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FINAL
REMEDIAL INVESTIGATION REPORT FOR HADNOT POINT INDUSTRIAL AREA OPERABLE UNIT SHALLOW SOILS AND CASTLE HAYNE AQUIFER CHARACTERIZATION STUDY TO DETERMINE EXISTENCE AND POSSIBLE MIGRATION OF SPECIFIC CHEMICALS IN SITU

VOLUME 1

MARINE CORPS BASE
Camp Lejeune, North Carolina

Contract No. N62470-83-C-6106

Prepared for:

NAVAL FACILITIES ENGINEERING COMMAND
Atlantic Division

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LIST OF ACRONYMS AND ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	centimeters per second
DPDO	Defense Property Disposal Office
DRMO	Defense Reutilization and Marketing Office
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
ft	feet
ft/day	feet per day
ft^2/day	square feet per day
ft BLS	feet below land surface
ft/ft	feet per foot
gal	gallons
GC	gas chromatograph
GC/MS	gas chromatography/mass spectrometry
gpd/ft	gallons per day per foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot
HPIA	Hadnot Point Industrial Area
IAS	Initial Assessment Study
ID	inside diameter
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCL	Maximum Contaminant Level

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued, 2 of 2)

MDL	method detection limit
MEK	methylethylketone
mmHg	millimeters of mercury
NACIP	Navy Assessment and Control of Installation Pollutants
NEESA	Naval Energy and Environmental Support Activity
O&G	oil and grease
OD	outside diameter
1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethene
PCB	polychlorinated biphenyl
POL	petroleum, oil, and lubricant
ppb	parts per billion
PVC	polyvinyl chloride
RI/FS	Remedial Investigation/Feasibility Study
SARA	Superfund Amendments and Reauthorization Act
TCE	trichloroethene
TCL	Target Contaminant List (volatile, semi-volatile, pesticides, metals)
TIC	tentatively identified compound
ug/L	microgram per liter
USGS	U.S. Geological Survey
VOC	volatile organic compound

EXECUTIVE SUMMARY

MCB Camp Lejeune is a training base for the Marine Corps, located in Onslow County, North Carolina. It covers approximately 170 square miles, and is bounded to the southeast by the Atlantic Ocean, to the west by U.S. 17, and to the northeast by State Road 24. The base is bisected by the New River estuary, which occupies approximately 30 square miles of the total area of the facility.

The Hadnot Point Industrial Area (HPIA) of MCB Camp Lejeune is located on the east side of the New River estuary. The HPIA is comprised of approximately 75 buildings and facilities. These include maintenance shops, gas stations, administrative offices, commissaries, snack bars, warehouses, storage yards and a dry cleaning facility. A steam plant and training facility occupy the southwest portion of HPIA. In addition, underground storage tanks, stormwater drains, and oil/water separators are present. As a result of Marine operations and activities, wastes that contain hazardous and toxic compounds are generated at the base. This has resulted in the storage, disposal, and/or spillage of these wastes. Several of the base's water supply wells at HPIA have been shut down as a result of the presence of contaminants.

Due to the potential of spillage of wastes in the HPIA, several investigations have been conducted to date on the Hadnot Point Operable Unit which is defined as that area bounded by Holcomb Boulevard to the west, Sneads Ferry Road to the north, Louis Street to the east, and the Main Service Road to the south. The Hadnot Point Operable Unit also includes the two primary hydrologic units; an unconfined surficial aquifer and a semi-confined potable aquifer (Castle Hayne). This report summarizes to date data which has been collected from the shallow and Castle Hayne aquifers and the unsaturated shallow soils.

A transformer storage yard (Site 21) and a fuel tank farm (Site 22) are located within the northern portion of HPIA. Two other study areas, the industrial area fly ash dump (Study Area 24) and the Hadnot Point burn dump (Study Area 28) lie to the south and southwest of the site. These areas of concern are not included in the operable unit and will be considered in separate studies at a later date.

The investigation of the HPIA has been completed as a phased approach, with the results of one investigation being the basis for the next phase. Three major investigations or Studies have been completed at the installation prior to the completion of this report. These investigations are described below.

An Initial Assessment Study (IAS) was conducted under the Navy Assessment and Control of Installation Pollutants (NACIP) program at MCB Camp Lejeune in 1983. The IAS report (Water and Air Research, 1983), which was a record search of the installation, identified a number of areas within MCB Camp Lejeune, including the HPIA, as potential sources of contamination. As a result of this study, Environmental Science and Engineering, Inc. (ESE) was contracted by the Navy to investigate the HPIA as well as other potential source areas.

The initial ESE investigation, referred to as the Confirmation Study is divided into two investigation steps: the Verification Step and the Characterization Step. The Verification Step at HPIA was conducted to determine if areas of suspected contamination, as documented in the IAS, were indeed contaminated. This investigation was conducted from April 1984 through January 1985, and involved the installation of three shallow groundwater monitor wells and the sampling of the potable water supply wells in the HPIA, as well as the investigation of other sites within Camp Lejeune. This step identified the presence of volatile organic compounds (VOCs) in the shallow aquifer in the vicinity of the Hadnot Point Industrial Area Tank Farm (Site 22) and in a single potable Supply Well (602).

Based on the results of the Verification Step, the Characterization Step was performed at HPIA during the period of 1986 through 1988. This phase was designed to evaluate the extent of the VOC contamination identified in the Verification Step within the HPIA. The Characterization Step consisted initially of a records search of available base records, a physical inspection of each building within HPIA, and a soil gas survey targeted to those areas identified by the records search as being potential contamination sources.

Each of the areas identified by the records search as potential sources of VOCs was investigated with the use of the soil gas technique which focused on TCE as the contaminant of concern. Areas which exhibited TCE or other VOC contamination in the soil included the areas around Bldgs. 901, 902, and 903, Bldg 1202, and Bldgs. 1502, 1601, and 1602.

Following analysis of the record search and soil gas data, locations were chosen for the installation of 27 shallow (25 feet), 3 intermediate (75 feet), and 3 deep (150 feet) monitoring wells to determine if contamination identified during the soil gas investigation had migrated to the shallow and deeper groundwater. All new and existing HPIA monitoring wells and nearby water supply wells were then sampled.

Aquifer testing of one deep potable supply well was conducted to evaluate the hydraulic parameters of the Castle Hayne aquifer and to determine the transport mechanisms between the shallow and Castle Hayne aquifers.

The Confirmation Study served to narrow the list of source areas to three primary areas, being the areas surrounding buildings 902, 1202, and 1601.

The Supplemental Characterization Step, performed at HPIA in 1990-1991, was designed to further evaluate the extent of contamination in the Castle Hayne aquifer and to characterize the contamination within the shallow soils at suspected source locations. The Supplemental Characterization Step consisted of 30 soil borings at the 3 suspected source locations (Bldgs. 902, 1202, and 1601) to characterize shallow soil contamination, installation of additional intermediate and deep monitoring wells into the Castle Hayne aquifer, and sampling of all new and existing HPIA monitoring wells and nearby water supply wells.

The groundwater sampling and analysis program continues to reflect two nodes of VOC and\or petroleum hydrocarbon contamination within the shallow aquifer. The northern node consists of two separate sources of contamination--one centered near the maintenance facility associated with Bldg. 901, and another centered at the Hadnot Point Fuel Tank Farm (Site 22). Contaminant isopleth modeling suggests that these two source areas may have effectively coalesced into one larger node of contamination. The southern node is centered near the maintenance facility associated with Bldg. 1601. The surficial aquifer will initially be remediated under an Interim Remedial Action which is the subject of reports prepared under separate cover.

A Risk Assessment (RA) has been completed for the shallow soils at the 3 remaining areas of concern. This assessment has shown that the low levels of contamination detected within the soils do not pose a human or ecological threat. This RA also addressed the groundwater within the Castle Hayne aquifer. While contaminants have been detected in one monitor well and in several potable wells, no current risk was identified. Additional studies addressing the extent of contamination within the Castle Hayne aquifer are being undertaken under separate cover.

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was listed on the National Priorities List (NPL) effective November 4, 1989. On February 13, 1991, the United States Department of the Navy (DON), the United States Environmental Protection Agency (EPA) Region IV, and the North Carolina Department of Environment, Health, and Natural Resources (DEHNR) entered into a Federal Facilities Agreement (FFA). In partial fulfillment of the FFA, the DON was required to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Hadnot Point Industrial Area (HPIA) at MCB Camp Lejeune.

The RI/FS at HPIA was performed by Environmental Science & Engineering, Inc. (ESE) in three phases under A&E Contract No. N62470-83-C-6106 with the Naval Facilities Engineering Command - Atlantic Division (LANTDIV).

A summary of the three RI phases and their findings are presented in this document. A FS report for the shallow groundwater at HPIA was submitted in May, 1988. The Risk Assessment and Feasibility Study for the deeper aquifer and the shallow soils will be presented under separate cover.

1.1 PURPOSE OF REPORT

The purpose of the RI Report is to present a description of the remedial investigation and the findings of that investigation. The Risk Assessment, an assessment of the RI findings in an evaluation of risks to public health and the environment, will be presented under separate cover.

1.2 SITE BACKGROUND, LOCATION, AND DESCRIPTION

1.2.1 MCB Camp Lejeune

MCB Camp Lejeune is a training base for the Marine Corps, located in Onslow County, North Carolina (**Figure 1-1**). It covers approximately 170 square miles, and is bounded to the southeast by the Atlantic Ocean, to the west by U.S. 17, and to the northeast by State Road 24. The base is bisected by the New River estuary, which occupies approximately 30 square miles of the total area of the facility.

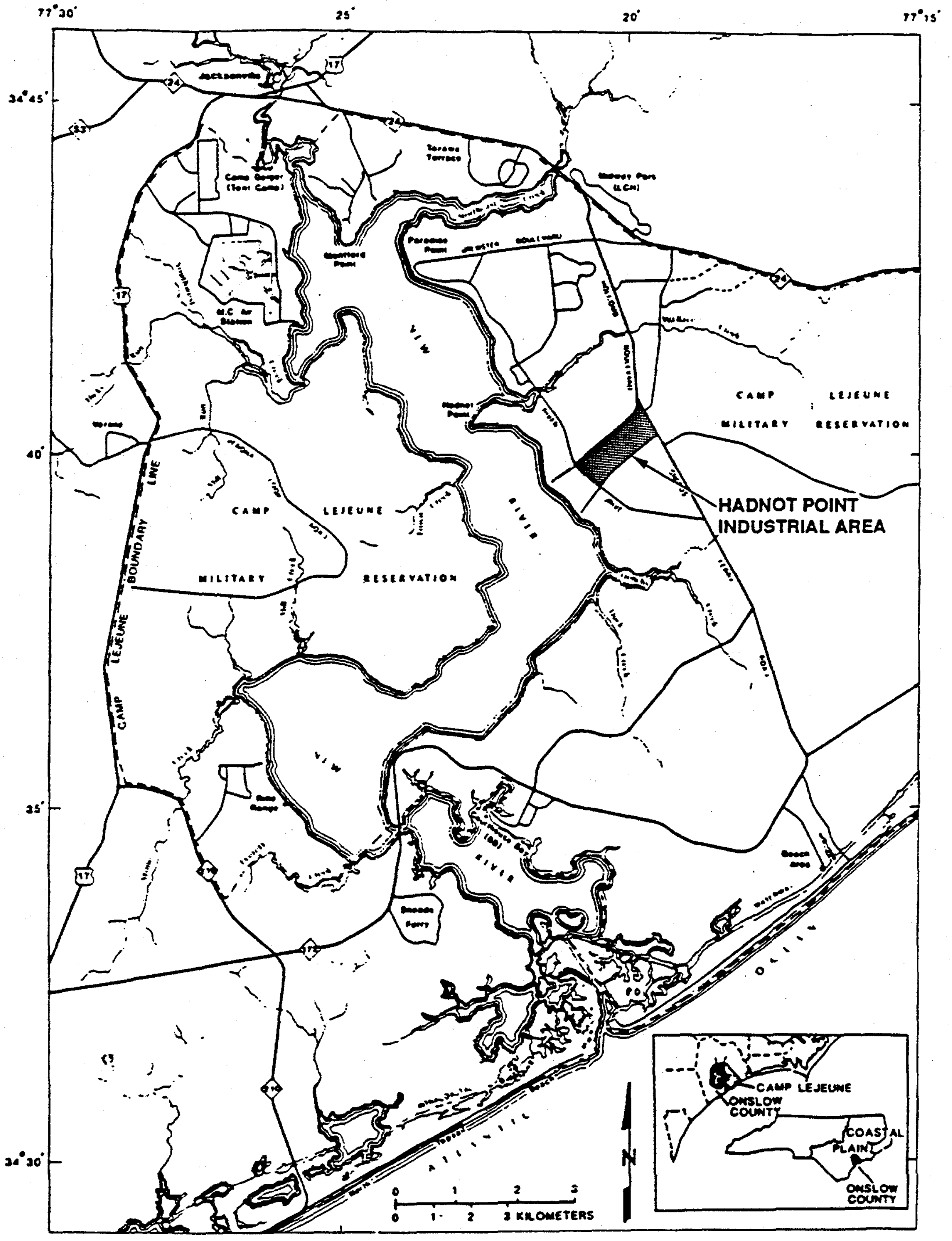
As a result of Marine operations and activities, wastes that contain hazardous and toxic organic compounds are generated at the base. This has resulted in the storage, disposal, and/or spillage of these wastes around the base. Several of the base's water supply wells have been shut down as a result of the presence of contaminants.

The Hadnot Point Industrial Area (HPIA) site is located within MCB Camp Lejeune and is described in the following section.

1.2.2 Hadnot Point Industrial Area

The HPIA of MCB Camp Lejeune is located on the east side of the New River estuary. For the purposes of this investigation, HPIA operable unit is defined as that area bounded by Holcomb Boulevard to the west, Sneads Ferry Road to the north, Louis Street to the east, and the Main Service Road to the south (**Figure 1-2**).

The HPIA is comprised of approximately 75 buildings and facilities. These include maintenance shops, gas stations, administrative offices, commissaries, snack bars, warehouses, storage yards and a dry cleaning facility. A steam plant and training facility occupy the southwest portion of HPIA. In addition, underground storage tanks, stormwater drains, and oil/water separators are present.



Base taken from Defense Mapping Agency Hydrographic Center
Camp Lejeune Special Map 1:50 000

Figure 1-1
CAMP LEJEUNE LOCATION

SOURCE: HARNED *et al.*, 1989.

MARINE CORPS BASE CAMP LEJEUNE

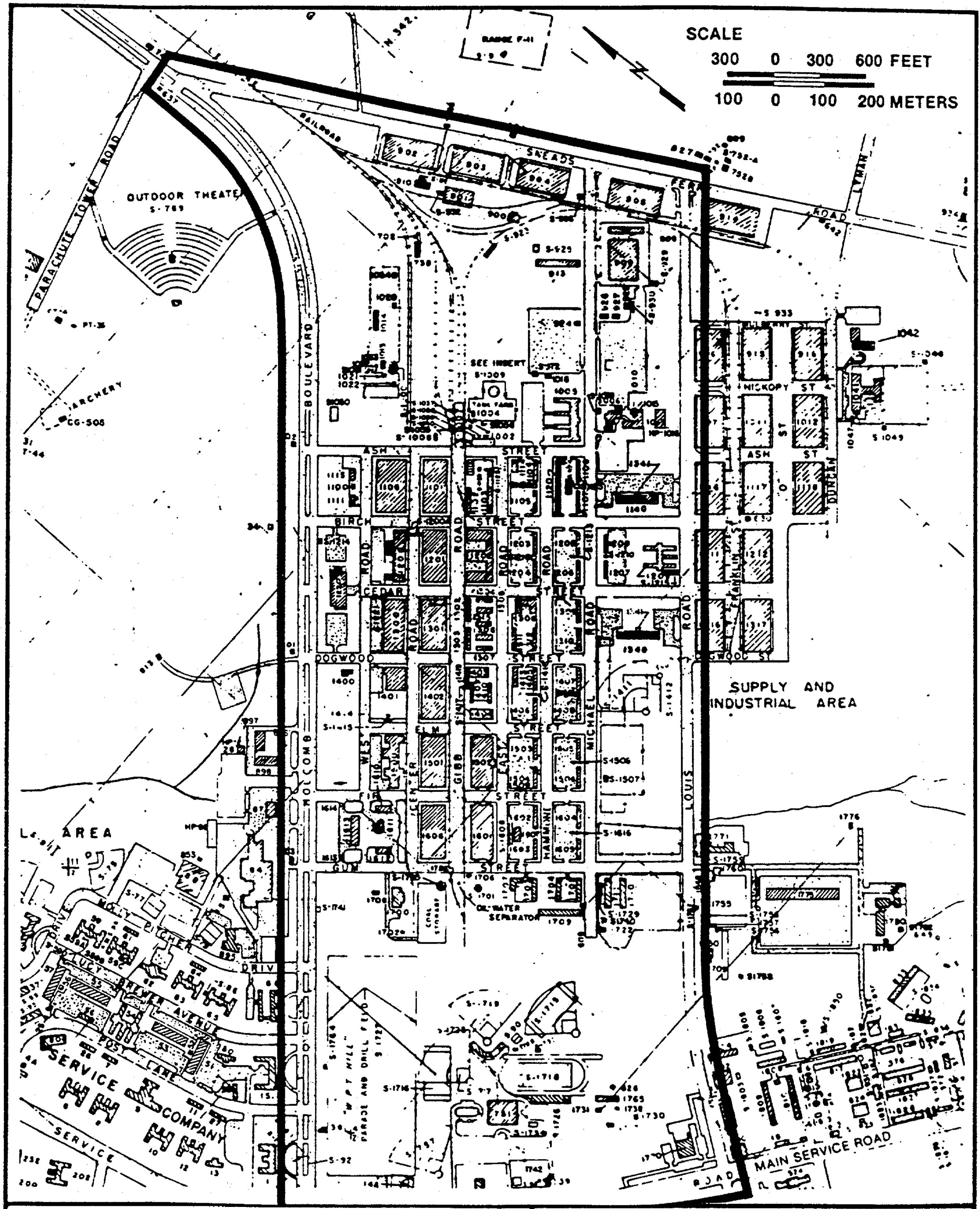


Figure 1-2
HADNOT POINT INDUSTRIAL AREA

SOURCE: CAMP LEJEUNE, 1987.

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A transformer storage yard (Site 21) and a fuel tank farm (Site 22) are located within the northern portion of HPIA. Two other study areas, the industrial area fly ash dump (Study Area 24) and the Hadnot Point burn dump (Study Area 28) lie to the south and southwest of the site **(Figure 1-3)**. These areas of concern are not included in this RI/FS, and are being considered in separate studies.

The establishment of MCB Camp Lejeune began in the late 1930s with the construction of the HPIA facility. Water supply for the base was furnished by wells which tapped a potable aquifer 50 to 300 feet below the base. In 1941, a water treatment system including 21 water supply wells was placed on-line at HPIA. This system serviced most of the base until the 1950s when additional wells and treatment facilities were installed because of the expanding needs of the base. Today, eight water treatment facilities and over 160 water supply wells serve the MCB at Camp Lejeune.

1.3 RI Approach and Scope

Investigations **(Section 2.0)** at the site have identified and/or documented the presence of contamination within the shallow and deeper groundwater, as well as in the soils above the water table. Physical and chemical data collected during previous investigations are summarized within this report.

The purpose of this investigation was to delineate the horizontal and vertical extent of contamination within the surficial and lower water bearing zones. Soil contamination within the shallow soils at suspected source locations was characterized as to its nature and extent.

Data collected during this investigation and previous investigations has been compiled within this Final Interim RI report. Specific investigative tasks and data collected during this investigation included:

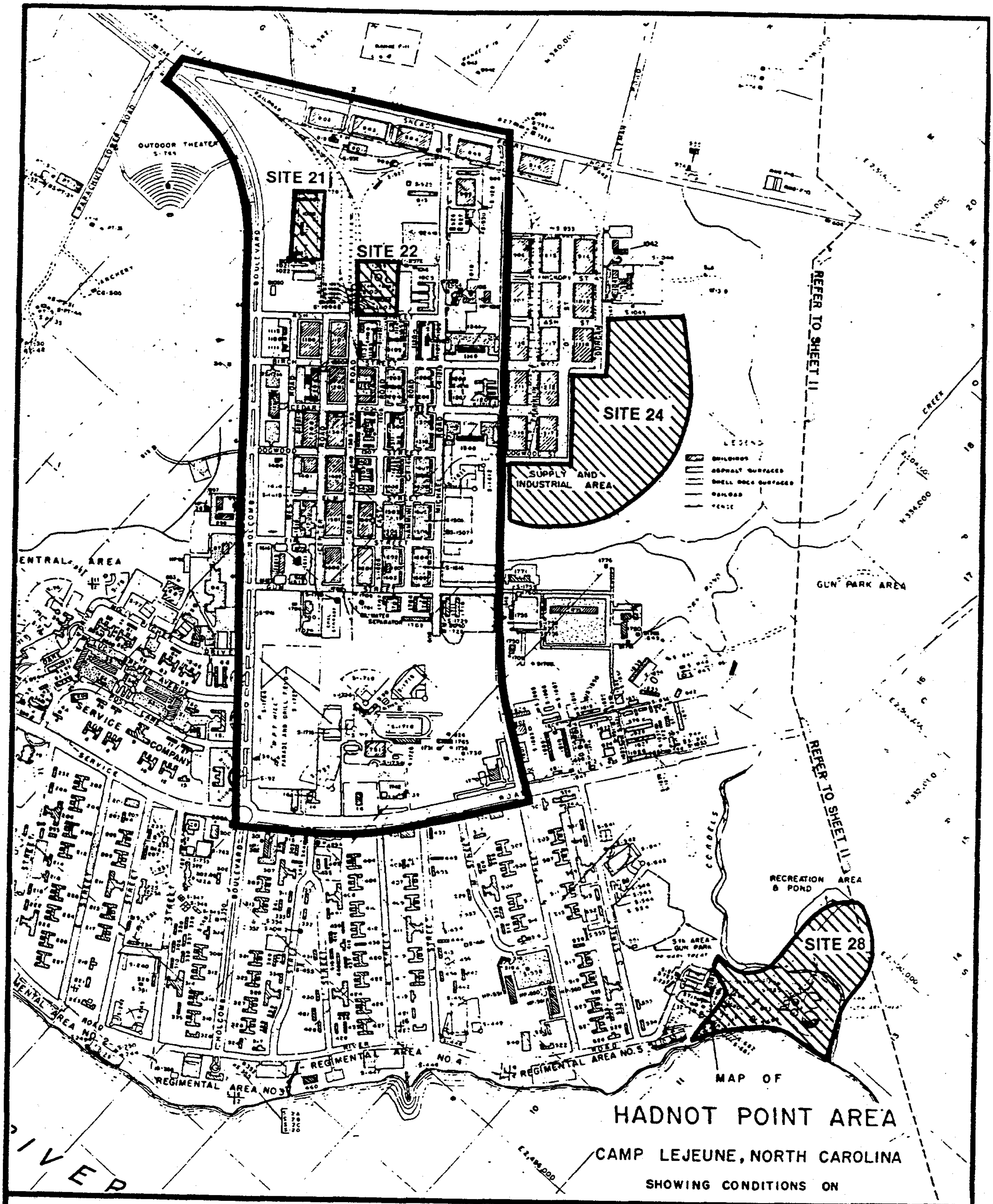

Figure 1-3
OTHER STUDY SITES ADJACENT TO HADNOT POINT INDUSTRIAL AREA

SOURCES: CAMP LEJEUNE, 1979; ESE.

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1. Installation of shallow, intermediate, and deep monitoring wells downgradient of potential source areas as identified during the investigations;

2. Collection of soil gas samples and analytical soil samples to the top of the water table at suspected source areas;

3. Determination of groundwater flow direction and groundwater gradients in the shallow and deeper water bearing zones; and

4. Collection of groundwater analytical data to characterize the nature, extent, and movement of the plumes.

All data collected and compiled within this RI report will be used to complete a Risk Assessment for the shallow soils and the lower water bearing zones and to conduct a FS to select remedial alternatives for the shallow soils and lower water bearing zones.

1.4 REPORT ORGANIZATION

This RI report is structured in general accordance with EPA format guidelines (EPA, 1988). This introduction (**Section 1.0**) presents a brief overview of the scope and structure of the RI Investigation. **Section 2.0** contain a summary of investigations. **Section 3.0** presents the methods and procedures used for conducting the field investigation. Hydrogeologic analysis and physical characteristics of the site are presented in **Section 4.0**. The nature and extent of contamination within the soils and groundwater at HPIA are summarized in **Section 5.0**. A summary of the site and the results of these investigations are summarized in **Section 6.0**.

The FS report for the shallow groundwater at HPIA was completed in May 1988. The RA and the FS for the shallow soils and the lower water bearing zones are to be prepared under separate covers.

2.0 SUMMARY OF INVESTIGATIONS

In response to the passage of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in 1980, the DON initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify, investigate, and clean up past hazardous waste disposal sites at Navy installations. The NACIP investigations were initiated by the Naval Energy and Environmental Support Activity (NEESA) and consisted of an Initial Assessment Study (IAS), similar to the U.S. EPA's Preliminary Assessment (PA). Subsequently, the DON conducted Confirmation Studies, similar to EPA's RI/FS. When the Superfund Amendment's and Reauthorization Act (SARA) was passed in 1986, the DON aborted the NACIP program in favor of the Installation Restoration Program (IRP), which adopted EPA Superfund terminology and procedures.

An IAS was conducted under the NACIP program at MCB Camp Lejeune in 1983. The IAS report (Water and Air Research, 1983) identified a number of areas within MCB Camp Lejeune as potential sources of contamination. As a result of this study, ESE was contracted by LANTDIV to investigate these potential source areas as per NACIP program protocol. A number of these potential source areas are located within HPIA.

The initial ESE investigation, referred to as a Confirmation Study, focused on those areas identified in the IAS. The Confirmation Study is divided into two investigation steps: the Verification Step and the Characterization Step. The final investigation completed was a Supplemental Characterization to collect additional data to complete the RI. These investigations are briefly described below.

2.1 VERIFICATION STEP

The Verification Step at HPIA was conducted from April 1984 through January 1985. This step identified the presence of volatile organic compounds (VOCs) in the shallow aquifer in the vicinity of the Hadnot Point Industrial Area Tank Farm (Site 22) and in a single Supply Well (602). Maximum contaminant levels detected in groundwater at Site 22 during this effort include 17,000 micrograms per liter (μg/l) of benzene and 27,000 μg/l of toluene. Benzene was detected in Supply Well 602 at a level of 38 μg/l.

As a result of the Verification step, Camp Lejeune closed Supply Well 602 and sampled other supply wells in the area. Four additional supply wells (601, 608, 634, and 637) were found to be contaminated with VOCs and were also shut down. Maximum levels of contaminants detected in these wells include 230 μg/l of trichloroethylene (TCE) in 601; 110 μg/l of TCE in 608; and 130 μg/l of methylene chloride in 634.

2.2 CHARACTERIZATION STEP

The Characterization Step, performed at HPIA in 1986-1988, was designed to evaluate the extent of the VOC contamination identified in the Verification Step. The Characterization Step consisted of the following five tasks:

1) Records search including detailed review of available base records and a physical inspection of each building within HPIA;

2) Soil gas survey targeted to those areas identified by the records search as being potential contamination sources;

3) Installation of 27 shallow (25 feet), three intermediate (75 feet), and three deep (150 feet) monitoring wells. Intermediate and deep wells were set into the Castle Hayne aquifer

4) Sampling of all HPIA monitoring wells (including those previously installed at Site 22) and nearby water supply wells (**Figure 2-1**); and,

5) Aquifer testing to evaluate the hydraulic parameters of the deep aquifer.

Significant results of the Characterization Step Investigation have been incorporated into **Section 5.0** of this report.

2.3 SUPPLEMENTAL CHARACTERIZATION

The Supplemental Characterization Step, performed at HPIA in 1990-1991, was designed to further evaluate the extent of contamination in the Castle Hayne aquifer and to characterize the contamination within the shallow unsaturated soils at suspected source locations. The Supplemental Characterization Step consisted of the following tasks:

1) Completion of 30 soil borings at three suspected source locations to characterize shallow unsaturated soil contamination;

2) Installation of four intermediate (75 feet), and four deep (150 feet) monitoring wells into the Castle Hayne aquifer, and

3) Sampling of all new and existing HPIA monitoring wells (including those previously installed at Sites 21 and 22) and nearby water supply wells (**Figure 2-1**).

