.06	NS	NS
RW04	Shallow	6.94	22.31	22.32	0.01	NS	NS

* - Estimated
NS - Not surveyed

Table 3-2
Summary of Laboratory Permeability Testing
OU 15, Site 88
MCB Camp Lejeune, NC

Well ID	Depth (ft. bgs)	Bulk Density (lbs/ft^3)	Vertical Permeability (ft./day)	Lithology
88-MW02	2-4	73.1	1.76	Silty Sand
88-MW04IW	16-18	88	1.28 x 10-4	Clay
88-SB04	20-22	85.85	1.79 x 10-4	Clay

4. Nature and Extent of Contamination

4.1 Nature of Contamination

Chlorinated hydrocarbons in soil and groundwater are the primary focus of the investigation at Site 88. Two general phases of site investigation have been conducted at Site 88: 1) Baker's 1997 focused RI which included the collection of both subsurface soil samples and groundwater samples, and 2) CH2M HILL's 2002 supplemental groundwater sampling event.

As reported in Baker (1998), the initial site investigation collected 29 subsurface soil samples which were analyzed for VOCs. PCE was detected in 18 of 29 soil samples with values as high as 237.6 µg/kg. TCE was detected in 8 of 29 soil samples. At the time, no detected VOCs exceeded the USEPA Region III Residential Risk-Based Concentrations (RBCs). However, four samples exceeded the USEPA Region III Soil Screening Level (SSL) for PCE.

In July 2002, CH2M HILL collected groundwater samples from 22 site wells. **Table 4-1** provides a summary of the wells sampled in July 2002. Wells were purged using peristaltic pumps and low-flow procedures. Water quality parameters were monitored during well purging to ensure the collection of representative groundwater samples from each well. **Table 4-2** presents a summary of the water quality field parameters measured at the time of sample collection. Following completion of the well purging, samples were placed into laboratory-supplied containers, labeled, and packed on ice for transportation under chain-of-custody control to CompuChem, Raleigh, North Carolina. Samples were analyzed for chloride, cyanide, ethane, ethene, methane, nitrate, total organic carbon, sulfate, sulfide, total TAL metals (including ferrous iron), and VOCs (including isopropanol).

PCE was detected in 12 of 24 samples (including 2 duplicate samples), with 7 samples exceeding the North Carolina Groundwater Quality Standard (NCGWQS) of 0.7 µg/L. **Table 4-1** summarizes contaminant detections and exceedances of the NCGWQS. **Figures 4-1** through **4-6** illustrate the dissolved-phase contaminant detections and exceedances resulting from the July 2002 sampling event at Site 88. TCE was detected in 14 of 24 samples, with 8 samples exceeding the NCGWQS of 2.8 µg/L. Iron was also detected at concentrations exceeding NCGWQS. Elevated iron concentrations have been detected at numerous sites at MCB Camp Lejeune, and are the subject of a current base-wide study. The Site 88 results will be compared to the base-wide study.

4.2 SEAR & RABITT Effects

Laboratory analysis of samples collected from the SEAR and RABITT study areas revealed the residual effects of these pilot studies. Elevated concentrations of acetone, calcium, isopropanol, and sodium were detected in former SEAR injection well IN01. While calcium and sodium were found to exceed Site 88 background concentrations in the RABITT study area.

4.3 Extent of Contamination

In 1997, Baker determined that the significance and extent soil contamination was minimal. In the five years that have passed since the focused RI, site conditions have likely changed, and discussion of the 1997 data is not relevant at this time.

The results of the July 2002 groundwater monitoring event show that significant groundwater contamination still exists at Site 88. Acetone, benzene, chlorobenzene, chloroform, chloromethane, 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, trans-1,2-DCE, PCE, TCE, and vinyl chloride were all detected above their respective NCGWQS. **Table 4-1** provides a summary of the detections and exceedances for the shallow, intermediate, and deep monitoring wells.

Figures 4-1 through **4-6** show the distribution of contaminant detections and exceedances extent for the July 2002 monitoring event. For clarity, contaminant concentrations which exceed the NCGWQS are highlighted.

The available data indicates a general northwest migration of contaminants at all three screened intervals, but especially in the shallow and intermediate wells. With the exception of the source area well IN01, the detected contaminant concentrations are generally greater in the intermediate wells than the shallow or deep wells, in some cases by more than an order of magnitude.

The vertical distribution of VOCs suggests that although appreciable volumes of DNAPL are observed to accumulate upon the shallow silt layer discussed in **Section 3.3**, this layer is not impermeable, and is evidently allowing dissolved-phase VOCs to migrate vertically to the intermediate depth wells.

4.4 Natural Attenuation Indicator Parameters

Groundwater samples were analyzed for natural attenuation indicator parameters (NAIPs), including: ethane, ethene, methane, ferrous iron, chloride, nitrate, sulfate, sulfide, and total organic carbon (TOC). **Table 4-1** presents the results of these analyses. Ethane, ethene, and methane are included as VOCs in **Figures 4-1**, **4-3**, and **4-5**. The remainder of the NAIPs are presented on **Figures 4-7** through **4-9**.

The NAIP data indicates the presence of methanogenic conditions in the source area (north of Building 25) and former RABITT study area. Nitrate and sulfate have been depleted in the source area wells (88-MW10IW and IN01), iron reduction has begun, and methane is being produced. Radiating from the source area, the redox conditions change to ferrogenic conditions at 88-GW03; as evidenced by depleted nitrate, the absence of sulfide, low levels of methane, and the presence of ferrous iron.

These indicators coupled with the complete degradation pathway from PCE to ethene provide confirmation of the successful natural attenuation of PCE at Site 88.

Table 4-1
Groundwater Contaminant Detections
OU 15, Site 88, MCB Camp Lejeune

					IR88-GW01-02C	IR88-GW02-02C	IR88-GW02DW-02C	IR88-GW02DW-P-02C	IR88-GW02IW-02C	IR88-GW03-02C	IR88-GW03DW-02C	IR88-GW03IW-02C
				Sample Date	7/23/2002	7/26/2002	7/24/2002	7/24/2002	7/26/2002	7/25/2002	7/26/2002	7/25/2002
Chemical Name	**NCGQWS**	**Frequency**	**Max Value**	**Max Location**								
Volatile Organic Compounds (ug/L)												
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	NS	1 / 24	12,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHANE	700	1 / 24	0.600 J	IR88-GW05IW-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHENE	7	5 / 24	53.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.5 J
4-METHYL-2-PENTANONE	NS	1 / 24	6.00 J	IR88-GWSRIW01-02C	10 U	10 UJ	10 U	10 U	10 UJ	10 U	10 U	10 U
ACETONE	700	1 / 24	5,000 J	IR88-GWSRIW01-02C	10 UJ	10 U	4 U	4 U	10 U	10 U	10 UJ	5 U
BENZENE	1	2 / 24	57.0	IR88-GW05-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CARBON DISULFIDE	700	1 / 24	2.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROBENZENE	50	2 / 24	60.0	IR88-GW05-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROETHANE	2,800	1 / 24	2.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROFORM	0.19	1 / 24	0.800 J	IR88-GW09-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROMETHANE	2.6	1 / 24	83.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CIS-1,2-DICHLOROETHENE	70	10 / 24	84,000 D	IR88-GWSRIW01-02C	10 U	10 U	34 U	36 U	60	1 U	10 U	22 U
ETHANE	NS	5 / 24	15.0	IR88-GW03DW-02C	2 U	2 U	2	2 U	2 U	8 U	2 U	15	2 U
ETHENE	NS	6 / 24	74.0 J	IR88-GWRAB1-02C	2 U	2 U	0.06 J	2 U	0.2 J	2 U	8 U	2 U
ETHYLBENZENE	29	1 / 24	4.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ISOPROPANOL	NS	1 / 24	4,600 D	IR88-GWSRIW01-02C	4 U	6 U	5 U	4 U	5 U	6 U	11 U	7 U
ISOPROPYLBENZENE	70	1 / 24	8.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
METHANE	NS	13 / 24	1,200	IR88-GWRAB1-02C	1 U	0.3 U	7	7	55	12	59	20
METHYL ACETATE	NS	1 / 24	6.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
METHYLENE CHLORIDE	5	1 / 24	10.00	IR88-GW03DW-02C	1 U	2 U	2 U	2 U	2 U	2 U	10	2 U
TETRACHLOROETHENE	0.7	12 / 24	20,000 D	IR88-GWSRIW01-02C	10 U	45	23	24	2,700 D	2 U	10 U	1,900 D
TOLUENE	1,000	2 / 24	58.0	IR88-GW05-02C	1 U	10 U	0.7 U	0.6 U	0.8 U	0.5 U	10 U	0.5 U
TRANS-1,2-DICHLOROETHENE	70	12 / 24	150.0	IR88-GWSRIW01-02C	10 U	10 U	0.5 J	0.4 J	2 J	10 U	10 U	0.8 J
TRICHLOROETHENE	2.8	14 / 24	2,600 JD	IR88-GWSRIW01-02C	10 U	1 J	2 J	2 J	410 D	1 J	10 U	410 D
TRICHLOROFLUOROMETHANE	2,100	1 / 24	0.500 J	IR88-GW01-02C	0.5 J	10 UJ	10 U	10 U	10 UJ	10 U	10 U	10 U
VINYL CHLORIDE	0.015	5 / 24	45,000 D	IR88-GWSRIW01-02C	10 U	10 U	0.5 J	10 U	10 U	10 U	10 U	10 U
XYLENE (TOTAL)	530	2 / 24	50.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Total Metals (ug/L)												
ALUMINUM	NS	9 / 24	1,540	IR88-GW03DW-02C	1,200	326	57.7 U	63.4 U	684	78.8 U	1,540	84.2 U
BARIUM	2,000	24 / 24	115.0 J	IR88-GW07IW-02C	45.2 J	15.6 J	65.9 J	55.7 J	77 J	56.8 J	25 J	24.4 J
CALCIUM	NS	24 / 24	179,000	IR88-GWRAB6-02C	14,400	22,700	76,400	77,500	29,500	4,190 J	98,500	101,000
CHROMIUM	50	1 / 24	2.60 J	IR88-GW04IW-02C	0.4 U	1.5 U	1.5 U	1.3 U	2.9 U	0.7 U	0.76 U	1.5 U
COBALT	NS	1 / 24	34.2 J	IR88-GW09IW-02C	0.8 U	0.4 U	1.4 U	0.68 U	0.4 U	0.4 U	0.4 U	0.4 U
CYANIDE	154	2 / 24	159.0	IR88-GW06-02C	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	47	1.5 U	1.5 U
IRON	300	19 / 24	47,400	IR88-GWSRIW01-02C	12,200	117	522	538	424	1,350	31.9 U	3,380
MAGNESIUM	NS	20 / 24	5,140	IR88-GW01-02C	5,140	796 J	2,610 J	2,650 J	941 J	1,580 J	461 U	2,950 J
MANGANESE	50	19 / 24	221.0	IR88-GWSRIW01-02C	41.5 J	3.1 U	10.9 J	10.7 J	11.9 J	18.4	1.3 U	39.6
MERCURY	1.1	1 / 24	0.110 J	IR88-GW02DW-02C	0.1 U	0.1 U	0.11 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
NICKEL	100	3 / 24	55.0	IR88-GW09IW-02C	5.6 J	0.7 U	2.4 U	1 U	3 U	1.3 U	1 U	0.92 U
POTASSIUM	NS	24 / 24	14,600	IR88-GW04IW-02C	2,770 J	1,340 J	1,590 J	1,580 J	2,960 J	1,220 J	3,620 J	1,560 J
SODIUM	NS	24 / 24	40,800	IR88-GWRAB1-02C	11,300	9,780	22,200	21,800	11,800	5,340	15,800	7,170
VANADIUM	NS	3 / 24	6.80 J	IR88-GWSRIW01-02C	2.9 U	2.2 U	1.7 U	0.84 U	2.6 U	1.4 U	6 J	0.48 U
ZINC	2,100	6 / 24	146.0	IR88-GW02IW-02C	29.9	12.4 U	0.7 U	0.7 U	146	3.6 U	0.7 U	0.7 U
Wet Chemistry (mg/L)												
CHLORIDE	250	24 / 24	238.0	IR88-GWSRIW01-02C	25.1	9.42	8.98	8.76	6.06	4.61	6.74	5.77
FERROUS IRON	0.3	10 / 24	43.3	IR88-GWSRIW01-02C	10.5	0.1 U	0.1 U	0.1 U	0.44	0.05 U	0.79	0.1 U	0.1 U
NITRATE	10	5 / 24	3.90	IR88-GW06-02C	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
SULFATE	250	22 / 24	180.0	IR88-GW04IW-02C	73.8	11.5	30.7	30.4	10.4	15.2	20.5	25.2
SULFIDE	NS	5 / 24	0.800	IR88-GWRAB1-02C	0.5 U	0.6 U	0.5 U	0.6 U	0.58 U	0.5 U	0.7 U	0.5 U
TOTAL ORGANIC CARBON	NS	5 / 24	126.0	IR88-GWSRIW01-02C	5 U	5 U	5 U	5 U	5.61	5 U	5 U	5 U

Note: Yellow highlight means above 2L standards, and orange highlight means above interim 2L standards.

NA - Not analyzed
U - Analyte not detected
J - Reported value is estimated
D - Result came from a diluted sample