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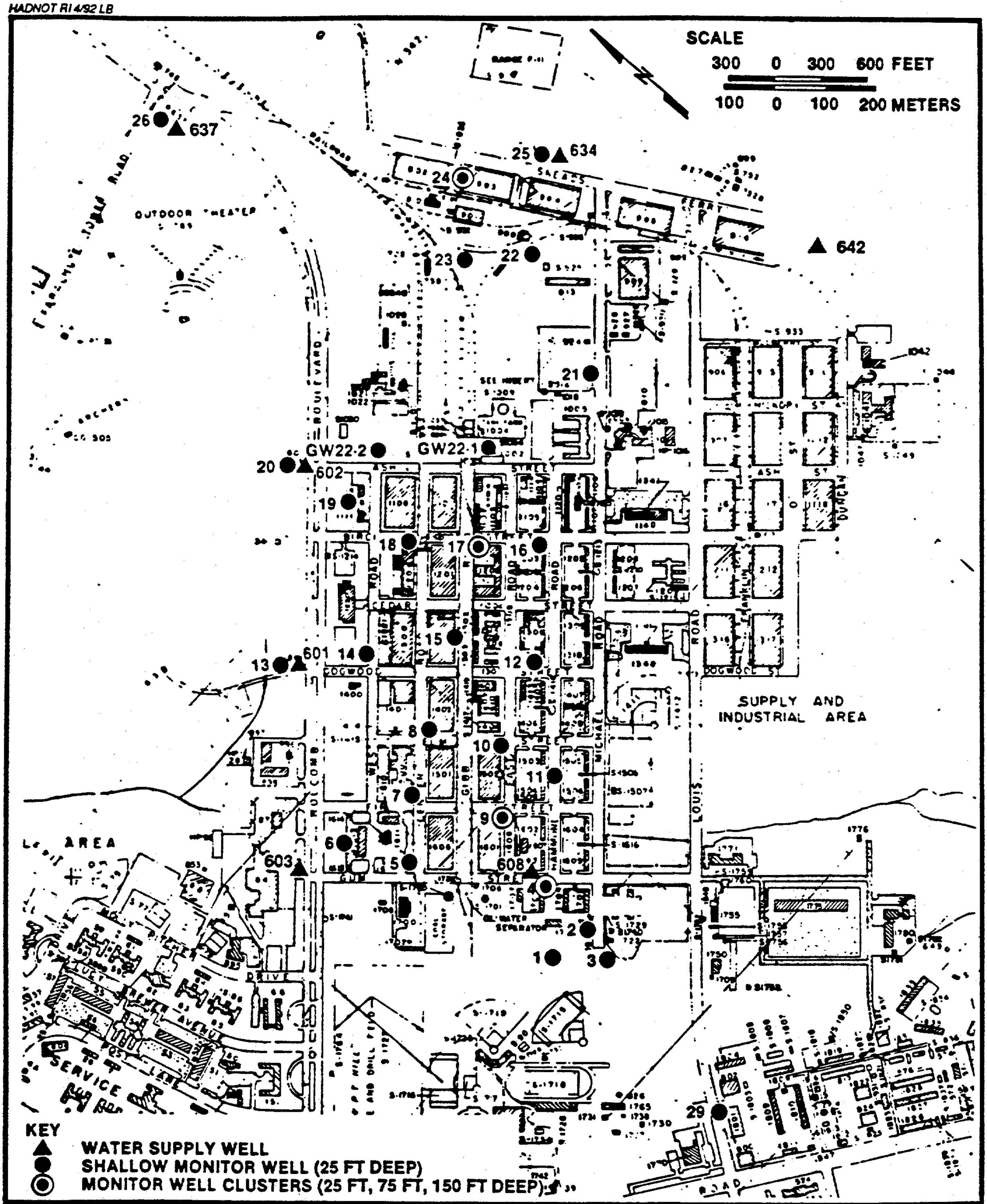

Figure 2-1
MONITOR WELLS AND WATER SUPPLY WELLS AT HADNOT POINT INDUSTRIAL AREA – CONFIRMATORY STUDY

SOURCE: ESE.

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2.4 OTHER INVESTIGATIONS

O'Brien and Gere Engineers, Inc. conducted a field investigation at Site 22 in 1988. Site 22 is situated in the northern portion of HPIA. Their investigation noted that floating petroleum product exists in six monitoring wells located on the western edge of the tank farm. These wells were installed by OB&G as part of the assessment of Site 22. The investigation also indicated the presence of a benzene contaminant plume in the vicinity of the tank farm (O'Brien & Gere, 1988). Well locations and additional information on this area is presented in the Site 22 assessment report (O'Brien & Gere, 1988).

In 1988, ESE conducted a focused FS for interim remediation within the surficial aquifer at HPIA. The database developed during the Characterization Step effort was utilized to select a cost-effective interim remedial alternative. A pump and treat alternative was determined to be the most feasible remedial alternative (ESE, 1988). It was anticipated that the groundwater pumped from the shallow aquifer would be treated at the Hadnot Point Sewage Treatment Plant.

3.0 SITE INVESTIGATION

Two field investigations in conjunction with this RI were conducted at HPIA from September 1986 through August 1987 and from December 1990 through February 1991. This investigation consisted of the following tasks:

- a record search of all buildings within HPIA;
- soil investigation which included a soil gas survey and soil borings to collect analytical samples;
- monitoring well installation and development;
- groundwater sampling;
- an aquifer pump test;
- water level measurements, and;
- surveying.

A description of each of these tasks is presented below.

3.1 RECORD SEARCH

The existing IAS report (NEESA, 1983) was reviewed, and potential sources of the contamination identified by the Verification Step efforts were noted. With the assistance of Camp Lejeune staff, a 2-person team from ESE conducted a building-by-building evaluation of all past and/or current activities that may have utilized any solvent compounds. As noted previously, buildings and other facilities identified in the IAS report were evaluated with extra caution. In many cases, the physical facilities of the buildings (i.e, floor drains, sumps, and unmarked pipe lines) were inspected to identify the general purpose and any interconnections. Any pits, tanks, or other drainage structures outside of the buildings were also closely investigated. No samples were collected from the pits or tanks as a part of this investigation.

3.2 SOIL INVESTIGATION

3.2.1 Soil Gas Survey

To optimally pick locations for monitor wells, soil gas sampling and analysis was conducted during October, 1986 in the vicinity of all buildings that could potentially act as VOC source areas, as indicated by the records search effort.

VOCs, if present in groundwater or in the soil matrix, occupy the interstices or voids in the soil. Vapors from the interstitial space were sampled and characterized using a portable gas chromatograph (GC). Soil gas analysis provided a rapid method for tracing potential plumes resulting from leaks and/or spills of many VOCs. The method is particularly useful for compounds [such as trichloroethene (TCE)] that are more volatile than xylene [vapor pressure greater than five millimeters of mercury (mmHg)]. TCE was used as the indicator compound at HPIA to trace volatile plumes, as it was detected in the deep potable aquifer in the vicinity of HPIA. TCE has a high vapor pressure (57.9 mmHg), which made it ideal to track with the portable GC unit. In addition to providing rapid results, substantially more samples were analyzed at a much lower cost per sample compared to well drilling and gas chromatography/mass spectrometry (GC/MS) analysis of water samples.

Soil Gas Sampling Grids

The soil gas sampling locations were selected using various grids and spaced intervals along selected transects. The locations of these grids and transects were determined by the physical location of suspected disposal features (i.e., tank or wash area) and as buildings, underground utilities, and pavement allowed. The specific sampling procedure was to obtain the initial samples from the central areas of the disposal features as determined by the records search. When the presence of VOCs was confirmed for a given feature/structure, the pattern of soil gas sampling was focused on delineating the extent of the soil gas plume. A total of 143 soil gas samples were obtained from HPIA and analyzed.

Soil Gas Sampling Procedure

Soil gas samples were collected in a grid pattern as described in the previous section. The grid in a specific sampling area was established manually using a surveyor's tape and was referenced to building corners and other permanent markers. To more easily correlate the results of the analyses, all soil gas samples were drawn from a depth of approximately four feet.

Once a sampling location was chosen, a pneumometer (soil gas sampling tube) was driven to its sampling depth by means of a pneumatic hammer. When the desired depth was reached, the deformed end of the pneumometer tube was cut off using a pipe cutter and a Teflon tube was attached using a silicone stopper. The other end of the tube was connected to a desiccator, and the system was evacuated to purge the existing air column and to draw in gases from the soil. A Tedlarsample bag was then connected inside the desiccator, and the system was pumped again to fill the sample bag. The bag was removed and transported to the ESE field laboratory at HPIA for analysis. Once all of the samples were collected, the pneumometers were either removed or driven below ground level.

3.2.2 Data Analysis

Sample locations during the soil gas sampling program were hand plotted in the ESE field office as they were available. When all data for a specific structure/feature were collected, those data were tabulated, and any data gaps or anomalies were noted. Additional samples were collected, or previously sampled sites were resampled at this time if required. Analytical results for each completed disposal structure/feature were then analyzed, and soil boring and monitor well locations were selected. Soil gas sample locations and tabulated data are presented in **Appendix P**.

3.2.3 Soil Borings

A total of thirty shallow soil borings were performed at HPIA at Camp Lejeune in January, 1991. The objective of the soil sampling program was to evaluate the extent of shallow (above the water table) soil contamination in three areas of concern at HPIA as determined by the Record Search and Soil Gas Investigation. These areas are located in the vicinity of Buildings 1601, 902, and 1202. **Figures 3-1**, **3-2**, and **3-3** show the approximate locations of the soil borings.

Before any soil sampling was conducted, all carbon steel split spoons as well as the stainless steel bowls and implements used to homogenize and handle the soil were decontaminated in accordance with the procedure set forth in the Work Plan (ESE, 1990a). The decontamination procedure is described in **Appendix A**.

Soil borings were drilled with 6.25-inch inner diameter hollow-stem augers. Two-inch and three-inch split spoons were utilized to obtain the soil samples ahead of the augers advance. In accordance with ASTM D1586-74, 2-inch split spoons were driven with a 140-pound hammer. Three-inch split spoons were driven with a 300-pound hammer.

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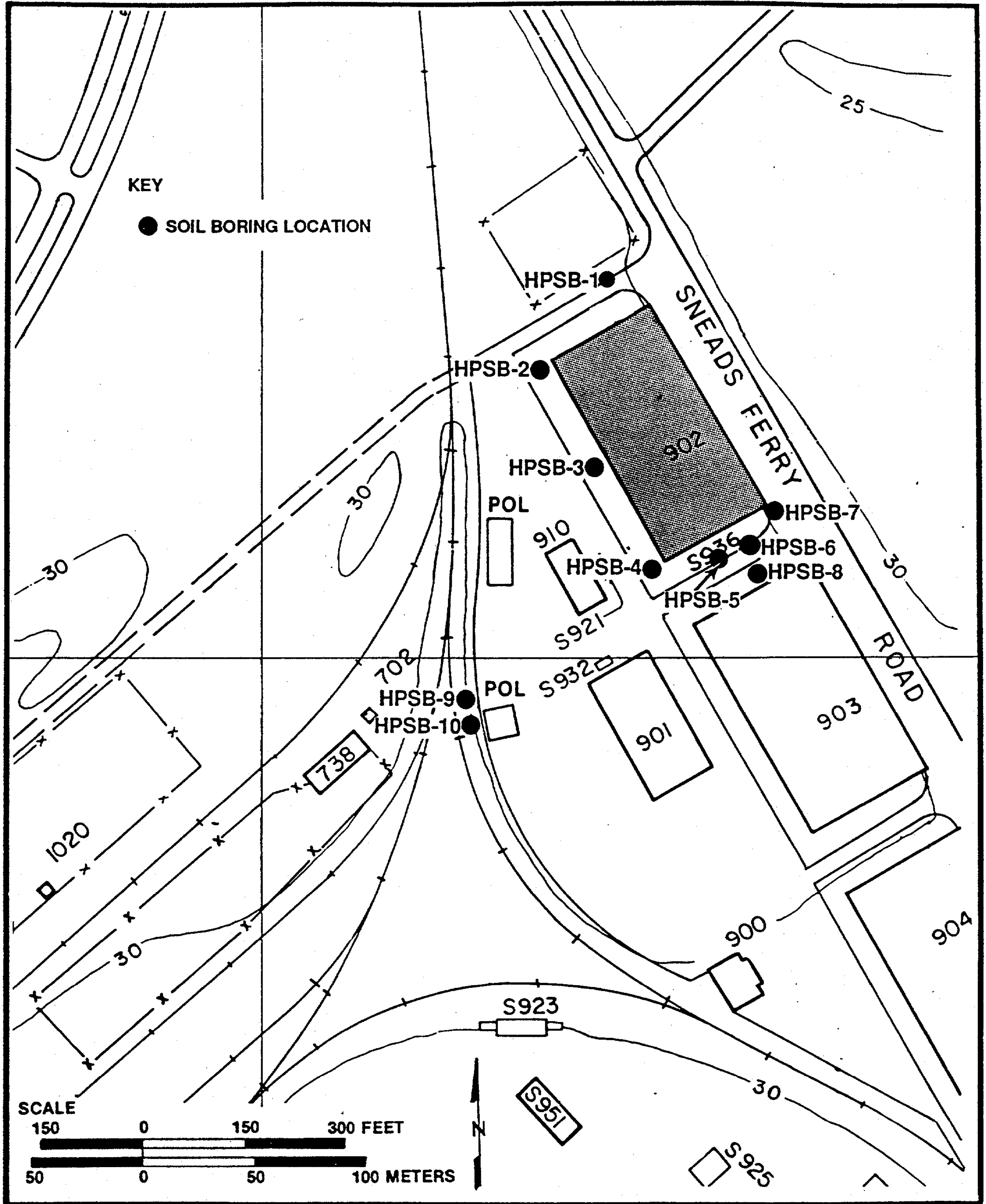

Figure 3-1
APPROXIMATE SOIL BORING LOCATIONS – BLDG. 902

SOURCE: ESE.

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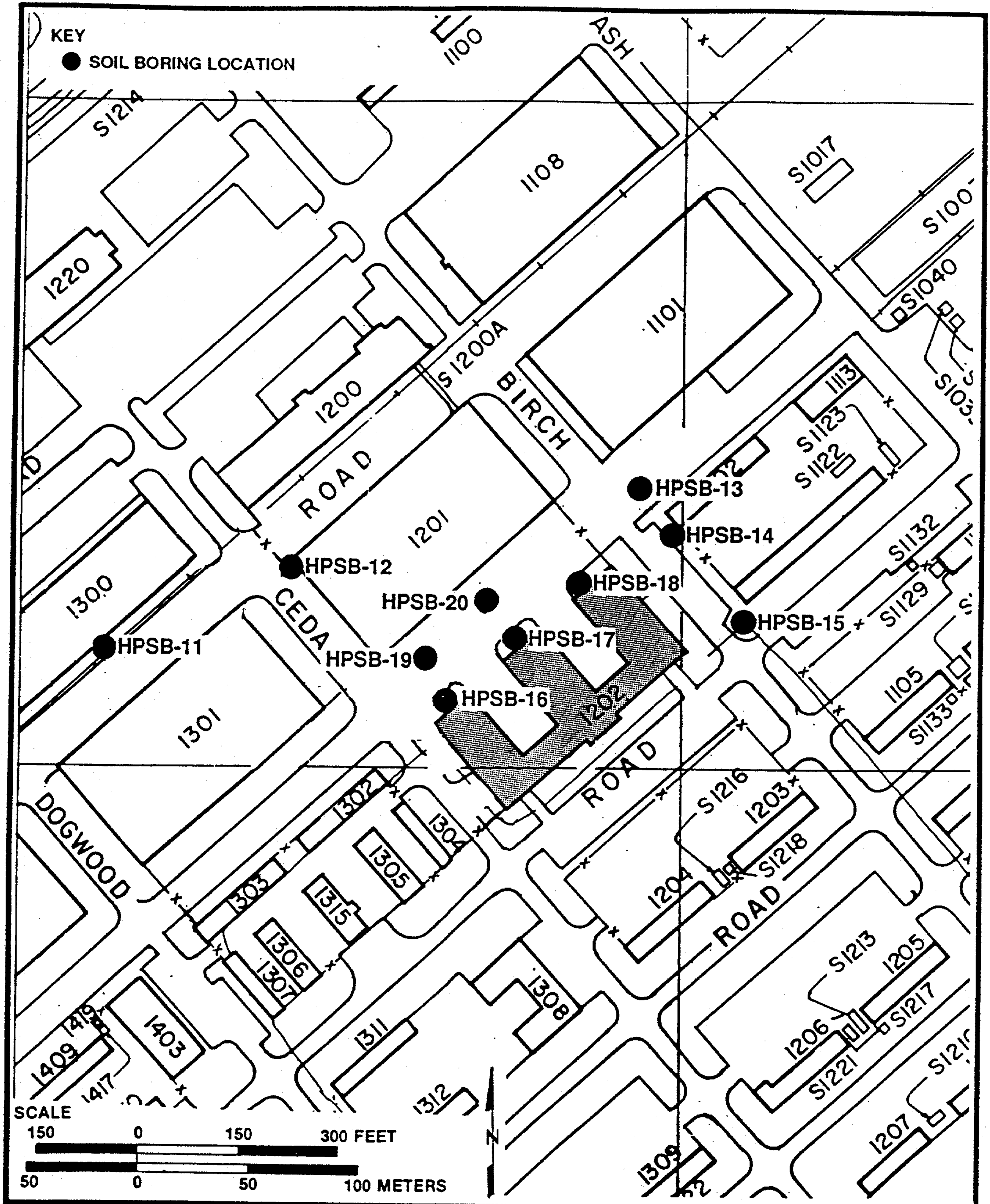

Figure 3-2
APPROXIMATE SOIL BORING LOCATIONS – BLDG. 1202

SOURCE: ESE.

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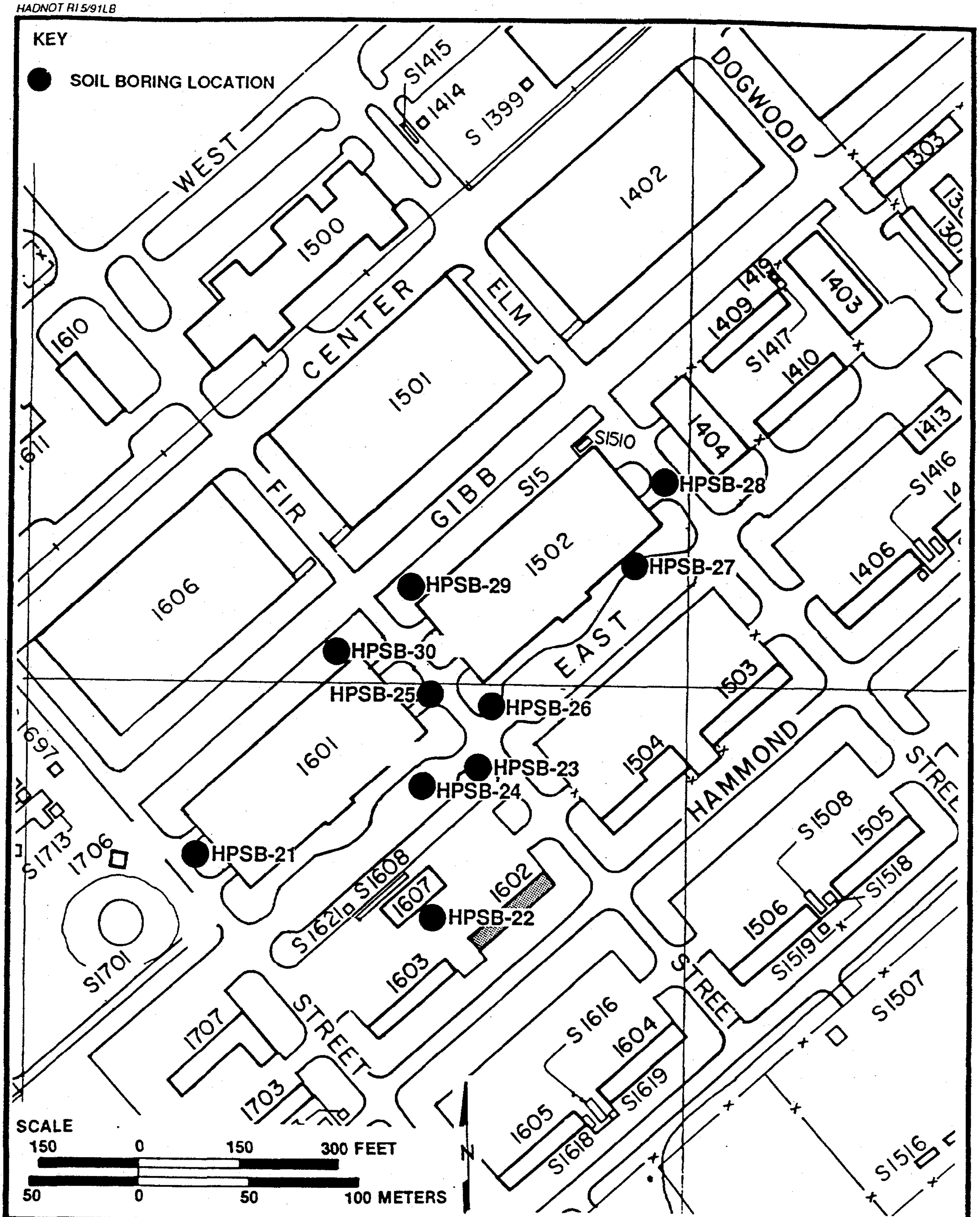

Figure 3-3
APPROXIMATE SOIL BORING LOCATIONS – BLDG. 1602

SOURCE: ESE.

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Borings were monitored by a project geologist who noted blow counts, organic vapor readings, percent recovery of sample, and sample description. Samples were classified based on visual observance using the Unified Soil Classification System (USCS). Boring logs for each boring are presented in **Appendix B**.

Continuous split spoon sampling was conducted to the top of the water table, and samples were screened for organic vapors with an photoionization detector (PID). Three samples were selected from each boring for chemical analysis, based upon the three highest readings of organic vapor levels recorded. In cases where the PID recorded levels of organic vapors equivalent to background atmospheric concentrations, samples were selected according to visual inspection for possible contamination. In the absence of any visible "contamination", the three samples were selected randomly. Where the water table proved to be too shallow to permit three different sampling intervals, samples were decreased in number accordingly.

A total of 96 soil samples were collected including nine duplicate samples. Nine of the analytical samples collected (including one duplicate sample) were analyzed for full Target Compound List (TCL) parameters. The remaining samples were analyzed for volatile organic compounds (TCL VOAs), pesticides and PCBs, and Toxicity Characteristic Leaching Procedure (TCLP) metals. VOA samples were collected immediately upon opening the split spoon, while all other fractions were homogenized in a decontaminated stainless steel bowl, prior to filling the sample containers.

Chain of custody documentation was prepared at the time the soil samples were collected and accompanied the samples until they reached the laboratory. Copies of this documentation is provided in **Appendix Q**.

3.3 GROUNDWATER INVESTIGATION

3.3.1 Monitor Wells

Groundwater monitor wells were installed during the Verification Step, the Characterization Step and the Supplemental Characterization Step. The locations, depths, and screened intervals of monitor wells were selected to delineate contaminant distribution and the geohydrological environment. The selection was based on information gathered during previous studies and subsurface conditions observed during drilling.

The hydrologic system at Camp Lejeune consists of an unconfined (surficial) aquifer and underlying semi-confined (Castle Hayne) aquifers. The surficial aquifer consists of approximately 30 feet of sands which overlie a discontinuous clay and sandy clay layer. All shallow groundwater monitor wells are set into this surficial aquifer. Below the clayey interval, the Castle Hayne aquifer consists of sand and limestone with varying amounts of silt, silty sand and rock. The intermediate and deep wells at the site have been set into these units.

A total of 33 wells were installed during the Characterization phase (September 1986 through August 1987); 27 shallow wells, three intermediate wells, and three deep wells. Additionally, two shallow wells were installed at the Hadnot Point Fuel Farm (Study Area 22) and one at the transformer storage yard (Study Area 21) during the verification investigation. These areas lie within HPIA but are being investigated under separate contract. Data from these wells has been incorporated into this investigation as appropriate.

In December 1990, four groundwater monitoring well clusters were installed down-gradient of the areas of concern as identified during earlier investigations in the Hadnot Point area at Camp Lejeune. Both an intermediate and deep well were installed into the Castle Hayne aquifer at each location in order to evaluate the vertical distribution of contaminants in the groundwater downgradient of specific areas of concern. The areas of concern are Building 1602, Building 902, Building 1202, and the Industrial Area Tank Farm (Site 22). The locations of the ground water monitoring wells within the HPIA are shown in **Figure 3-4**.

Monitoring wells were numbered sequentially within HPIA. All intermediate wells in the study area were denoted with an end designator number of "2", appearing after the main sequence number (i.e. HPGW1-2). Similarly, deep wells were assigned a designator number of "3" after the main sequence number (HPGW1-3). Main sequence numbers for shallow wells run from HPGW1 to HPGW29. Intermediate and deep wells which were not clustered to a shallow well are assigned the numbers HPGW30-2, HPGW30-3, HPGW31-2, HPGW31-3, HPGW32-2, and HPGW32-3. Wells within the other study areas inside of the HPIA were assigned numbers to correspond to those study areas (21GW-1, 22GW-1, and 22GW-2)

During all drilling activities at HPIA, an ESE site geologist was present at each active drill rig. The geologist was responsible for supervision of borehole drilling, well installation, and supervision of subcontractor personnel. The geologist was familiar with the specific objectives of the investigation as outlined in the Work Plan, and was furnished with a copy of the approved Safety Plan for the investigation, a 10x hand lens, and a weighted tape.

Prior to the commencement of drilling at HPIA, the following requirements were completed:

1. Personnel scheduled to be involved with the drilling program, including ESE personnel and subcontractors, were safety trained in accordance with OSHA regulations and informed about onsite safety protocols by the ESE Safety Officer.

HADNOT RI 8/91 LB

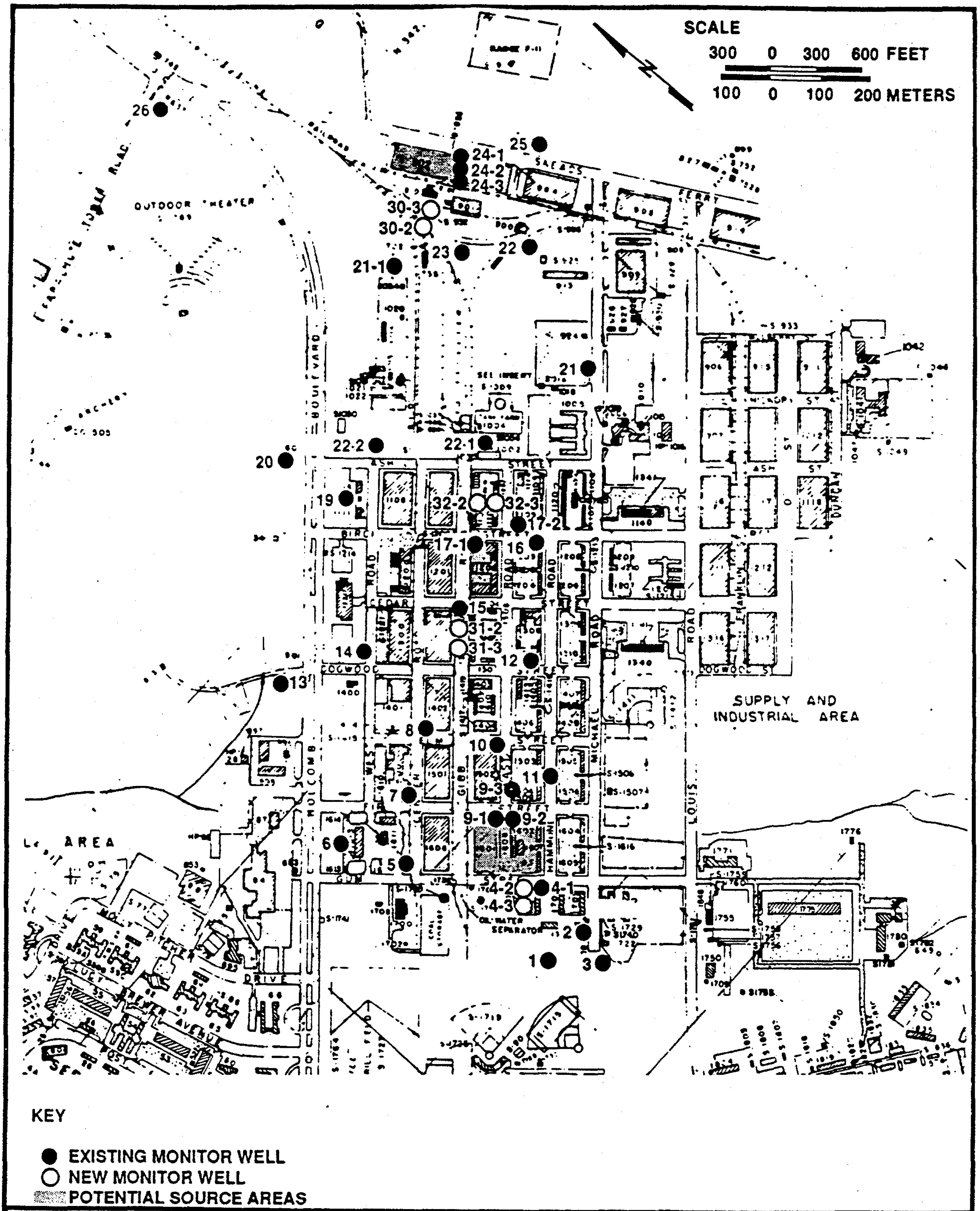


Figure 3-4
NEW AND EXISTING MONITOR WELLS
AT HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE

2. Permits were obtained for the installation of the wells from the State of North Carolina Department of Natural Resources and Community Development.

3. All drilling equipment, including water tanks, were steam cleaned prior to arrival at HPIA.

4. All drilling equipment and supplies were stored in a secure area onsite.

Drilling was performed under contract by Davis Drilling, Inc., ATEC and Associates, Inc., and Environmental Monitoring and Testing, and proceeded under the following guidelines:

1. Unchlorinated water for drilling and well installation was obtained from the installation's fire supply lines. A sample of the drilling mud was obtained and analyzed as part of the QA/QC program.

2. Drilling was conducted under the direct supervision of the ESE geologist.

3. Between borings, all downhole drilling equipment, including the weighted steel tape used by the geologist, was cleaned using unchlorinated water from the approved source using a high pressure spray.

4. All safety matters were the responsibility of the site geologist who acted as the on-site safety officer.

5. During drilling of monitor wells, continuous soil samples were collected using split spoon sampler or a 5-feet soil core barrel. Soil

samples were collected from the deep boring of each well pair only when drilling the well clusters.

6. All drilling sites were arranged to minimize the possibility of material, sediment, or fluids produced during drilling entering the borehole.

7. Drill rigs were carefully leveled at each site prior to drilling and were inspected by the site geologist.

All wells were drilled, logged, and constructed as described in the following sections. Boring logs are presented in **Appendices C** and **D**.

Drilling Techniques

The shallow monitor wells were installed using hollow stem augers. Intermediate and deep monitor wells were installed using a water rotary drill rig. Boreholes for the intermediate and deep wells were initially drilled with a 4-3/4-inch O.D. roller bit, and subsequently reamed with a 9-7/8-inch O.D. roller bit. Continuous samples were taken in the deep well borehole for geological characterization using a split spoon or a soil core barrel (which allowed a maximum recovery of 5-feet with each penetration).

The monitoring wells within a cluster were positioned a minimum of eight feet from each other and any previously existing well. Shallow wells were completed to a depth of 25 feet. Each of the intermediate wells were screened from approximately 65 to 75 feet below grade. The deep wells were screened from approximately 140 to 150 feet below grade. The intermediate and deep wells are completed into the Castle Hayne aquifer.

Borehole Logs and Documentation

Each well was fully described on a boring log as it was being drilled by the site geologist. Data collected in the borehole logs are identified in this section of the report. The following procedures were followed during borehole logging:

1. Depths were recorded in feet and tenths of feet.

2. Soil descriptions were prepared in the field by the ESE geologist following the USCS.

3. Individual soil samples were fully described on the log. The descriptions included:
    a. Classification,
    b. USCS symbol,
    c. Secondary components and estimated percentages of each,
    d. Color,
    e. Plasticity,
    f. Consistency (for cohesive soils) or density (for noncohesive soils),
    g. Moisture content,

4. Numerical, visual estimates were made of secondary soil constituents. Estimates only were used during borehole logging; qualitative terms were not used.

5. The length of sample recovered or the percentage of sample recovered for each core sample was recorded.

6. The interval for each sample was specified and noted on the borehole log.

7. Depth to first water was indicated along with the method of determination. Any distinct increases or decreases of water occurrence below the first zone were also recorded.

8. The dates for start and completion of all borings were recorded.

9. Lithologic boundaries were noted on the boring log.

Well Construction

Plumbness of the completed boring was ensured by the careful leveling of the drill rig prior to initiation of the drilling process. Additionally, a drilling rate compatible with both the drilling equipment and the downhole materials was maintained so as not to force the drilling tools to diverge from a vertical direction. Well construction began immediately after completion of the boring, if possible.

The following materials were used in monitor well construction:

1. Casing used in the well was 4-inch-diameter polyvinyl chloride (PVC) Schedule 40 with flush-threaded joints. The well screen was factory slotted with a slot width of 0.010 inch.

2. A 20- to 30- mesh silica sand was used in the filter envelope around the well screen to ensure compatibility with the screen slot size and natural subsurface materials. The sand extended approximately two feet above the screen.

3. Bentonite pellets used in the seal were a commercially available product designed for well-sealing purposes. A minimum one foot seal was installed over the sand.

4. Grout was composed of a mixture of Portland Type I/II cement and approximately 5-10 percent powdered bentonite to prevent shrinkage. The bentonite-cement grout seal extended from the top of the bentonite seal to the land surface. Grouting was completed in two stages on the deeper wells in order to allow the grout to cure and prevent damage to the PVC riser pipe due to the heat of hydration. The grout was pumped into the annular space under low pressure using a PVC tremie pipe placed at the top of the bentonite seal to ensure that a continuous grout seal was emplaced.

5. After grouting, flush mount well covers were installed above the PVC riser pipes for all the wells, with the exception of intermediate well HPGW4-2, which was completed with an above-ground steel casing. A concrete pad was constructed around the flush mount well covers and the above-ground steel casing. In each case, the concrete was contoured to slope away from the flush-mount cover/steel casing.

6. A sketch of the well installation was included on the boring log and showed, by depth, the bottom of the boring, screen location, granular backfill, seals, grout, and height of riser above ground surface.

7. The grout seal was checked after approximately 24 hour (hr) for settlement, and additional grout (of approved composition) was added to fill any depressions.

Monitor well construction details for each well are presented with the boring logs in **Appendices C** and **D**.

3.3.2 Monitoring Well Development

All monitoring wells were developed by air-lift pumping, or with a centrifugal pump. The primary purpose of well development was to maximize the production of low turbidity water by removing fines from the filter pack and surrounding aquifer. The development of the shallow, intermediate and deep wells installed at Hadnot Point was performed immediately after completion of each well, after the grout had been given sufficient time to cure.

During development, a steam-cleaned 1-inch O.D. flexible PVC pipe was inserted to the bottom of each well and attached to the pump to be used. An oil filter was installed between the compressor and hose when using air-lift to prevent any oil from entering the well. Development continued until the water was visibly free of fines. Samples were taken before and after the development of each well and measured for pH and specific conductivity with a portable Hydrolab unit. Well development records are presented in **Appendix E.**

3.3.3 Groundwater Sampling

Characterization Phase

Each of the shallow wells installed during the Characterization were sampled three times during the phase, with a period of approximately 60 days between sampling events. The intermediate and deep wells were sampled once during this phase. All samples collected were analyzed for lead, oil and grease and volatile organics (EPA Method 624). Results of the groundwater analytical investigation are presented in **Section 5.3** of this report.

Supplemental Characterization

Thirty (30) existing shallow wells (27 at HPIA, two at Site 22, and one at Site 21), eight newly installed intermediate and deep wells, six existing intermediate and deep wells, and nine water supply wells were scheduled to be sampled during the field investigation. **Figure 2-5** shows the locations of the wells. The monitoring wells scheduled to be sampled included HPGW1 through HPGW26, HPGW29, 22GW1, 22GW2, and 21GW1. The water supply wells scheduled to be sampled included 601 (replaced and renumbered as 660), 602, 603, 608, 634, 637, 642, and 652.

Shallow well HPGW18, and deep well HPGW17-3, could not be sampled because they could not be located after numerous attempts to find them. Water supply wells 608 and 630 were not sampled because the wells were either welded shut (608) or demolished (630).

All groundwater samples collected during this phase were analyzed for full TCL parameters. Field measurements of pH, specific conductivity and temperature were measured throughout purging and final readings are presented in **Table 3-1**. Results of the groundwater analytical investigation are presented in **Section 5.3** of this report.

Sampling Procedures

Wells were not sampled until a minimum of 14 days had elapsed following development.

The following procedures were used when sampling groundwater monitor wells:

1. The depth to water was measured from the top of casing to within 0.01 foot.

Table 3-1. HADNOT POINT GROUNDWATER FIELD MEASUREMENTS SUMMARY

Well I.D.	pH	Specific Conduct.	Temp. (C)	Sample Date	Time
HPGW1	3.12	445	21.94	1/16/91	15:00
HPGW2	6.49	300	23.00	1/16/91	10:50
HPGW3	5.30	353	21.83	1/16/91	09:40
HPGW4	8.19	450	21.30	1/11/91	09:00
HPGW4-2	11.30	669	21.80	1/11/91	09:20
HPGW4-3	7.20	311	20.40	1/11/91	12:15
HPGW5	4.56	610	17.70	1/10/91	16:15
HPGW6	4.26	140	18.30	1/10/91	09:25
HPGW7	7.67	170	18.50	1/09/91	16:30
HPGW8	4.93	116	15.17	1/08/91	13:30
HPGW9	4.97	525	22.28	1/17/91	13:30
HPGW9-2	5.11	500	19.90	1/08/91	12:00
HPGW9-3	10.90	143	19.50	1/09/91	16:05
HPGW10	8.78	200	16.70	1/09/91	14:00
HPGW11	4.72	130	18.00	1/09/91	15:20
HPGW12	6.17	290	17.10	1/09/91	11:30
HPGW13	6.38	230	18.50	1/12/91	09:15
HPGW14	5.11	150	20.70	1/10/91	12:15
HPGW15	5.20	180.5	8.28	1/08/91	11:50
HPGW16	5.14	160	24.70	1/09/91	09:15
HPGW17	6.03	350	20.00	1/07/91	12:10
HPGW17-2	6.65	570	18.90	1/08/91	09:41
HPGW19	7.80	210	17.60	1/11/91	11:50
HPGW20	7.06	410	21.50	1/12/91	10:15
HPGW21	3.51	364	20.00	1/17/91	14:50
HPGW22	6.12	455	14.50	1/18/91	13:40
HPGW23	3.79	162	13.94	1/18/91	10:55
HPGW24	5.59	203	6.44	1/08/91	16:15
HPGW24-2	4.92	400	18.90	1/08/91	15:50
HPGW24-3	7.40	349	18.90	1/09/91	12:05
HPGW25	4.20	149	17.11	1/18/91	14:45
HPGW26	4.20	98.3	8.17	1/19/91	09:20
HPGW29	7.51	390	18.20	1/12/91	11:30
HPGW30-2	7.50	693	21.30	1/10/91	11:15
HPGW30-3	7.80	428	20.80	1/10/91	13:11
HPGW31-2	7.65	391	21.91	1/17/91	10:35
HPGW31-3	11.31	1106	20.78	1/17/91	10:10
HPGW32-2	10.80	489	22.60	1/12/91	11:00
HPGW32-3	9.90	307	22.50	1/12/91	10:37
21GW1	3.25	679	9.11	1/24/91	11:35
22GW1	5.51	245	9.61	1/18/91	09:25
22GW2	5.60	829	7.83	1/24/91	10:05
WS602	6.98	826	18.07	1/22/91	10:47
WS603	7.13	574	19.49	1/22/91	11:35
WS634	7.36	358	17.92	1/22/91	13:55
WS637	7.08	418	16.83	1/22/91	10:15
WS642	7.33	458	16.90	1/22/91	11:54
WS651	7.42	315	17.72	1/22/91	14:34
WS652	6.89	424	16.97	1/22/91	13:22
WS653	7.10	433	16.89	1/22/91	15:17
WS660	7.03	590	18.32	1/22/91	11:20

Note: All monitor wells are 25 ft. deep except those with suffix -2 (75 ft.) and -3 (150 ft.).
Source: ESE, 1991

2. The volume of water in the well casing and saturated annulus was calculated.

3. Standing water in the well casing and saturated annulus was evacuated prior to sampling. Sample protocol required purging five times the amount of standing water. The amount of water purged was measured and recorded.

4. To protect the wells from external contamination during sampling procedures, the following guidelines were followed:

   a. Groundwater samples were collected using decontaminated PVC bailers for the monitoring wells and from bypass pipes in the water supply wells. A separate bailer, constructed prior to the start of the field effort, was provided for each monitor well. Each bailer was suspended from a Teflon-coated stainless steel leader attached to a polypropylene monofilament rope. The leader was 8-feet in length to ensure that the rope did not come in contact with the groundwater being sampled.

   b. When a pump was used to purge the standing water from the well, the pump and the hoses were thoroughly cleaned between samples. Decontamination procedures are presented in **Appendix A**.

   c. All sampling and well purging equipment were protected from ground contact by placing the equipment on disposable polyethylene plastic sheeting.

   d. Samples were collected from background wells and wells suspected of being free from contamination before wells that were suspected or known to contain contaminants were sampled.

e. Field parameters were measured and recorded in the bound field book.

f. When sampling the potable wells, the sample containers were filled directly from the sample tap in the water pipeline, labeled, and placed on ice.

g. Samples were preserved according to their analytical fraction (planned analysis). Groundwater samples were not filtered prior to preservation in accordance with EPA protocols. Analysis of unfiltered samples provides an approach to the investigation that reveals the total compound of interest rather than just the dissolved portion. While this may result in higher concentrations of compounds to be considered during the Risk Assessment and potential cleanup, it is a conservative approach in that all phases of the compound are addressed.

Onsite measurements of water quality obtained during the groundwater sampling consisted of conductivity, temperature, and pH. Measurements were made using a Hydrolab® 4000. These measurements were made at the start, at least once during, and at the end of the fluid purging procedure for groundwater monitor wells and prior to sampling only when at public supply wells. Calibration standards were run and recorded prior to, during, and after each sampling day. Three saline [potassium chloride (KCl)] solutions of known conductivity [(141, 718, and 1,413 micromhos per centimeter (μmho/cm)] were measured at each calibration check. If calibration indicated that the instrument was not responding correctly, a backup unit was used. The pH calibration consisted of testing pH buffer standards (pH 4.0, 7.0, and 10) and adjustment of the Hydrolab® function to read specified pH units. A backup pH meter was used if the calibration procedure indicated improper meter response.

During the sampling of each monitor well, the following data were recorded in a bound field notebook:

1. Well number;
2. Date;
3. Time;
4. Static water level;
5. Depth of well;
6. Number of bailer volumes removed, if applicable;
7. Pumping rate and type of pump, if applicable;
8. Time of pumping, if applicable;
9. Deepest water level during purging;
10. In situ water quality measurements of pH, specific conductance, and temperature;
11. Other pertinent observations of water samples (color, turbidity, odor, particulates);
12. Fractions sampled and preservatives used;
13. Weather conditions and miscellaneous observations; and
14. Signature of sampler and date and time of sample collection.

Samples were collected in a manner that minimized aeration and prevented oxidation of reduced compounds. Each sample container was carefully labeled, including the project number, sample number, time and date, pH and conductivity measurements, and sampler's initials. Samples were shipped in insulated coolers by overnight courier and were kept chilled from time of sample collection until analysis.

Chain of custody documentation was prepared at the time the water samples were collected and accompanied the samples until they reached the laboratory. Copies of this documentation is provided in **Appendix Q**.

3.3.4 Water Level Measurements

Water level measurements have been collected from wells within the HPIA during all phases of the investigation. Two rounds of water level measurements were taken at HPIA during the supplemental characterization investigation to determine horizontal and vertical groundwater flow gradients at the site for this report. The first water level measurements were taken on January 25, 1991, and the second round of measurements were taken on February 20, 1991. All water level measurements were taken to the nearest 0.01 feet using an electronic water level indicator. Only the most recent water level measurements are presented in **Section 4.3.2**.

3.3.5 Well Location and Elevation Survey

Locations and elevations of monitoring wells and water supply wells at HPIA were surveyed by a licensed surveyor in January-February 1991. Elevations of well casings, and ground surface were established to the nearest 0.01 foot with respect to mean sea level (msl). Survey data was obtained to determine direction and gradients of groundwater flow at HPIA. Elevation data is presented in **Section 4.3.2**.

3.4 PUMP TESTING

An aquifer pumping test was conducted at HPIA in April, 1987 to determine site-specific aquifer characteristics for the Castle Hayne aquifer, and to evaluate the interconnection between this unit and the surficial aquifer. The pump test was conducted with water supply well 642 as the pumping well. Three observation wells were used to provide drawdown data for analyses. Water supply well 642 was selected for the pumping test because it was the closest, active well to HPIA that was not within the zone of deep contamination. Additionally, the existing well log for well 642 indicated that the subsurface materials were most typical of those encountered throughout HPIA; ensuring that aquifer parameters quantified by the pumping test would be representative of HPIA as a whole. The three observation wells included in the pumping test were a U.S. Geological Survey (USGS) well located 90 feet from the pumping well; and two observation wells, Nos. 642-1 and 642-2, located 200 feet and 300 feet from the pumping well, respectively. The USGS well is 90 feet deep. The observation wells are 200 feet deep. Additionally, water level measurements were obtained from all shallow groundwater monitor wells in the area during the test.

Drawdown data from the pumping test was analyzed by a number of analytical methods. The methods of Theis (1985), Hantush (1955), and Walton (1962) were employed to analyze drawdown data for values of transmissivity and storage coefficient. The distance drawdown method of Cooper and Jacob (1946) was also used to analyze drawdown data. Additionally, the methods of Hantush and Jacob (1955) and Walton (1962) were used to evaluate properties of the semi-confining layer.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

Initial investigations at the HPIA were conducted under ESE's QA/QC plan. Following inclusion of the site on the NPL, the supplemental characterization was conducted under EPA's SOP's. The RI at HPIA was finalized under the regulations, guidelines, and criteria established by EPA Region IV for Superfund sites.

QA/QC protocol during the supplemental characterization sampling event included the collection of trip blanks, equipment rinsate blanks, potable water blanks, deionized water blanks, and drilling mud blanks. Trip blanks were collected at a frequency of 1/day of aqueous volatile organic sampling. Aqueous volatile organic sampling was performed on 12 days resulting in the collection of 12 trip blanks. Trip blanks were analyzed for TCL VOAs.

Equipment rinsate blanks were required and collected at a frequency of 1/day/-sampling procedure if decontamination was performed in the field, and 1/day of decontamination effort if decontamination was performed in the laboratory. Bailers for groundwater sampling were decontaminated at the ESE Gainesville Laboratory. All other sampling equipment was decontaminated in the field. Equipment rinsate blanks were analyzed for the same parameters as associated environmental samples. The decontamination procedure applied to sampling equipment used during this investigation is presented in **Appendix A.**

One deionized water (DI) blank was collected for each lot (batch) of deionized water used for decontamination in the field. Three lots of DI were used during the field investigation. The three blanks were analyzed for full TCL compounds. DI water was furnished by the ESE Gainesville Laboratory.

In order to evaluate the quality of potable water used for decontamination during the field investigation, one potable water blank (field blank) was collected during the investigation. One drilling mud blank was collected during monitoring well installation. The drilling mud sample was collected prior to the start of drilling from the mud tub used to mix the drilling mud. Potable water and drilling mud blanks were analyzed for full TCL compounds.

Duplicate samples were collected for each matrix sampled (groundwater and soil) at a frequency of 10 percent. As per Navy protocol, an additional sample was collected for matrix spike and matrix spike duplicate (MS/MSD) analyses at each duplicate sample location. For the aqueous matrix, a total of 51 samples were collected, resulting in the collection of seven duplicate and MS/MSD samples to exceed the 10 percent frequency requirement. For the soil matrix, a total of 87 samples were collected. Nine duplicate and MS/MSD samples were collected to meet the 10% frequency requirement for the soil matrix.

All analytical data obtained during the HPIA RI/FS is the result of analysis under Data Quality Objective (DQO) Level D. DQO Level D correlates to EPA Level 4, and is required for sites that are on or about to be on the NPL. Level D QC includes review and approval of the laboratory QA plan, the site work plan, and the field QA plan.

The laboratories must successfully analyze a performance sample, undergo an audit, correct deficiencies found during the audit, and provide monthly progress reports (MPRs) on QA. These activities are administered and evaluated by the NEESA Contract Representative (NCR). This audit and the analysis performance sample are in addition to those related to the EPA Superfund Program. The laboratory that performs Level D QC must have passed the performance sample furnished through the Superfund Contract Laboratory Protocol (CLP) and must be able to generate the CLP deliverables. For a level D site, the CLP methods are used and the CLP package generated.

The ESE Denver Laboratory performed all aqueous sample analysis. Ceimic Laboratory performed the analysis on all soil samples. Both laboratories are Navy-approved to perform Level D analysis. A summary of QA/QC samples collected is presented in **Table 3-2**. The analytical results of the QA/QC samples are presented in **Appendix F** and a discussion of the QA/QC results is presented in **Appendix G**.

Table 3-2. QA/QC SAMPLE SUMMARY

		------ Associated QA/QC Sample ------		
Sample I.D.	Analysis	Duplicates MS/MSD	Equipment Blank	Trip Blank
Groundwater				
HPGW1	Full TCL	**	EB001	TB009
HPGW2	Full TCL	**	EB001	TB009
HPGW3	Full TCL	**	EB001	TB009
HPGW4	Full TCL	GWDUP5	EB002	TB005
HPGW4-2	Full TCL	**	EB013	TB005
HPGW4-3	Full TCL	**	EB013	TB005
HPGW5	Full TCL	**	EB002	TB004
HPGW6	Full TCL	**	EB001	TB004
HPGW7	Full TCL	**	EB001	TB003
HPGW8	Full TCL	**	EB001	TB002
HPGW9	Full TCL	**	EB001	TB010
HPGW9-2	Full TCL	GWDUP1	EB001	TB002
HPGW9-3	Full TCL	GWDUP3	EB002	TB003
HPGW10	Full TCL	**	EB002	TB003
HPGW11	Full TCL	**	EB001	TB003
HPGW12	Full TCL	GWDUP2	EB002	TB003
HPGW13	Full TCL	**	EB001	TB006
HPGW14	Full TCL	**	EB001	TB004
HPGW15	Full TCL	**	EB002	TB002
HPGW16	Full TCL	**	EB002	TB003
HPGW17	Full TCL	**	EB001	TB001
HPGW17-2	Full TCL	**	EB002	TB002
HPGW19	Full TCL	**	EB001	TB005
HPGW20	Full TCL	**	EB002	TB006
HPGW21	Full TCL	**	EB001	TB010
HPGW22	Full TCL	**		TB011
HPGW23	Full TCL	**	EB001	TB011
HPGW24	Full TCL	**	EB001	TB002
HPGW24-2	Full TCL	**	EB001	TB002
HPGW24-3	Full TCL	**	EB002	TB003
HPGW25	Full TCL	**	EB001	TB011
HPGW26	Full TCL	GWDUP8	EB001	TB012
HPGW29	Full TCL	**		TB006
HPGW30-2	Full TCL	GWDUP4	EB013	TB004
HPGW30-3	Full TCL	**	EB013	TB004
HPGW31-2	Full TCL	**	EB013	TB010
HPGW31-3	Full TCL	**	EB013	TB010
HPGW32-2	Full TCL	**	EB013	TB006
HPGW32-3	Full TCL	**	EB013	TB006
21GW1	Full TCL	**	EB001	TB015
22GW1	Full TCL	**	EB001	TB011
22GW2	Full TCL	**	EB001	TB015

Table 3-2. QA/QC SAMPLE SUMMARY (Continued)

Sample I.D.	Analysis	Duplicates MS/MSD	Equipment Blank	Trip Blank
		------ Associated QA/QC Sample ------		
Water Supply				
WS602	Full TCL	**	**	TB013
WS603	Full TCL	**	**	TB013
WS608	Full TCL	**	**	TB013
WS630	Full TCL	**	**	TB013
WS634	Full TCL	GWDUP9	**	TB013
WS637	Full TCL	**	**	TB013
WS642	Full TCL	**	**	TB013
WS652	Full TCL	**	**	TB013
WS660	Full TCL	**	**	TB013
Soil				
HPSO1-1	Full TCL	HPSOD1	EB003	**
HPSO1-2	**	**	EB003	**
HPSO1-3	**	**	EB003	**
HPSO2-1	**	**	EB003	**
HPSO2-2	**	HPSOD2	EB003	**
HPSO3-1	**	HPSOD3	EB003	**
HPSO4-1	**	**	EB003	**
HPSO4-2	**	HPSOD4	EB003	**
HPSO4-3	**	**	EB003	**
HPSO5-1	**	**	EB003	**
HPSO5-2	**	**	EB003	**
HPSO5-3	**	**	EB003	**
HPSO6-1	Full TCL	**	EB004	**
HPSO6-2	**	**	EB004	**
HPSO6-3	**	**	EB004	**
HPSO7-1	**	**	EB004	**
HPSO7-2	**	**	EB004	**
HPSO7-3	**	**	EB004	**
HPSO8-1	**	**	EB004	**
HPSO8-2	**	**	EB004	**
HPSO8-3	**	**	EB004	**
HPSO9-1	**	**	EB005	**
HPSO9-2	**	**	EB005	**
HPSO9-3	**	**	EB005	**
HPSO10-1	Full TCL	**	EB005	**
HPSO10-2	**	**	EB005	**
HPSO10-3	**	**	EB005	**
HPSO11-1	Full TCL	**	EB005	**
HPSO11-2	**	**	EB005	**
HPSO11-3	**	HPSOD5	EB005	**

Table 3-2. QA/QC SAMPLE SUMMARY (Continued)

Sample I.D.	Analysis	------ Associated QA/QC Sample ------		
		Duplicates MS/MSD	Equipment Blank	Trip Blank
Soil (cont.)				
HPSO12-1	**	**	EB011	**
HPSO12-2	**	**	EB011	**
HPSO12-3	**	**	EB011	**
HPSO13-1	**	**	EB007	**
HPSO13-2	***	**	EB007	**
HPSO13-3	***	**	EB007	**
HPSO14-1	***	**	EB007	**
HPSO14-2	**	**	EB007	**
HPSO14-3	**	**	EB007	**
HPSO15-1	Full TCL	**	EB005	**
HPSO15-2	**	**	EB005	**
HPSO15-3	**	**	EB005	**
HPSO16-1	**	**	EB006	**
HPSO16-2	**	**	EB006	**
HPSO16-3	**	**	EB006	**
HPSO17-1	**	HPSOD6	EB006	**
HPSO17-2	**	**	EB006	**
HPSO17-3	**	**	EB006	**
HPSO18-1	**	**	EB006	**
HPSO18-2	**	**	EB006	**
HPSO18-3	**	**	EB006	**
HPSO19-1	**	**	EB006	**
HPSO19-2	**	**	EB006	**
HPSO19-3	**	**	EB006	**
HPSO20-1	Full TCL	**	EB005	**
HPSO20-2	**	**	EB005	**
HPSO20-3	**	**	EB005	**
HPSO21-1	Full TCL	**	EB008	**
HPSO21-2	**	**	EB008	**
HPSO21-3	**	**	EB008	**
HPSO22-1	**	HPSOD7	EB010	**
HPSO22-2	**	**	EB010	**
HPSO22-3	**	**	EB010	**
HPSO23-1	**	**	EB008	**
HPSO23-2	**	**	EB008	**
HPSO23-3	**	**	EB008	**
HPSO24-1	**	HPSOD9	EB010	**
HPSO24-2	**	**	EB010	**
HPSO24-3	**	**	EB010	**
HPSO25-1	Full TCL	**	EB008	**
HPSO25-2	**	**	EB008	**
HPSO25-3	**	**	EB008	**

Table 3-2. QA/QC SAMPLE SUMMARY (Continued)

Sample I.D.	Analysis	Duplicates MS/MSD	Equipment Blank	Trip Blank
		------ Associated QA/QC Sample ------		
Soil (cont.)				
HPSO26-1	**	HPSOD8	EB010	**
HPSO26-2	**	**	EB010	**
HPSO26-3	**	**	EB010	**
HPSO27-1	**	**	EB010	**
HPSO27-2	**	**	EB010	**
HPSO27-3	**	**	EB010	**
HPSO28-1	**	**	EB008	**
HPSO28-2	***	**	EB008	**
HPSO28-3	***	**	EB008	**
HPSO29-1	***	**	EB010	**
HPSO29-2	**	**	EB010	**
HPSO29-3	**	**	EB010	**
HPSO30-1	Full TCL	**	EB008	**
HPSO30-2	**	**	EB008	**
HPSO30-3	**	**	EB008	**
Soil (resampling 2/21/91)				
HPSO12-2	TCL VOA only	**	EB017	**
HPSO12-3	TCL VOA only	**	EB017	**
HPSO24-1	TCL VOA only	**	EB017	**
HPSO26-1	TCL VOA only	HPSOD8	EB017	**
HPSO26-2	TCL VOA only	**	EB017	**
HPSO26-3	TCL VOA only	**	EB017	**
HPSO27-1	TCL VOA only	**	EB017	**
HPSO27-2	TCL VOA only	**	EB017	**
HPSO27-3	TCL VOA only	**	EB017	**
HPSO29-1	TCL VOA only	**	EB017	**
HPSO29-2	TCL VOA only	**	EB017	**
HPSO29-3	TCL VOA only	**	EB017	**

4.0 PHYSICAL CHARACTERIZATION OF STUDY AREA

4.1 TOPOGRAPHY AND SURFACE WATER DRAINAGE

MCB Camp Lejeune is situated on relatively flat coastal terrain which includes swamps, estuaries, savannas, and forest lands. Land surface elevations range from msl to 72 feet above msl. Average elevations for the base range from 10 to 40 feet above msl.

The drainage at MCB Camp Lejeune is predominantly toward the New River although coastal areas drain directly to the Atlantic Ocean via the Intracoastal Waterway. Natural drainage has been altered in developed areas such as HPIA by the installation of drainage ditches, storm sewers, and extensive paving, creating numerous drainage sub-basins on the base. **Figure 4-1** shows surface water drainage sub-basins in the Hadnot Point area (Water and Air Research, 1983; NAVFACENGCOM, 1975).

Approximately 70 percent of MCB Camp Lejeune is in the broad, flat interstream areas (Atlantic Division, Bureau of Yards and Docks, 1965). Drainage in these areas is poor, and the soils are often wet.

Flooding is a potential problem for areas of MCB Camp Lejeune within the 100-year floodplain. The U.S. Army Corps of Engineers has mapped the limits of the 100 year floodplain at MCB Camp Lejeune at 7.0 feet above msl in the upper reaches of the New River (Natural Resources Management Plan, 1975). The elevation at the 100-year floodplain increases downstream and is 11.0 feet above msl on the open coast.

Stream flow measurements have not been determined for the New River below Jacksonville because the standard measurements employed by the U.S. Geological

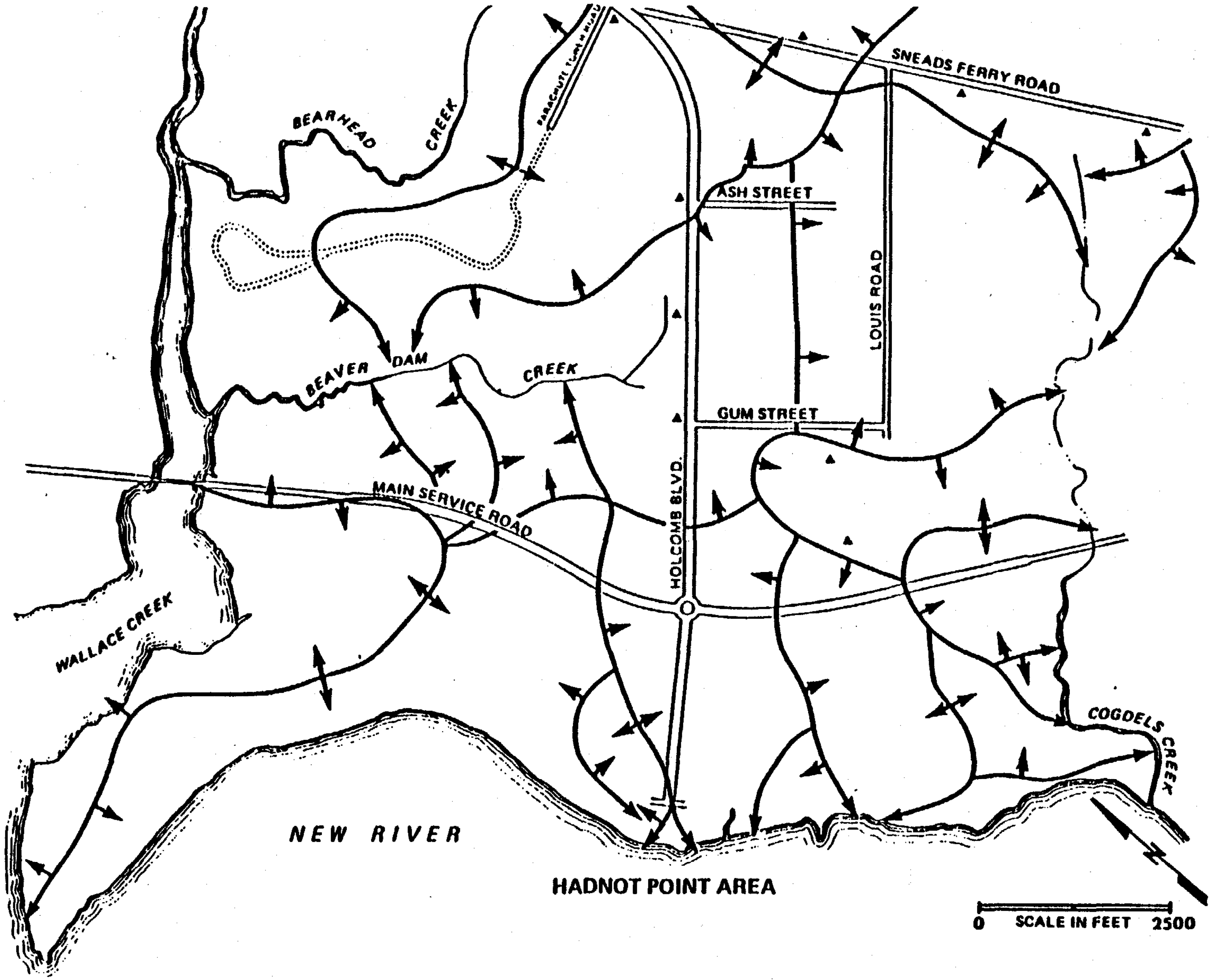


Figure 4-1
SURFACE WATER DRAINAGE SUBBASINS AT HADNOT POINT, CAMP LEJEUNE

SOURCE: NAVFACENGCOM, 1975.