Table 4-1
Groundwater Contaminant Detections
OU 15, Site 88, MCB Camp Lejeune

				Sample Date	IR88-GW04-02C 7/23/2002	IR88-GW04DW-02C 7/24/2002	IR88-GW04IW-02C 7/23/2002	IR88-GW05-02C 7/25/2002	IR88-GW05DW-02C 7/24/2002	IR88-GW05DW-P-02C 7/24/2002	IR88-GW05IW-02C 7/25/2002	IR88-GW06-02C 7/23/2002
Chemical Name	**NCGQWS**	**Frequency**	**Max Value**	**Max Location**								
Volatile Organic Compounds (ug/L)												
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	NS	1 / 24	12,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHANE	700	1 / 24	0.600 J	IR88-GW05IW-02C	10 U	10 U	10 U	10 U	10 U	10 U	0.6 J	10 U
1,1-DICHLOROETHENE	7	5 / 24	53.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	50	10 U	10 U	9 J	10 U
4-METHYL-2-PENTANONE	NS	1 / 24	6.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ACETONE	700	1 / 24	5,000 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	14 UJ	10 UJ	4 U	9 U	10 U
BENZENE	1	2 / 24	57.0	IR88-GW05-02C	10 U	10 U	10 U	57	10 U	10 U	10 U	10 U
CARBON DISULFIDE	700	1 / 24	2.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROBENZENE	50	2 / 24	60.0	IR88-GW05-02C	10 U	10 U	10 U	60	10 U	10 U	10 U	10 U
CHLOROETHANE	2,800	1 / 24	2.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROFORM	0.19	1 / 24	0.800 J	IR88-GW09-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROMETHANE	2.6	1 / 24	83.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CIS-1,2-DICHLOROETHENE	70	10 / 24	84,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	40	15	15	2,200 D	10 U
ETHANE	NS	5 / 24	15.0	IR88-GW03DW-02C	2 U	2 U	2 U	2 U	0.04 J	2 U	0.04 J	2 U
ETHENE	NS	6 / 24	74.0 J	IR88-GWRAB1-02C	2 U	2 U	2 U	2 U	0.09 J	2 U	2 U	2 U
ETHYLBENZENE	29	1 / 24	4.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ISOPROPANOL	NS	1 / 24	4,600 D	IR88-GWSRIW01-02C	4 U	6 U	4 U	4 U	6 U	4 U	7 U	4 U
ISOPROPYLBENZENE	70	1 / 24	8.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
METHANE	NS	13 / 24	1,200	IR88-GWRAB1-02C	0.3 U	0.3 U	0.2 U	0.6 U	2 U	0.3 U	12	0.7 U
METHYL ACETATE	NS	1 / 24	6.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
METHYLENE CHLORIDE	5	1 / 24	10.00	IR88-GW03DW-02C	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
TETRACHLOROETHENE	0.7	12 / 24	20,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	2,300	290	390	3,400 D	0.4 J
TOLUENE	1,000	2 / 24	58.0	IR88-GW05-02C	0.7 U	0.9 U	0.8 U	58	0.8 U	0.8 U	0.8 U	0.8 U
TRANS-1,2-DICHLOROETHENE	70	12 / 24	150.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	0.4 J	0.8 J	0.8 J	19	10 U
TRICHLOROETHENE	2.8	14 / 24	2,600 JD	IR88-GWSRIW01-02C	10 U	10 U	10 U	95	110	120	2,300 D	10 U
TRICHLOROFLUOROMETHANE	2,100	1 / 24	0.500 J	IR88-GW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
VINYL CHLORIDE	0.015	5 / 24	45,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	1 J	10 U
XYLENE (TOTAL)	530	2 / 24	50.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Total Metals (ug/L)												
ALUMINUM	NS	9 / 24	1,540	IR88-GW03DW-02C	499	19 U	108 U	487	138 U	119 U	108 U	102 U
BARIUM	2,000	24 / 24	115.0 J	IR88-GW07IW-02C	35.5 J	6.5 J	42.7 J	26.7 J	31.6 J	30.1 J	30.9 J	11.5 J
CALCIUM	NS	24 / 24	179,000	IR88-GWRAB6-02C	5,090	64,100	9,840	8,130	69,600	72,300	98,500	25,400
CHROMIUM	50	1 / 24	2.60 J	IR88-GW04IW-02C	0.4 U	0.64 U	2.6 J	1 U	0.4 U	0.4 U	0.76 U	0.4 U
COBALT	NS	1 / 24	34.2 J	IR88-GW09IW-02C	0.99 U	0.4 U	3.9 U	0.5 U	0.4 U	0.4 U	0.59 U	0.4 U
CYANIDE	154	2 / 24	159.0	IR88-GW06-02C	2.2 U	3.7 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	159
IRON	300	19 / 24	47,400	IR88-GWSRIW01-02C	9.5 U	299	86.4 U	322	800	868	795	38 U
MAGNESIUM	NS	20 / 24	5,140	IR88-GW01-02C	3,310 J	1,430 J	2,270 J	476 U	2,220 J	2,350 J	4,510 J	504 U
MANGANESE	50	19 / 24	221.0	IR88-GWSRIW01-02C	2.8 U	7 J	41.8 J	7.2 J	14.1 J	15 J	29.9	0.2 U
MERCURY	1.1	1 / 24	0.110 J	IR88-GW02DW-02C	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
NICKEL	100	3 / 24	55.0	IR88-GW09IW-02C	0.6 U	0.6 U	3.9 J	0.6 U	0.64 U	0.6 U	1.4 U	0.6 U
POTASSIUM	NS	24 / 24	14,600	IR88-GW04IW-02C	823 J	1,020 J	14,600	1,680 J	10,500	9,520	2,040 J	2,700 J
SODIUM	NS	24 / 24	40,800	IR88-GWRAB1-02C	4,800 J	6,120	21,500	2,730 J	15,700	15,500	7,540	7,070
VANADIUM	NS	3 / 24	6.80 J	IR88-GWSRIW01-02C	0.7 U	0.3 U	3.9 J	1.1 U	0.61 U	0.53 U	1 U	2.8 U
ZINC	2,100	6 / 24	146.0	IR88-GW02IW-02C	1.8 U	38.5	26.2	3.3 U	2.1 U	1.8 U	52.1	1.8 U
Wet Chemistry (mg/L)												
CHLORIDE	250	24 / 24	238.0	IR88-GWSRIW01-02C	9.98	4.41	20	6.26	6.85	6.69	12.7	11.6
FERROUS IRON	0.3	10 / 24	43.3	IR88-GWSRIW01-02C	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
NITRATE	10	5 / 24	3.90	IR88-GW06-02C	0.05 U	0.05 U	0.07	0.07	0.05 U	0.05 U	0.05 U	3.9
SULFATE	250	22 / 24	180.0	IR88-GW04IW-02C	43.6	15.7	180	15.9	28.4	28.2	22.6	20.4
SULFIDE	NS	5 / 24	0.800	IR88-GWRAB1-02C	0.56	0.5 U	0.52	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
TOTAL ORGANIC CARBON	NS	5 / 24	126.0	IR88-GWSRIW01-02C	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

Note: Yellow highlight means above 2L standards, and orange highlight mean

NA - Not analyzed
U - Analyte not detected
J - Reported value is estimated
D - Result came from a diluted sample

Table 4-1
Groundwater Contaminant Detections
OU 15, Site 88, MCB Camp Lejeune

				Sample Date	IR88-GW07-02C 7/24/2002	IR88-GW07IW-02C 7/25/2002	IR88-GW09-02C 7/24/2002	IR88-GW09IW-02C 7/25/2002	IR88-GW10IW-02C 7/25/2002	IR88-GWRAB1-02C 7/23/2002	IR88-GWRAB6-02C 7/23/2002	IR88-GWSRIW01-02C 7/26/2002
Chemical Name	**NCGQWS**	**Frequency**	**Max Value**	**Max Location**								
Volatile Organic Compounds (ug/L)												
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	NS	1 / 24	12,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	12,000 D
1,1-DICHLOROETHANE	700	1 / 24	0.600 J	IR88-GW05IW-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	10 U
1,1-DICHLOROETHENE	7	5 / 24	53.0	IR88-GWSRIW01-02C	10 U	2 J	10 U	10 U	10 U	10 U	13 U	53
4-METHYL-2-PENTANONE	NS	1 / 24	6.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 UJ	10 U	10 U	13 U	6 J
ACETONE	700	1 / 24	5,000 J	IR88-GWSRIW01-02C	10 UJ	10 UJ	10 U	10 U	10 UJ	12 UJ	7 U	5,000 J
BENZENE	1	2 / 24	57.0	IR88-GW05-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	1 J
CARBON DISULFIDE	700	1 / 24	2.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 UJ	10 U	13 U	2 J
CHLOROBENZENE	50	2 / 24	60.0	IR88-GW05-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	4 J
CHLOROETHANE	2,800	1 / 24	2.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 U	10 U	2 J	10 U
CHLOROFORM	0.19	1 / 24	0.800 J	IR88-GW09-02C	10 U	10 U	0.8 J	10 U	10 U	10 U	13 U	10 U
CHLOROMETHANE	2.6	1 / 24	83.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	83
CIS-1,2-DICHLOROETHENE	70	10 / 24	84,000 D	IR88-GWSRIW01-02C	2 J	49	10 U	2 U	4 U	2 J	6 J	84,000 D
ETHANE	NS	5 / 24	15.0	IR88-GW03DW-02C	2 U	3 U	2 U	2 U	150 U	150 U	8 J	30 U
ETHENE	NS	6 / 24	74.0 J	IR88-GWRAB1-02C	2 U	3 U	2 U	2 U	150 U	74 J	48 J	5 J
ETHYLBENZENE	29	1 / 24	4.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	4 J
ISOPROPANOL	NS	1 / 24	4,600 D	IR88-GWSRIW01-02C	4 U	15 U	4 U	19 U	5 U	5 U	4 U	4,600 D
ISOPROPYLBENZENE	70	1 / 24	8.00 J	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	10 U	13 U	8 J
METHANE	NS	13 / 24	1,200	IR88-GWRAB1-02C	18	17	0.2 U	0.6 U	590	1,200	910	180
METHYL ACETATE	NS	1 / 24	6.00 J	IR88-GWRAB6-02C	10 U	10 U	10 U	10 U	10 UJ	10 U	6 J	10 U
METHYLENE CHLORIDE	5	1 / 24	10.00	IR88-GW03DW-02C	1 U	2 U	2 U	2 U	15 U	2 U	2 U	2 U
TETRACHLOROETHENE	0.7	12 / 24	20,000 D	IR88-GWSRIW01-02C	10 U	10 U	0.5 J	10 U	1 U	10 U	13 U	20,000 D
TOLUENE	1,000	2 / 24	58.0	IR88-GW05-02C	0.8 U	0.7 U	0.7 U	10 U	1 U	0.8 U	1 U	27
TRANS-1,2-DICHLOROETHENE	70	12 / 24	150.0	IR88-GWSRIW01-02C	10 U	4 J	10 U	10 U	10 U	10	7 J	150
TRICHLOROETHENE	2.8	14 / 24	2,600 JD	IR88-GWSRIW01-02C	3 U	31	10 U	11	2 J	10 U	13 U	2,600 JD
TRICHLOROFLUOROMETHANE	2,100	1 / 24	0.500 J	IR88-GW01-02C	10 U	10 U	10 U	10 UJ	10 U	10 U	13 U	10 UJ
VINYL CHLORIDE	0.015	5 / 24	45,000 D	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	4 J	220	45,000 D
XYLENE (TOTAL)	530	2 / 24	50.0	IR88-GWSRIW01-02C	10 U	10 U	10 U	10 U	10 U	0.4 J	13 U	50
Total Metals (ug/L)												
ALUMINUM	NS	9 / 24	1,540	IR88-GW03DW-02C	142 U	27.1 U	92.4 U	549	201	7.6 U	7.6 U	383
BARIUM	2,000	24 / 24	115.0 J	IR88-GW07IW-02C	39.7 J	115 J	11.3 J	62.8 J	13.9 J	57.8 J	61.5 J	46 J
CALCIUM	NS	24 / 24	179,000	IR88-GWRAB6-02C	1,790 J	25,200	3,380 J	8,570	8,400	175,000	179,000	89,700
CHROMIUM	50	1 / 24	2.60 J	IR88-GW04IW-02C	0.4 U	0.43 U	0.4 U	1.1 U	1.8 U	0.4 U	0.4 U	1.8 U
COBALT	NS	1 / 24	34.2 J	IR88-GW09IW-02C	0.86 U	0.4 U	0.51 U	34.2 J	0.4 U	0.4 U	0.4 U	0.4 U
CYANIDE	154	2 / 24	159.0	IR88-GW06-02C	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U
IRON	300	19 / 24	47,400	IR88-GWSRIW01-02C	2,290	1,080	18.8 U	544	1,830	2,520	4,260	47,400
MAGNESIUM	NS	20 / 24	5,140	IR88-GW01-02C	2,280 J	1,060 J	240 U	1,720 J	1,020 J	4,260 J	4,020 J	4,980 J
MANGANESE	50	19 / 24	221.0	IR88-GWSRIW01-02C	10.7 J	21.6 J	0.2 U	34.5	30.7	46 J	44.8 J	221
MERCURY	1.1	1 / 24	0.110 J	IR88-GW02DW-02C	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
NICKEL	100	3 / 24	55.0	IR88-GW09IW-02C	0.86 U	1.4 U	0.6 U	55	1.1 U	0.6 U	0.6 U	0.7 U
POTASSIUM	NS	24 / 24	14,600	IR88-GW04IW-02C	978 J	1,520 J	1,050 J	2,900 J	2,120 J	3,000 J	3,400 J	4,380 J
SODIUM	NS	24 / 24	40,800	IR88-GWRAB1-02C	5,150	6,280	2,830 J	9,180	10,600	40,800	37,000	30,700
VANADIUM	NS	3 / 24	6.80 J	IR88-GWSRIW01-02C	0.37 U	0.51 U	0.32 U	1.6 U	1.1 U	0.3 U	0.47 U	6.8 J
ZINC	2,100	6 / 24	146.0	IR88-GW02IW-02C	12.4 U	8.7 U	1.9 U	102	0.7 U	1.8 U	3.2 U	5.5 U
Wet Chemistry (mg/L)												
CHLORIDE	250	24 / 24	238.0	IR88-GWSRIW01-02C	18.5	14.3	4.57	5.72	7.12	23.2	22.1	238
FERROUS IRON	0.3	10 / 24	43.3	IR88-GWSRIW01-02C	1.8	0.11	0.1 U	0.34	0.84	0.68	0.8	43.3
NITRATE	10	5 / 24	3.90	IR88-GW06-02C	0.05 U	0.05 U	0.38	0.05 U	0.05	0.05 U	0.05 U	0.05 U
SULFATE	250	22 / 24	180.0	IR88-GW04IW-02C	8.87	7.73	7.34	12.2	5 U	70.5	91.2	5 U
SULFIDE	NS	5 / 24	0.800	IR88-GWRAB1-02C	0.5 U	0.56	0.5 U	0.5 U	0.68 U	0.8	0.76	2.74 U
TOTAL ORGANIC CARBON	NS	5 / 24	126.0	IR88-GWSRIW01-02C	5 U	5 U	5 U	5 U	5.87	43.2	25.6	126

Note: Yellow highlight means above 2L standards, and orange highlight mean

NA - Not analyzed
U - Analyte not detected
J - Reported value is estimated
D - Result came from a diluted sample

Table 4-2
Ground Water Quality Data
OU 15, Site 88
MCB Camp Lejeune, NC

Well ID	Date	Purge Volume (Gal)	Water Quality Parameters				
			Temperature (C)	Conductivity (mS/cm)	DO (mg/L)	pH	ORP (mV)
88-MW01	7/23/2002	7.0	26.2	301	1.0	4.3	-59.9
88-MW02	7/26/2002	7.8	25.6	166	5.5	5.8	90.4
88-MW02IW	7/26/2002	6.5	23.6	187	0.5	6.2	-76.5
88-MW02DW	7/24/2002	8.5	22.8	449	0.4	7.3	-151.3
88-MW03	7/25/2002	4.1	26.1	95	0.0	4.8	-13.9
88-MW03IW	7/25/2002	5.5	23.2	489	-0.3	6.6	-124.1
88-MW03DW	7/26/2002	15.0	23.3	783	2.3	10.5	-226.5
88-MW04	7/23/2002	5.2	22.8	115	3.9	4.3	172.4
88-MW04IW	7/23/2002	7.0	22.7	229	2.5	5.5	132.8
88-MW04DW	7/24/2002	11.0	22.4	325	0.4	7.1	-88.6
88-MW05	7/25/2002	7.1	23.0	82	0.5	4.4	127.4
88-MW05IW	7/25/2002	6.0	22.2	478	0.1	6.7	-117.1
88-MW05DW	7/24/2002	10.6	22.2	419	0.4	7.5	-184.4
88-MW06	7/23/2002	4.0	25.2	196	5.0	5.6	111.1
88-MW07	7/24/2002	5.5	20.4	90	0.2	4.9	-1.2
88-MW07IW	7/25/2002	8.2	19.7	148	-0.3	6.0	-123.8
88-MW09	7/24/2002	8.5	21.5	52	4.1	6.3	90.3
88-MW09IW	7/25/2002	4.6	20.5	84	0.1	4.9	54.5
88-MW10IW	7/25/2002	5.5	24.8	123	0.0	5.3	-81.6
88-RABMW01	7/23/2002	3.0	21.7	890	1.0	6.4	-208.8
88-RABMW06	7/23/2002	2.5	21.9	915	1.0	6.5	-196.9
88-SEARIW01	7/26/2002	5.3	24.4	844	3.7	4.6	-82.2

5. Data Limitations

5.1 Site Characteristics

The characteristics of the subsurface environment underlying Site 88 have not been adequately investigated. The primary data gaps include lithology and stratigraphic control, groundwater hydrology, and aquifer properties. The following sections describe the specific data gaps.

5.1.1 Site Lithology and Stratigraphy

The four deep wells (88-MW02, 88-MW03, 88-MW04, and 88-MW05) provide the only source of detailed lithologic information extending to the base of the undifferentiated Formation and the transition to the River Bend Fm.

Past investigations have identified two important geologic horizons that appear to inhibit the vertical migration of dissolved-phase contaminants. The first occurs within the undifferentiated Fm., and is represented by an apparently discontinuous silt/clay layer, first encountered at an elevation of approximately 10 ft msl. In July 2002, significant accumulations of DNAPL were measured in five source area wells constructed on top of the silt/clay layer (see **Table 3-1**). Elevated VOC concentrations have also been detected in intermediate-depth wells constructed beneath this layer. This suggests that secondary porosity features or localized facies changes may be present within this layer that were not identified in the boring logs.

The second geologic horizon observed to retard vertical contaminant migration at Site 88 was identified by Baker at an elevation of approximately –30 ft. msl. The lithology of this zone is predominantly fine sand with an increasing proportion of silt and shell fragments, and a significant increase in formation density. Dissolved-phase VOC concentrations show a significant decrease across this zone, as indicated by the intermediate and deep wells.

The continuity of these features has not been investigated beyond the immediate source area.

5.1.2 Groundwater Flow Regime

Considering the size of Site 88 and the complexity of the local hydrogeology, there are very few monitoring wells with which to accurately predict the groundwater flow regime. The current monitoring well network provides only a rudimentary understanding of the potential contaminant flow paths.

5.1.3 Aquifer Properties

Slug tests have been conducted in several site wells, yielding useful information with regards to the hydraulic conductivity of the aquifer materials immediately surrounding these wells. However, no attempt has been made to investigate the degree of hydraulic connection and fluid interaction between the surficial aquifer and the underlying upper

Castle Hayne aquifer. Such a study would require an aquifer pumping test utilizing an intermediate or deep pumping well and observation wells in the surficial and upper Castle Hayne aquifers. An appropriately designed test may provide horizontal conductivity data for the upper Castle Hayne aquifer, and allow the calculation of the vertical conductivity of the silt/clay layer.

5.2 Extent of Contamination

The extent of contaminant migration in both groundwater and soil has not been determined.

5.2.1 Groundwater

Chlorinated hydrocarbons have been detected in peripheral wells (88-MW07, 88-MW07IW, 88-MW09 and 88-MW09IW), indicating that the extent of groundwater contamination has not been delineated. The inter-well spacing of the current monitoring well network is too great to accurately delineate the horizontal and vertical extent of groundwater contaminants. This issue is only compounded by the apparent loss of three wells, 88-MW06IW, 88-MW08, and 88-MW08IW, likely due to utility construction activities.

5.2.2 Soil

A limited soil investigation was conducted during the focused RI in 1997. However, given the organic nature of the site contaminants, the 1997 information may no longer be representative of current site conditions.

6. Recommendations

The information contained in this report has resulted in the formulation of several recommendations for further investigation at Site 88.

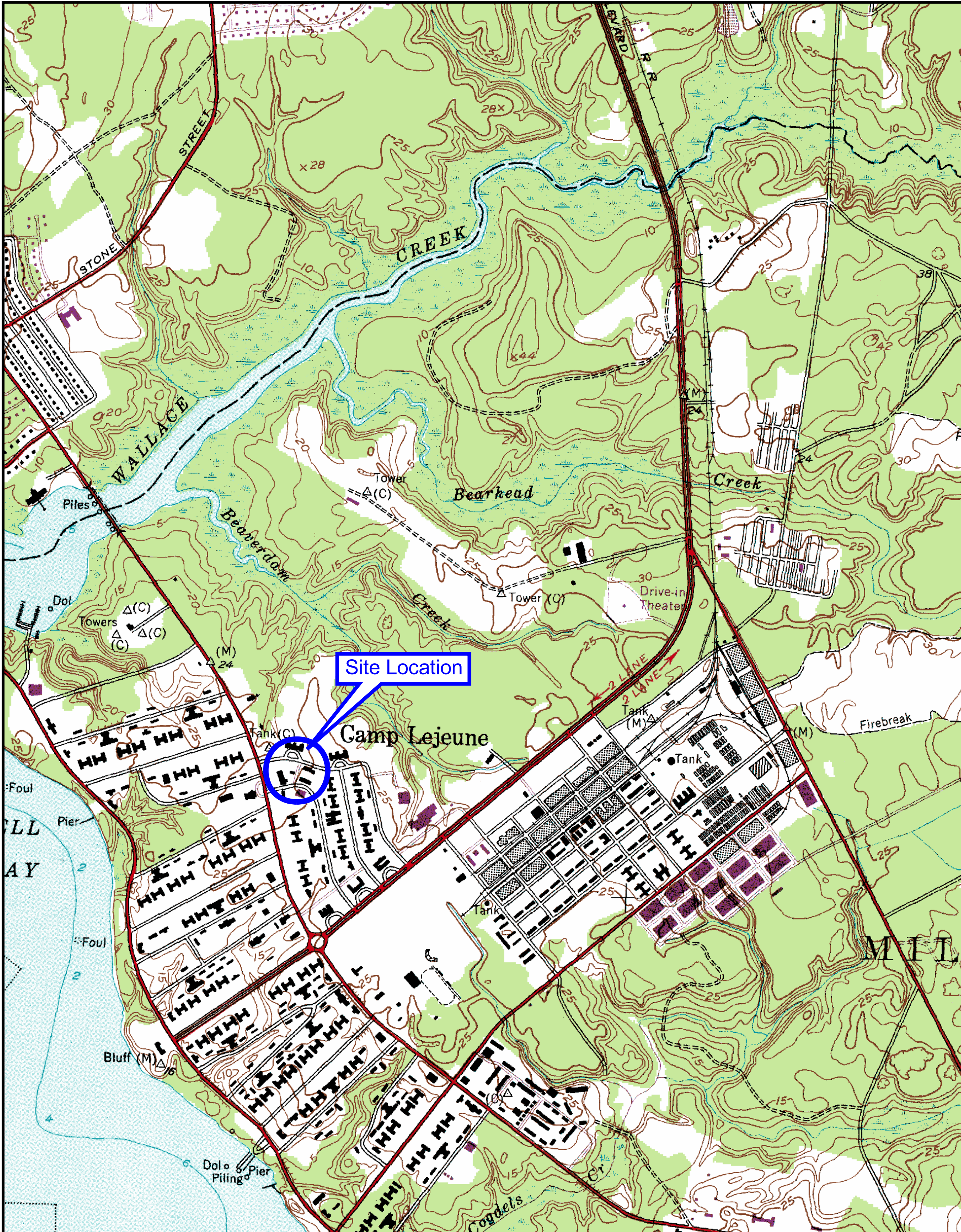
1. Additional investigation is required to evaluate the areal extent and continuity of the lithologic units (silt/clay layer and high density silty sand zone) that appear to be significantly influencing vertical contaminant migration. This will require the installation of several [i.e., as many as seven wells] deep wells within the source area and at the periphery of the site. It is recommended that continuous soil samples be collected from these well borings, and that representative undisturbed samples from each lithology be submitted for laboratory testing to evaluate physical properties.
2. The current understanding of the local groundwater flow regime is very limited. Additional shallow and intermediate depth wells are required in order to better resolve groundwater flow patterns.
3. It is important to quantify the properties of the two aquifers and aquitards identified at Site 88. Consequently, it is recommended that two 72-hr aquifer pumping test be conducted using purpose-built intermediate and deep pumping wells. These wells should be located in such a manner so as to minimize contaminant migration. It may be necessary to install additional monitoring wells to serve as observation wells for these tests.
4. In order to complete the delineation of the VOC plumes in shallow, intermediate and deep zones, additional monitoring wells will be required. However, it is likely that wells cited in the preceding recommendations will accomplish the goal of plume delineation.
5. Given the historical practice of disposing spent PCE into the sewer system and the northwesterly propagation of the dissolved-phase VOC groundwater plume, it is recommended that a soil contamination investigation be conducted using direct push technology along the alignment of the buried utility lines to west and northwest of Site 88. The goal of this investigation should be to identify secondary source material that may be contributing to the northwesterly expansion of the VOC plume.

7. References

Baker Environmental, Inc., May 15, 1998, *Focused Remedial Investigation Report, Operable Unit No. 15 (Site 88)*

United States Department of Defense – Environmental Security Technology Certification Program, August 2001, *Cost and Performance Report – Surfactant Enhanced DNAPL Removal.*

United States Department of Defense – Environmental Security Technology Certification Program , August 17, 2001. *Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT) Treatability Test – Interim Report*



USGS 7.5 Minute Quadrangle
Camp Lejeune, NC
Contour Interval 5 feet

N

0 1000 2000 3000 4000 Feet

Figure 1-1
Site Location Map
O.U. 15, Site 88, MCB Camp Lejeune

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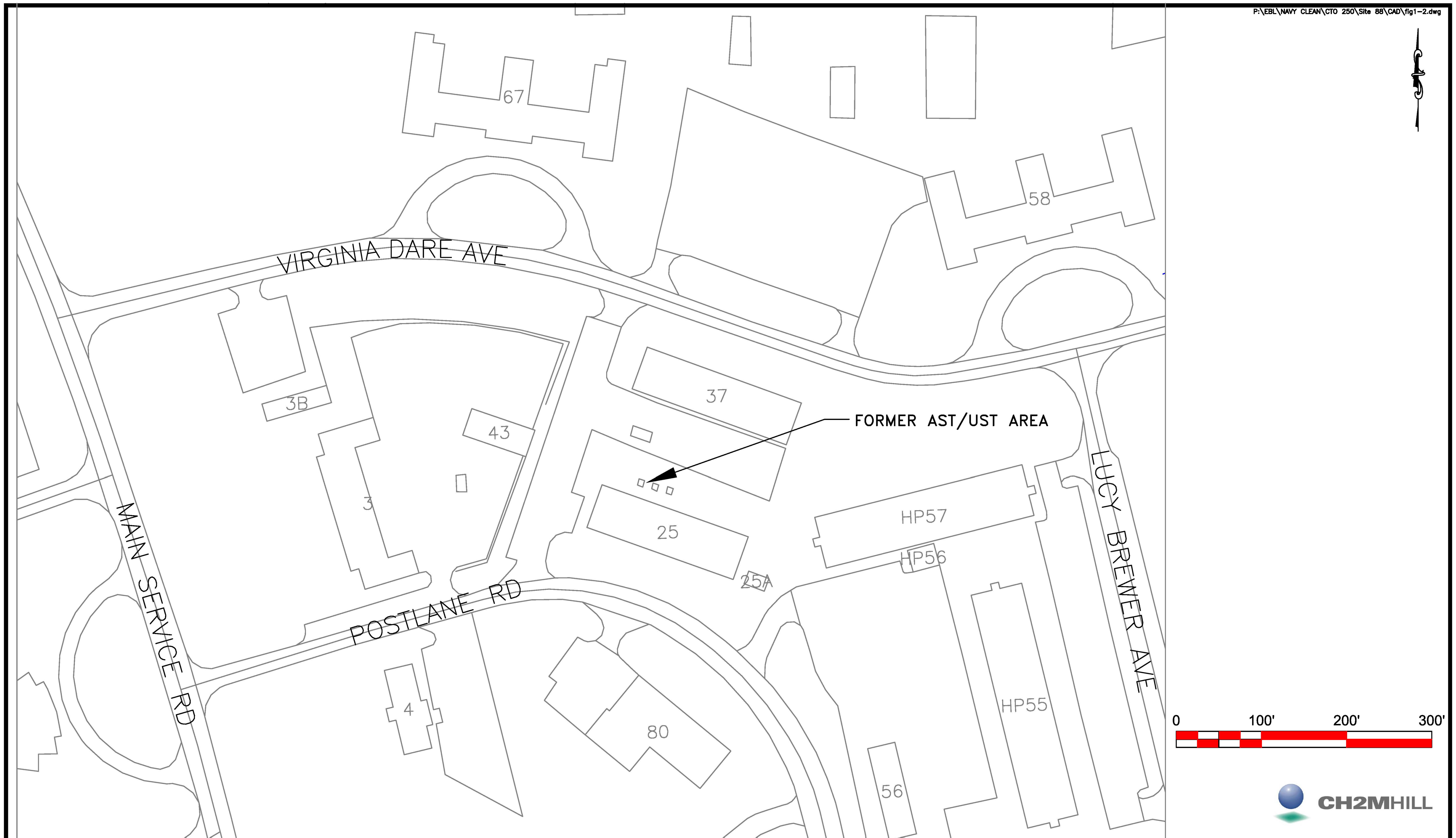
File Path: G:\projects2\CampLejeune\mxd\figure1-1.apr 09/13/02



SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 1–2
SITE PLAN
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

P:\EBL\NAVY CLEAN\CTO 250\Site 88\CAD\26120DE01_utilities.dwg

LEGEND:

UTIL–HEAT–COOL–LINE1

UTIL–STORM–SEWER–LINE

UTIL–WASTEWATER–LINE

UTIL–WATER–LINE

0 100' 200' 300'