MARINE CORPS BASE
CAMP LEJEUNE

Survey are not applicable in low gradient, tidal conditions. At the New River Inlet, the normal range of tides is 3.0 feet, and the spring range is 3.6 feet (U.S. Department of Commerce, 1979). Further upstream, the tidal range diminishes to approximately one foot at Jacksonville (Howard, 1982). The average annual runoff at MCB Camp Lejeune has not been determined.

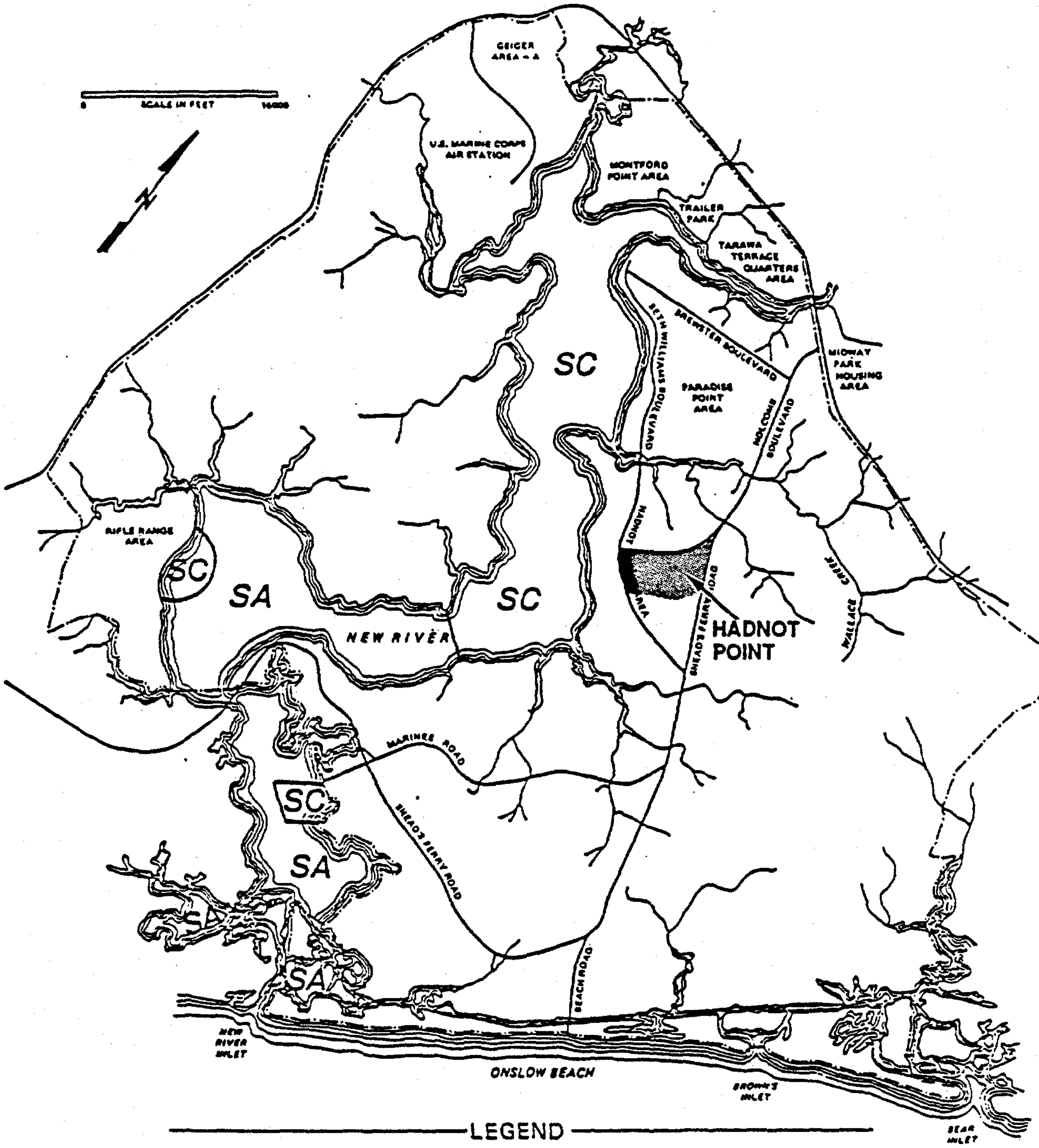
At MCB Camp Lejeune, water in the New River can be characterized as brackish, shallow, and warm. Salinity of the water varies as a function of distance from the ocean and rainfall. At Jacksonville, salinities may reach 10 parts per thousand (ppt) during extended periods of low rainfall. At the New River Inlet, salinities are approximately equivalent to sea water (35 ppt); however salinities may become significantly lower during periods of heavy rainfall (Brunette, 1977).

Water quality criteria for surface waters in North Carolina have been published under Title 15 of the North Carolina Administrative Code. At MCB Camp Lejeune, the New River falls into two classifications, SC and SA (**Figure 4-2**) (Water and Air Research, 1983). The SC classification applies to three areas of the New River at MCB Camp Lejeune, the rest of the New River at MCB Camp Lejeune falls into the SA classification. The surface water classification of the New River adjacent to HPIA is SC. The best usage of class SC waters is "fishing, secondary recreation, and any other usage except primary recreation or shellfishing for market purposes." The best usage of class SA waters, the highest estuarine classification, is "shellfishing for market purposes and any other usage specified by the SC designation."

4.2 GEOLOGY

4.2.1 Regional Geology

MCB Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments are layered



LEGEND

SC	ESTUARINE WATERS NOT SUITED FOR BODY CONTACT SPORTS OR COMMERCIAL SHELLFISHING	SA	ESTUARINE WATERS SUITED FOR COMMERCIAL SHELLFISHING

Figure 4-2
WATER QUALITY CLASSIFICATIONS FOR NEW RIVER, CAMP LEJEUNE

SOURCE: NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES, 1977.

MARINE CORPS BASE CAMP LEJEUNE

in interfingering beds and lenses that gently dip and thicken to the southeast (Todd, 1983). Regionally, they comprise ten aquifers and nine confining units which overlie igneous and metamorphic basement rocks of pre-Cretaceous age.

These sediments were deposited in marine or near-marine environments (Brown et. al., 1972) and range in age from early Cretaceous to Quaternary time. **Figure 4-3** presents a generalized stratigraphic column for this area (Harned et. al., 1989).

4.2.2 Hadnot Point Industrial Area Geology

Geologic information specific to HPIA was obtained during the Confirmation Study conducted by ESE (May 1988) and during the intermediate and deep monitoring well installation, also carried out by ESE, in December 1990 as part of this RI/FS. The information gathered focused on the shallow aquifer extending down to approximately 25 feet below land surface (bls), and on material underlying this 25 feet level down to approximately 150 feet. The shallow wells installed during this investigation (25 ft) are screened within the surficial aquifer. Deeper wells (75 and 150 ft) are screened within the Castle Hayne aquifer which separated from the surficial aquifer by a discontinuous clay and sandy clay layer.

Cross-sections generated from lithologic information obtained during monitoring well installation at HPIA as part of the Confirmation Study indicate that the shallow aquifer in this area is primarily silty sand with extensive but discontinuous layers of silty clay and silty sand clay. These layers dip to the south-southwest. Peat, wood fragments, and plant debris are present in a 1-2 foot layer in the southwest portion of HPIA. Peat was also encountered at a depth of 18 feet in the northwest portion of the site. Marl was noted to be present in some of the boreholes. Layers of fill up to four feet thick are present in areas adjacent to developed areas.

Site-specific information on the deeper portion of the aquifer beneath HPIA is limited to the 14 deep boreholes which have been drilled to date. Intermediate (75 feet) and

GEOLOGIC UNITS			HYDROGEOLOGIC UNITS
SYSTEM	SERIES	FORMATION	AQUIFER AND CONFINING UNIT
Quaternary	Holocene Pleistocene	Undifferentiated	Surficial aquifer
Tertiary	Pliocene	Yorktown Formation[1]	Yorktown confining unit
	Miocene	Eastover Formation[1]	Yorktown aquifer
		Pungo River Formation[1]	Pungo River confining unit
			Pungo River aquifer
		Belgrade Formation[2]	Castle Hayne confining unit
	Oligocene	River Bend Formation	Castle Hayne aquifer
	Eocene	Castle Hayne Formation	Beaufort confining unit[3]
	Paleocene	Beaufort Formation	Beaufort aquifer
			Peedee confining unit
Cretaceous	Upper Cretaceous	Peedee Formation	Peedee aquifer
			Black Creek confining unit
		Black Creek and Middendorf Formations	Black Creek aquifer
			Upper Cape Fear confining unit
		Cape Fear Formation	Upper Cape Fear aquifer
			Lower Cape Fear confining unit
			Lower Cape Fear aquifer
	Lower Cretaceous[1]	Unnamed deposits[1]	Lower Cretaceous confining unit
			Lower Cretaceous aquifer[1]
Pre-Cretaceous basement rocks		--	--

[1] Geologic and hydrologic units probably not present beneath 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.

Figure 4-3
GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE COASTAL PLAIN OF NORTH CAROLINA

SOURCE: HARNED *et al.*, 1989.

MARINE CORPS BASE
CAMP LEJEUNE

deep (150 feet) wells drilled at HPIA penetrated intervals of silty sand and sandy clay down to a depth of 56 feet. Beneath this depth, layers consisting of sand, shells, and cemented clastics were encountered interbedded with lenses consisting of different proportions of these components. All intermediate and deep borings penetrated the Castle Hayne aquifer. A geologic cross-section generated from lithologic information obtained during present and past investigations is presented in **Figure 4-5.**

4.3 HYDROLOGY

4.3.1 Regional Hydrology

USGS studies at MCB Camp Lejeune (Harned et. al., 1989) indicate that the base is underlain by seven sand and limestone aquifers separated by confining units of silt and clay. These include the water table surficial, Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear aquifers. The combined thickness of these sediments is approximately 1,500 feet. Less permeable clay and silt beds function as confining units or semi-confining units which separate the aquifers and impede the flow of groundwater between aquifers. A hydrogeologic cross-section of this area is presented in **Figure 4-4**. This cross-section illustrates the relationship between the aquifers in this area (Harned et. al., 1989).

Freshwater is present in the surficial and Castle Hayne aquifers at MCB Camp Lejeune and they are, therefore, the hydrogeologic units of concern with respect to this study. Fresh water extends to a depth of approximately 300 feet (Harned et. al., 1989). Aquifers below this depth have been affected by saltwater intrusion.

The surficial aquifer at MCB Camp Lejeune is composed of Quaternary and Miocene sand, silt, and clay. This aquifer ranges in thickness from 0 feet in the channels of the New River and its tributaries to 75 feet in the southeastern portion of Camp Lejeune (Harned et. al., 1989). Due to the low yield, no wells are screened in this aquifer in Camp Lejeune.

HADNOT RI 5/91LB

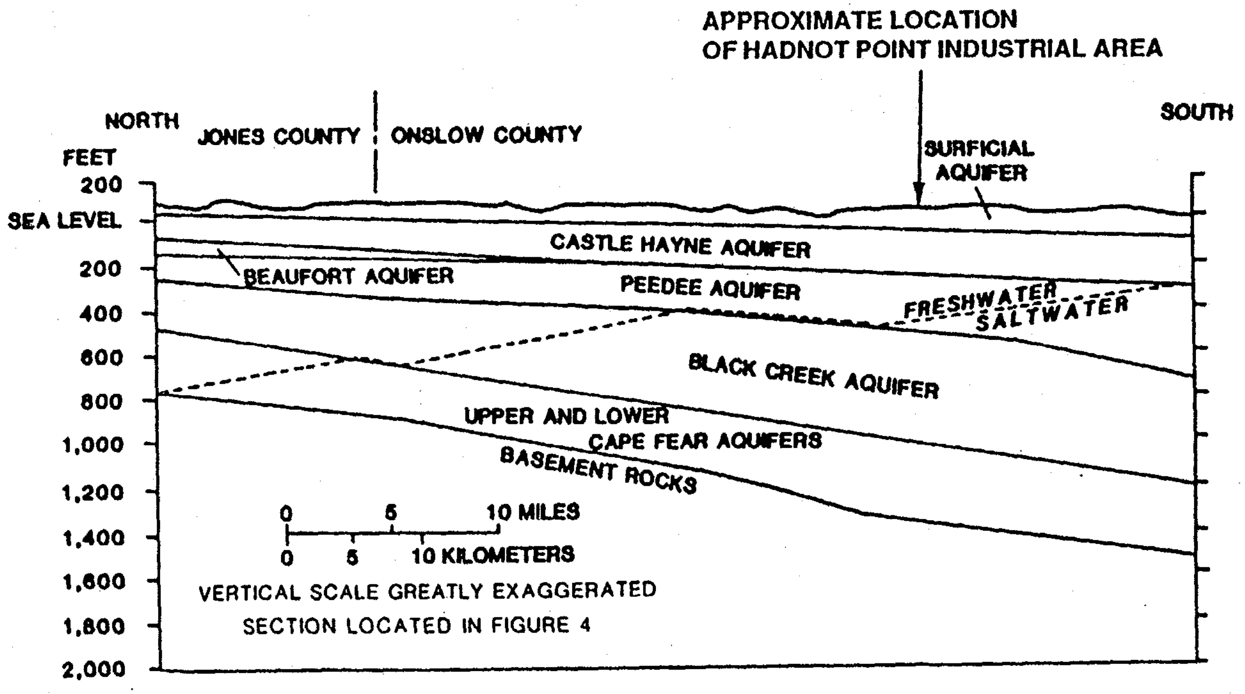


Figure 4-4
GENERALIZED HYDROGEOLOGIC CROSS SECTION
JONES AND ONSLOW COUNTIES, NORTH CAROLINA

SOURCE: HARNED *et al.*, 1989.

MARINE CORPS BASE
CAMP LEJEUNE

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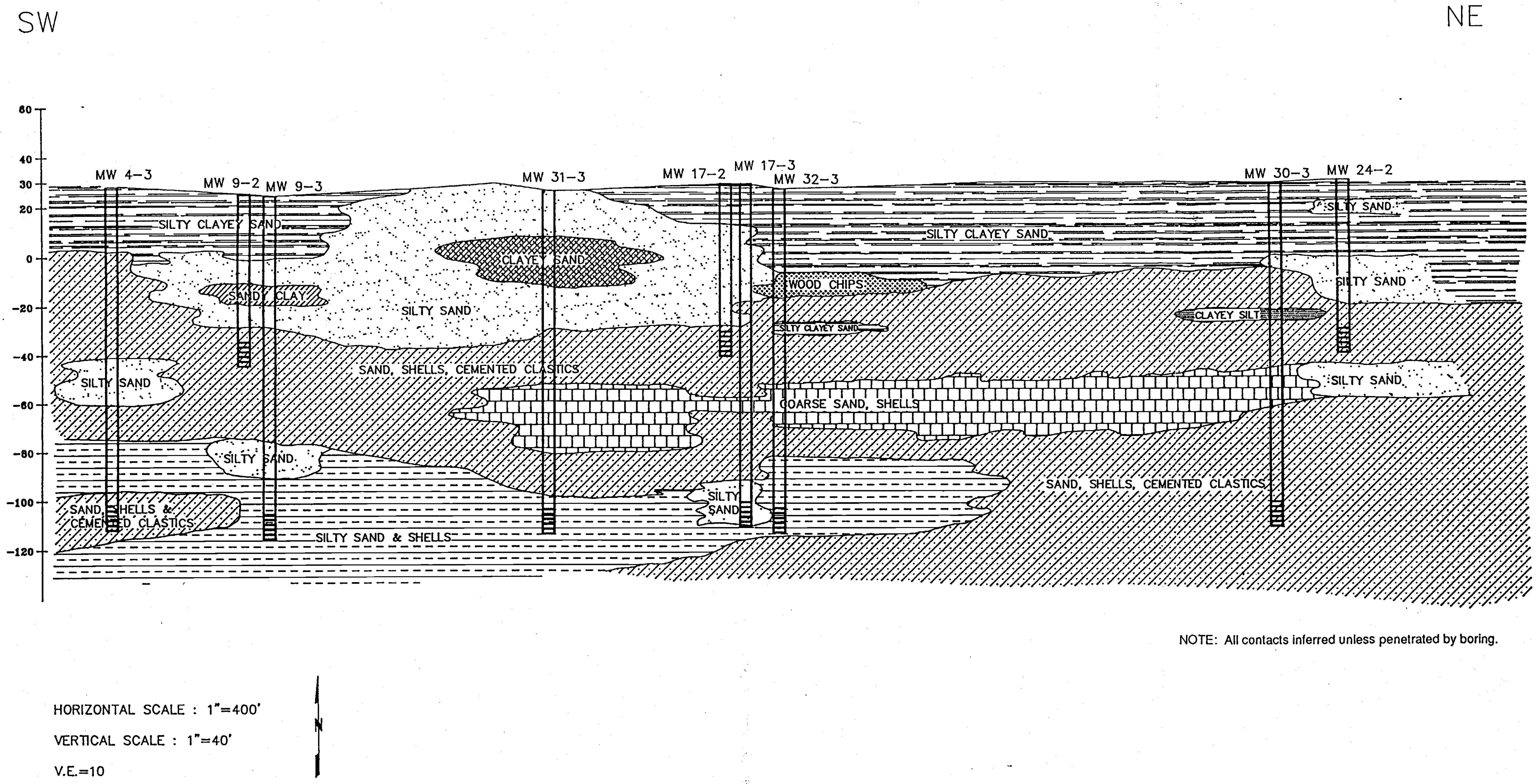


NOTE: All contacts inferred unless penetrated by boring.

HORIZONTAL SCALE : 1"=400'

VERTICAL SCALE : 1"=40'

V.E.=10

Figure 4-5
GENERALIZED CROSS SECTION OF HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE

01516M01Z

The Castle Hayne aquifer is composed of sand and limestone of Oligocene and Middle Eocene age (Harned et. al., 1989). The upper portion of the aquifer is primarily unconsolidated sand. The lower portion is partially consolidated sand and limestone. Thin clay layers are found throughout the unit. The Castle Hayne aquifer thickens toward the southeast, from 175 feet in the northern portion of the base to 375 feet at the coast. The Castle Hayne aquifer is approximately 340 feet thick in the Hadnot Point Area (Harned et. al., 1989).

4.3.2 Hadnot Point Industrial Area Hydrology

In general, the hydrologic system at Camp Lejeune consists of an unconfined (surficial) aquifer and underlying semi-confined (Castle Hayne) aquifers. The sequence of hydrologic materials at the HPIA begins with a interval of sands approximately 30 feet thick, which overlies a clay and sandy clay layer. The clayey layer is discontinuous and variable in thickness. Below the clayey interval, the remainder of the material consists of sand and limestone with minor amounts of silt, silty sand and rock.

The presence of water within this sequence of materials creates two aquifers separated by a clayey interval. From the surface of the shallow groundwater (at depths ranging from 6.67 to 23.18 feet below land surface as measured in the monitor wells (January and February, 1991), to the top of the clayey interval, an unconfined aquifer is present in the near surface sands. There is no on-site usage of water from this surficial aquifer. The clay interval acts as a semi-confining unit retarding flow between the unconfined surficial aquifer above and the semi-confined Castle Hayne aquifer present in the sand and limestone below.

Water elevation measurements collected during the supplemental investigation are presented in **Tables 4-1** and **4-2**. Seasonal water level fluctuations range from one to four feet (Harned et. al, 1989). A potentiometric surface map of the surficial aquifer (<25 feet) is presented in **Figure 4-6**. Generally, the shallow groundwater flows

Table 4-1. HADNOT POINT WATER LEVELS (1/25/91)

Well I.D.	Elevation TOC (MSL)	Elevation Ground (MSL)	DTW (ft)	Elevation Water (MSL)
HPGW1	32.39	30.59	NM	NM
HPGW2	32.23	29.99	6.67	25.56
HPGW3	31.89	29.69	22.21	9.68
HPGW4	31.66	29.06	23.18	8.48
HPGW4-2	31.03	29.07	22.35	8.68
HPGW4-3	28.44	28.68	NM	NM
HPGW5	28.49	26.52	14.02	14.47
HPGW6	27.92	25.54	18.60	9.32
HPGW7	27.81	25.72	16.73	11.08
HPGW8	28.67	25.55	16.04	12.63
HPGW9	29.16	26.81	NM	NM
HPGW9-2	27.48	25.56	17.45	10.03
HPGW9-3	27.02	24.77	NM	NM
HPGW10	28.17	25.95	14.78	13.39
HPGW11	28.26	25.77	16.29	11.97
HPGW12	30.09	27.70	13.78	16.31
HPGW13	25.78	23.57	13.95	11.83
HPGW14	26.99	25.07	13.31	13.68
HPGW15	26.89	26.81	NM	NM
HPGW16	32.39	30.20	14.40	17.99
HPGW17	30.06	27.90	13.95	16.11
HPGW17-2	32.15	29.69	16.52	15.63
HPGW19	29.20	27.01	9.87	19.33
HPGW20	25.10	22.83	10.58	14.52
HPGW21	33.59	31.39	14.18	19.41
HPGW22	32.35	30.50	NM	NM
HPGW23	32.09	30.27	NM	NM
HPGW24	32.31	30.76	8.32	23.77
HPGW24-2	33.73	30.85	16.31	16.00
HPGW24-3	32.80	30.56	15.35	18.38
HPGW25	32.58	30.41	10.52	22.28
HPGW26	34.95	32.62	NM	NM
HPGW29	28.82	26.43	NM	NM
HPGW30-2	29.75	29.96	13.30	16.45
HPGW30-3	29.72	29.96	13.42	16.30
HPGW31-2	26.23	26.52	13.17	13.06
HPGW31-3	25.98	26.44	12.86	13.12
HPGW32-2	26.77	27.01	11.61	15.16
HPGW32-3	27.11	27.28	12.42	14.69
21GW1	31.74	29.74	NM	NM
22GW1	31.52	29.01	11.69	19.83
22GW2	28.84	26.20	9.76	19.08

Notes: DTW - Depth to Water
TOC - Top of Casing
MSL - Mean Sea Level
NM - Not Measured

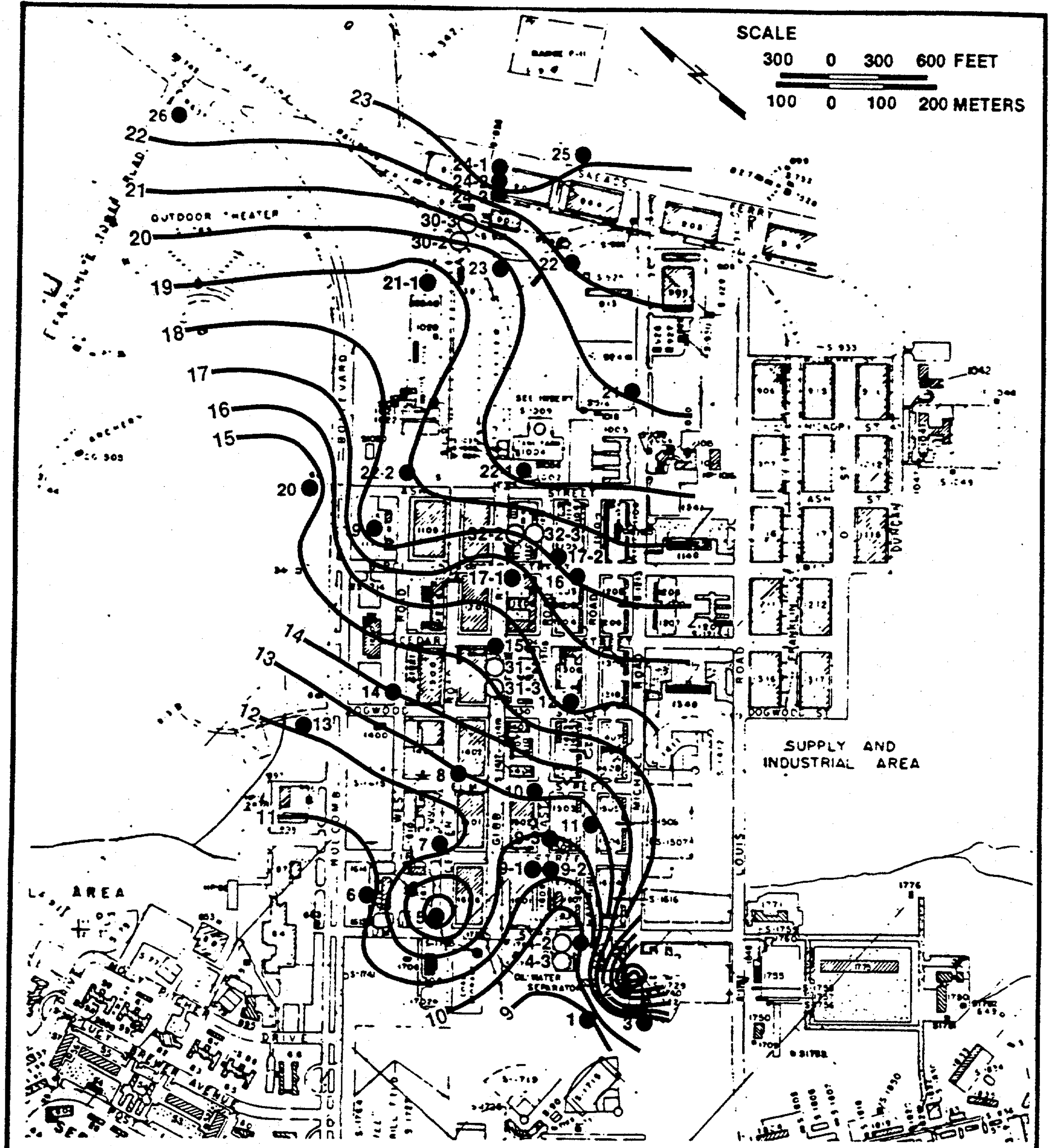
Source: ESE, 1991.

Table 4-2. HADNOT POINT WATER LEVELS (2/20/91)

Well I.D.	Elevation TOC (MSL)	Elevation Ground (MSL)	DTW (ft)	Elevation Water (MSL)
HPGW1	32.39	30.59	23.82	8.57
HPGW2	32.23	29.99	8.15	24.08
HPGW3	31.89	29.69	20.08	11.81
HPGW4	31.66	29.06	22.75	8.91
HPGW4-2	31.03	29.07	21.94	9.09
HPGW4-3	28.44	28.68	19.35	9.09
HPGW5	28.49	26.52	13.34	15.15
HPGW6	27.92	25.54	17.51	10.41
HPGW7	27.81	25.72	16.39	11.42
HPGW8	28.67	25.55	15.58	13.09
HPGW9	29.16	26.81	17.64	11.52
HPGW9-2	27.48	25.56	16.93	10.55
HPGW9-3	27.02	24.77	16.08	10.94
HPGW10	28.17	25.95	14.70	13.47
HPGW11	28.26	25.77	15.71	12.55
HPGW12	30.09	27.70	13.66	16.43
HPGW13	25.78	23.57	13.60	12.18
HPGW14	26.99	25.07	12.89	14.10
HPGW15	26.89	26.81	11.42	15.47
HPGW16	32.39	30.20	14.12	18.27
HPGW17	30.06	27.90	13.57	16.49
HPGW17-2	32.15	29.69	16.05	16.10
HPGW19	29.20	27.01	10.14	19.06
HPGW20	25.10	22.83	10.45	14.65
HPGW21	33.59	31.39	12.52	21.07
HPGW22	32.35	30.50	10.12	22.23
HPGW23	32.09	30.27	12.74	19.35
HPGW24	32.31	30.76	8.12	23.97
HPGW24-2	33.73	30.85	16.05	16.26
HPGW24-3	32.80	30.56	14.42	19.31
HPGW25	32.58	30.41	9.79	23.01
HPGW26	34.95	32.62	12.22	22.73
HPGW29	28.82	26.43	22.36	6.46
HPGW30-2	29.75	29.96	12.41	17.34
HPGW30-3	29.72	29.96	12.89	16.83
HPGW31-2	26.23	26.52	12.70	13.53
HPGW31-3	25.98	26.44	12.52	13.46
HPGW32-2	26.77	27.01	11.18	15.59
HPGW32-3	27.11	27.28	11.80	15.31
21GW1	31.74	29.74	13.06	18.68
22GW1	31.52	29.01	10.87	20.65
22GW2	28.84	26.20	9.93	18.91

Notes: DTW - Depth to Water
TOC - Top of Casing
MSL - Mean Sea Level
NM - Not Measured

Source: ESE, 1991.



KEY

● EXISTING MONITOR WELL
○ NEW MONITOR WELL

NOTE: Contour interval 1 ft. except near well 2, where it changes to 2 ft.

Figure 4-6
POTENTIOMETRIC SURFACE – SHALLOW WELLS (2-20-91)

SOURCE: ESE.

MARINE CORPS BASE CAMP LEJEUNE

toward the New River. The actual shallow groundwater flow trends from southwest in the southern half of HPIA to west-southwest in the northern and central portions of HPIA. Some mounding of groundwater occurs in the southern corner of HPIA around monitoring wells HPGW2 and HPGW5 near a surface drainage ditch which is typically full of water acting as a recharge point for the surficial aquifer.

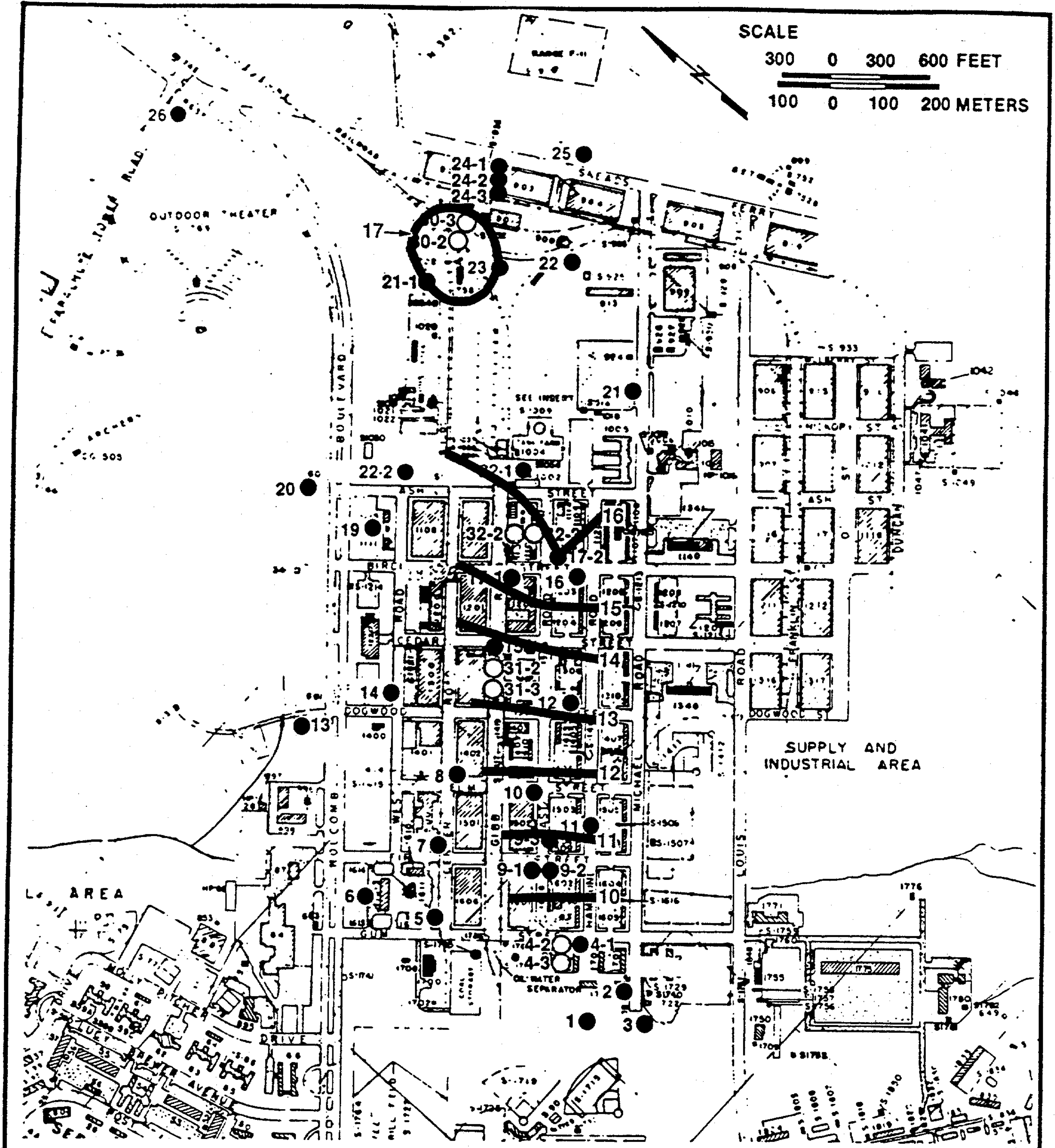
4.3.3 Hydraulic Gradients

Water level measurements in the shallow, intermediate, and deep wells were taken on January 25, and February 20, 1991; and are presented in **Tables 4-1** and **4-2**. Over this one-month period water level elevations fluctuated 0.08 to 2.13 feet in the shallow wells, 0.26 to 0.89 feet in the intermediate wells, and 0.20 to 0.62 feet in the deep wells (ESE, 1991).

A potentiometric surface map of the surficial aquifer was constructed from water level measurements taken in shallow wells on Feb. 20, 1991 and presented in **Figure 4-6**. Equipotential lines trend approximately south-southeast to north-northwest, except in the west-central portion of HPIA where they bend to the northeast. Groundwater flow in the surficial aquifer is predominantly to the southwest in the southern portion of HPIA. In the northern and central portions of HPIA, groundwater flow is to the west-southwest. Some mounding of groundwater appears to be present in the southern portion of HPIA. This mounding may generate localized radial flow in this area.

Potentiometric maps were also prepared using the limited data from the intermediate and deep wells. These maps are presented as **Figures 4-7** and **4-8**. Both of these figures show that water in both zones of the Castle Hayne aquifer trends in generally the same direction (southwest) as that in the surficial.

Horizontal hydraulic gradients in the surficial aquifer at HPIA were determined from the potentiometric surface map. In general, the horizontal hydraulic gradient in the



KEY

● EXISTING MONITOR WELL
○ NEW MONITOR WELL

Figure 4-7
POTENTIOMETRIC SURFACE –
INTERMEDIATE WELLS (2-20-91)

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE

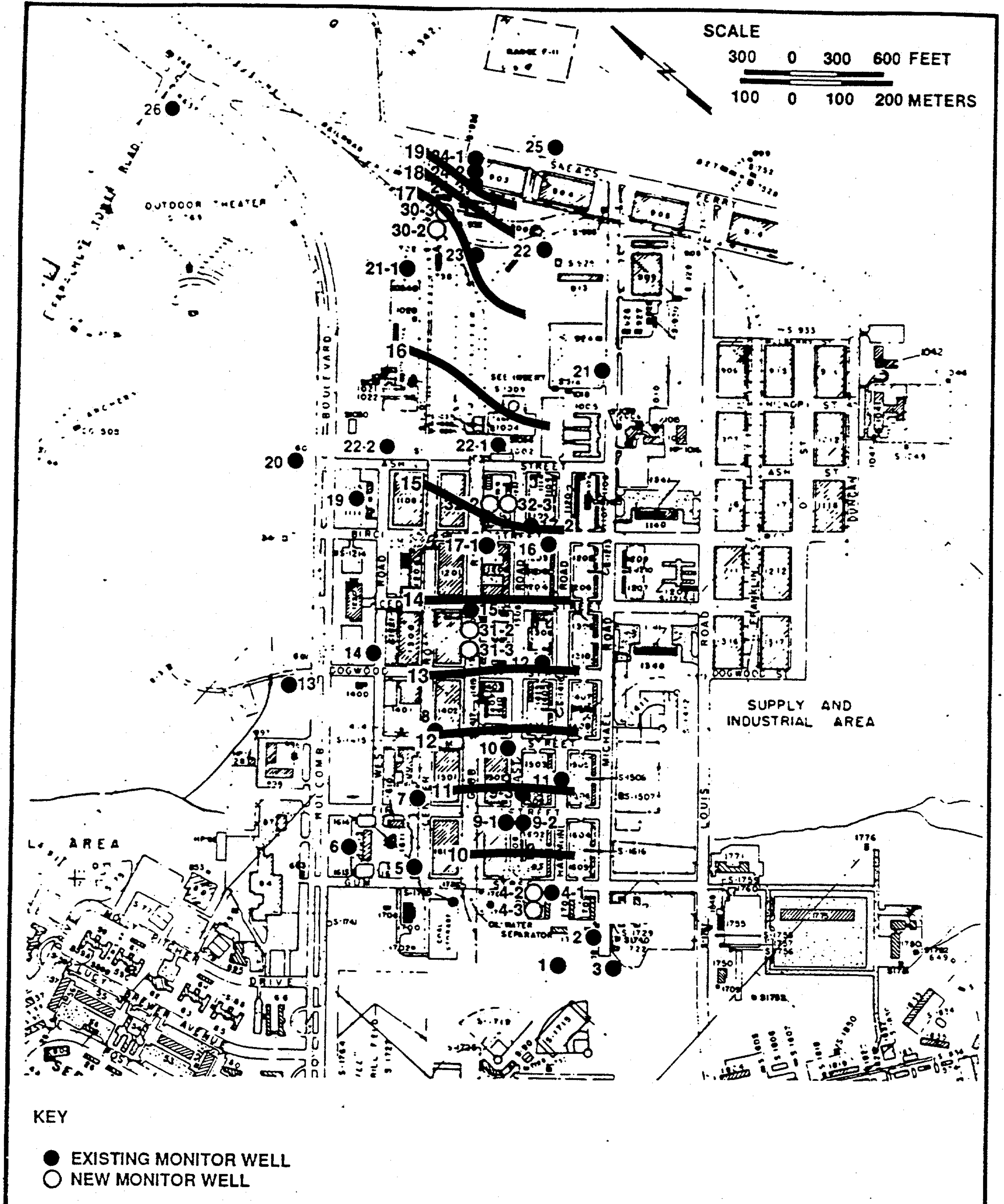


Figure 4-8
POTENTIOMETRIC SURFACE – DEEP WELLS
(2-20-91)

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE

surficial aquifer at HPIA is approximately 0.003 feet/foot. Specifically, the northern and southern portions of HPIA exhibit a horizontal hydraulic gradient of 0.003 feet/foot. However, the west-central portion of HPIA exhibits a horizontal hydraulic gradient of approximately 0.004 feet/foot (ESE, 1991). These horizontal hydraulic gradients compare favorably with previously reported values by Harned et. al. (1989) and ESE (1988).

Hydraulic gradients were also calculated for the deep and intermediate zones of the Castle Hayne aquifer. Due to there being fewer measured points in these zones, the gradients are calculated from one end of the site to the other between well clusters four and 24 (wells 4-2 and 24-2 for the intermediate, and 4-3 and 24-3 for the deep). The calculated gradient for the intermediate zone was 0.0015 feet/foot and for the deep zone the gradient was 0.0021 feet/foot. All gradients were calculated using the Feb. 1991 data which is presented in **Table 4-1**.

Vertical flow gradients were determined at monitoring well cluster locations by comparing water level measurements taken from shallow, intermediate, and deep monitoring wells. The shallow monitoring wells are approximately 25 feet deep, the intermediate monitoring wells are approximately 75 feet deep, and the deep monitoring wells are approximately 150 feet deep. The monitoring well clusters include HPGW4-1, 4-2, 4-3; HPGW9-1, 9-2, 9-3; HPGW17-1, 17-2, 17-3; HPGW24-1, 24-2, 24-3; HPGW30-2, 30-3; HPGW31-2, 31-3; and HPGW32-2, 32-3. The -1, -2, and -3 suffixes denote shallow, intermediate, and deep wells, respectively.

In general, the water levels within the intermediate and deep well of each well cluster are nearly the same with the exception of cluster 24 which shows an upward gradient. This data reflects the fact that the intermediate and deep zones behave hydrologically as one unit.

The vertical gradient between the surficial aquifer and the Castle Hayne aquifer is in the downward direction and increases as you move upgradient across the site. This downward gradient is most pronounced in cluster 24. The occurrence of this downward gradient is most likely a result of pumping from the Castle Hayne for potable uses and provides the hydrologic mechanism to carry contaminants from the shallow to the Castle Hayne. No pumping of potable wells is currently occurring in the Hadnot Point Area, however it continues outside of the area. The closest producing wells are located to the northwest (approximately 2,500 feet upgradient of the area) and accounts for the increased downward gradient in this direction.

4.3.4 Hydraulic Conductivity

Hydraulic conductivities were determined for the surficial and Castle Hayne aquifers. Surficial aquifer hydraulic conductivity was determined by O'Brien & Gere Engineers, Inc. using short term pump tests on two recovery wells near the fuel farm. These tests yielded an average transmissivity value of 500 gallons per day per foot (gpd/foot). Assuming a saturated thickness of 19-22 ft, this yields an average horizontal hydraulic conductivity of approximately 3.35 feet/day.

To determine aquifer characteristics in the Castle Hayne, a 72 hour pumping test performed at HPIA by ESE in 1987. This test indicates average transmissivity and storage coefficient values of 9.6×10^3 gpd/ft and 8.8×10^{-4} respectively, for the limestone portion of the deep (Castle Hayne) aquifer. These values are in general agreement with those reported by the USGS (Harned et. al., 1989). Horizontal hydraulic conductivity for the Castle Hayne in this area is reported by the USGS to be an average of 35 feet/day with a range between 19-82 feet/day (Harned et. al., 1989).

Analysis of the ESE pumping test data indicates that the portion of the deep aquifer screened by Camp Lejeune potables wells (100-200 ft bls) is semi-confined. Recharge occurs through a clayey layer overlying the aquifer. Vertical hydraulic conductivity for this layer is estimated at 4.6×10^{-3} foot/day, typical of silty sands and silty clays.

4.4 METEOROLOGY

The MCB Camp Lejeune, which is located in the North Carolina coastal plain area, is influenced by mild winters and humid summers with typically elevated temperatures. Rainfall typically averages more than 50 inches a year, and potential evapotranspiration varies from 34 to 36 inches of rainfall equivalent per year (Narkunas, 1980; Water and Air Research, 1983). The wet seasons typically occur during the winter and summer months. During January, typical temperature ranges are reported to be from 33°F to 53°F; and during July the typical temperature ranges are reported to be from 71°F to 88°F (Odell, 1970; Water and Air Research, 1983). During the warm seasons, winds are generally from the south-southwest; while during the cooler seasons they are generally from the north-northwest. The area has a relatively long growing season of 230 days. **Figure 4-9** is a summary of regional climatic conditions (Water and Air Research, 1983; NAVFACENGCOM, 1975).

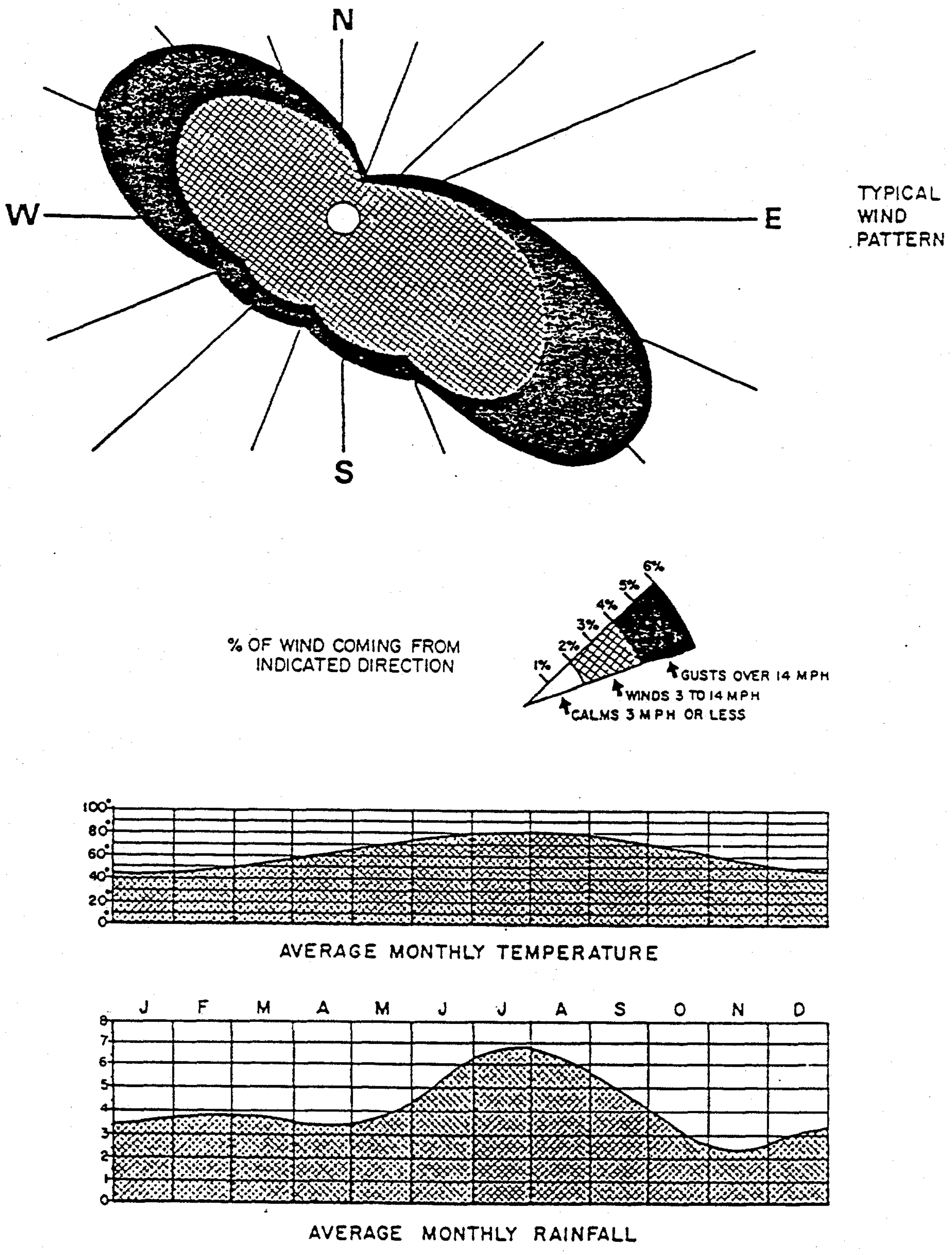


Figure 4-9
REGIONAL CLIMATIC CONDITIONS AT CAMP LEJEUNE

SOURCE: NAVFACENGCOM, 1975.

MARINE CORPS BASE
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5.0 RESULTS OF INVESTIGATION

This report is the result of three investigative phases which have been completed at the Hadnot Point Industrial Area. These investigations have included a records search to determine potential contaminant sources and have examined soil gas data, shallow soil samples and shallow and deep groundwater samples. The results have been summarized in the section by sample medium, and are broken down within each medium by area of investigation. The results of the pump test are also presented in **Section 5.4**.

QA/QC samples were collected and analyzed during the Supplemental Characterization in accordance with EPA procedures as required by the Federal Facilities Agreement. The results of these analysis is presented in the **Section 5.4**. One of the main concerns noted during the QA/QC program was the finding of laboratory contaminants in many of the QA/QC samples. These compounds (acetone, methylene chloride and carbon disulfide) were detected in many of the laboratory blanks as well as in field samples. Most of the hits were at concentrations which were below the certified reporting level of the analytical instrument. These compounds are routinely used within the laboratory for glassware cleaning, equipment cleaning and for sample extraction. No widespread use of these compounds was noted in the Record Search which would account for their presence in so many samples. Therefore, the presence of these compounds in the analytical samples is being attributed to laboratory contamination.

5.1 RECORDS SEARCH

ESE survey crews conducted a detailed records and physical search within HPIA to identify the presence of potential waste solvent disposal features/structures. The physical facilities of the buildings (i.e, floor drains, sumps, and unmarked pipe lines) were inspected to identify the general purpose of each and note any interconnections. The records search identified several primary potential sources of contamination. They are:

- An underground tank utilized for storage of trichloroethene (TCE) adjacent to Bldg. 902. The area around Bldg. 902 was identified as a long-term vehicle maintenance area.
- The Base Maintenance Shop (Bldg 1202), located in the north-central portion of HPIA, was identified as a potential contaminant source because of documented VOC storage and usage.
- Bldg. 1602, located in the south-central portion of HPIA, was identified as a heavy vehicle maintenance facility with a long term record of VOC storage and usage.

5.2 SOILS INVESTIGATION

The shallow soils at the HPIA were investigated using soil gas screening and soil borings for the collection of analytical samples. Soil gas results were used to locate potential source locations following the record search and to aid in determining the location of groundwater monitoring wells. Analytical samples collected from soil borings were used to characterize the soils in the source areas as identified during the soil gas survey.

5.2.1 Soil Gas Survey

Each of the areas identified by the records search as potential sources of VOCs was investigated with the use of the soil gas technique. This section discusses those areas in which VOC contamination was detected in the soil gas. Original soil gas sampling location maps and all soil gas analytical data is presented in **Appendix P**.

Bldgs. 901, 902, and 903

The IAS identified the presence of a 440-gallon (gal) underground tank at Bldg. 901. This tank was used for storage of TCE that was used to degrease engines. Available information at the time of the IAS indicated that the contents of the tank had been drained and sent to the Defense Property Disposal Office (DPDO), which now operates under the title of the Defense Reutilization and Marketing Office (DRMO). No information regarding spills, leaks, or discharges from the tank while it was in active use was available.

Additional inquiries conducted as part of the current Confirmation Study reconfirmed the presence of the underground tank adjacent to the eastern side of Bldg. 901; it remains in-place but is reportedly empty and/or filled with sand.

The documented presence of the underground tank and the use of TCE strongly indicated that a soil gas investigation should be conducted in the area between Bldgs. 902 and 903. Subsequent conversations, during the well drilling phase of the field efforts, with active Marine Corps staff working in the vicinity of Bldgs. 901, 902, and 903 indicated that degreasing of engines took place over a large area between Bldgs. 902 and 903 and the railroad lines.

The results of the soil gas investigation **(Figure 5-1)** identified the presence of TCE vapors in the soil column in the vicinity of the underground tank, verifying the records search data.

Bldg. 1100

This building was a small service station when it was first constructed (1943). It was most recently used as a printing plant. An empty drum labeled as 1,1,2,2-tetrachloroethane was found adjacent to the building at the time of the investigation. The field staff was verbally informed that this drum had developed a leak and was placed outside; the contents of the drum drained onto the ground. A single value of TCE was detected to the west of Bldg. 1100, although two samples obtained to the

1911

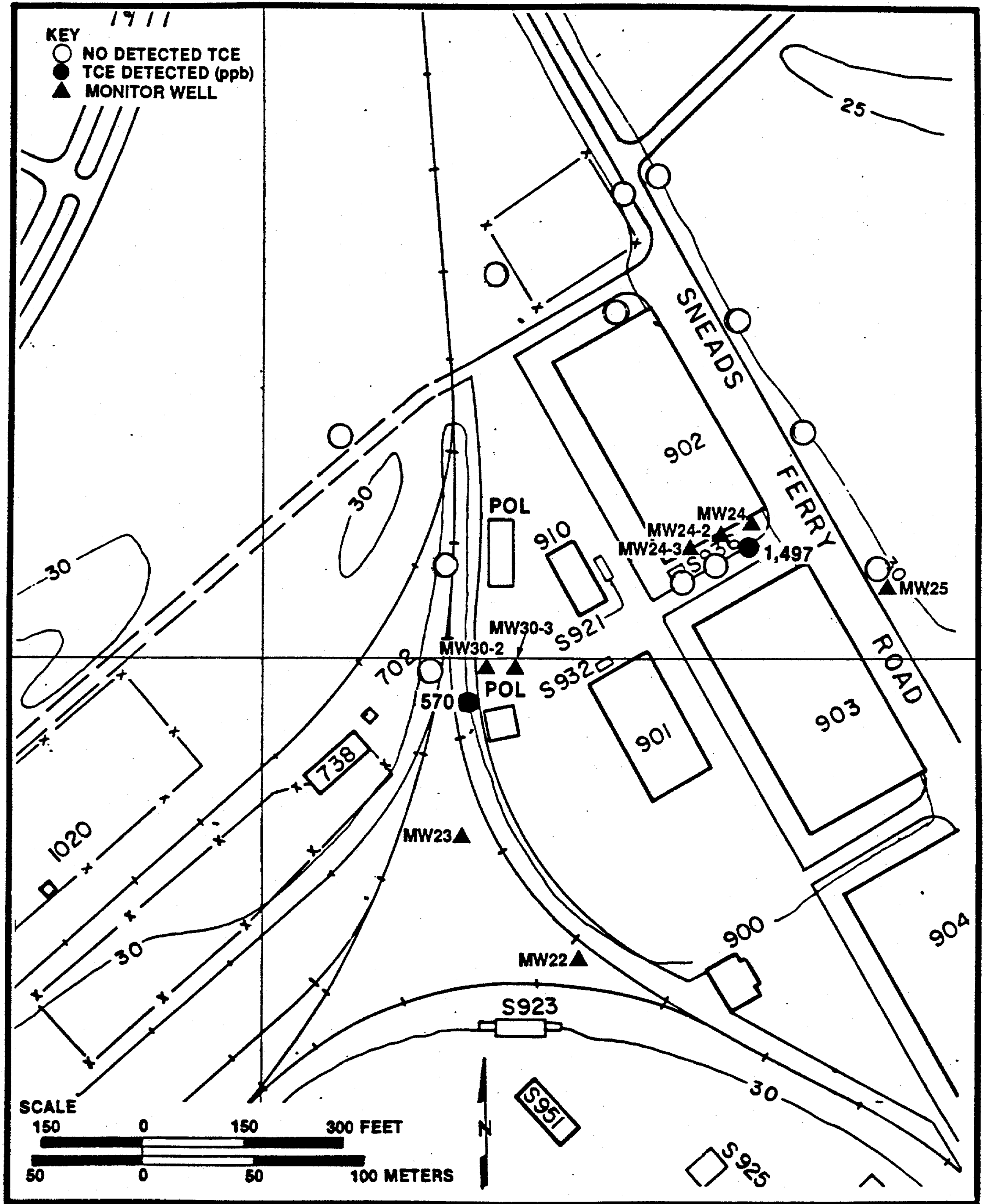

Figure 5-1
SOIL GAS FINDINGS – BLDGS. 901, 902, AND 903 – CONFIRMATORY STUDY

SOURCE: ESE.

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east of the building had high detection limits due to the presence of other unknown compounds.

Bldgs. 1101, 1102, 1202, 1300, 1301, and 1302

The IAS identified and described several of the industrial/maintenance activities that have or are now occurring at Bldg. 1202, Base Maintenance Shop. No specific contaminant sources were identified by the database available at that time. Further inspection of Bldg. 1202 as part of the Confirmation Study identified a number of potential sources of VOC contamination. The most significant areas warranting further study are the location(s) of former underground storage tanks, and storage areas for drums and other containers of waste thinners, paints, and solvents. Currently, the handling of potentially toxic or hazardous materials at Bldg. 1202 appears to be within applicable protocols and guidelines. The area is well kept and visually clean. However, because of past practices, and the fact that pavement covers most of the area surrounding the structures precluding inspection of possible ground staining, the area surrounding Bldg. 1202 was included in the soil gas investigation. Bldgs. 1101, 1102, 1301, and 1302 are general-purpose storage warehouses and are involved in the investigation only because of proximity to Bldg. 1202. Bldg. 1300 is a cold storage facility and does contain a maintenance shop. It was included as a separate potential source of contaminants.

TCE was detected in the soil vapors over a major portion of the western and northwestern areas of the Bldg. 1202 complex, with values ranging from 15 to 36,770 parts per billion (ppb). The highest concentrations were located at the northern and southwestern ends of the building (**Figure 5-2**). This corresponds closely with use and disposal history of solvents at this facility. A single value of TCE was detected on the eastern side of Bldg. 1300, but may be related to the TCE seen throughout the western side of Bldg. 1202 and adjacent facilities.

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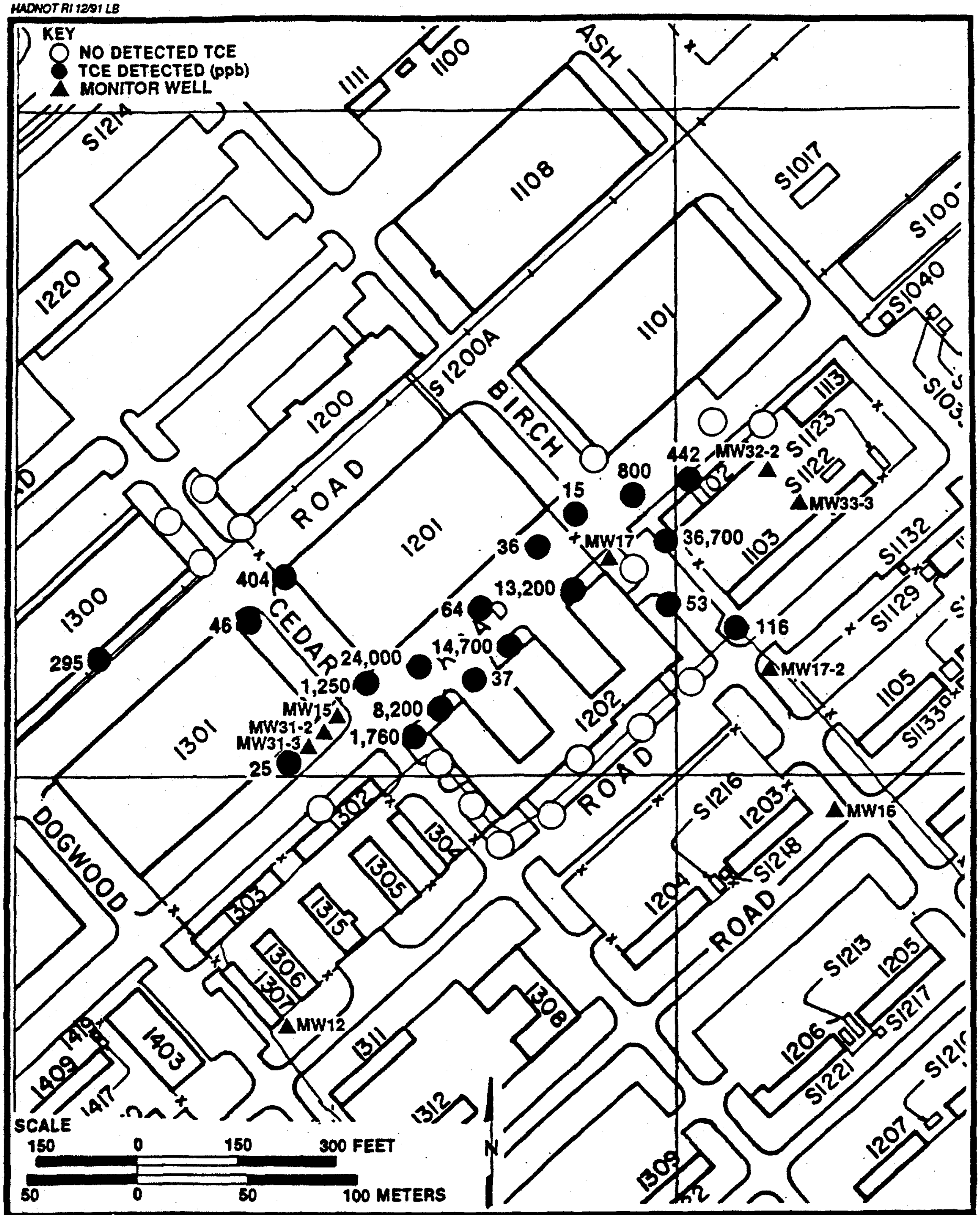

Figure 5-2
SOIL GAS FINDINGS – BLDGS. 1101, 1102, 1202, 1300, 1301, AND 1302 – CONFIRMATORY STUDY

SOURCE: ESE.