CH2MHILL

FIGURE 1–3

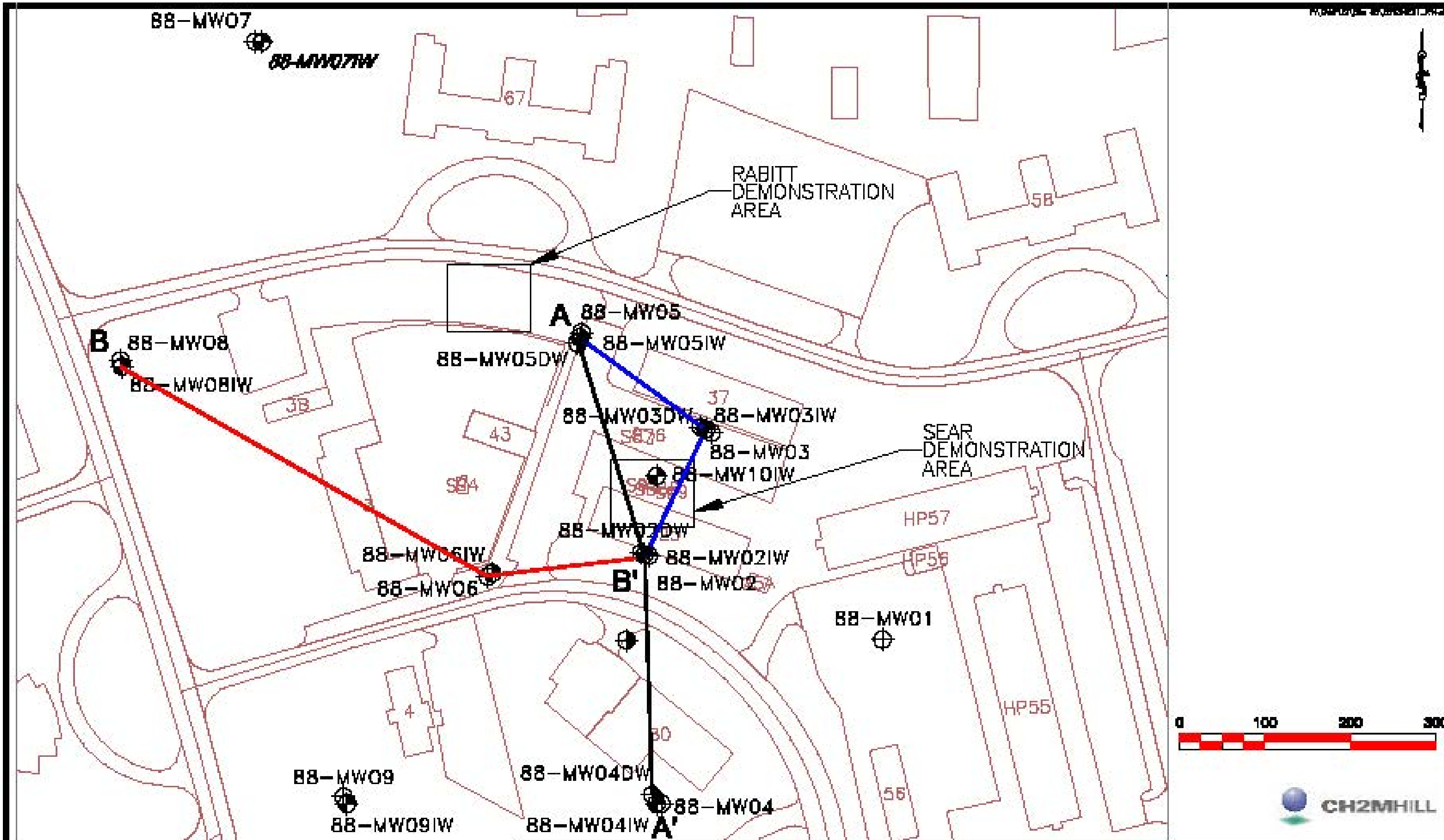
UNDERGROUND UTILITY MAP

OU 15 SITE 88

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA

SOURCE: MCB, CAMP LEJEUNE MARCH 2000



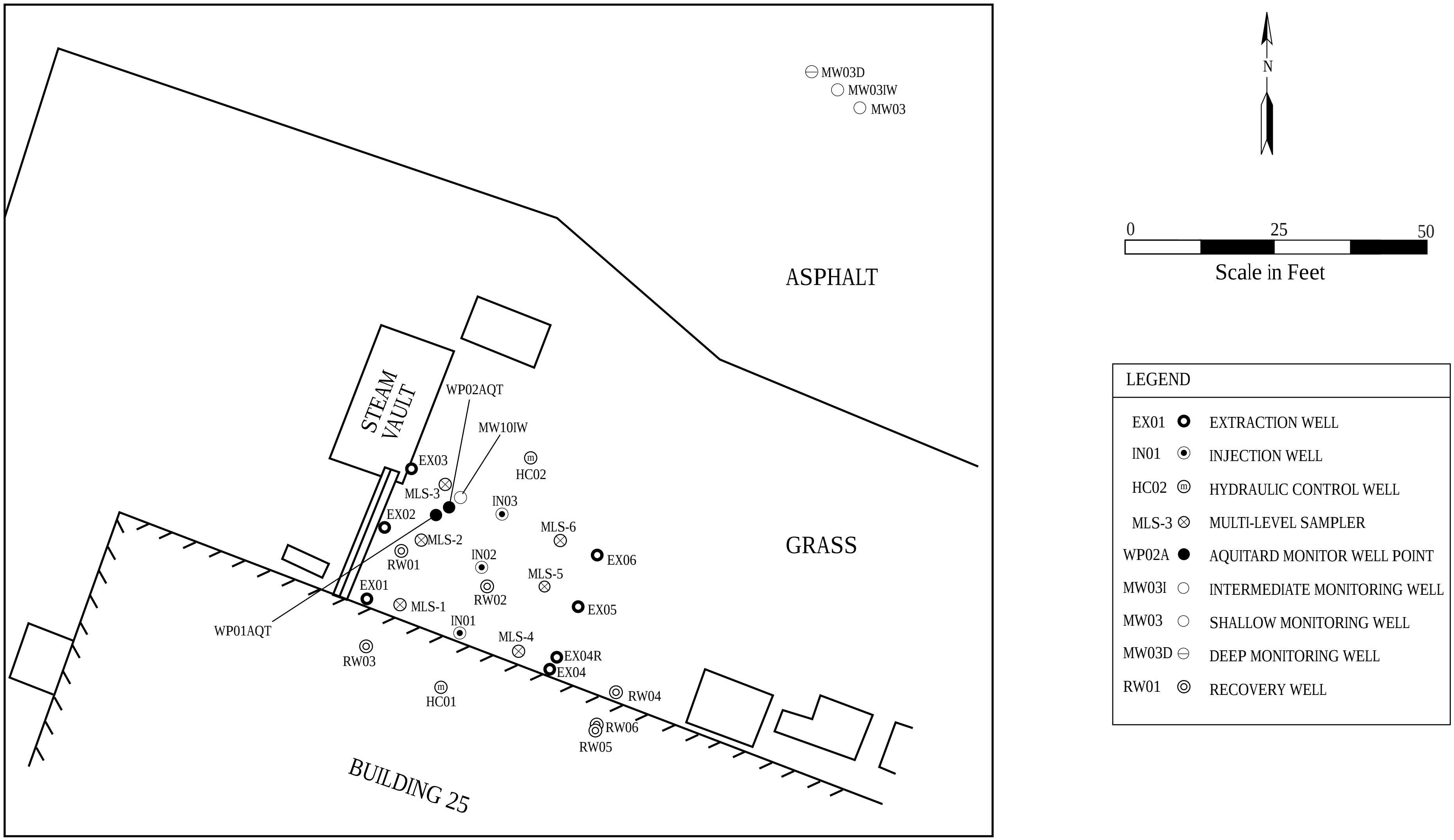
LEGEND

- SHALLOW MONITORING WELL
- INTERMEDIATE MONITORING WELL
- DEEP MONITORING WELL

A——A' GEOLOGIC X-SECTION

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

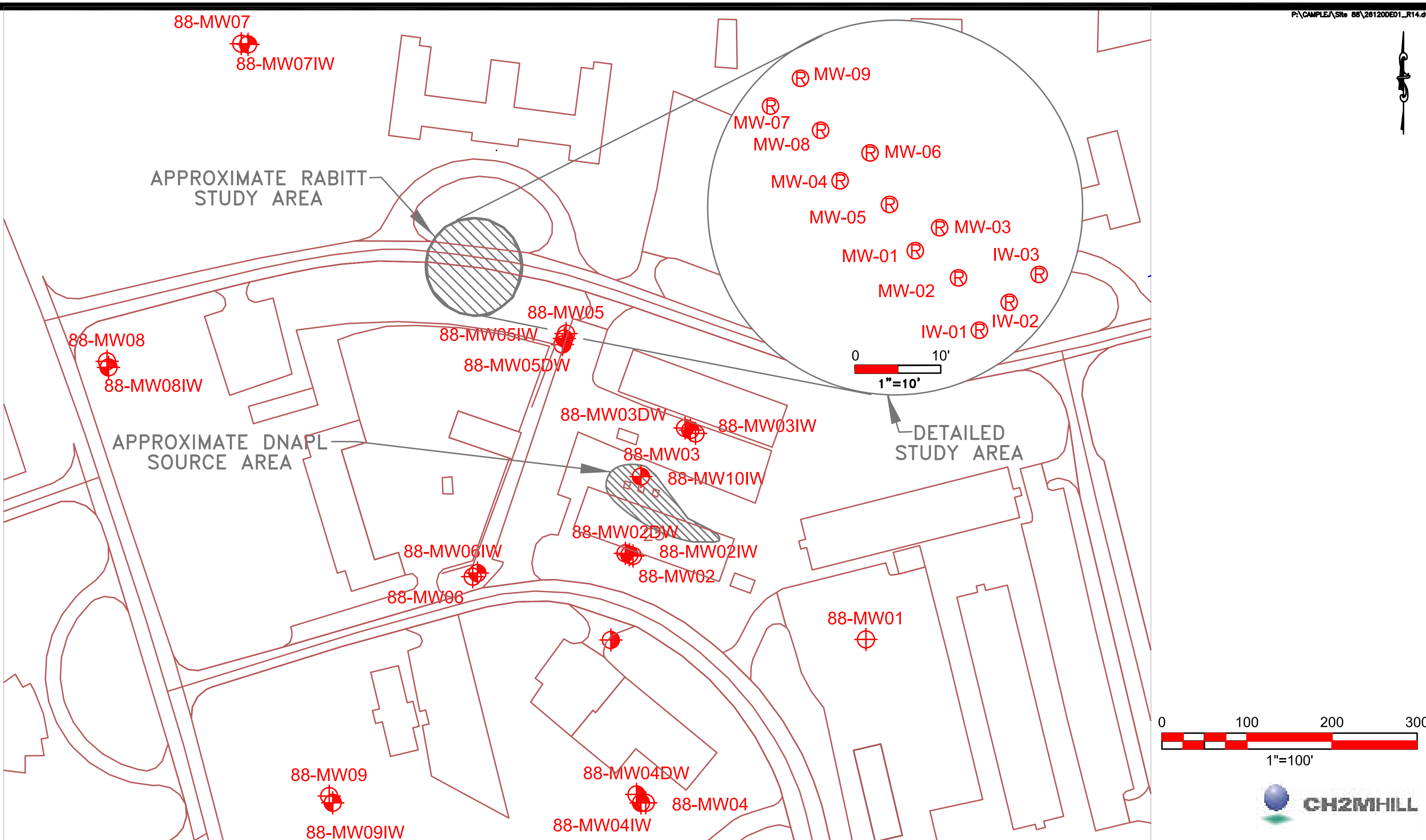
FIGURE 2-1
PERMANENT WELL LOCATION MAP
OPERABLE UNIT No. 15 – SITE 88
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND		
EX01	●	EXTRACTION WELL
IN01	⊙	INJECTION WELL
HC02	ⓜ	HYDRAULIC CONTROL WELL
MLS-3	⊗	MULTI-LEVEL SAMPLER
WP02A	●	AQUITARD MONITOR WELL POINT
MW03I	○	INTERMEDIATE MONITORING WELL
MW03	○	SHALLOW MONITORING WELL
MW03D	⊖	DEEP MONITORING WELL
RW01	◎	RECOVERY WELL

SOURCE: Duke Engineering and Services in cooperation with Baker Environment, Inc.

Figure 2-2
SEAR Well Location Map
Operable Unit 15 - Site 88
MCB Camp Lejeune, North Carolina



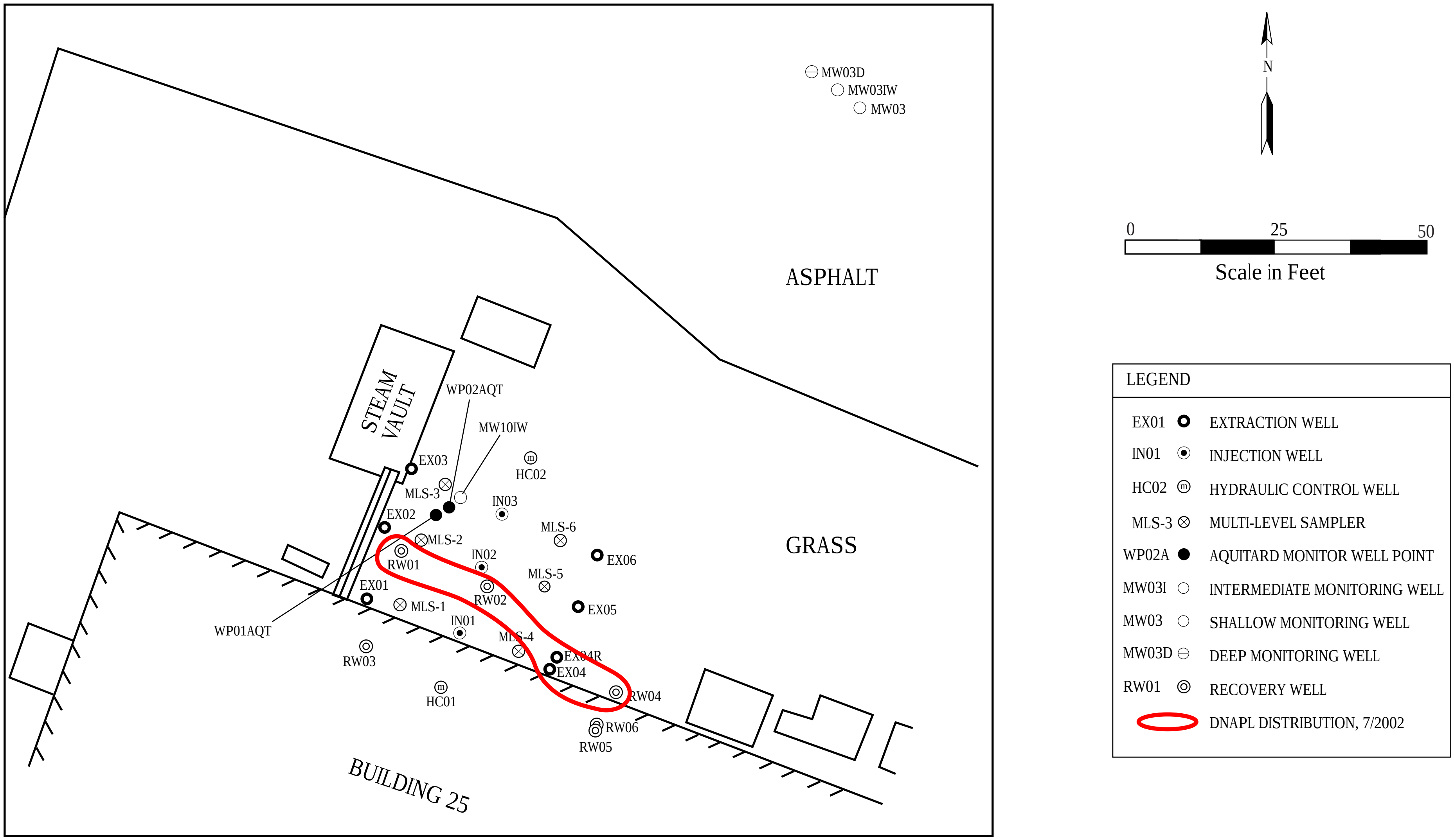
NOTE:
THE LOCATION OF THE WELLS WITHIN THE ENLARGED AREA ARE APPROXIMATE

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

LEGEND

- SHALLOW MONITORING WELL
- INTERMEDIATE MONITORING WELL
- DEEP MONITORING WELL
- RABITT WELL
- INJECTION WELL

FIGURE 2-3 RABITT WELL SAMPLING LOCATION MAP
OPERABLE UNIT No. 15 – SITE 88
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SOURCE: Duke Engineering and Services in cooperation with Baker Environment, Inc.

Figure 2-4
DNAPL Distribution Map
Operable Unit 15 - Site 88
MCB Camp Lejeune, North Carolina

CH2MHILL

E082002007ATL/LANTDIV 100.ai

Figure 3-1

Hydrostratigraphic units of North Carolina Coastal Plain.

<table>
<tr><th colspan="3">Geologic Units</th><th>Hydrogeologic Units</th></tr>
<tr><th>System</th><th>Series</th><th>Formation</th><th>Aquifer and Confining Unit</th></tr>
<tr><td>Quaternary</td><td>Holocene/Pleistocene</td><td>Undifferentiated</td><td>Surficial aquifer</td></tr>
<tr><td rowspan="11">Tertiary</td><td>Pliocene</td><td rowspan="2">Yorktown[1]</td><td>Yorktown confining unit</td></tr>
<tr><td rowspan="5">Miocene</td><td>Yorktown Aquifer</td></tr>
<tr><td>Eastover[1]</td><td rowspan="2">Pungo River confining unit</td></tr>
<tr><td rowspan="2">Pungo River[1]</td></tr>
<tr><td>Pungo River Aquifer</td></tr>
<tr><td>Belgrade[2]</td><td>Castle Hayne confining unit</td></tr>
<tr><td>Oligocene</td><td>River Bend</td><td rowspan="2">Castle Hayne Aquifer</td></tr>
<tr><td rowspan="2">Eocene</td><td rowspan="2">Castle Hayne</td></tr>
<tr><td>Beaufort confining unit[3]</td></tr>
<tr><td rowspan="2">Paleocene</td><td rowspan="2">Beaufort</td><td>Beaufort Aquifer</td></tr>
<tr><td rowspan="2">Peedee confining unit</td></tr>
<tr><td rowspan="11">Cretaceous</td><td rowspan="11">Upper Cretaceous

Lower Cretaceous</td><td rowspan="2">Peedee</td></tr>
<tr><td>Peedee Aquifer</td></tr>
<tr><td rowspan="3">Black Creek and Middendorf</td><td>Black Creek confining unit</td></tr>
<tr><td>Black Creek Aquifer</td></tr>
<tr><td rowspan="2">Upper Cape Fear confining unit</td></tr>
<tr><td rowspan="4">Cape Fear</td></tr>
<tr><td>Upper Cape Fear Aquifer</td></tr>
<tr><td>Lower Cape Fear confining unit</td></tr>
<tr><td>Lower Cape Fear Aquifer</td></tr>
<tr><td rowspan="2">Unnamed deposits[1]</td><td>Lower Cretaceous confining unit</td></tr>
<tr><td>Lower Cretaceous Aquifer[1]</td></tr>
<tr><td colspan="2">Pre-Cretaceous basement rocks</td><td></td><td></td></tr>
</table>

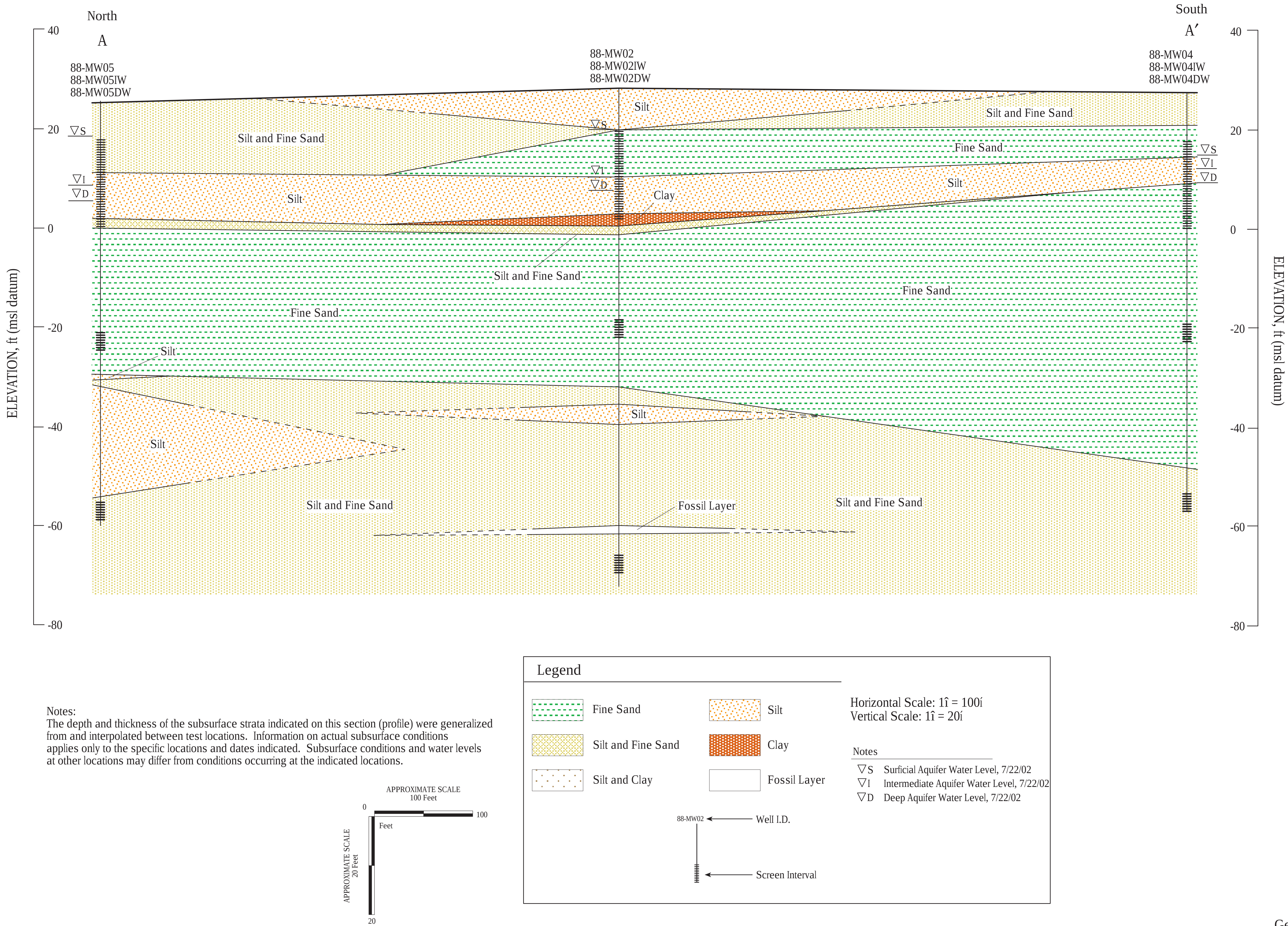
Notes:

(1) Geologic and hydrologic units probably not present beneath MCB Camp Lejeune.

(2) Constitutes part of the surficial aquifer and Castle Hayne confining unit in the study area.

(3) Estimated to be confined to deposits of Paleocene age in the study area.

Source: Harned et al., 1989.



Notes:
The depth and thickness of the subsurface strata indicated on this section (profile) were generalized from and interpolated between test locations. Information on actual subsurface conditions applies only to the specific locations and dates indicated. Subsurface conditions and water levels at other locations may differ from conditions occurring at the indicated locations.

Figure 3-**2**
Geologic Cross-Section A-A'
Operable Unit 15, Site 88
MCB Camp Lejeune, NC

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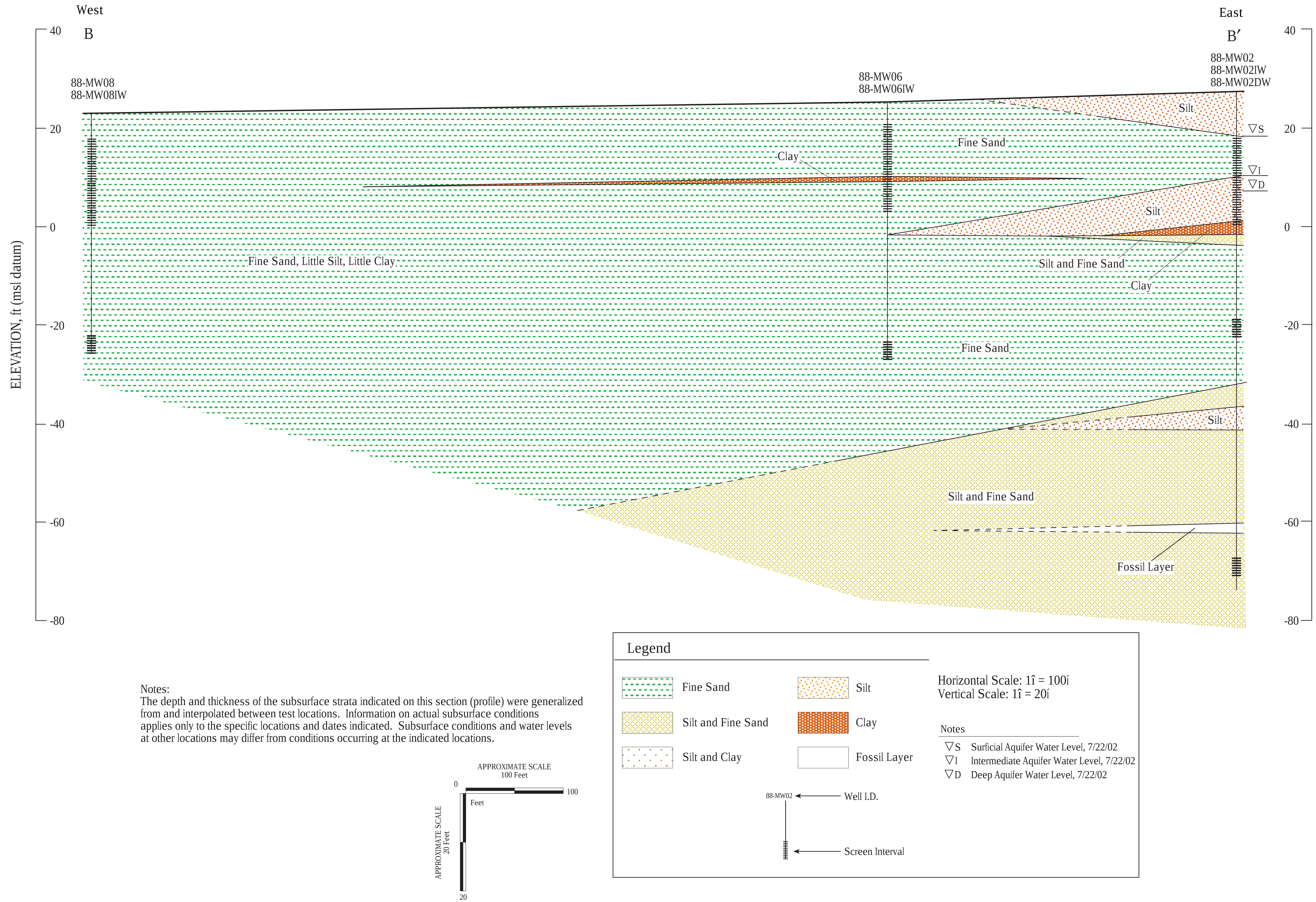

Notes:
The depth and thickness of the subsurface strata indicated on this section (profile) were generalized from and interpolated between test locations. Information on actual subsurface conditions applies only to the specific locations and dates indicated. Subsurface conditions and water levels at other locations may differ from conditions occurring at the indicated locations.

Figure 3-3
Geologic Cross-Section B-B'
Operable Unit 15, Site 88
MCB Camp Lejeune, NC

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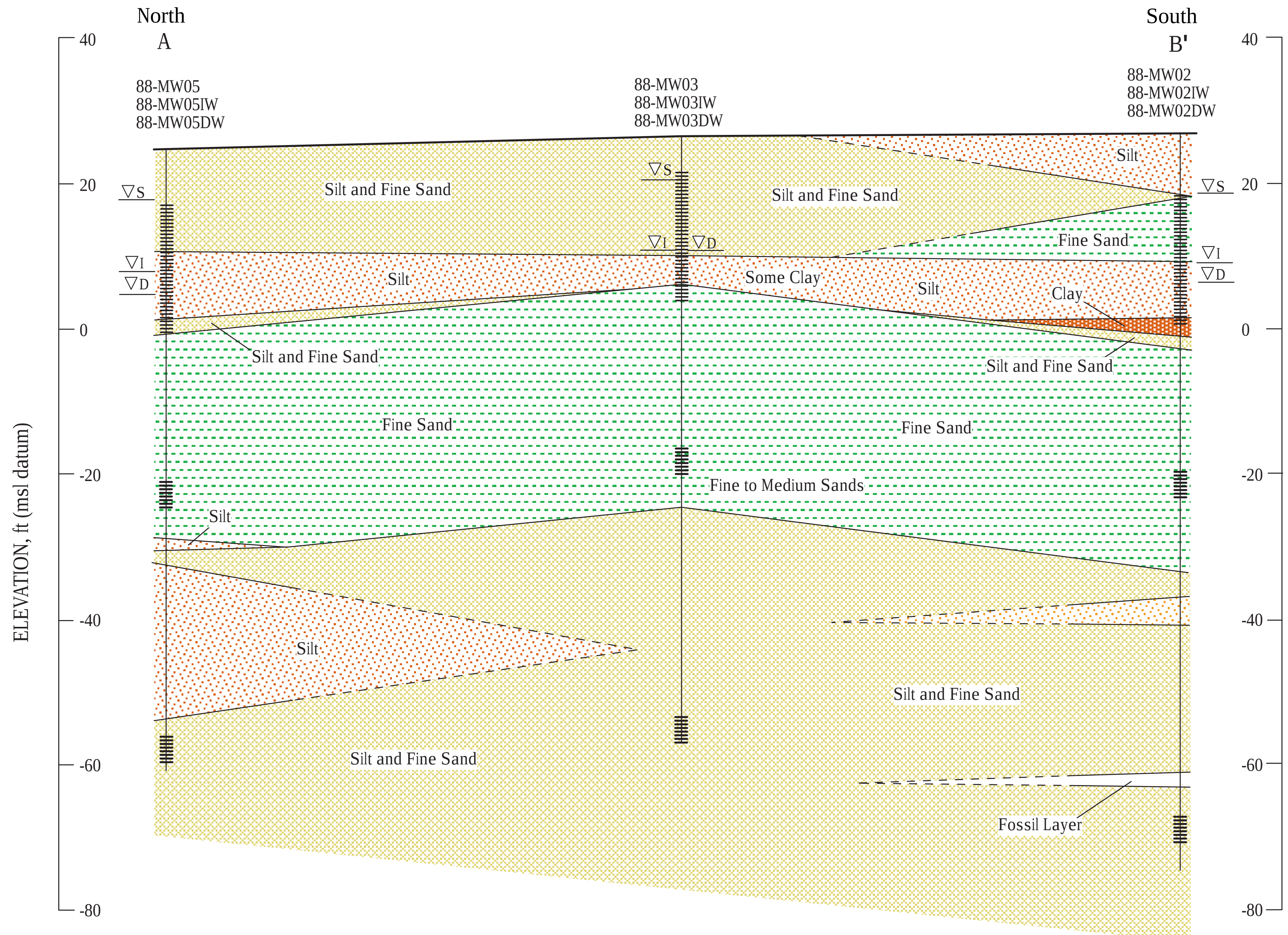
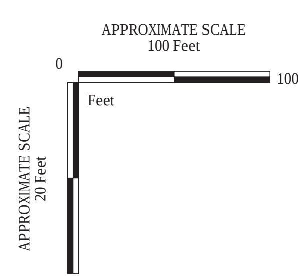


Notes:
The depth and thickness of the subsurface strata indicated on this section (profile) were generalized from and interpolated between test locations. Information on actual subsurface conditions applies only to the specific locations and dates indicated. Subsurface conditions and water levels at other locations may differ from conditions occurring at the indicated locations.



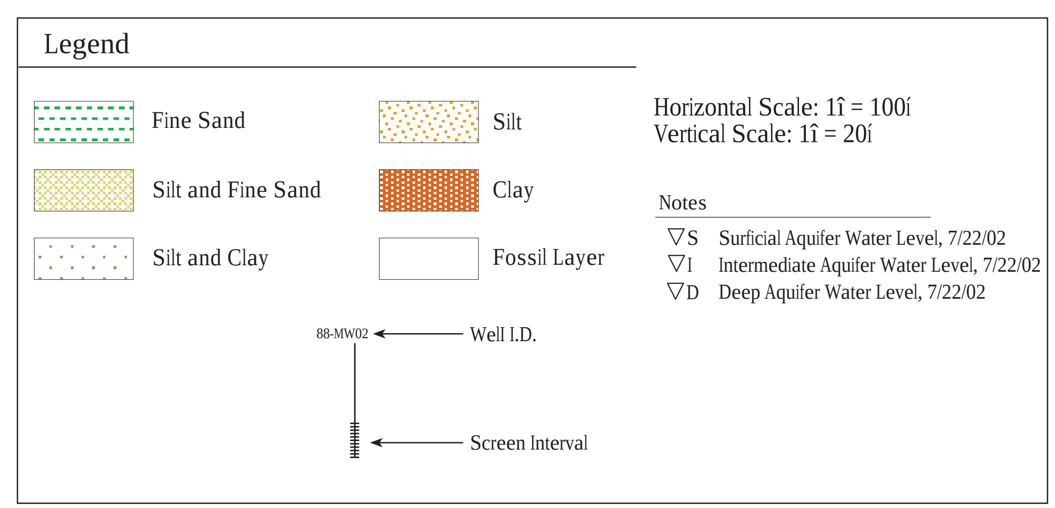
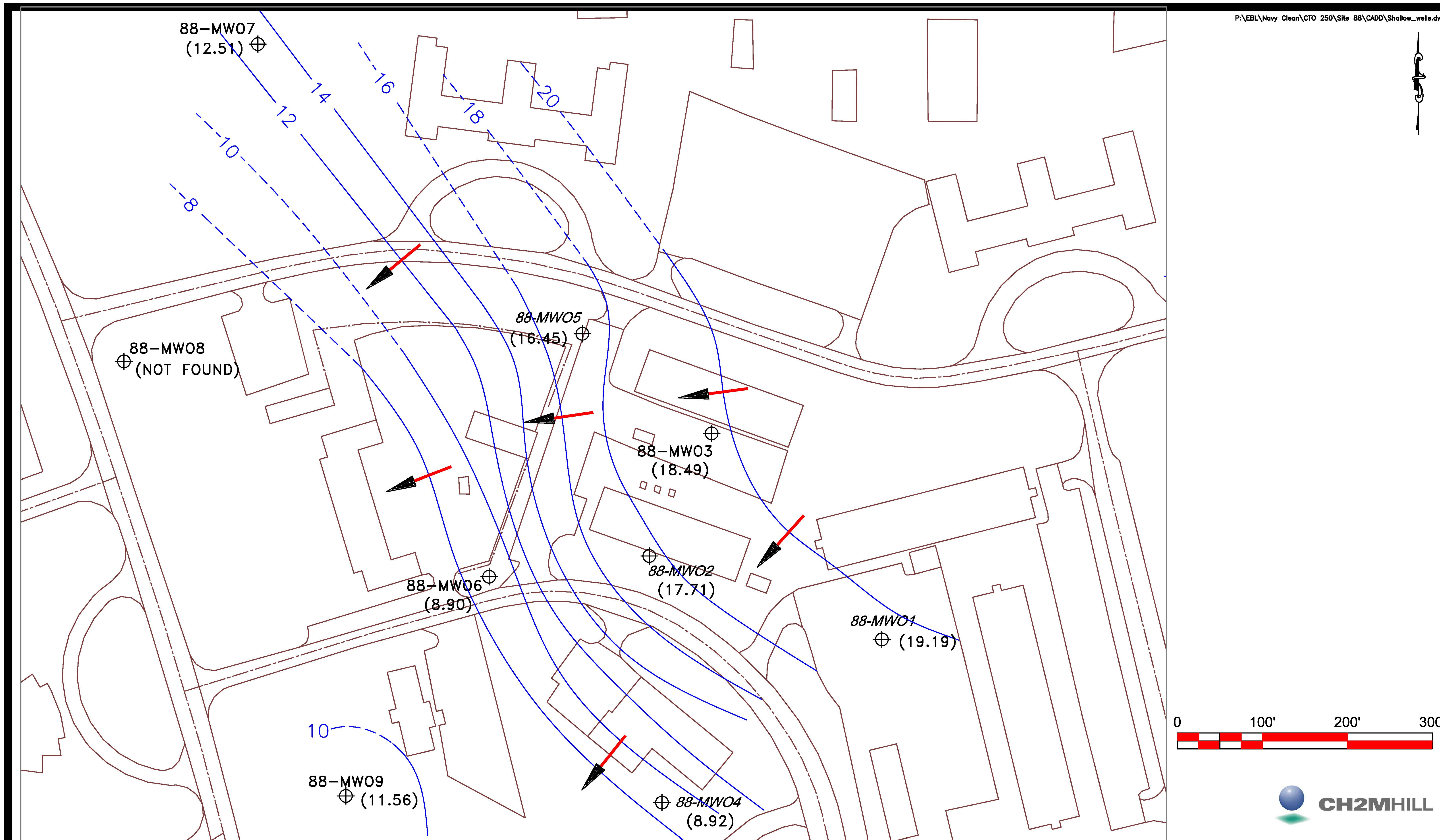