MARINE CORPS BASE
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Bldgs. 1502, 1601, and 1602

The area encompassed by Bldgs. 1502, 1601, and 1602 has been a vehicle maintenance and repair facility since initial construction (circa 1942-1943). The IAS identified the presence of a 440-gal underground storage tank of TCE at Bldg. 1601, the current status of which is unknown. The Confirmation Study records search documented heavy solvent and petroleum, oil, and lubricant (POL) usage. In addition, heavy ground staining was observed. The results of the soil gas investigation (**Figure 5-3**) strongly corroborate the records search data. The soil vapors in the area between Bldgs. 1601 and 1502 are highly contaminated with TCE, with levels as high as 703,000 ppb. In addition, soil gas sampling stations on all sides of Bldg. 1502 recorded TCE contamination. Similarly, TCE contamination was detected at sampling stations on the southern and eastern sides of Bldg. 1601. High levels of TCE contamination in the soil adjacent to these buildings resulted in a high-priority classification of this study site in the following investigative efforts.

Bldgs. 1709 and 1710

The area encompassing Bldgs. 1709 and 1710 has been a combat vehicle maintenance area, paint shop, and general maintenance area for much of its history. Underground "waste" tanks were identified at Bldg. 1709; the current status of these tanks is not known. Bags of soil marked as contaminated were found to the south of Bldg. 1709. These bags were exposed to weather and were in very poor condition.

The soil gas investigation identified TCE in the soil vapors in only two locations, both adjacent to the bags of contaminated soil. However, in a large number of samples obtained from an area to the south of Bldg. 1710, the method detection limit was extremely high due to dilution of the samples in an attempt to resolve a large unknown peak in the data. Although not specifically analyzed, it appears that a large amount of O&G is present in the soil in the vicinity of these samples. TCE may be present, but was not detected because of the sample dilution process.

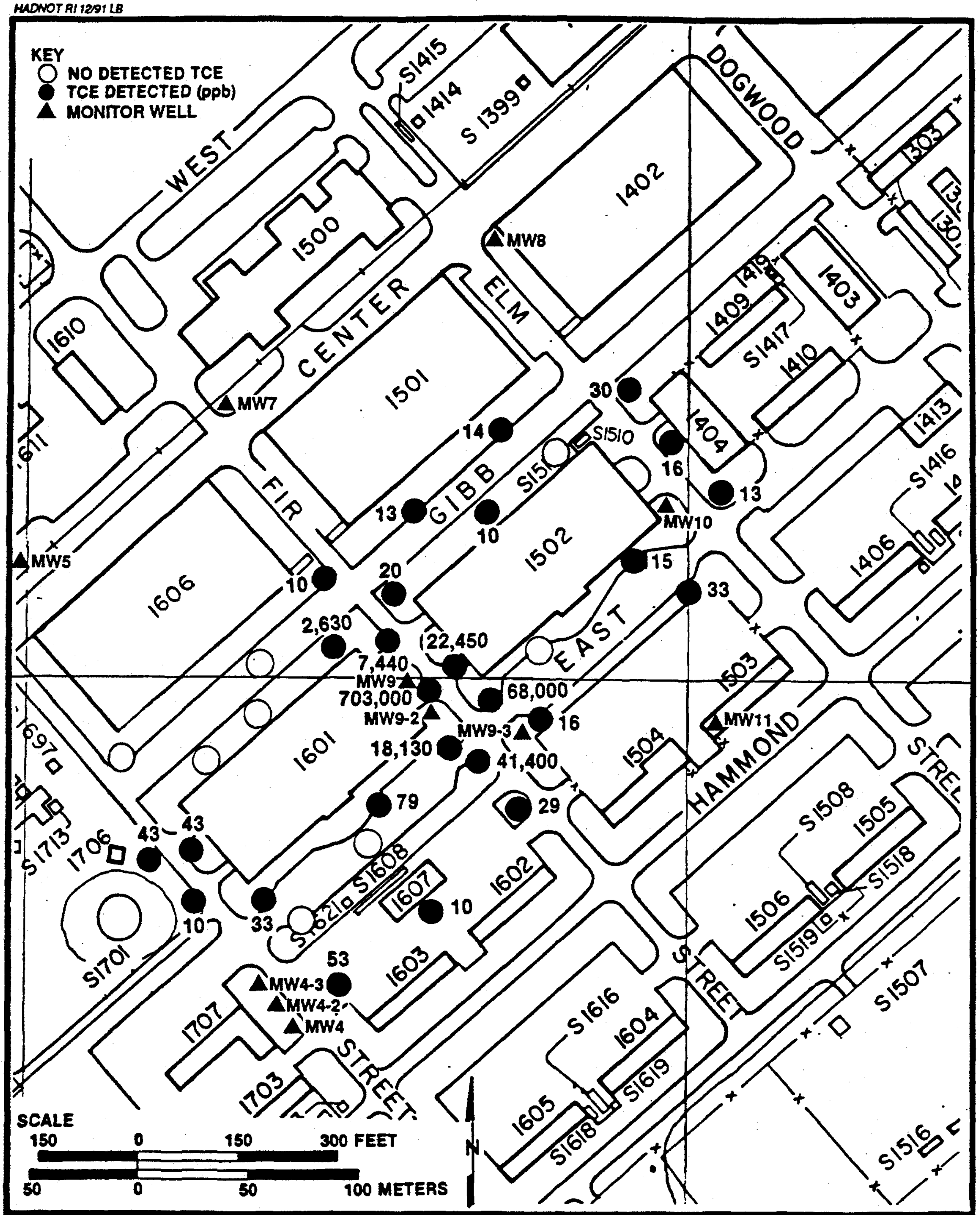

Figure 5-3
SOIL GAS FINDINGS – BLDGS. 1502, 1601, AND 1602 – CONFIRMATORY STUDY

SOURCE: ESE.

MARINE CORPS BASE
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5.2.2 Soil Borings

A total of 30 shallow soil borings were performed at HPIA at Camp Lejeune in January, 1991. The objective of the soil sampling program was to evaluate the extent of shallow (above the water table) soil contamination in three areas of concern at HPIA. These areas are located in the vicinity of Buildings 1601, 902, and 1202. **Figures 3-1**, **3-2**, and **3-3** show the approximate locations of the soil borings.

Each soil boring was advanced to the first encountered water, which varied depending on the boring location. Continuous split spoon sampling was conducted while vapor monitoring with an photoionization detector (PID). Three samples were selected from each boring for chemical analysis, based upon the three highest readings of organic vapor levels recorded. In cases where the PID recorded levels of organic vapors equivalent to background atmospheric concentrations, samples were selected according to visual inspection for possible contamination. In the absence of any visible "contamination", the three samples were selected randomly. Where the water table proved to be too shallow to permit three different sampling intervals, samples were decreased in number accordingly.

A total of 96 soil samples were collected including nine duplicate samples. Nine of the analytical samples collected (including one duplicate sample) were analyzed for full Target Compound List (TCL) parameters. The remaining samples were analyzed for volatile organic compounds (TCL VOAs), pesticides and PCBs, and Toxicity Characteristic Leaching Procedure (TCLP) metals.

The analytical results presented in the following text are grouped according to study areas of interest. All soils data are presented in **Appendix H**. The significance of the analytical data will be discussed in the Risk Assessment for HPIA. A discussion of the QA/QC data including the blanks is presented in **Appendix G**.

Building 902

Soil borings HBSB-1 through HBSB-10 were completed in the vicinity of this building. Five of these borings were completed along or near the southeast wall where a buried TCE tank was reported during the record search. The locations of these soil borings is presented in **Figure 3-1**. Analytical hits for volatile, semi-volatile and pesticide compounds are presented in **Table 5-1**. Full soils analytical data are presented in **Appendix H.**

A total of 27 samples were collected and analyzed for volatile organic compounds. Four of these samples were collected in duplicate for QA purposes. Methylene chloride and Acetone were detected in 19 of these samples. These compounds were mainly reported as unquantifiable identified compounds (UIC) which were identified at concentrations below the certified reporting limit; or were also found in the accompanying analytical field blanks. Both these compounds are routinely used for laboratory analysis or glassware cleaning and are not chemicals used routinely at the HPIA. They therefore are assumed to be laboratory contaminants. Only one boring (HPSB-5) located near the reported TCE tank contained quantifiable concentrations of VOCs. The samples collected from the depths of 2 to 4 feet and 4 to 6 feet contained 1,2-dichloroethene (1,2-DCE) at concentrations of 55 mg/kg and 120 mg/kg respectively. The sample collected from 4 to 6 feet also contained TCE (120 mg/kg). Other unquantifiable VOC's included chloromethane (HPSB-1), TCE (HPSB-4), 2-hexanone (HPSB-10) and toluene (HPSB-5).

The sample collected from the 0 to 2-foot depth of boring HPSB-6 contained quantifiable concentrations of phenanthrene (500 mg/kg), fluoranthene (690 mg/kg), and pyrene (530 mg/kg). Other unquantifiable UICs were identified in this sample and the sample collected from 0 to 2 feet in boring HPSB-1. As these were the only samples in this area analyzed for the full TCL parameters, the horizontal and vertical extent of soil contamination cannot be readily defined for these parameters.

Table 5-1. Soil Sample Analytical Hits - Bldg 902 Area (pg 1 of 3)

	SB-1				SB-2			SB-3		SB-4			
	HPSO1-1	HPSO1-1D (HPSOD1)	HPSO1-2	HPSO1-3	HPSO2-1	HPSO2-2	HPSO2-2D (HPSOD2)	HPSO3-1	HPSO3-1D (HPSOD-3)	HPSO4-1	HPSO4-2	HPSO4-2D (HPSOD-4)	HPSO4-3
COMPOUND depth:	0-2'	0-2'	2-4'	4-6'	0-2'	2-4'	2-4'	0-2'	0-2'	0-2'	2-4'	2-4'	4-6'
Chloromethane	11U	11U	11U	11U	12U	11U	11U	11U	11U	7BJ	9BJ	12U	11U
Methylene Chloride	1BJ	2BJ	1BJ	2BJ	2BJ	2BJ	2BJ	2BJ	2BJ	6U	6U	6U	6U
Acetone	8BJ	11U	9BJ	11U	18B	11U	11U	11U	11U	5BJ	12U	77B	54B
1,2-Dichloroethene (total)	5U	6U	6U	5U	6U	6U	6U	5U	5U	6U	6U	6U	6U
Trichloroethene	5U	6U	6U	5U	6U	6U	6U	5U	5U	6U	4J	6U	6U
2-Hexanone	11U	11U	11U	11U	12U	11U	11U	11U	11U	11U	12U	12U	11U
Toluene	5U	6U	6U	5U	6U	6U	6U	5U	5U	6U	6U	6U	6U
Acenaphthylene	370U	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	370U	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	94J	290J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	370U	67J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	100J	360J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	94J	320J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	41J	100J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	44J	110J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	39J	59J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	48JX	82JX	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	370U	65J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	370U	37J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	370U	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: All concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Table 5-1. Soil Sample Analytical Hits - Bldg 902 Area (pg 2 of 3)

	SB-5			SB-6			SB-7			SB-8		
	HPSO5-1	HPSO5-2	HPSO5-3	HPSO6-1	HPSO6-2	HPSO6-3	HPSO7-1	HPSO7-2	HPSO7-3	HPSO8-1	HPSO8-2	HPSO8-3
COMPOUND depth:	0-2'	2-4'	4-6'	0-2'	2-4'	4-6'	0-2'	2-4'	4-6'	0-2'	2-4'	4-6'
Chloromethane	11U	12U	12U	11U	12U	12U	11U	11U	12U	12U	11U	11U
Methylene Chloride	6U	6U	6U	6U	6U	6U	2BJ	4BJ	2BJ	2BJ	6U	2BJ
Acetone	11U	12U	4BJ	21B	35	13B	27B	23B	15B	12U	11U	6J
1,2-Dichloroethene (total)	6U	55 1	20	6U	6U	6U	6U	6U	6U	6U	6U	6U
Trichloroethene	6U	6U 1	20	6U	6U	6U	6U	6U	6U	6U	6U	6U
2-Hexanone	11U	12U	12U	11U	12U	12U	11U	11U	12U	12U	11U	11U
Toluene	6U	10	4J	6U	6U	6U	6U	6U	6U	6U	6U	6U
Acenaphthylene	NA	NA	NA	350U	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	48J	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	500	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	NA	NA	NA	180J	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	690	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	530	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	280J	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	NA	NA	NA	260J	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	250J	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	210J	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	240J	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA	130J	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	110J	NA	NA	NA	NA	NA	NA	NA	NA

Note: All concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Table 5-1. Soil Sample Analytical Hits - Bldg 902 Area (pg 3 of 3)

	SB-9			SB-10		
	HPSO9-1	HPSO9-2	HPSO9-3	HPSO10-1	HPSO10-2	HPSO10-3
COMPOUND *depth:*	0-2'	2-4'	4-6'	0-2'	2-4'	4-6'
Chloromethane	11U	11U	12U	12U	12U	12U
Methylene Chloride	6U	2BJ	2BJ	2BJ	2BJ	3BJ
Acetone	6J	20	13	5J	9J	12U
1,2-Dichloroethene (total)	6U	6U	6U	6U	6U	6U
Trichloroethene	6U	6U	6U	6U	6U	6U
2-Hexanone	11U	11U	12U	12U	12U	1J
Toluene	6U	6U	6U	6U	6U	6U
Acenaphthylene	NA	NA	NA	380U	NA	NA
Fluorene	NA	NA	NA	380U	NA	NA
Phenanthrene	NA	NA	NA	380U	NA	NA
Anthracene	NA	NA	NA	380U	NA	NA
Fluoranthene	NA	NA	NA	380U	NA	NA
Pyrene	NA	NA	NA	380U	NA	NA
Benzo(a)anthracene	NA	NA	NA	380U	NA	NA
Chrysene	NA	NA	NA	380U	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	380U	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	380U	NA	NA
Benzo(a)pyrene	NA	NA	NA	380U	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA	380U	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	380U	NA	NA

Note: All concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

No pesticide compounds were detected in any samples collected from this area. Select metals (aluminum, calcium, and iron) were abundant in all three soil samples analyzed in concentrations greater than 1,000 mg/kg. Many of the other metals analyzed for were also detected, but were detected in concentrations below the certified detection limits. TCLP analysis of 27 samples showed detectable quantities of virtually all analytes with the exception of mercury and silver, which were not detected in any sample. Those analytes which were detected typically were detected in concentrations below the certified detection limit.

Building 1202

Soil borings HBSB-11 through HBSB-20 were completed in the vicinity of this building. The locations of these soil borings is presented in **Figure 3-2**. analytical hits for volatile, semi-volatile and pesticide compounds are presented in **Table 5-2.** Full soils analytical data are presented in **Appendix H**.

A total of 32 samples were collected and analyzed for volatile organic compounds. Two of these samples were collected in duplicate for QA purposes. Methylene chloride and/or Acetone were detected in 29 of these samples. These compounds were mainly reported as UICs or were also found in the accompanying analytical field blanks. Both these compounds are routinely used for laboratory analysis or glassware cleaning and are not chemicals used routinely at the HPIA. They therefore are assumed to be laboratory contaminants. Only one boring (HPSB-14) located adjacent to building S1122 across the street from building 1202 contained quantifiable concentrations of VOCs. The sample collected from the depths of 8 to 10 feet contained ethylbenzene (62 mg/kg) and xylene (580 mg/kg). Other unquantifiable VOC's included chlorobenzene (HPSB-11 [4-6 ft] and HPSB-13 [0-2 ft]) and TCE (HPSB-15 [0-2 ft] and HPSB-16 [0-2 ft and 8-10 ft]).

None of the three samples analyzed for semi-volatile compounds revealed any quantifiable concentrations. Unquantifiable UICs were identified in the three samples submitted.

Table 5-2. Soil Sample Analytical Hits - Bldg 1202 Area (page 1 of 3)

	SB-11				SB-12			SB-13			SB-14		
	HPSO11-1	HPSO11-2	HPSO11-3	HPSO11-3D (HPSOD-5)	HPSO12-1	HPSO12-2	HPSO12-3	HPSO13-1	HPSO13-2	HPSO13-3	HPSO14-1	HPSO14-2	HPSO14-3
COMPOUND depth:	0-2'	2-4'	4-6'	4-6'	0-2'	2-4'	8-10'	0-2'	6-8'	8-10'	2-4'	4-6'	8-10'
Methylene Chloride	5U	6U	2BJ	2BJ	1BJ	3BJ	4BJ	4BJ	2BJ	3BJ	3BJ	2BJ	10BJ
Acetone	360BE	72B	19B	22B	20B	9J	13	8BJ	47B	16B	20B	21B	100B
Trichloroethene	5U	6U	6U	6U	6U	6U	6U	6U	5U	6U	6U	6U	30U
Chlorobenzene	5U	6U	3J	1J	6U	6U	6U	1J	5U	6U	6U	6U	30U
Ethylbenzene	5U	6U	6U	6U	6U	6U	6U	6U	5U	6U	6U	6U	62
Total Xylenes	5U	6U	6U	6U	6U	6U	6U	6U	5U	6U	1J	6U	580
1,4-Dichlorobenzene	350U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	72J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	72J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	63J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	210J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	350U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	350U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	200J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	120J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	70J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	95J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	350U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	120J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	79J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	64J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	37J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	350U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	8.4U	12	9.3U	9.4U	8.9U	8.9U	9.3U	9.1U	8.5U	9.3U	9.0U	8.9U	9.4U
Endosulfan I	8.4U	16	9.3U	9.4U	8.9U	8.9U	9.3U	9.1U	8.5U	9.3U	9.0U	8.9U	9.4U
Dieldrin	17U	18U	19U	19U	18U	18U	19U	18U	17U	19U	18U	18U	19U
4,4'-DDE	17U	18U	19U	19U	18U	18U	19U	18U	17U	19U	18U	18U	19U
4,4'-DDT	17U	22	19U	19U	18U	18U	19U	18U	17U	19U	18U	18U	19U
Aroclor-1260	290	1800	1000	670	180U	180U	190U	180U	170U	190U	180U	180U	190U

Note: All Concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
E = Concentration exceeded calibration
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Table 5-2. Soil Sample Analytical Hits - Bldg 1202 Area (page 2 of 3)

	SB-15			SB-16			SB-17				SB-18		
	HPSO15-1	HPSO15-2	HPSO15-3	HPSO16-1	HPSO16-2	HPSO16-3	HPSO17-1	HPSO17-1D (HPSOD6)	HPSO17-2	HPSO17-3	HPSO18-1	HPSO18-2	HPSO18-3
COMPOUND depth:	0-2'	6-8'	8-10'	0-2'	6-8'	8-10'	0-2'	0-2'	6-8'	8-10'	4-6'	6-8'	8-10'
Methylene Chloride	3BJ	6U	6U	6U	6U	6U	6U	5U	5U	3BJ	6U	4BJ	6U
Acetone	11U	11U	25B	23	15	43	12	11U	22	20	59	39	10J
Trichloroethene	2J	6U	6U	2J	6U	3J	6U	5U	5U	6U	6U	6U	6U
Chlorobenzene	6U	6U	6U	6U	6U	6U	6U	5U	5U	6U	6U	6U	6U
Ethylbenzene	6U	6U	6U	6U	6U	6U	6U	5U	5U	6U	6U	6U	6U
Total Xylenes	6U	6U	6U	6U	6U	6U	6U	5U	5U	6U	6U	6U	6U
1,4-Dichlorobenzene	48J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	210J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	43J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	72J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	370J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	290J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	140J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	170J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	54J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	140J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	150JX	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	140J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	82J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	72J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	8.8U	8.9U	9.0U	8.9U	8.8U	9.7U	8.9U	8.8U	8.8U	9.5U	9.1U	8.9U	9.0U
Endosulfan I	8.8U	8.9U	9.0U	8.9U	8.8U	9.7U	8.9U	8.8U	8.8U	9.5U	9.1U	8.9U	9.0U
Dieldrin	38	18U	18U	18U	18U	19U	18U	18U	18U	19U	18U	18U	18U
4,4'-DDE	97	18U	18U	18U	18U	19U	18U	18U	18U	19U	18U	18U	18U
4,4'-DDT	140	18U	18U	18U	18U	19U	18U	18U	18U	19U	18U	18U	18U
Aroclor-1260	180U	180U	180U	180U	180U	190U	180U	180U	180U	190U	180U	180U	180U

Note: All Concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
E = Concentration exceeded calibration
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Table 5-2. Soil Sample Analytical Hits - Bldg 1202 Area (page 3 of 3)

	SB-19			SB-20		
	HPSO19-1	HPSO19-2	HPSO19-3	HPSO20-1	HPSO20-2	HPSO20-3
COMPOUND depth:	0-2'	2-4'	8-10'	0-2'	6-8'	8-10'
Methylene Chloride	8U	6U	6U	6U	5U	6U
Acetone	15J	15	12U	19	14	13
Trichloroethene	8U	6U	6U	6U	5U	6U
Chlorobenzene	8U	6U	6U	6U	5U	6U
Ethylbenzene	8U	6U	6U	6U	5U	6U
Total Xylenes	8U	6U	6U	6U	5U	6U
1,4-Dichlorobenzene	NA	NA	NA	47J	NA	NA
Acenaphthene	NA	NA	NA	370U	NA	NA
Dibenzofuran	NA	NA	NA	370U	NA	NA
Fluorene	NA	NA	NA	370U	NA	NA
Phenanthrene	NA	NA	NA	370U	NA	NA
Anthracene	NA	NA	NA	370U	NA	NA
Di-n-butylphthalate	NA	NA	NA	370U	NA	NA
Fluoranthene	NA	NA	NA	370U	NA	NA
Pyrene	NA	NA	NA	370U	NA	NA
Benzo(a)anthracene	NA	NA	NA	370U	NA	NA
Chrysene	NA	NA	NA	370U	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	370U	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	370U	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	370U	NA	NA
Benzo(a)pyrene	NA	NA	NA	370U	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA	370U	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	370U	NA	NA
Heptachlor epoxide	13U	8.9U	9.5U	8.9U	8.4U	9.0U
Endosulfan I	13U	8.9U	9.5U	8.9U	8.4U	9.0U
Dieldrin	26U	18U	19U	18U	17U	18U
4,4'-DDE	26U	18U	19U	18U	17U	18U
4,4'-DDT	26U	18U	19U	18U	17U	18U
Aroclor-1260	260U	180U	190U	180U	170U	180U

Note: All Concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
E = Concentration exceeded calibration
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Pesticide compounds were detected in samples from two soil borings (HPSB-11 and HPSB-15). In boring HPSB-11, these compounds included Arochlor-1260 (0 to 2 feet 290 mg/kg and 4 to 6 feet 670 mg/kg), heptachlor epoxide (12 mg/kg 2 to 4 feet), endosulfan I (16 mg/kg 2 to 4 feet), and 4-4'-DDT (22 mg/kg 2 to 4 feet). Three compounds were detected in the sample collected from 0 to 2-foot depth in HPSB-15. These compounds were dieldrin (38 mg/kg), 4,4'-DDE (97 mg/kg), and 4,4'-DDT (140 mg/kg).

Select metals (aluminum, calcium, magnesium and iron) were abundant in two of the three soil samples analyzed in concentrations greater than 1,000 mg/kg. Many of the other metals analyzed for were also detected, with some being detected in concentrations below the certified detection limit. TCLP analysis of 29 samples showed detectable quantities of virtually all analytes with the exception of mercury and silver. There was one detectable concentration of mercury (1.0 mg/kg) in the sample collected from 4 to 6 feet in HPSB-11. Those analytes which were detected typically were detected in concentrations below the certified detection limit.

Building 1602

Soil borings HBSB-21 through HBSB-30 were completed in the vicinity of this building. TCE was detected in high concentration on all sides of this building during the soil gas investigation. The locations of these soil borings is presented in **Figure 3-3**. Analytical hits for volatile, semi-volatile and pesticide compounds are presented in **Table 5-3**. Full soils analytical data are presented in **Appendix H.**

A total of 33 samples were collected and analyzed for volatile organic compounds. Three of these samples were collected in duplicate for QA purposes. Methylene chloride and/or Acetone were detected in 32 of these samples. These compounds were mainly reported as UICs or were also found in the accompanying analytical field blanks. Both these compounds are routinely used for laboratory analysis or glassware cleaning and are not chemicals used routinely at the HPIA. They therefore are assumed to be laboratory contaminants. No other quantifiable concentration of

Table 5-3. Soil Sample Analytical Hits - Bldg 1602 Area (page 1 of 2)

	SB-21			SB-22				SB-23			SB-24				SB-25		
	HPSO21-1	HPSO21-2	HPSO21-3	HPSO22-1	HPSO22-1D (HPSOD-7)	HPSO22-2	HPSO22-3	HPSO23-1	HPSO23-2	HPSO23-3	HPSO24-1	HPSO24-1D (HPSOD-9)	HPSO24-2	HPSO24-3	HPSO25-1	HPSO25-2	HPSO25-3
COMPOUND depth:	0-2'	2-4'	4-6'	0-2'	0-2'	2-4'	4-6'	0-2'	2-4'	4-6'	0-2'	0-2'	4-6'	6-8'	0-2'	2-4'	6-8'
Chloromethane	11U	11U	13U	11U	3J	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
Bromomethane	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
Vinyl Chloride	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
Chloroethane	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
Methylene Chloride	2BJ	2BJ	2BJ	6U	6U	6U	6U	2BJ	6U	5U	4BJ	1J	6U	6U	5U	5U	6U
Acetone	5BJ	3BJ	17B	25	11J	26	31	11U	12U	5J	20	38B	14	40	10J	12	8J
Carbon Disulfide	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,1-Dichloroethene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,1-Dichloroethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,2-Dichloroethene (total)	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Chloroform	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,2-Dichloroethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
2-Butanone	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
1,1,1-Trichloroethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Carbon Tetrachloride	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Vinyl Acetate	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
Bromodichloromethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,2-Dichloropropane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
cis-1,3-Dichloropropene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Trichloroethene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	4J	5U	6U
Dibromochloromethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,1,2-Trichloroethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Benzene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
trans-1,3-Dichloropropene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Bromoform	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
4-Methyl-2-Pentanone	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	11U	11U	11U	11U	11U	11U
2-Hexanone	11U	11U	13U	11U	11U	11U	13U	11U	12U	11U	11U	2J	11U	11U	11U	11U	11U
Tetrachloroethene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
1,1,2,2-Tetrachloroethane	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Toluene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Chlorobenzene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Ethylbenzene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Styrene	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Total Xylenes	6U	6U	6U	6U	6U	6U	6U	6U	6U	5U	5U	5U	6U	6U	5U	5U	6U
Naphthalene	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	370U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dieldrin	18U	18U	20U	18U	18U	18U	21U	92	18U	17U	17U	17U	18U	18U	17U	17U	18U
4,4'-DDE	18U	18U	20U	18U	18U	18U	21U	78	18U	17U	17U	17U	18U	18U	17U	17U	18U
4,4'-DDT	18U	18U	20U	18U	18U	18U	21U	40	18U	17U	17U	17U	18U	18U	17U	17U	18U

Note: All concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

Table 5-3. Soil Sample Analytical Hits - Bldg 1602 Area (page 2 of 2)

	SB-26				SB-27			SB-28			SB-29			SB-30		
	HPSO26-1	HPSO26-1D (HPSOD-8)	HPSO26-2	HPSO26-3	HPSO27-1	HPSO27-2	HPSO27-3	HPSO28-1	HPSO28-2	HPSO28-3	HPSO29-1	HPSO29-2	HPSO29-3	HPSO30-1	HPSO30-2	HPSO30-3
COMPOUND depth:	0-2'	0-2'	6-8'	8-10'	2-4'	4-6'	8-10'	0-2'	2-4'	8-10'	0-2'	2-4'	10-12'	0-2'	2-4'	10-12'
Chloromethane	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Bromomethane	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Vinyl Chloride	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Chloroethane	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Methylene Chloride	3BJ	4BJ	4BJ	5BJ	4BJ	15B	5BJ	5U	6U	6U	14B	2BJ	8B	2BJ	2BJ	1BJ
Acetone	6J	11	9BJ	19	11U	30B	50B	97	3BJ	8BJ	6BJ	7BJ	6BJ	6BJ	7BJ	7BJ
Carbon Disulfide	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,1-Dichloroethene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,1-Dichloroethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,2-Dichloroethene (total)	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Chloroform	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,2-Dichloroethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
2-Butanone	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
1,1,1-Trichloroethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Carbon Tetrachloride	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Vinyl Acetate	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Bromodichloromethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,2-Dichloropropane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
cis-1,3-Dichloropropene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Trichloroethene	2J	2J	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Dibromochloromethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,1,2-Trichloroethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Benzene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
trans-1,3-Dichloropropene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Bromoform	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
4-Methyl-2-Pentanone	11U	11U	11U	11U	2J	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
2-Hexanone	11U	11U	11U	11U	11U	11U	12U	11U	11U	12U	11U	11U	11U	11U	11U	12U
Tetrachloroethene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
1,1,2,2-Tetrachloroethane	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Toluene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Chlorobenzene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Ethylbenzene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Styrene	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Total Xylenes	5U	5U	6U	6U	5U	5U	6U	5U	6U	6U	5U	5U	5U	6U	6U	6U
Naphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	220J	NA	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	300J	NA	NA
Dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	51J	NA	NA
Phenanthrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	110J	NA	NA
Dieldrin	17U	17U	18U	18U	17U	17U	19U	17U	18U	19U	18U	18U	18U	18U	18U	19U
4,4'-DDE	17U	17U	18U	18U	17U	17U	19U	17U	18U	19U	18U	18U	18U	18U	18U	19U
4,4'-DDT	17U	17U	18U	18U	17U	17U	19U	17U	18U	19U	18U	18U	18U	18U	18U	19U

Note: All concentrations ug/kg
Volatile, semivolatile and pesticide compounds only
NA = Not Analyzed
U = Not detected (Detection limit)
J = Unquantifiable identified compound
B = Detected also in associated blank

Source: ESE, 1992

volatile contaminants analyzed for were detected in any of these samples. Other unquantifiable VOC's included chloromethane (HPSB-22), TCE (HPSB-25 and HPSB-26), 2-hexanone (HPSB-24) and 4-methyl-2-pentanone (HPSB-27).