Figure 3-**4**
Geologic Cross-Section A-B'
Operational Unit 15, Site 88
MCB Camp Lejeune, NC

CH2MHILL

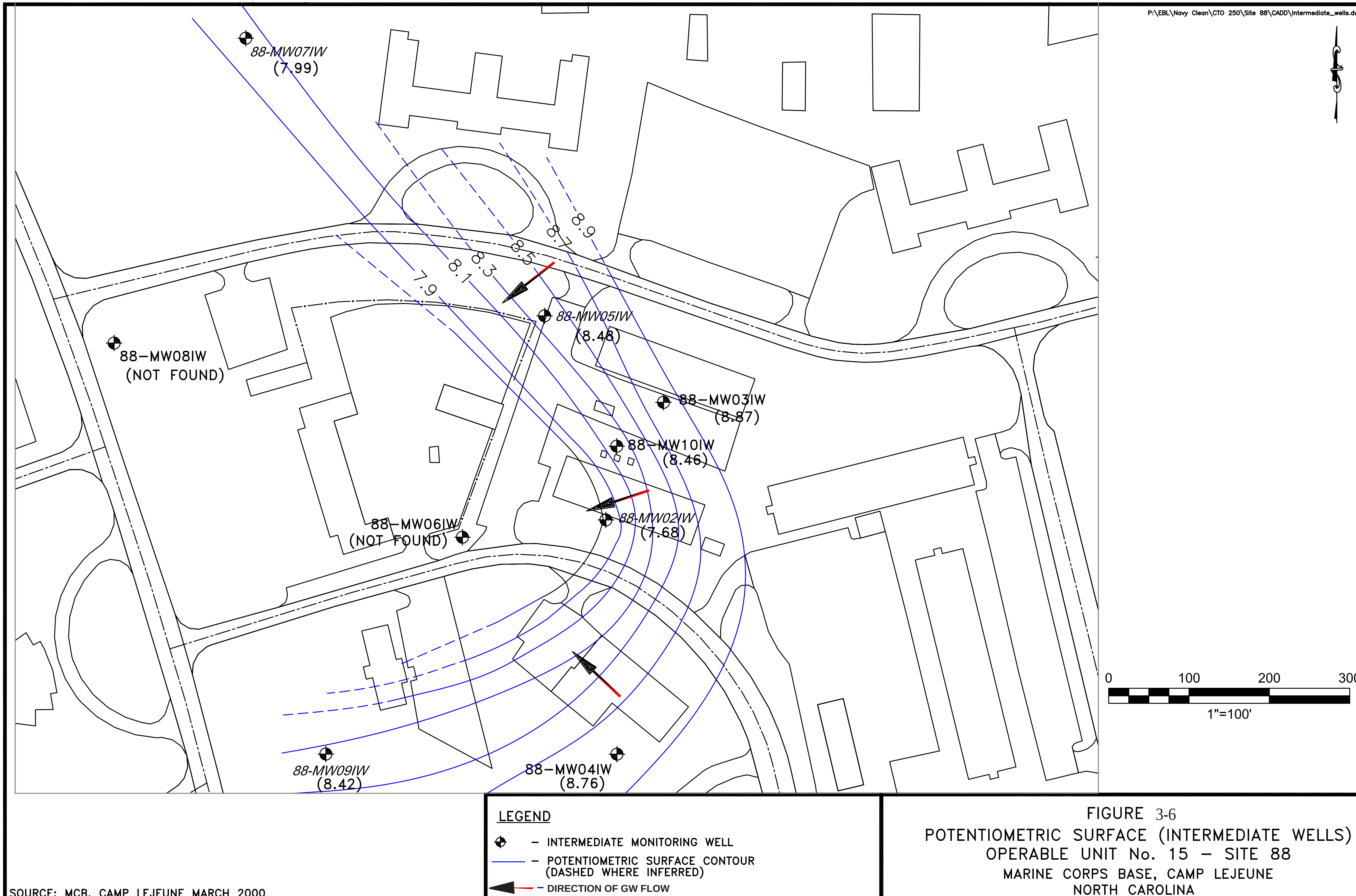
E082002007ATL\LANTDIV 103.fh8



SOURCE: MCB, CAMP LEJEUNE MARCH 2000

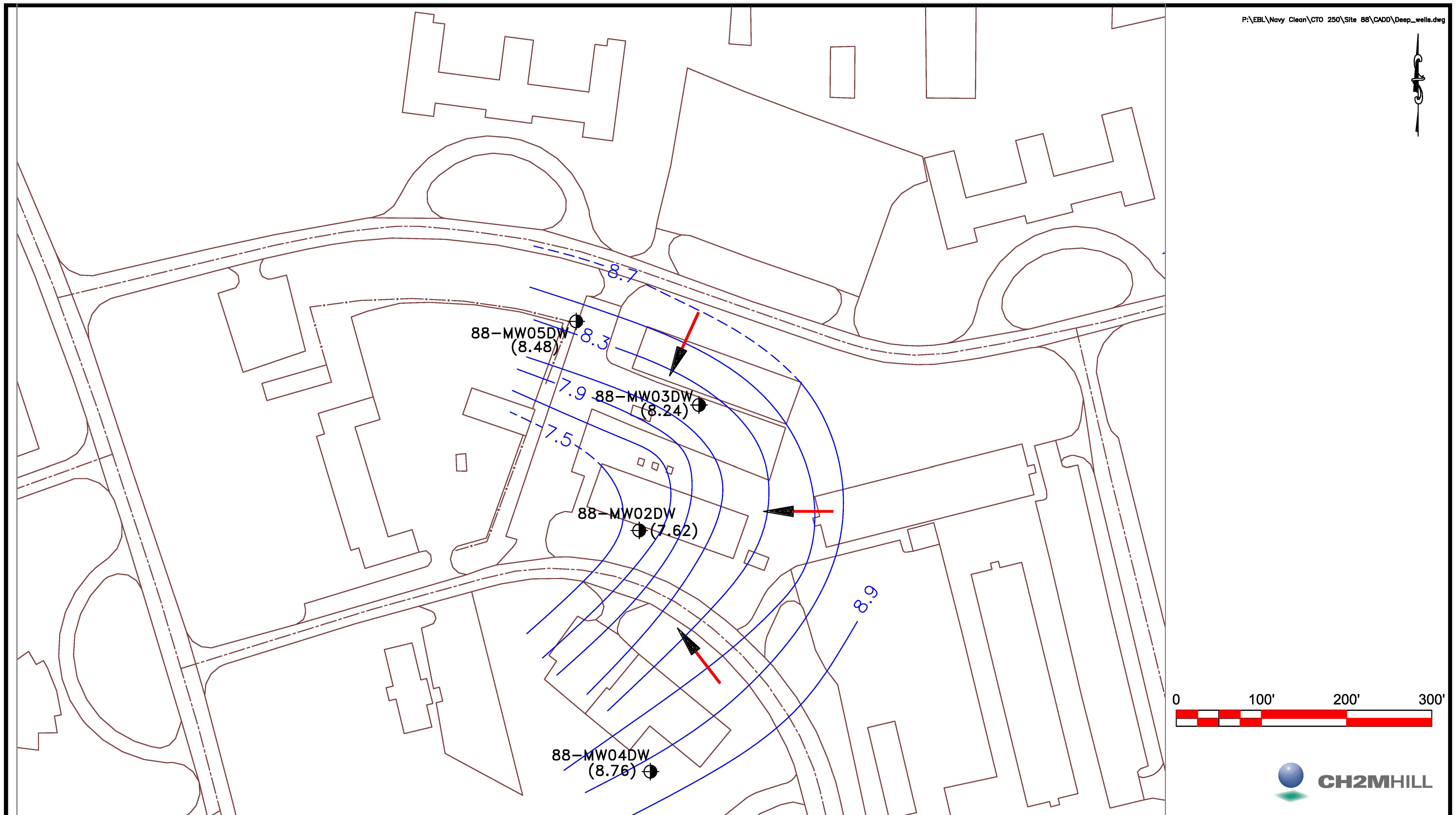
LEGEND
- SHALLOW MONITORING WELL
- POTENTIOMETRIC SURFACE CONTOUR - 07/22/02 (DASHED WHERE INFERRED)
- DIRECTION OF GW FLOW

FIGURE 3-5
POTENTIOMETRIC SURFACE (SHALLOW WELLS)
OPERABLE UNIT No. 15 – SITE 88
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 3-6
POTENTIOMETRIC SURFACE (INTERMEDIATE WELLS)
OPERABLE UNIT No. 15 – SITE 88
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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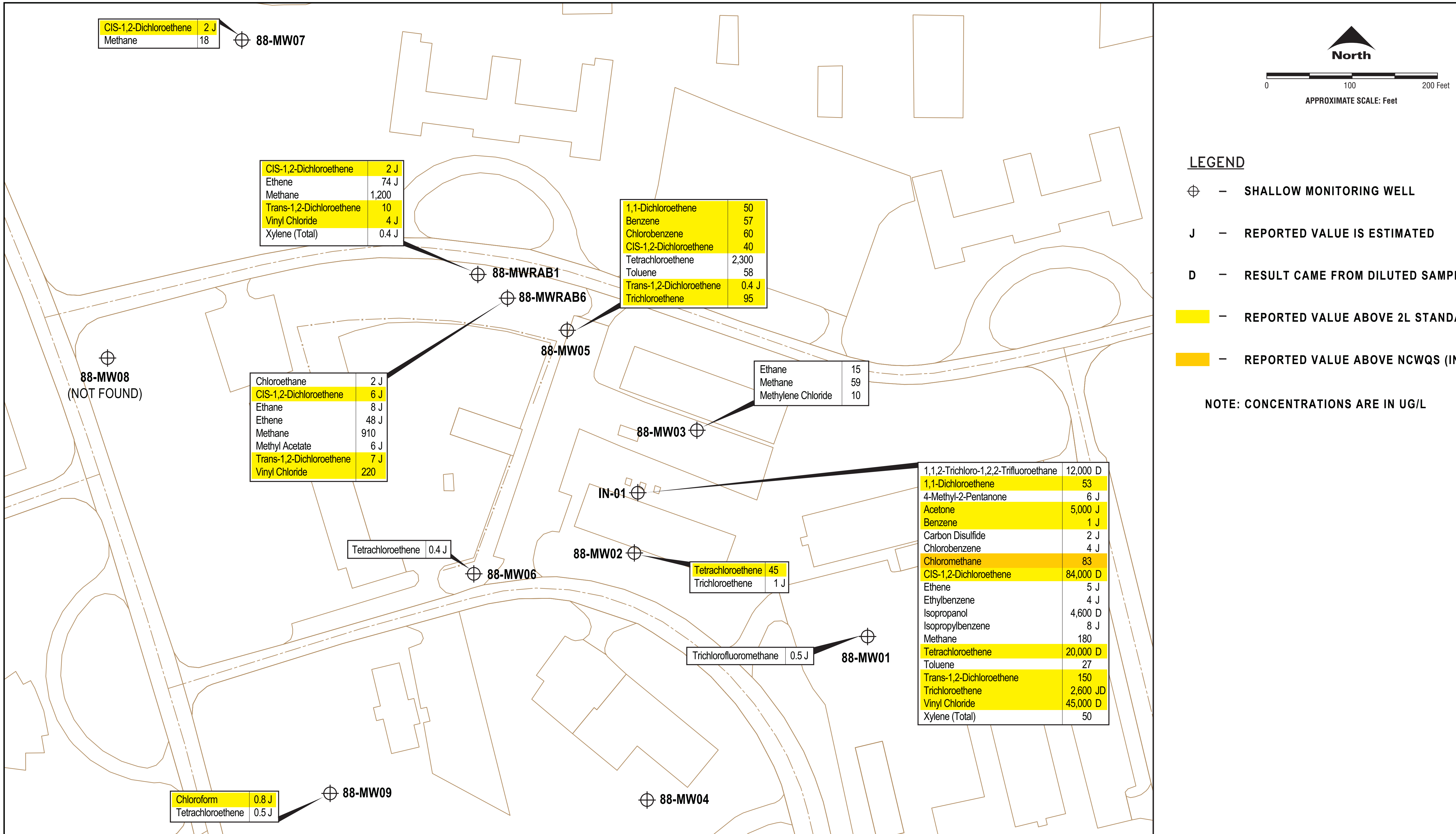
SOURCE: MCB, CAMP LEJEUNE MARCH 2000

LEGEND

- DEEP MONITORING WELL
- POTENTIOMETRIC SURFACE CONTOUR - 07/22/02 (DASHED WHERE INFERRED)
- DIRECTION OF GW FLOW

FIGURE 3-7
POTENTIOMETRIC SURFACE (DEEP WELLS)
OPERABLE UNIT No. 15 - SITE 88
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

⊕ – SHALLOW MONITORING WELL

J – REPORTED VALUE IS ESTIMATED

D – RESULT CAME FROM DILUTED SAMPLE

(yellow) – REPORTED VALUE ABOVE 2L STANDARDS

(orange) – REPORTED VALUE ABOVE NCWQS (INTERIM)

NOTE: CONCENTRATIONS ARE IN UG/L

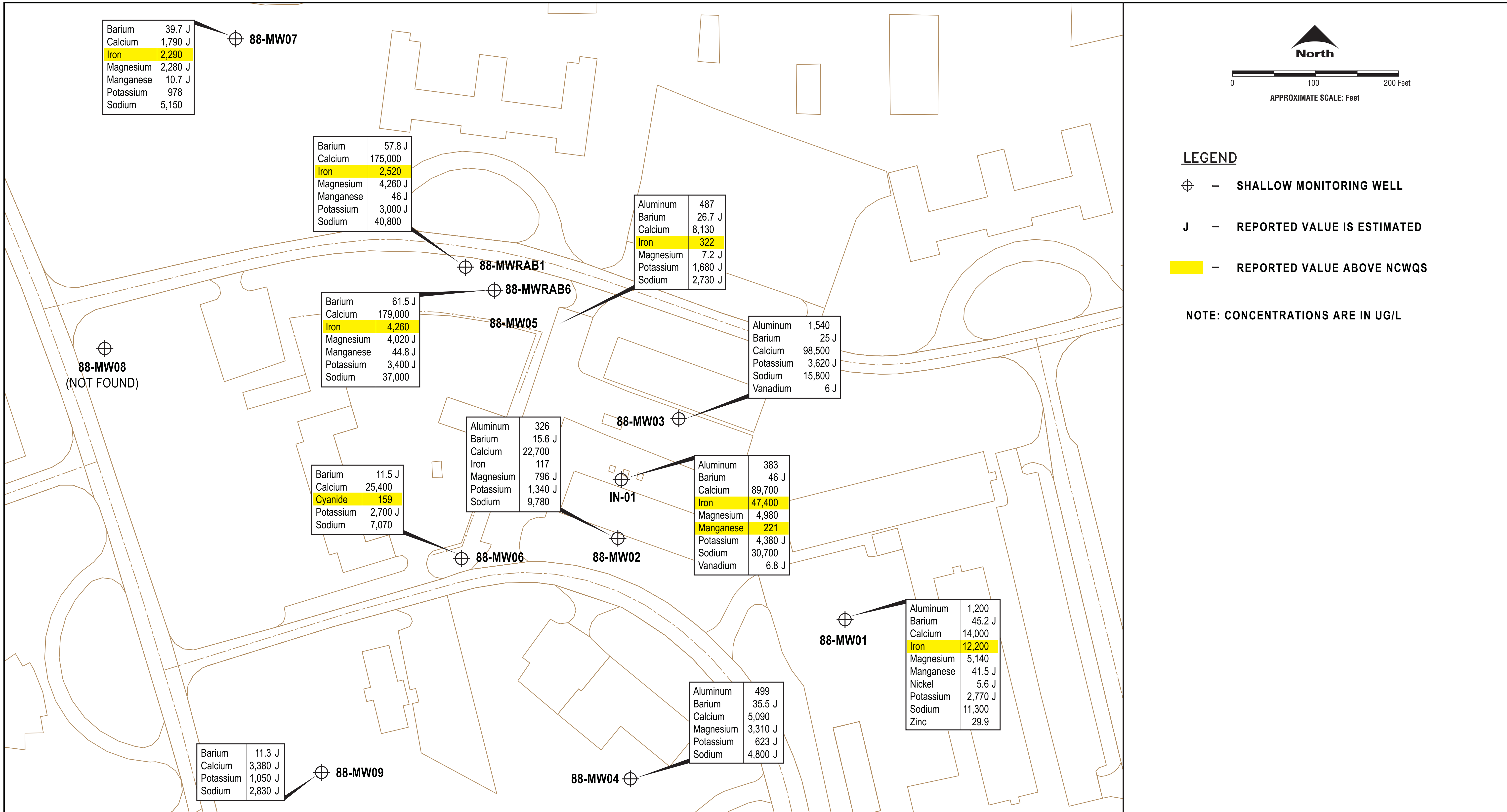
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-1
VOLATILE ORGANIC COMPOUNDS CONCENTRATION MAP
(SHALLOW WELLS)
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-VOC-Shallow.ai