Neither of the two samples analyzed for semi-volatile compounds revealed any quantifiable concentrations. Four unquantifiable UICs were identified in one of the borings (HPSB-30).

Pesticide compounds were detected in the shallow sample (0 to 2 feet) from one soil boring (HPSB-23). These compounds included Dieldrin (92 mg/kg), 4,4'-DDE (78 mg/kg), and 4,4'-DDT (40 mg/kg).

Select metals (aluminum, calcium, and iron) were abundant in both soil samples analyzed in concentrations greater than 1,000 mg/kg. Many of the other metals analyzed for were also detected, with some being detected in concentration below the certified detection limit. TCLP analysis of 29 samples showed detectable quantities of virtually all analytes with the exception of mercury and silver. Those analytes which were detected typically were detected in concentrations below the certified detection limit.

5.3 GROUNDWATER INVESTIGATION

The 27 shallow groundwater monitoring wells at HPIA were sampled three times in 1987 (January, March, and May). The groundwater samples were analyzed for VOCs (EPA Method 624 parameters), lead and oil & grease. All shallow wells were again sampled in 1991 and samples were analyzed for full Target Contaminant List (TCL) parameters. Shallow well HPGW18 could not be sampled as it could not be located after numerous attempts to find it. All monitoring well locations within the HPIA are shown in **Figure 3-4**. A comparison of shallow groundwater volatile analytical hits is presented in **Table 5-4**.

Table 5-4. COMPARISON OF ANALYTICAL RESULTS - HITS ONLY SHALLOW GROUNDWATER MONITOR WELLS

	MCL PPB	HPGW1 1/87	HPGW1 3/87	HPGW1 5/87	HPGW1 1/91	HPGW2 1/87	HPGW2 3/87	HPGW2 5/87	HPGW2 1/91	HPGW3 1/87	HPGW3 3/87	HPGW3 5/87	HPGW3 1/91	HPGW4 1/87	HPGW4 3/87	HPGW4 5/87	HPGW4 1/91
Benzene	1	43	3.9			12				1.4				25	3.2		
Chloroform	19																
Chloromethane	-					5											
1,1-Dichloroethane	-																
Trans 1,2-Dichloroethene	70				73									1.9	2.2		.6J
Ethylbenzene	29	12								8.2	9						
Toluene	1,000	100	12			38								35	8.2		
1,1,1-Trichloroethane	200										13						
Trichloroethene	2.8				91									3.4			.9J
Trichlorofloromethane	-																
Vinyl Chloride	0.015																
Xylenes	400	62				28											

	MCL PPB	HPGW5 1/87	HPGW5 3/87	HPGW5 5/87	HPGW5 1/91	HPGW6 1/87	HPGW6 3/87	HPGW6 5/87	HPGW6 1/91	HPGW7 1/87	HPGW7 3/87	HPGW7 5/87	HPGW7 1/91	HPGW8 1/87	HPGW8 3/87	HPGW8 5/87	HPGW8 1/91
Benzene	1																
1,1-Dichloroethane	-																
Trans 1,2-Dichloroethene	70																
Ethylbenzene	29																
Toluene	1,000																
Trichloroethene	2.8																2J
Trichlorofloromethane	-													14	96		
Vinyl Chloride	0.015																
Xylenes	400																

	MCL PPB	HPGW9 1/87	HPGW9 3/87	HPGW9 5/87	HPGW9 1/91	HPGW10 1/87	HPGW10 3/87	HPGW10 5/87	HPGW10 1/91	HPGW11 1/87	HPGW11 3/87	HPGW11 5/87	HPGW11 1/91	HPGW12 1/87	HPGW12 3/87	HPGW12 5/87	HPGW12 1/91
Benzene	1	*	*														
Chloroform	.19	*	*		15					3.2	2.2						
Chloromethane	-	*	*														
1,1-Dichloroethane	-	*	*														
Trans 1,2-Dichloroethene	70	*	*		1,200					13	7.2						
Ethylbenzene	29	1,100	*		700												
Tetrachloroethene	.7	*	*												3.6		
Toluene	1,000	*	*		330J												
Trichloroethene	2.8	5,000	6,100		14,000		8.6			49	34						
Trichlorofloromethane	-	*	*														
Vinyl Chloride	0.015	*	*														
Xylenes	400	4,500	*		3,300												

Note: MCL's are for State of North Carolina
All concentrations ug/L
Analytical hits only presented
* - Elevated detection limit due to analytical dilution
- no MCL
NS = Not sampled

Table 5-4. COMPARISON OF ANALYTICAL RESULTS - HITS ONLY SHALLOW GROUNDWATER MONITOR WELLS (Continued)

	MCL PPB	HPGW13 1/87	HPGW13 3/87	HPGW13 5/87	HPGW13 1/91	HPGW14 1/87	HPGW14 3/87	HPGW14 5/87	HPGW14 1/91	HPGW15 1/87	HPGW15 3/87	HPGW15 5/87	HPGW15 1/91	HPGW16 1/87	HPGW16 3/87	HPGW16 5/87	HPGW16 1/91
Benzene	1																
1,1-Dichloroethane	-																
Trans 1,2-Dichloroethene	70																
Ethylbenzene	29												7				
Toluene	1,000																
1,1,1-Trichloroethane	200																
Trichloroethene	2.8												4J				
Trichlorofloromethane	-															7.1	
Vinyl Chloride	0.015																
Xylenes	400																

	MCL PPB	HPGW17 1/87	HPGW17 3/87	HPGW17 5/87	HPGW17 1/91	HPGW18 1/87	HPGW18 3/87	HPGW18 5/87	HPGW18 1/91	HPGW19 1/87	HPGW19 3/87	HPGW19 5/87	HPGW19 1/91	HPGW20 1/87	HPGW20 3/87	HPGW20 5/87	HPGW20 1/91
Benzene	1								Missing								
1,1-Dichloroethane	-								Missing								
Trans 1,2-Dichloroethene	70								Missing	2.5			.8J				
Ethylbenzene	29								Missing								
Toluene	1,000								Missing								
Trichloroethene	2.8								Missing	6			2J				
Tetrachloroethene	0.7								Missing				2J				
Trichlorofloromethane	-								Missing							7.1	
Vinyl Chloride	0.015								Missing								
Xylenes	400								Missing								

	MCL PPB	HPGW21 1/87	HPGW21 3/87	HPGW21 5/87	HPGW21 1/91	HPGW22 1/87	HPGW22 3/87	HPGW22 5/87	HPGW22 1/91	HPGW23 1/87	HPGW23 3/87	HPGW23 5/87	HPGW23 1/91	HPGW24 1/87	HPGW24 3/87	HPGW24 5/87	HPGW24 1/91
Benzene	1												24	2			3J
Chloroform	.19																65
Chloromethane	-													12			
1,1-Dichloroethane	-									830	6,100	7,100	8,900	6,400	4,300	4,000	42,000
1,2-Dichloroethane	.38																.8J
Trans 1,2-Dichloroethene	70																3J
Ethylbenzene	29				.9J								9				3J
Toluene	1,000																
1,1,1-Trichloroethane	200												13				13
Trichloroethene	2.8				3J					830	13,000	4,300	3,700	57			180
Trichlorofloromethane	-																
Vinyl Chloride	0.015												8	190		250	
Xylenes	400				5								41				10

Note: MCL's are for State of North Carolina
All concentrations ug/L
Analytical hits only presented
* - Elevated detection limit due to analytical dilution
- no MCL
NS = Not sampled

Table 5-4. COMPARISON OF ANALYTICAL RESULTS - HITS ONLY SHALLOW GROUNDWATER MONITOR WELLS (Continued)

	MCL PPB	HPGW25 1/87	HPGW25 3/87	HPGW25 5/87	HPGW25 1/91	21GW1 1/87	21GW1 3/87	21GW1 5/87	21GW1 1/91	22GW1 1/87	22GW1 3/87	22GW1 5/87	22GW1 1/91	22GW2 1/87	22GW2 3/87	22GW2 5/87	22GW2 1/91
Benzene	1					NS	NS	NS		12,000	10,000	13,000	7,900				
Chloroform	.19					NS	NS	NS		*	*	*					
Chloromethane	-					NS	NS	NS		*	*	*					
1,1-Dichloroethane	-					NS	NS	NS		*	*	*					
1,2-Dichloroethane	.38					NS	NS	NS		*	*	*	110				
Trans 1,2-Dichloroethene	70					NS	NS	NS		*	*	*					
Ethylbenzene	29					NS	NS	NS		1,800	*	*	1,900J				
Toluene	1,000					NS	NS	NS		15,000	18,000	24,000	16,000				
1,1,1-Trichloroethane	200					NS	NS	NS		*	*	*					
Trichloroethene	2.8					NS	NS	NS		*	*	*	5J				
Trichlorofloromethane	-					NS	NS	NS		*	*	*					
Vinyl Chloride	0.015					NS	NS	NS		*	*	*					
Xylenes	400					NS	NS	NS		9,000	*	*	9,800				

Note: MCL's are for State of North Carolina
All concentrations ug/L
Analytical hits only presented
* - Elevated detection limit due to analytical dilution
- no MCL
NS = Not sampled

The intermediate and deep wells installed during the Characterization investigation were sampled in August, 1987. Samples collected were analyzed for VOCs only (EPA Method 624 parameters). Following the installation of eight new intermediate and deep wells during the supplemental characterization investigation, all intermediate and deep wells were sampled again (Jan, 1991). All samples collected were analyzed for full TCL parameters. Deep well HPGW17-3 could not be sampled as it could not be located after numerous attempts to find it.

Potable wells within the HPIA (601, 602, 608, 634, and 637) have been sampled a number of times since 1984 by ESE and by Camp Lejeune (Verification and Characterization investigations). The water supply wells scheduled to be sampled during the supplemental characterization investigation included 601 (replaced and renumbered as 660), 602, 603, 608, 634, 637, 642, and 652. Water supply wells 608 and 630 were not sampled because the wells were either welded shut (608) or demolished (630).

The analytical results presented in the following text are grouped according to study areas of interest. Some shallow wells are discussed in more than one area as these wells serve dual purposes of monitoring suspected sources and being paired with water supply wells. All shallow well groundwater data are presented in **Appendices I** and **J**. Intermediate well analytical data is presented in **Appendices K** and **L**, and deep well analytical data is presented in **Appendices M** and **N**. The analytical data collected from the water supply wells during the supplemental characterization investigation is presented in **Appendix O**. The following text is only a presentation of data and observed trends. The significance of the analytical data will be discussed in the Risk Assessment for HPIA. A discussion of the QA/QC data including the blanks is presented in **Appendix G**.

It should be noted at this point that only unfiltered groundwater samples have been analyzed during all phases of this investigation. In many cases, the water collected from the shallow monitor wells was very turbid due to the fine nature of much of the shallow sediments and the slow yield of the wells which hampered development of the wells. Preservation of the turbid metals fraction (pH <2) can release metals which are a part of the sediment material, yielding higher concentrations of these metals. Use of this data in the follow on Risk Assessment is considered a very conservative approach as risks are then calculated on all phases of the compound of concern, not just the dissolved phase.

5.3.1 Surficial Aquifer

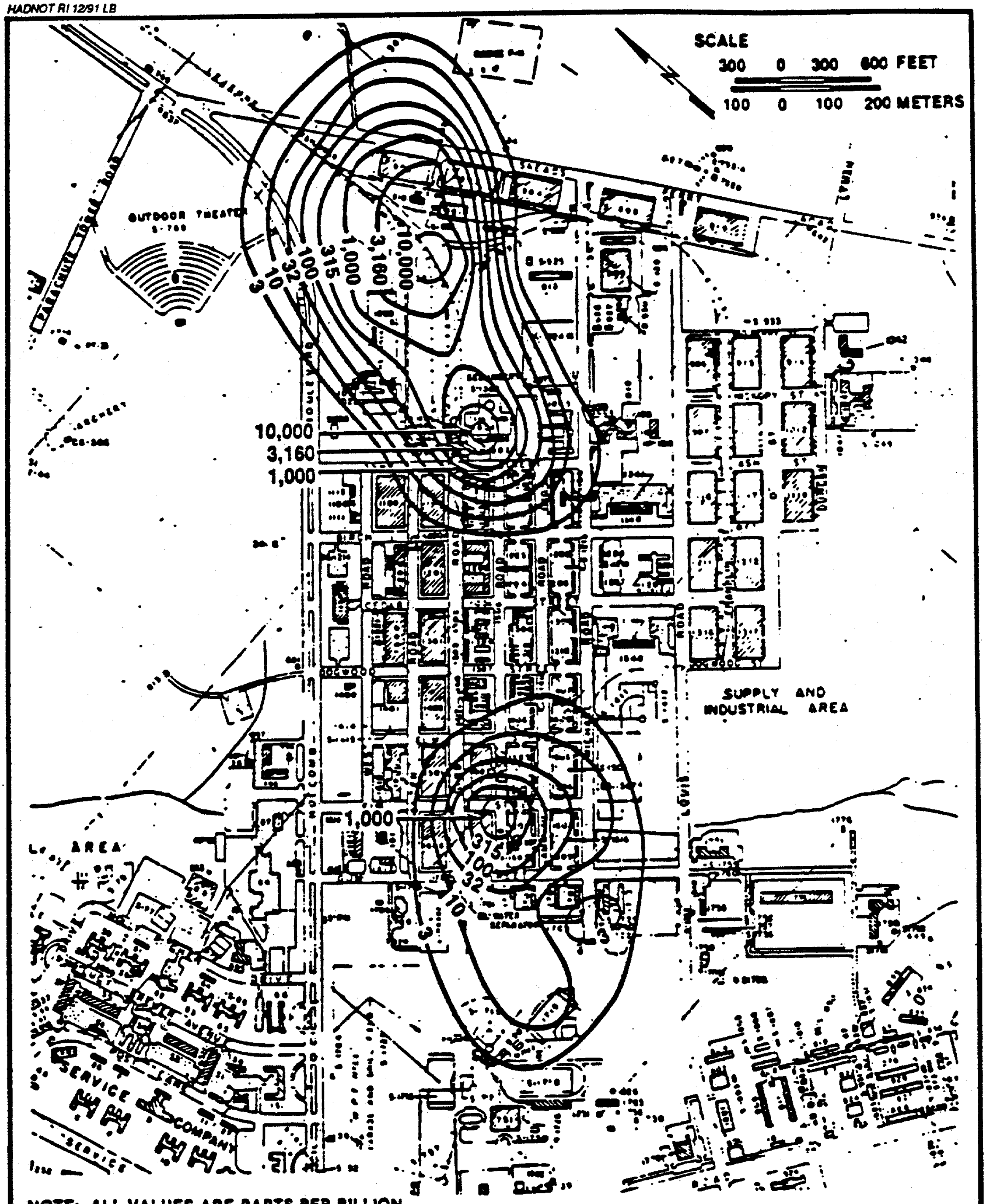
Two nodes of VOC contamination were delineated during the Characterization Investigation and were confirmed during the Supplemental Characterization. Total VOC isopleth maps were prepared using the data from 1987 and from 1991. These maps are presented as **Figures 5-4** and **5-5**. The following text further examines the distribution of contamination within the surficial aquifer. A comparison of shallow groundwater volatile analytical hits is provided in **Table 5-1**.

Hadnot Point Fuel Tank Farm

The shallow wells situated near this site are 22GW1 and 22GW2. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

In the Set One data, Well 22GW1, located next to the fuel tanks, was found to contain elevated levels of O&G (7,000 ug/L), benzene (12,000 ug/L), ethylbenzene (1,800 ug/L), toluene (15,000 ug/L), and xylene (9,000 ug/L). All of these compounds are related to documented fuel leaks at the facility. Well 22GW2, located to the west of the facility, was found to contain only O&G (0.8 mg/L) and methylene chloride (7.3 ug/L).

Well 22GW1 was found to contain elevated levels of benzene (10,000 ug/L), toluene (18,000 ug/L), and O&G (11,000 ug/L) in the Set Two sampling effort. The levels

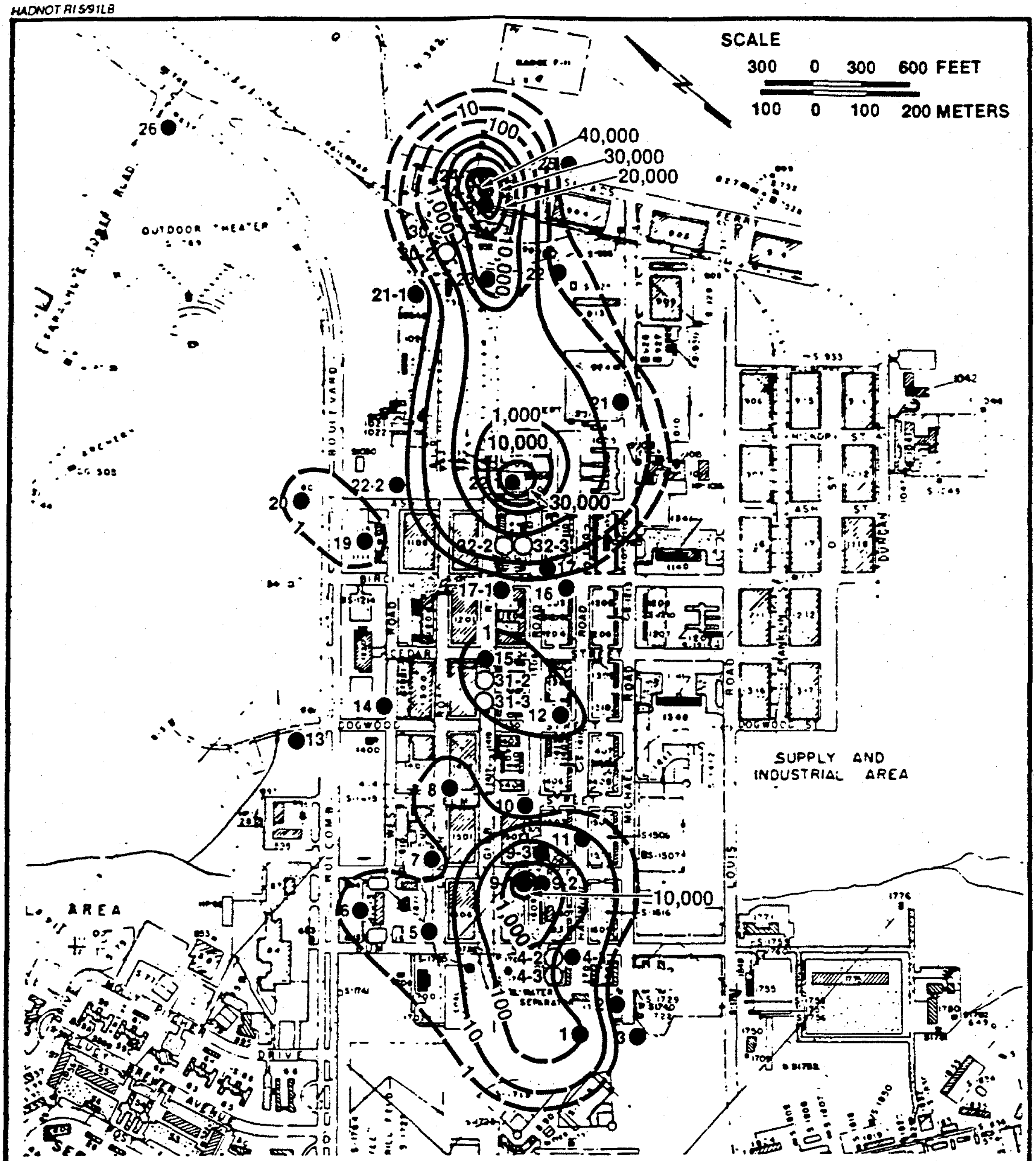


NOTE: ALL VALUES ARE PARTS PER BILLION.

Figure 5-4
TOTAL VOC ISOPLETH MAP – SHALLOW AQUIFER, CONFIRMATORY STUDY (MAY 1987), HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE



NOTE:
1. All valves are ppb - January 1991 data.
2. Contours dashed where inferred.

Figure 5-5
TOTAL VOC ISOPLETH MAP–SHALLOW AQUIFER, SUPPLEMENTAL CONFIRMATORY STUDY, HADNOT POINT INDUSTRIAL PARK

SOURCE: ESE.

MARINE CORPS BASE
CAMP LEJEUNE

are similar to those in the Set One data; however, the Set One data had also identified elevated levels of ethylbenzene and xylene. It is probable that these compounds were present in the Set Two samples, but the dilution required to quantify the largest peak in the chromatograph (toluene) reduced several other peaks to less than the post-dilution detection limit. No target analytes were identified in the Set Two data from Well 22GW2, located to the west of the facility.

In the Set Three data, Well 22GW1 was found to contain elevated levels of benzene (13,000 ug/L), toluene (24,000 ug/L), lead (78 ug/L), and O&G (9,000 ug/L). The levels of VOCs are generally similar to those in the Set One and Set Two data; however, the Set One data had identified elevated levels of ethylbenzene and xylene. As described for the Set Two data, it is probable that these compounds were present in the Set Three samples, but the dilution required to quantify the largest peak in the chromatograph (toluene) reduced several other peaks to less than the post-dilution detection limit. The lead values for Set One (22GW1 @ 33 ug/L and 22GW2 @ 28 ug/L) and for Set Two (22GW1 @ 29 ug/L and 22GW2 @ <27 ug/L) were below the North Carolina (NC) MCL in effect at that time (50 ug/L). However, the lead concentration in the Set Three data (78 ug/L) is greater than the old MCL of 50 ug/L. Set Three samples from Well 22GW2 did not contain detectable quantities of any of the target analytes.

Volatile contamination detected during the Supplemental investigation occurred at well 22GW1. Contaminants included the gasoline components of benzene (7,900 ug/L), toluene (16,000 ug/L), ethylbenzene (a UIC at 1,900 ug/L) and xylene (9,800 ug/L). Semi-volatile contaminants (naphthalene 130 ug/L and 2-methylnaphthalene 28 ug/L) were detected in the same well. Metals (Iron [101,000 and 16,200 ug/L], manganese [284 and 763 ug/L], and sodium [9560 and 8,570 ug/L) were detected in both wells above primary or secondary drinking water standards. Additionally arsenic (50.3 ug/L), chromium (33,800 ug/L) and lead (307 ug/L) were detected in 22GW1 above the NC standards. No pesticides or PCB compounds were detected.

Buildings 1709 and 1710

The shallow wells situated near this site are HPGW1, HPGW2, HPGW3, and HPGW4. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

TCE was detected only in the Set One water samples from HPGW4 (3.4 ug/L), suggesting that the TCE detected in the soil gas near HPGW1 may be present in the soil matrix only. Additionally, the TCE in HPGW4 may be related to Bldg. 1601 as HPGW4 is hydrologically downgradient of this building. Trace levels of two additional solvent compounds were detected in two other wells (5.0 ug/L chloromethane--HPGW2, 1.9 ug/L T12DCE--HPGW4) in this area. The compounds which caused interference with the detection of TCE in the soil gas appear to be related to spills and/or leaks of fuels. O&G, benzene, ethylbenzene, toluene, and xylene were detected in most of the four wells in this area. Well HPGW2, which has never contained TCE, is located immediately adjacent to Water Supply Well 608 (closed) and suggests that the contaminants detected in Water Supply Well 608 (TCE and T12DCE) are not from contamination of the shallow aquifer in the vicinity of the well.

The suite of detected VOCs in the Set Two data were similar to those detected in the Set One data. In most cases, however, the Set Two levels were lower than the Set One levels. None of the detected analytes in the Set Two data were above applicable action limits; however, this is not a permanent condition, as the Set One data indicate that benzene in wells HPGW1, HPGW2, and HPGW4 periodically exceeds the NC MCL of 1 ug/L and chloromethane in HPGW2 periodically exceeds the Water Quality Criterion of 0.19 ug/L (10^{-6} risk level).

The distribution of contamination by VOCs at this site as indicated by the Set Three data was decreased relative to the Set Two data. VOCs were detected only in Well HPGW4. The levels of specific VOCs in this well have changed in an erratic fashion; benzene and toluene have decreased relative to Set Two, whereas T12DCE and TCE have increased. In addition, an unknown compound similar to methylethylketone (MEK) was detected for the first time. Of the detected analytes in the Set Three data, only TCE is above the applicable NC water quality standards (2.8 ug/L). However, this is not a permanent condition, as the Set One data indicate that several other compounds periodically exceed the applicable NC standards.

Volatile contamination detected during the Supplemental investigation occurred at well HPGW1. Contaminants included 1,2-DCE (73 ug/L) and TCE (91 ug/L). TCE was detected as a UIC in well HPGW4. Acetone, a laboratory contaminant was also detected in both of these wells. No semi-volatile contaminants, pesticides or PCB compounds were detected in any of the wells. Metals (Iron, manganese, and sodium) were detected in all four wells above NC drinking water standards. Additionally chromium was detected in three wells (HPGW1, HPGW2, and HPGW4) and lead was detected in HPGW4 above the standards.

Building 1613 (Exchange Service Station

The shallow wells situated near this site are HPGW5, HPGW6, and HPGW7. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

O&G was the only target analyte detected in these wells during the characterization investigation, suggesting the station has released waste O&G from maintenance operations but that fuel leaks do not appear to have occurred.

Set Two data from wells HPGW5 through HPGW7 suggest that some petroleum hydrocarbons (oil and grease) are present in the shallow groundwater, but that fuel leaks have not occurred, as there is an absence of volatile compounds. Lead concentration in both the Set One and Set Two data are not of concern as their concentrations are near or below the detection limit.

No target analytes were detected in the Set Three data. This may be attributed to changes in groundwater levels as summer (i.e., dry season) conditions became prevalent at the site.

No volatile contamination was detected during the Supplemental investigation in any of these wells. Acetone, a laboratory contaminant was also detected as a UIC in wells HPGW5 and HPGW6. No semi-volatile contaminants, pesticides or PCB compounds were detected in any of the wells. Metals (Iron, manganese, and sodium) were detected in all three wells above NC primary or secondary drinking water standards. Additionally chromium and lead were detected in two wells (HPGW6 and HPGW7) above the standards.

Buildings 1502, 1601, and 1602

During the soil gas investigation, very high levels of TCE were detected between Bldgs. 1502 and 1601, with lower levels detected between Bldgs. 1601 and 1602. As a result, four shallow monitor wells were installed (HPGW8 through 11) to characterize the groundwater quality. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

Well HPGW9-1, located at the center of the soil gas high, was found to contain high levels of O&G (32,000 ug/L), 1,2-DCE (740 ug/L), ethylbenzene (1,100 ug/L), TCE (5,000 ug/L), and xylene (4,500 ug/L) in the Set One data. This suite of detected contaminants is consistent with the usage of this area as a vehicle maintenance facility. The remaining wells in this area were found to contain a similar suite of contaminants, although at lesser concentrations and with a somewhat sporadic distribution. In addition, levels of other volatile compounds such as chloroform, chloromethane, methylene chloride, and trichlorofluoromethane were detected on a sporadic basis in the other wells in this area.

The Set One data indicated a sporadic distribution of VOCs in this area. This pattern was verified by the Set Two data, with some variations. Well HPGW9-1, in the center of the soil gas hot spot, continued to be the most highly contaminated, with elevated levels of lead (92 ug/L), O&G (11,000 ug/L), and TCE (6,100 ug/L). Other VOCs detected in Set One may have been present in Set Two, but were obscured by the strength of the TCE peak. The level of trichlorofluoromethane at well HPGW8 had increased with time (14 ug/L to 96 ug/L).

The Set One and Set Two data had indicated a sporadic distribution of VOCs in this area. With the Set Three data, a pattern was delineated. Well HPGW9-1, in the center of the soil gas hot spot, was consistently the most highly contaminated, with elevated levels of lead (70 ug/L), O&G (6,000 ug/L), and VOCs. The specific VOCs present in each data set from this well varies, with T12DCE (2,700 ug/L) and xylene (4,000 ug/L) present in the Set Three data. Other VOCs detected in previous data sets may be present in Set Three, but were obscured by the strength of the T12DCE and xylene peaks. Of significance in the Set Three data was the lack of high-level contamination by TCE which was noted in the previous sets. The second most highly contaminated well was HPGW11. This well was the only one in Set Three to contain detectable quantities of TCE (24 ug/L). No target analytes were detected in HPGW8 and HPGW10 in Set Three; these wells had previously contained sporadic low-level contamination by VOCs and O&G.

Volatile contamination detected during the Supplemental investigation occurred primarily at well HPGW9-1. Contaminants included carbon disulfide (13 ug/L), 1,2-DCE (1,200 ug/L), chloroform (15 ug/L), TCE (14,000 ug/L), toluene (as a UIC at 330 ug/L), ethylbenzene (700 ug/L) and xylene (3,300 ug/L). Carbon disulfide was also detected at well HPGW-11 (11 ug/L) and TCE as a UIC (2 ug/L) at well HPGW8). Semi-volatile contaminants (naphthalene 190 ug/L and hexachlorocyclopentadiene 49 ug/L) were detected in the same well. Metals (chromium, Iron, lead, and sodium) were detected in all four wells above NC primary or secondary drinking water standards. Additionally, manganese was detected in wells HPGW10 and HPGW11 above the standards. No pesticides or PCB compounds were detected.