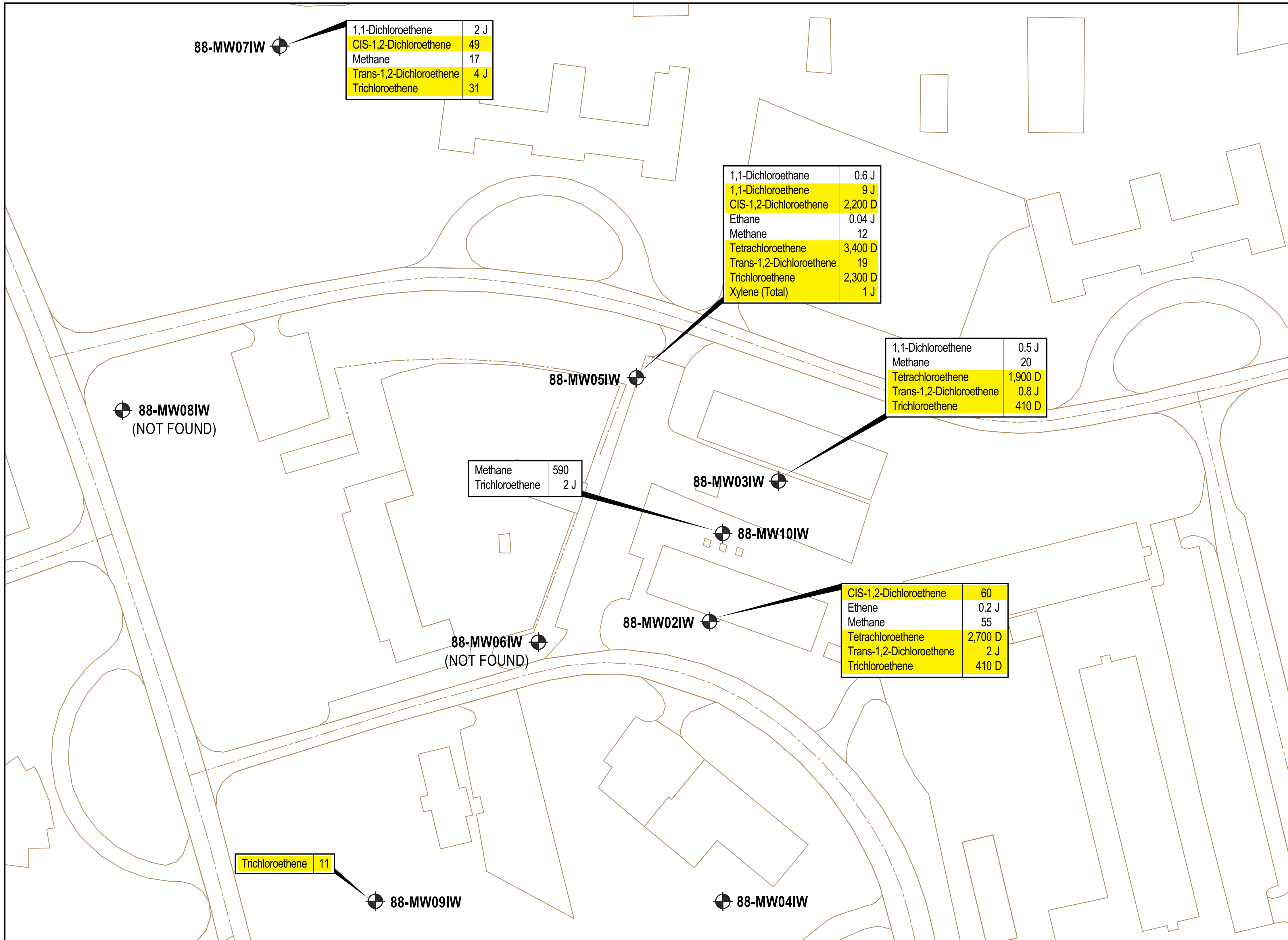
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-2
TOTAL METALS CONCENTRATION MAP
(SHALLOW WELLS)
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-TMC-Shallow.ai



North

0 100 200 Feet

APPROXIMATE SCALE: Feet

LEGEND

⊕ – INTERMEDIATE MONITORING WELL

J – REPORTED VALUE IS ESTIMATED

D – RESULT CAME FROM DILUTED SAMPLE

(yellow) – REPORTED VALUE ABOVE NCWQS

NOTE: CONCENTRATIONS ARE IN UG/L

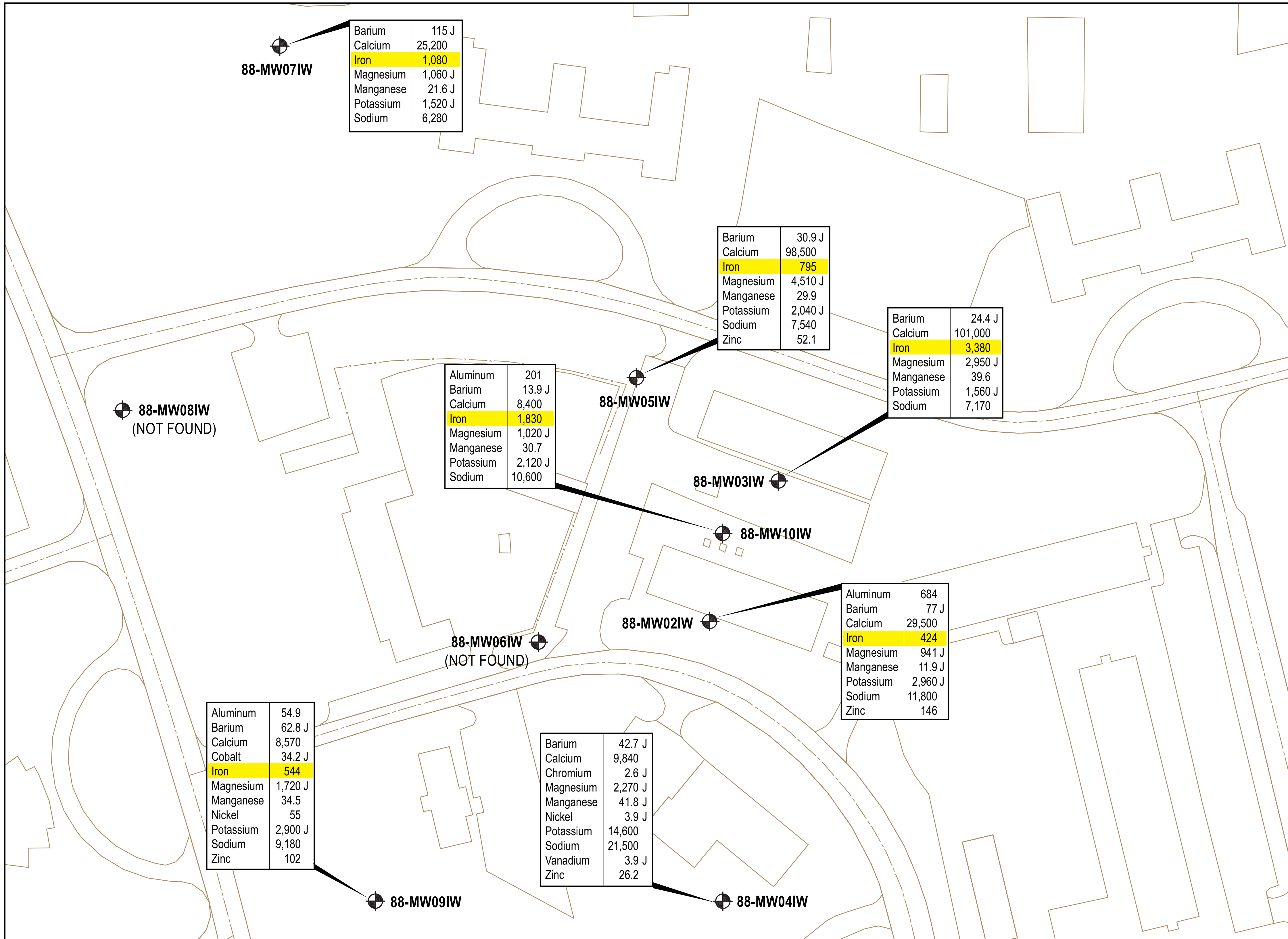
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-3
VOLATILE ORGANIC COMPOUNDS CONCENTRATION MAP
(INTERMEDIATE WELLS)
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-VOC-Intermediate.ai



88-MW07IW

Barium	115 J
Calcium	25,200
Iron	1,080
Magnesium	1,060 J
Manganese	21.6 J
Potassium	1,520 J
Sodium	6,280

88-MW05IW

Barium	30.9 J
Calcium	98,500
Iron	795
Magnesium	4,510 J
Manganese	29.9
Potassium	2,040 J
Sodium	7,540
Zinc	52.1

88-MW03IW

Barium	24.4 J
Calcium	101,000
Iron	3,380
Magnesium	2,950 J
Manganese	39.6
Potassium	1,560 J
Sodium	7,170

88-MW10IW

Aluminum	201
Barium	13.9 J
Calcium	8,400
Iron	1,830
Magnesium	1,020 J
Manganese	30.7
Potassium	2,120 J
Sodium	10,600

88-MW02IW

Aluminum	684
Barium	77 J
Calcium	29,500
Iron	424
Magnesium	941 J
Manganese	11.9 J
Potassium	2,960 J
Sodium	11,800
Zinc	146

88-MW09IW

Aluminum	54.9
Barium	62.8 J
Calcium	8,570
Cobalt	34.2 J
Iron	544
Magnesium	1,720 J
Manganese	34.5
Nickel	55
Potassium	2,900 J
Sodium	9,180
Zinc	102

88-MW04IW

Barium	42.7 J
Calcium	9,840
Chromium	2.6 J
Magnesium	2,270 J
Manganese	41.8 J
Nickel	3.9 J
Potassium	14,600
Sodium	21,500
Vanadium	3.9 J
Zinc	26.2

North

0 100 200 Feet

APPROXIMATE SCALE: Feet

LEGEND

⌖ – INTERMEDIATE MONITORING WELL

J – REPORTED VALUE IS ESTIMATED

(yellow) – REPORTED VALUE ABOVE NCWQS

NOTE: CONCENTRATIONS ARE IN UG/L

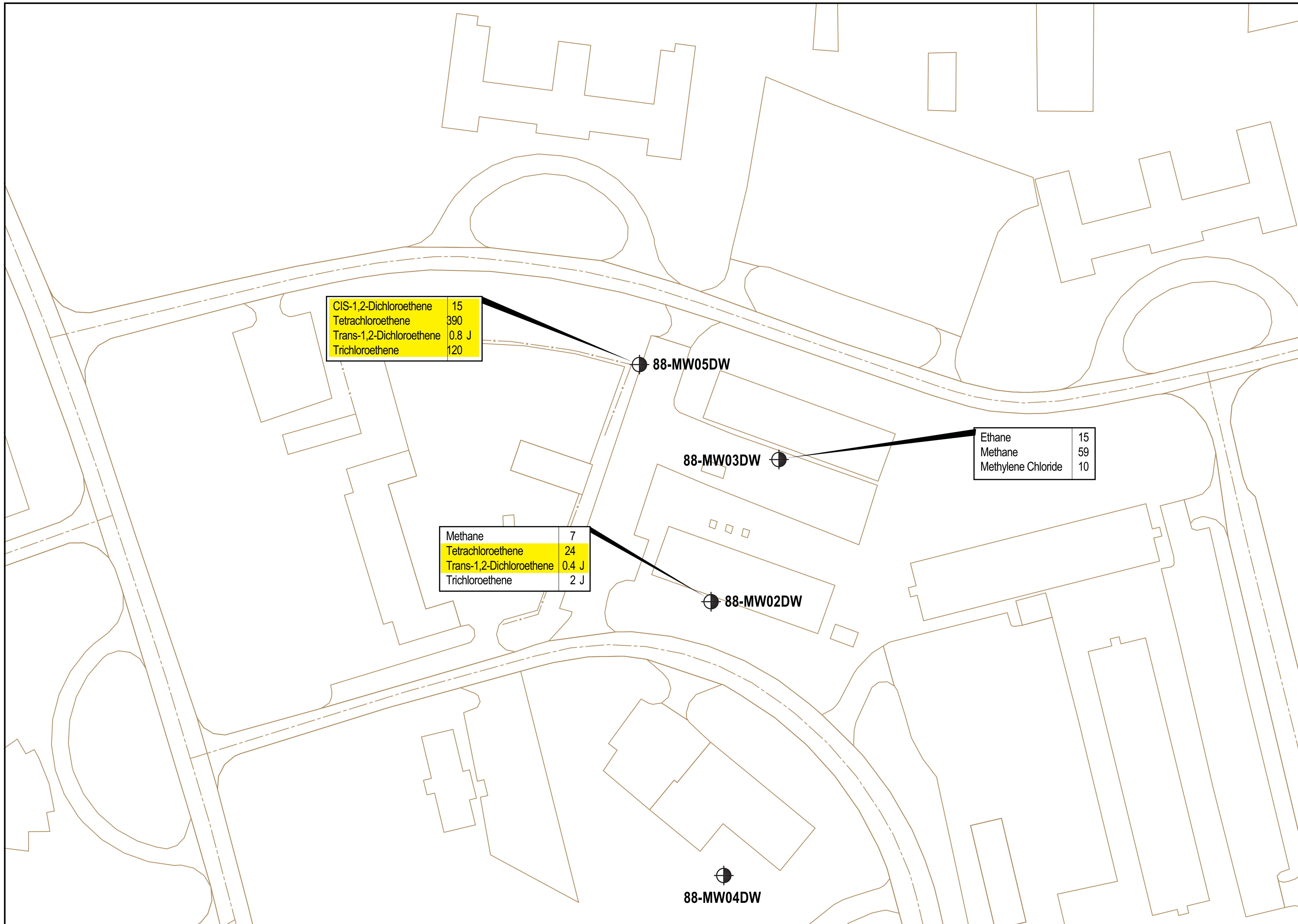
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-4
TOTAL METALS CONCENTRATION MAP
(INTERMEDIATE WELLS) July 2002
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-TMC-Intermediate.ai



North

0 100 200 Feet

APPROXIMATE SCALE: Feet

LEGEND

- DEEP MONITORING WELL
J – REPORTED VALUE IS ESTIMATED
– REPORTED VALUE ABOVE NCWQS

NOTE: CONCENTRATIONS ARE IN UG/L

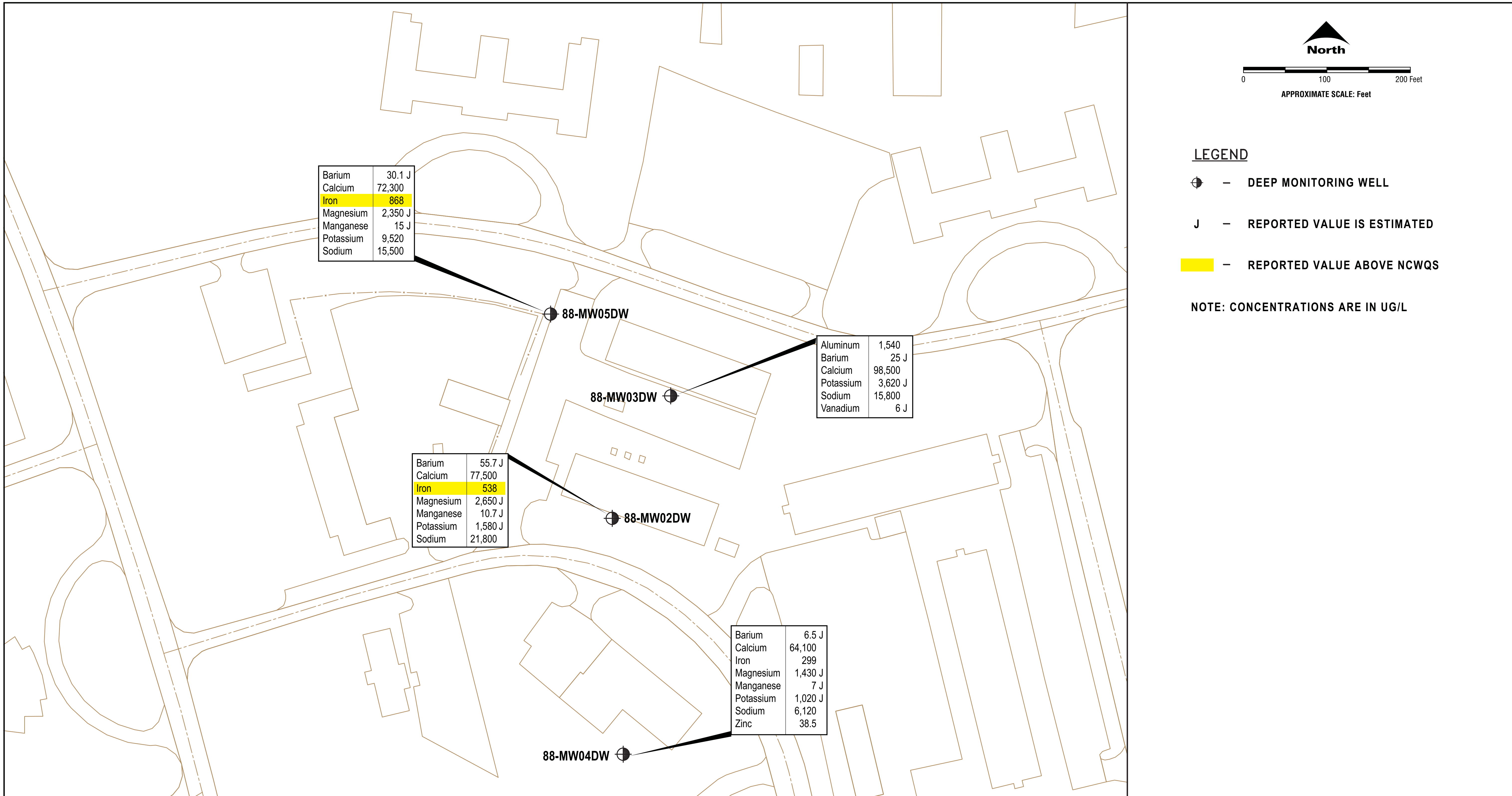
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-5
VOLATILE ORGANIC COMPOUNDS CONCENTRATION MAP
(DEEP WELLS)
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-VOC-Deep.ai



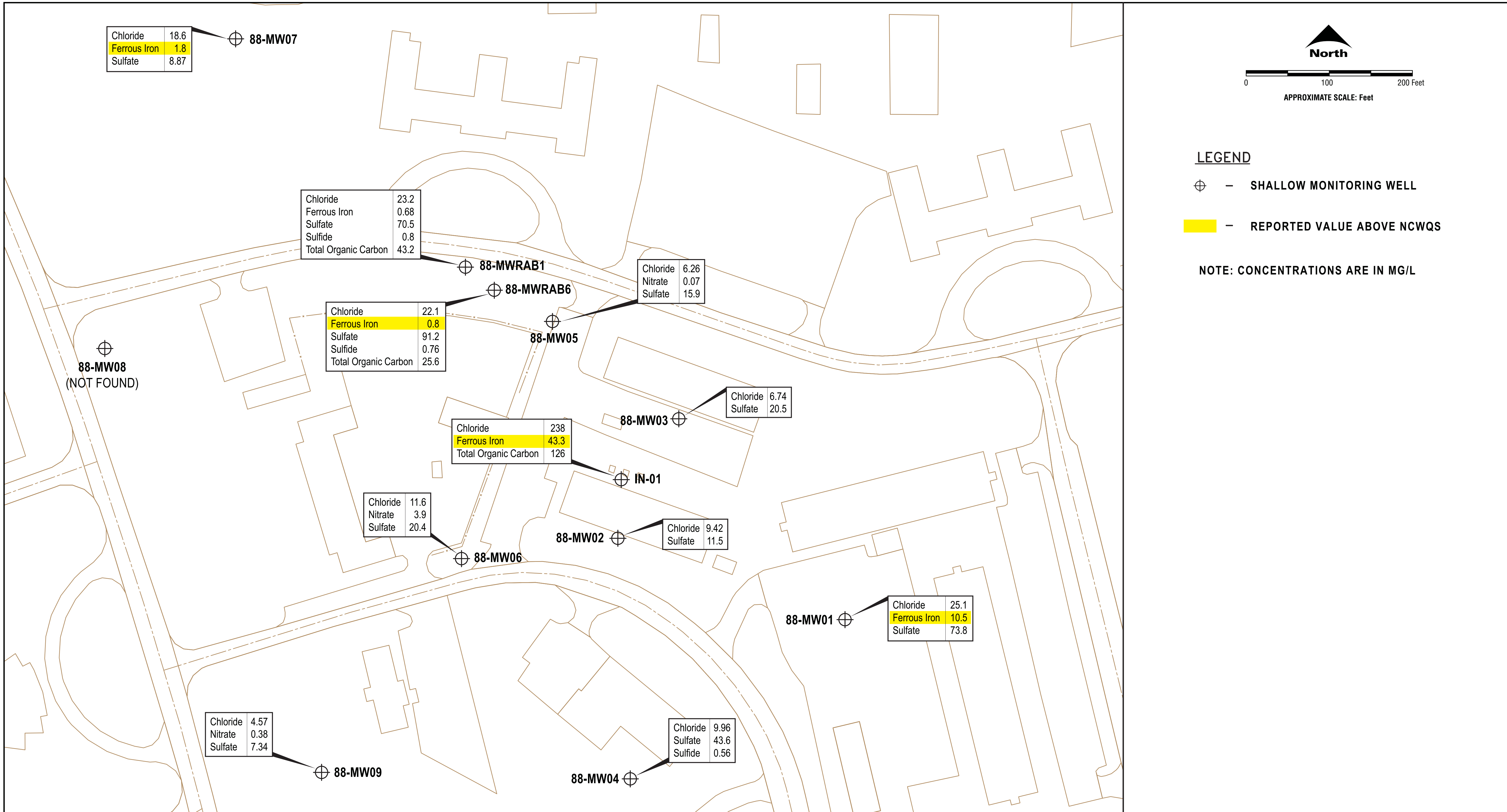
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-6
TOTAL METALS CONCENTRATION MAP
(DEEP WELLS) July, 2002
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-TMC-Deep.ai



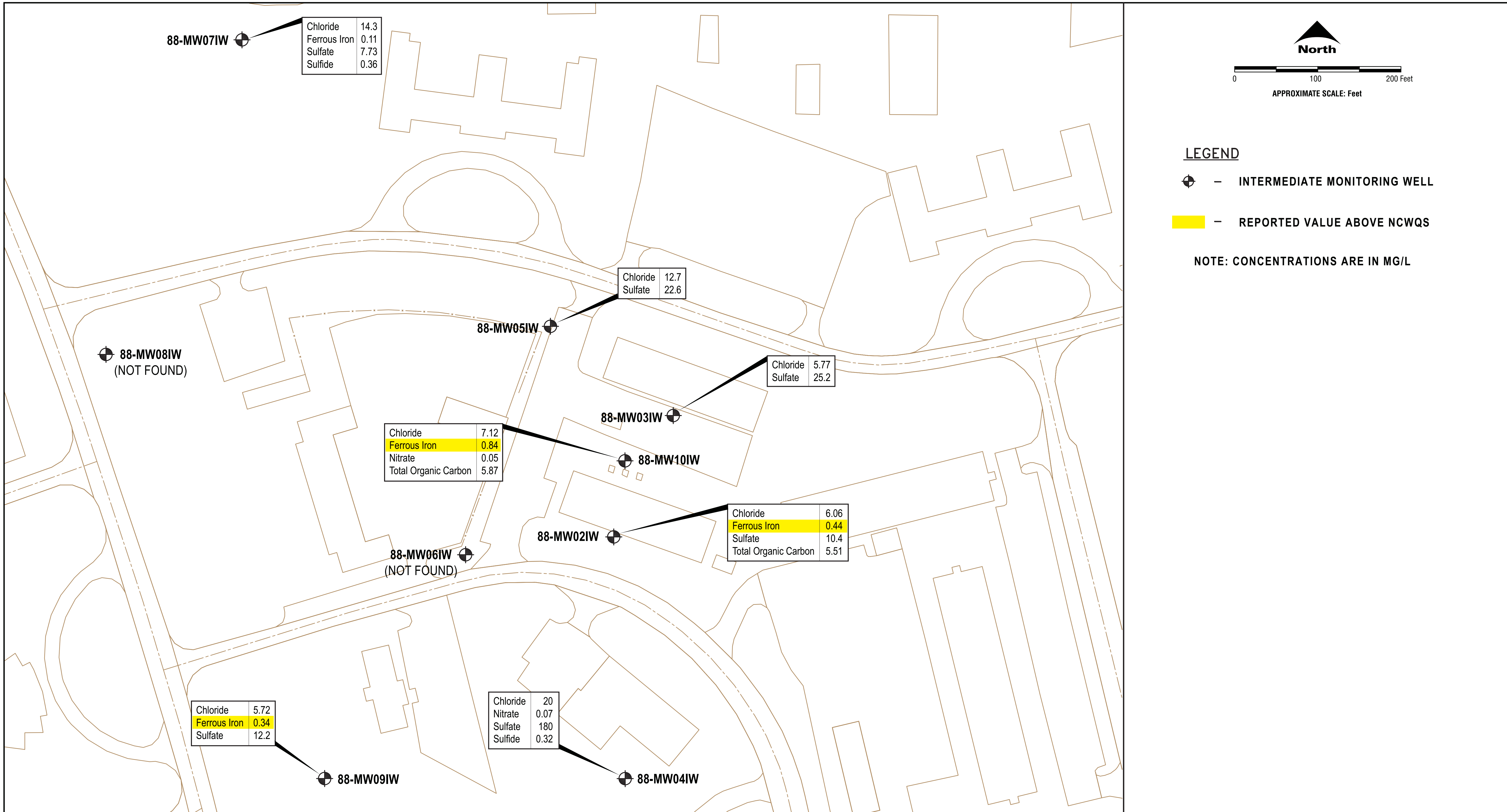
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-7
NATURAL ATTENUATION INDICATOR PARAMETERS MAP
(SHALLOW WELLS)
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-WCC-Shallow.ai



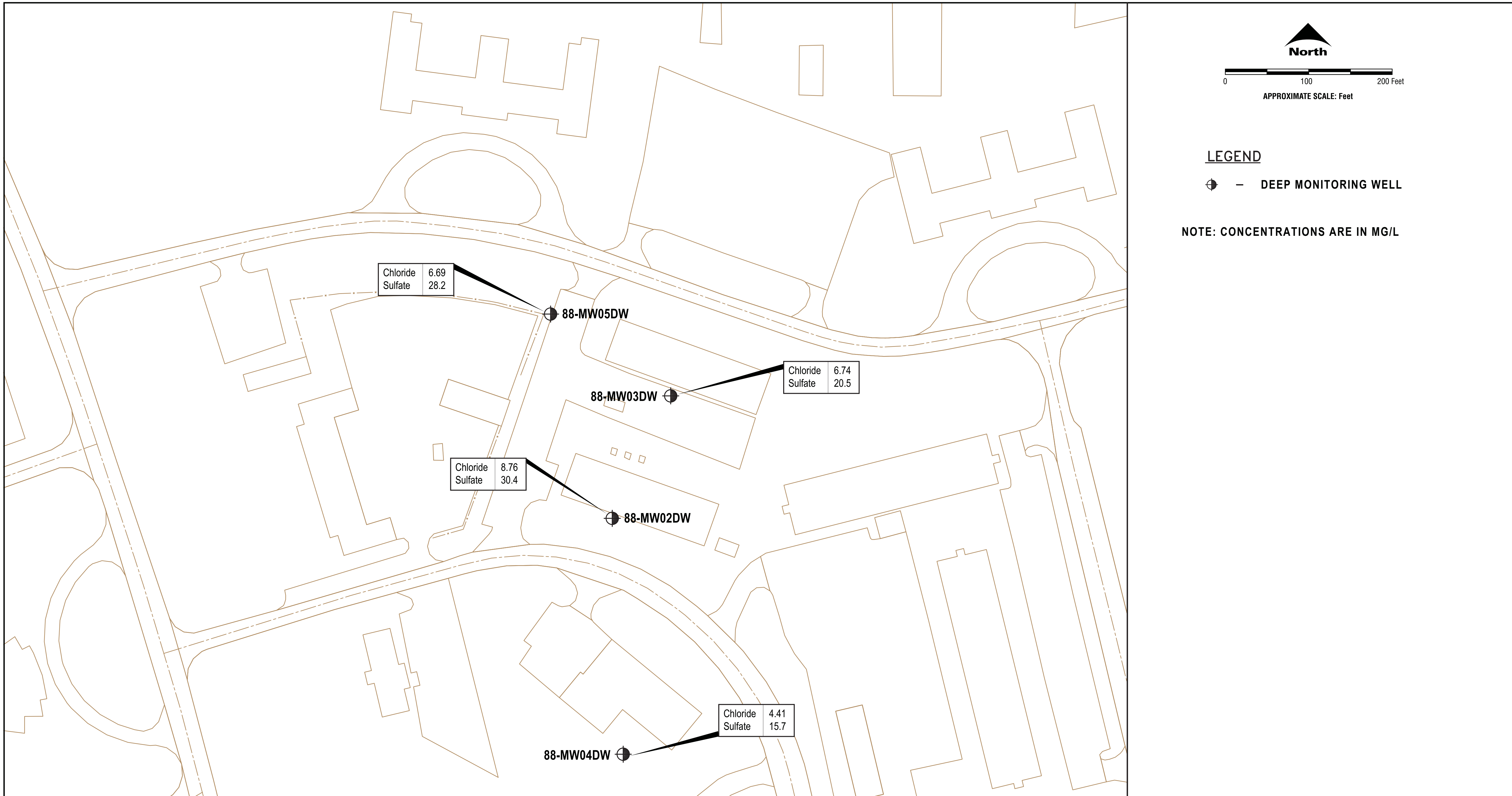
CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-8
NATURAL ATTENUATIONINDICATOR PARAMETERS MAP
(INTERMEDIATE WELLS) July 2002
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-WCC-Intermediate.ai



CH2MHILL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000

FIGURE 4-9
NATURAL ATTENUATION INDICATOR PARAMETERS MAP
(DEEP WELLS) July 2002
OPERABLE UNIT No. 15 - SITE 88

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

E082002007ATL/100-WCC-Deep.ai