Building 1202

The soil gas investigation identified the presence of high levels of TCE in the vicinity of Bldg. Four wells were installed near this site (HPGW15, HPGW16, HPGW17-1, and HPGW18) to determine the extent of the groundwater contamination associated with the contamination in the soils. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters) Well HPGW 18 could not be located during the Supplemental investigation and may have been destroyed.

One target analyte (O&G) was detected in only one well (HPGW16) in the Set One data. No VOCs were detected in wells HPGW15 through HPGW18 in the Set Two data. O&G and lead were the only two target analytes detected in the samples.

The Set Three data detected trichlorofluoromethane in Well HPGW15. O&G and lead were not detected in Set Three; both analytes had been detected in Set One and Set Two. Although lead was not detected in the Set Three data, the MDL was greater than the concentrations detected in previous samples, but less than the MCL.

Only slight volatile contamination was detected during the Supplemental investigation at well HPGW15. Contaminants included 1,2-DCE (7 ug/L) and TCE as a UIC (4 ug/L) No semi-volatile contaminants were detected in any of wells. Metals (Iron and sodium) were detected in all three wells above NC primary or secondary drinking water standards. Additionally chromium, lead and manganese were detected in HPGW16 above the standards. Dieldrin in well HPGW17-1 (0.11 ug/L) was the only pesticide detected.

Building 1100

TCE was detected in this area during the soil gas investigation. A single shallow well (HPGW19) was installed near this site. This well was sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

O&G (200 ug/L), T12DCE (2.5 ug/L), and TCE (6 ug/L) were detected in this well in the Set One data, consistent with past usage of this area as a service station conducting limited amounts of vehicle maintenance.

The detectable contamination at well HPGW19 was limited to O&G (2,000 ug/L) in the Set Two data. The low levels of T12DCE and TCE detected in the Set One data were reduced to less than the MDL at the time of the Set Two sampling.

No contamination was detected at well HPGW19 in the Set Three data. Previously, low levels of T12DCE and TCE (Set One) and O&G (Set Two) had been detected at this well. Physical conditions at the site, such as low water table, may have reduced contaminant levels to less than the MDL at the time of the Set Three sampling.

Only slight volatile contamination was detected during the Supplemental investigation at well HPGW19. Contaminants detected were limited to three UICs and included 1,2-DCE (.8 ug/L), TCE (2 ug/L), and tetrachloroethane (2 ug/L). No semi-volatile or pesticide contaminants were detected in the well. Metals (Iron, manganese and sodium) were detected above NC primary or secondary drinking water standards.

Buildings 901, 902, and 913

The location of a TCE storage tank next to the building was identified during the records review and the area surrounded by the four monitoring wells was previously utilized for maintenance of heavy equipment. The soil gas investigation detected TCE in a single data point each at both Bldgs. 901 and 902. The shallow wells situated near this site are HPGW22, HPGW23, HPGW24-1 and HPGW25. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

In the Set One data, all monitor wells detected O&G (100 to 1,000 ug/L); 1,2-DCE (830 and 6,400 ug/L) and TCE (830 and 57 ug/L) were detected in HPGW23 and HPGW24-1; and vinyl chloride (190 ug/L), 1,1-dichloroethane (12 ug/L)), and benzene (2 ug/L) were detected in HPGW24-1. These detected analytes are consistent with the use of TCE and the maintenance of equipment documented to have occurred in this area.

In the Set Two data, all wells were found to contain O&G at levels ranging from 200 to 3,000 ug/L. Very high levels of 1,2-DCE (6,100 and 4,300 ug/L) were identified in HPGW23 and HPGW24-1; these levels are greater than those detected in Set One. TCE was also detected in well HPGW23 at a concentration of 13,000 ug/L. Methylene chloride, a probable laboratory contaminant, was detected in HPGW23 and HPGW25 for the first time in the Set Two data. It is possible that other VOCs, at low levels, may be present in some of the samples but the required pre-analysis dilutions could have rendered them undetectable.

High levels of T12DCE (7,100 ug/L) and TCE (4,300 ug/L) were identified in Well HPGW23 in the Set Three data; these levels are less than those detected in Set Two. TCE was detected in Well HPGW23 at a level less than half that for the Set Two samples. Vinyl chloride was detected in HPGW24-1 (250 ug/L), as it had been in the Set One samples. This target analyte was less than the MDL in the Set Two data. The required pre-analysis dilutions may have rendered other VOCs undetectable.

The greatest volatile contamination detected in the HPIA area during the Supplemental investigation occurred in wells HPGW23 and HPGW24-1 and represented both solvent and fuel related components. Contaminants detected in HPGW23 included carbon disulfide (5 ug/L), 1,2-DCE (8,900 ug/L), TCE (3,700 ug/L), benzene (24 ug/L), toluene (13 ug/L), ethylbenzene (9 ug/L) and xylene (41 ug/L) with vinyl chloride being detected as a UIC (8 ug/L). Contaminants detected in HPGW24-1 included carbon disulfide (7 ug/L), 1,1-dichloroethene (65 ug/L), 1,2-DCE (45,000 ug/L identified in an analysis at a secondary dilution factor), TCE (180 ug/L), toluene (13 ug/L), and xylene (10 ug/L) with 1,2-dichloroethane (0.8 ug/L), 1,1,2-trichloroethane (3 ug/L), benzene (3 ug/L) and ethylbenzene (3 ug/L) being detected as UICs. Acetone, a laboratory contaminant was detected in well HPGW22 (9 ug/L). No volatile contaminants were detected in well HPGW25. Naphthalene (130 ug/L) was detected in HPGW24-1. Additional contaminants as UICs were identified in HPGW22 (acenaphthene at 3 ug/L, dibenzofuran at 2 ug/L, and 4-nitroaniline at 5 ug/L), HPGW23 (bis[2-ethylhexyl]phthalate at 3 ug/L) and HPGW24-1 (2-methylnaphthalene at 3 ug/L and acenaphthalene at 6 ug/L). No semi-volatile contaminants were detected in well HPGW25. Metals (iron, manganese, and sodium) were detected in all four wells above primary or secondary drinking water standards. Additionally, chromium was detected in wells HPGW22, HPGW23 and HPGW25, and lead was detected in well HPGW25 above the standards. No pesticides or PCB compounds were detected.

Well Pairs with Water Supply Wells

A shallow monitor well was installed next to each of five closed water supply wells in HPIA (HPGW2 - WS608, HPGW13 - WS601 replaced as WS660, HPGW20 - WS602, HPGW25 - WS634, and HPGW26 - WS637) to determine if contamination observed in the water supply originated at the surface near the well. These wells were sampled 3 times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

In the Set One data, Well HPGW2 (paired with Supply Well 608) was found to contain O&G (700 ug/L), benzene (12 ug/L), chloromethane (5 ug/L), toluene (38 ug/L), and xylene (28 ug/L). This contamination identified in the shallow aquifer appears to be derived from fuel, whereas Supply Well 608 has been found to contain solvent-based VOCs. It appears that the two aquifer zones at this well pair are not well connected hydraulically because the types of contamination are dissimilar. The deep contamination may have migrated to the supply wells via flow in the deeper aquifer, augmented by the drawdown in the deep aquifer caused by the wells when they were active. An alternative transport mechanism is that the solvent-derived VOCs observed in the deeper aquifer have migrated downward, preferentially relative to the lighter fuel-derived contaminants observed in the shallow groundwater. At Wells HPGW13 (paired with 601), HPGW25 (paired with 634), and HPGW26 (paired with 637), O&G (200 ug/L in each well), was the only detected target analyte, suggesting that the shallow aquifer at each of these deep wells is not the source of the detected contamination. Similarly, Well HPGW20 (paired with 602) did not contain detectable quantities of any of the target analytes.

The Set Two data indicate that the low levels of O&G identified in the Set One data for HPGW13 (with 601) were no longer detectable. No other target analytes were identified. The suite of detected contaminants in HPGW20 (with 602) increased by two contaminants (O&G and methylene chloride) in the Set Two data versus the Set One data. The O&G (3,000 ug/L) concentration is typical of that observed in the shallow aquifer throughout much of Camp Lejeune. No target analytes were detected in HPGW2. Well HPGW25 (with 634) contained detectable concentrations of O&G (300 ug/L) and methylene chloride (2.9 ug/L) in the Set Two sampling. Well HPGW26 (with 637) was found to contain detectable levels of O&G (2,000 ug/L) and methylene chloride (6.5 ug/L).

The Set Three data showed no detectable levels of any of the target analytes in any of the wells paired with the water supply wells.

Samples collected from wells HPGW2 and HPGW25 showed no detectable volatile, semi-volatile or pesticide contaminants. Volatile contaminants as UICs were detected in HPGW13 (methylene chloride, a laboratory contaminant at 1 ug/L), HPGW20 (carbon disulfide at 2 ug/L and methylene chloride, a laboratory contaminant at 0.9 ug/L) and HPGW26 (methylene chloride [3 ug/L] and acetone [7 ug/L] which are laboratory contaminants and carbon disulfide at 2 ug/L). Metals (iron and sodium) were detected in all wells above primary or secondary drinking water standards. Additionally, chromium and manganese were detected in wells HPGW2, HPGW20 and HPGW25, and lead was detected in well HPGW25 above the standards.

Other Monitor Wells

Four monitor wells (HPGW12, HPGW14, HPGW21 and HPGW29) were installed to aid in the definition of the overall flow pattern(s) within the surficial aquifer within HPIA and/or to help define the downgradient limit of contaminant plumes thought to be present near specific source areas. These wells were sampled three times in 1987 during the Characterization Investigation (analyzed for VOCs, lead and oil and grease) and in 1991 during the Supplemental Characterization (analyzed for full TCL parameters).

Well HPGW12, located approximately midway between suspected source areas at Bldgs. 1202 and 1501, was found to contain O&G only in the Set One data. In the Set Two data, only tetrachloroethane was detected. Well HPGW12 was not found to contain detectable levels of the target analytes in the Set Three data. Only metals (iron and sodium above NC standards) were detected during the supplemental investigation.

Well HPGW14, situated midway between suspected contaminant sources in the industrial area and Supply Well 601, was found to contain detectable levels of O&G only in Set One data, and no target analytes were detected in the Set Two or Set Three data. Only elevated metals (chromium, iron, lead, manganese, and sodium above the NC primary or secondary drinking water standards) were detected during the supplemental investigation.

Well HPGW21 was installed to the northwest of the fuel tanks at Site 22 and was found to contain only O&G in the Set One and Set Two data and no target analytes in the Set Three data. During the supplemental characterization, this well contained volatile contamination as UICs as well as elevated metals. These contaminants included the laboratory contaminants methylene chloride (4 ug/L) and acetone (4 ug/L), TCE (3 ug/L), ethylbenzene (0.9 ug/L) and xylene (5 ug/L) as well as iron, manganese and sodium above NC primary or secondary drinking water standards.

Well HPGW29 was installed next to Bldg. 1801, which was found to have a vehicle wash rack and a solvent storage shed associated with it. O&G was the only target analyte detected in the Set One data and lead exceeded the MCL in the Set Two data. No target analytes were detected in the Set Three samples from Well HPGW29. Methylene chloride was detected as a UIC (0.9 ug/L) and metals (chromium, iron, manganese and sodium) exceeded primary or secondary drinking water standards.

5.3.2 Castle Hayne Aquifer

After analysis of the data derived from the shallow well network, a need was recognized for groundwater quality data from the Castle Hayne aquifer. The deep aquifer monitoring system is composed of wells set to the intermediate depth (75-ft) and the deep wells (150-ft). This zone comprises one aquifer unit, but is broken into two monitored zones to better delineate the vertical extent of contamination. Water quality data from the Castle Hayne aquifer may identify the presence of VOCs which may have migrated downward as a result of their high density relative to water or which have been drawn down by pumping of the previously active water supply wells.

During the Characterization investigation, two additional monitor wells were installed: one well to a depth of approximately 75 feet and another to a depth of 150 feet, at each of three potential source areas as identified during the Characterization Study. The northernmost cluster of wells (HPGW24, HPGW24-2, and HPGW24-3) is situated adjacent to the TCE tank next to Bldg. 901. The second cluster (HPGW17, HPGW17-2, and HPGW17-3) was installed adjacent to Bldg. 1202. The southernmost cluster (HPGW9, HOGW9-2, and HPGW9-3) was installed within the zone of contamination identified at Bldgs. 1502 and 1601. Four additional clusters were added during the Supplemental Characterization downgradient of buildings 1602 (wells HPGW4-2 and HPGW4-3), 902 (wells HPGW30-2 and HPGW30-3), 1202 (wells HPGW31-2 and HPGW31-3), and downgradient of the Industrial Area Tank Farm (wells HPGW32-2 and HPGW32-3). The 75-foot wells are identified by the -2 suffix, and the 150-foot wells with the -3 suffix.

Intermediate Depth Wells

The three intermediate depth wells installed during the Characterization Investigation were sampled during that investigation and analyzed for VOCs, lead and oil and grease. Four additional intermediate depth wells were installed during the Supplemental Characterization and all intermediate depth wells were sampled and analyzed for full TCL parameters. Analytical results are presented in **Appendices K and L.**

No target analytes were detected during the Characterization sampling in the three intermediate depth wells (HPGW9-2, HPGW 17-2, and HPGW 24-2).

Low concentrations of volatile contamination were detected in six of the seven intermediate depth wells sampled during the Supplemental Characterization. Those wells and the contaminants quantified included HPGW4-2 (acetone at 19 ug/L and carbon disulfide at 10 ug/L); HPGW9-2 (carbon disulfide at 22 ug/L and 1,2-DCE at 11 ug/L); HPGW17-2 (carbon disulfide at 14 ug/L); HPGW 24-2 (carbon disulfide at 9 ug/L); HPGW 30-2 (vinyl chloride at 12 ug/L and 1,2-DCE at 12 ug/L); and HPGW 32-2 (acetone at 19 ug/L, benzene at 27 ug/L, toluene at 31 ug/L, and xylene at 8 ug/L). Since well HPGW32-2 is located downgradient of the Hadnot Point Fuel Farm, the discovery of fuel related compounds in this well is not unexpected.

Contaminants detected as UICs included methylene chloride (HPGW4-2); acetone (HPGW30-2 and HPGW 31-2), carbon disulfide (HPGW31-2 and HPGW32-2), 1,2-DCE (HPGW17-2), benzene (HPGW 17-2 and HPGW 30-2), toluene (HPGW4-2 and HPGW30-2) ethylbenzene (HPGW30-2) and xylene (HPGW30-2).

Naphthalene was the only semi-volatile compound quantified and was detected in two of the intermediate depth wells; HPGW17-2 (56 ug/L), HPGW 30-2 (270 ug/L). Additional semi-volatile compounds were detected as UICs including 2-methylnaphthalene (HPGW17-2 and HPGW30-2), acenaphthene (HPGW17-2 and HPGW30-2) and bis(2-ethylhexyl)phthalate (HPGW9-2, HPGW17-2, and HPGW30-2).

Iron was the only metal detected above primary or secondary drinking water standards in all the intermediate wells. Elevated levels of manganese and sodium were also detected in well HPGW30-2.

No pesticide compounds were detected in any of the intermediate depth wells.

Deep Wells

The three deep wells installed during the Characterization Investigation were sampled during that investigation and analyzed for VOCs, lead and oil and grease. Four additional deep wells were installed during the Supplemental Characterization and all deep depth wells were sampled and analyzed for full TCL parameters. Deep well HPGW-3 could not be located during the Supplemental Characterization and is assumed to have been destroyed. Analytical results are presented in **Appendices M and N.**

Of the target analytes during the Characterization Investigation, only MEK was detected and in only two of the 150-foot wells (HPGW9-3 and HPGW17-3). MEK was previously unidentified at HPIA, with the exception of the detection of an unknown compound similar to MEK at shallow well HPGW4.

Low concentrations of volatile contamination were detected in two of the six deep wells sampled during the Supplemental Characterization. The sample collected from well HPGW31-3 contained carbon disulfide (6 ug/L) and acetone (27 ug/L) which is a laboratory solvent that was also detected in the associated blank. The sample collected from well HPGW32-3 contained toluene (34 ug/L), ethylbenzene (12 ug/L), xylene (51 ug/L) and acetone (13 ug/L) which is a laboratory solvent. Since well HPGW32-3 is located downgradient of the Hadnot Point Fuel Farm, the discovery of fuel related compounds in this well is not unexpected.

Contaminants detected as UICs included methylene chloride (a laboratory solvent) in HPGW4-3, HPGW24-3, HPGW32-3; acetone (a laboratory solvent) in HPGW4-3; carbon disulfide (HPGW4-3), 2-butanone (HPGW9-3), and tetrachloroethane (HPGW 9-3).

Bis(2-ethylhexyl)phthalate was detected as a UIC in samples collected from HPGW9-3 and HPGW24-3. No other semi-volatile compounds were detected in the samples collected from the deep wells.

Iron was detected above primary or secondary drinking water standards in all the intermediate wells. Elevated levels of manganese were also detected in well HPGW4-3.

No pesticide compounds were detected in any of the intermediate depth wells.

Water Supply Wells

Site 22 is the site of documented fuel leaks from the Hadnot Point Fuel Farm. Two Verification Step monitor wells were installed to determine the presence of fuel-derived contamination within the shallow groundwater in the vicinity of the tank farm. In addition to sampling and analysis of groundwater samples from these monitor wells, sampling and analysis of samples from adjacent Water Supply Well 602 was conducted. The samples from Well 22GW1 were found to contain high levels of fuel-derived compounds such as benzene, ethylbenzene, toluene, and lead. Only oil and grease (O&G) was detected in Well 22GW2, indicating that the zone of shallow groundwater contamination did not extend from the tank farm to Well 22GW2, a distance of approximately 500 feet (ft).

Benzene, ethylbenzene, 1,2-dichloroethane (12DCA), trans-1,2-dichloroethene (T12DCE), toluene, and trichlorofluoromethane were detected in deep Water Supply Well 602, located approximately 1,200 feet to the west of the fuel tanks. These data strongly indicated that contamination from the tank leaks was migrating significant distances from the source area via the deep potable aquifer. In addition, the detected VOCs (i.e., non fuel-derived contamination) suggested that other sources of contamination, in addition to those identified by IAS, existed within HPIA. A separate effort is currently underway to identify and recover fuel in the subsurface in the vicinity of the Site 22 fuel tank farm.

As a result of the Confirmation Study sampling and analysis, Camp Lejeune initiated a sampling program that included all water supply wells within HPIA. This effort identified contamination by VOCs water supply wells in and adjacent to HPIA. The water supply wells were sampled as part of the Confirmation Study and by Camp Lejeune staff. The results of these efforts, shown in **Table 5-5**, identified the presence of VOCs in the deep aquifer. All affected water supply wells were immediately shut down by Camp Lejeune utilities staff.

The water supply wells were again tested during the Supplemental Characterization. Samples were analyzed for full TCL parameters. Detected target analytes are presented in **Table 5-6**. Potable well depths and screen intervals are presented in **Table 5-7**.

WS601 was first sampled on December 5, 1984 and contained detectable concentrations of three volatile compounds (1,2-DCE, TCE, and tetrachloroethane). This

Table 5-5. DETECTED TARGET ANALYTES CHARACTERIZATION INVESTIGATION-POTABLE WELLS

Parameter	Concentration by Well Number (ug/L)							
	601*	602	603	608	634	637	642	652
<u>Sampled 7/84 - ESE, Inc.</u>								
Benzene	NA	380	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	46	NA	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	7.8	NA	NA	NA	NA	NA	NA
Ethylbenzene	NA	8	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane	NA	3	NA	NA	NA	NA	NA	NA
Toluene	NA	10	NA	NA	NA	NA	NA	NA
<u>Sampled 12/5/84 - JTC Environmental</u>								
Benzene	BDL	120	NA	3.7	BDL	BDL	NA	NA
1,2-Dichloroethene	88	630	NA	5.4	BDL	BDL	NA	NA
Trichloroethene	210	1,600	NA	110	BDL	BDL	NA	NA
Toluene	BDL	5.4	NA	BDL	BDL	BDL	NA	NA
Tetrachloroethene	5.0	24	NA	BDL	BDL	BDL	NA	NA
Vinyl Chloride	BDL	18	NA	BDL	BDL	BDL	NA	NA
<u>Sampled 12/12/84 - JTC Environmental</u>								
Benzene	BDL	720	NA	4.0	BDL	BDL	NA	NA
1,2-Dichloroethene	99	380	NA	2.4	2.3	BDL	NA	NA
Trichloroethene	230	540	NA	13	BDL	BDL	NA	NA
Tetrachloroethene	4.4	BDL	NA	BDL	BDL	BDL	NA	NA
Methylene Chloride	10	BDL	NA	14	130	BDL	NA	NA

Table 5-5. DETECTED TARGET ANALYTES CHARACTERIZATION INVESTIGATION-POTABLE WELLS (Continued)

Parameter	Concentration by Well Number (ug/L)							
	601*	602	603	608	634	637	642	652
Sampled 12/19/84 - JTC Environmental								
Benzene	NA	230	NA	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	230	NA	NA	NA	NA	NA	NA
Trichloroethene	NA	340	NA	NA	NA	NA	NA	NA
Toluene	NA	340	NA	NA	NA	NA	NA	NA
Sampled 1/85 - ESE, Inc.								
1,2-Dichloroethene	8.8	NA	NA	NA	700	BDL	NA	NA
Trichloroethene	26	NA	NA	NA	1,300	BDL	NA	NA
Tetrachloroethene	BDL	NA	NA	NA	10	BDL	NA	NA
Sampled 11/86 - ESE, Inc.								
Iron, Total	12,800	15,200	NA	3,600	2,830	NA	NA	NA
Manganese, Total	97.6	134	NA	67.8	19.5	NA	NA	NA
Sulfate (mg/L)	5,170	92	NA	12	BDL	NA	NA	NA
Benzene	BDL	50	NA	BDL	BDL	NA	NA	NA
1,2-Dichloroethane	BDL	9.2	NA	BDL	BDL	NA	NA	NA
1,2-Dichloroethene	BDL	14	8.5	NA	2.9	NA	NA	NA
Trichloroethene	BDL	2.2	NA	66	BDL	NA	NA	NA
Bis (2-ethylhexyl)phthalate	1.3	BDL	NA	BDL	BDL	NA	NA	NA

Note:		
	ug/L	- Micrograms per Liter
	mg/L	- Milligrams per Liter
	NA	- Not Analyzed
	BDL	- Below Detection Limit
	*	- Well WS601 abandonded and redrilled as WS660

Source: ESE, 1991.

Table 5-6. DETECTED TARGET ANALYTES - POTABLE WELLS SUPPLEMENTAL CHARACTERIZATION INVESTIGATION

Parameter	Concentration by Well Number (ug/L)							
	660*	602	603	608	634	637	642	652
Volatiles								
Methylene Chloride	BDL	21	BDL	NA	BDL	BDL	BDL	20
1,2-Dichloroethene	2.J	12	BDL	NA	1.J	BDL	BDL	BDL
1,2-Dichloroethane	BDL	8	BDL	NA	BDL	BDL	BDL	BDL
Trichloroethene	1.J	0.7J	1.J	NA	BDL	0.9J	BDL	BDL
Benzene	BDL	17	BDL	NA	BDL	BDL	BDL	BDL
Semi-Voaltiles								
bis(2-ethylhexyl)phthalate	3.J	BDL	BDL	NA	BDL	BDL	BDL	BDL
Metals								
Iron	11,500	12,800	1,030	NA	1,420	4,620	1,150	65,000
Manganese	75.6	120	22.2	NA	12.5B	28.3	24.6	151

Note:
ug/L - Micrograms per Liter
NA - Not Analyzed
BDL - Below Detection Limit
* - Well WS601 abandoned and redrilled as WS660
J - Value is estimated as a tentatively identified compound (TIC).

Source: ESE, 1991.

Table 5-4. **WATER SUPPLY WELLS CONSTRUCTION DETAIL**

Well #	Depth	Screen Interval	Well #	Depth	Screen Interval
601	195	95-100	634	225	65-70
		115-130			73-78
		175-195			83-88
					93-98
					104-114
					121-126
					132-137
					150-160
					167-172
					192-197
					212-222
660	190	94-99	637	180	66-70
		108-140			78-82
		175-187			90-98
					102-114
					120-128
					140-148
					156-172
602	160	70-80	642	206	112-124
		100-105			136-144
		120-125			157-163
		145-150			174-174
		155-160			188-196
603	195	70-80	652	183	120-130
		100-110			148-158
		130-140			163-168
		160-170			173-178
		190-195			
608	161.5	59.5-79.5			
		87.5-97.5			
		117.5-127.5			

Note: All depths are feet below land surface.

well was resampled the following week and contained similar concentrations of the same contaminants plus methylene chloride. Additional sampling in January, 1985 and November 1986 showed the contaminants decreased in concentration (BDL in 1986). This well was destroyed and replaced by well WS660 which was sampled during the Supplemental Characterization. Sampling showed only 1,2-DCE, TCE and bis(2-ethylhexyl)phthalate as UICs. Iron and manganese were also detected over NC primary or secondary water standards.

WS602 was first sampled in July, 1984 and contained detectable concentrations of several volatile compounds (**Table 5-5**). This well was resampled 12/5/84 and the following two weeks and contained similar contaminants at greater concentrations. Additional sampling in November 1986 showed the contaminants had decreased in concentration. This well was sampled during the Supplemental Characterization. Sampling showed the same contaminants at reduced concentrations. Iron and manganese were also detected over NC primary or secondary water standards.

WS603 was sampled only during the Supplemental Characterization. TCE was detected as a UIC, and iron and manganese were over the NC primary or secondary water standards.

WS608 was sampled on 12/5/84 and 12/12/84. Three volatile compounds were detected in each sample, and methylene chloride was detected in the second sample. TCE was the only compound that changed concentrations significantly, decreasing from 110 ug/L to 13 ug/L.

WS634 was sampled four times during the Characterization Investigation and again during the Supplemental Characterization. All analytes were below the detection limit in the first sample, and 1,2-DCE was detected in the second sample at 2.3 ug/L. Contamination increased significantly in the January 1985 sample with 1,2-DCE (700 ug/L), TCE (1,300 ug/L), and tetrachloroethane (10 ug/L) being detected. When sampled in November 1986, 1,2-DCE was detected at 2.9 ug/L and iron was at 2,830 ug/L. Only 1,2-DCE was detected in the Supplemental Characterization as a UIC, and iron was detected at a concentration that was over the NC primary or secondary water standards.

WS637 was sampled three times during the Characterization Investigation and again during the Supplemental Characterization. All analytes were below the detection limit in the samples collected during the Characterization Investigation. TCE was detected in the Supplemental Characterization as a UIC, and iron was detected at a concentration that was over the NC primary or secondary water standards.

WS642 and WS652 were sampled only during the Supplemental Characterization. Only WS652 had a detectable concentration of a volatile compound; methylene chloride at 20 ug/L. Both wells contained concentrations of iron, and WS652 a concentration of manganese which exceeded the NC primary or secondary water standards.

5.4 QA/QC Samples

Soil QA/QC Samples

A total of nine duplicate soil samples and nine equipment blanks (EB prefix) were collected during the Supplemental Characterization soil boring program. Duplicate soil samples (except volatile fractions) were collected from a homogenized portion of the soil sample collected. Equipment blanks were collected by pouring ultrapure (organic free) water over decontaminated soil sampling equipment and catching the rinsate in sample containers. These samples were analyzed for the full TCL parameters. A list of the QA/QC samples and their associated analytical samples is presented in **Table 3-2**.

The analysis of soil duplicates was within the expected variability expected for a soil matrix as described in **Appendix G**. Two soil equipment blanks had notable concentrations of parameters of concern (TCL). Equipment blank EB-011 contained sodium at a concentration of 401,000 ug/L. The three soil samples which were collected in association with this blank were analyzed for volatile components only. Equipment blank EB-012 contained assorted metals at elevated concentrations. No samples associated with this blank were submitted for laboratory analysis.

Sample duplicates are presented in the appropriate appendix with the duplicated sample. All other analytical results for QA/QC samples is presented in **Appendix F** and a discussion of QA/QC samples is provided in **Appendix G.**

Groundwater QA/QC Samples

A total of seven duplicate water samples, 12 trip blanks (TB prefix) and nine equipment blanks (EB prefix) were collected during the Supplemental Characterization groundwater sampling program. Duplicate samples were collected by alternately filling sample containers and duplicate containers from each bailer of water. Equipment blanks were collected by pouring ultrapure water over decontaminated soil sampling equipment and catching the rinsate in sample containers. These samples were analyzed for the full TCL parameters. Trip blanks were prepared in the laboratory and accompanied the sample containers into the field. One trip blank was included with each volatile sample shipment back to the lab. Trip blanks were analyzed for volatile compounds only. A list of the QA/QC samples and their associated analytical samples is presented in **Table 3-2.**

The analysis of groundwater duplicates shows a significant variability in the analytical results in some paired samples. A review of this data (**Appendix G**) has attributed this variability to the sediment load in the samples. One equipment blank (EB-001) had a high concentration of iron (888 ug/L) and a small amount of cyanide (15.1 ug/L). The iron concentration observed did not affect the associated groundwater samples as iron concentrations in these samples ranged from 10,000 ug/L to over 265,000 ug/L. Cyanide concentrations were all below the detection limit (10.0 ug/L) with the exception of one sample (HPGW3 at 11.2 ug/L). Zinc was present in equipment blank EB-009, but no samples were collected in association with this blank.

The only volatile components detected in the trip blanks were acetone, methylene chloride and carbon disulfide. These compounds have also been detected in low concentrations in many of the samples collected during this investigation. These compounds are routinely used in laboratory analysis and equipment cleaning and, as they are not compounds typically used at Camp Lejeune, have therefore been determined to be laboratory contaminants.

Sample duplicates are presented in the appropriate appendix with the duplicated sample. All other analytical results for QA/QC samples is presented in **Appendix F** and a discussion of QA/QC samples is provided in **Appendix G.**

Decon Water QA/QC Blanks

One sample of the potable water (FB-001) and three samples of the DI water (DI-001, 002, and 003) used for cleaning field equipment was sampled during this investigation. As the field blank was collected from the potable water supply, its analysis reflects the groundwater at the site containing high concentrations of calcium, iron and sodium. The DI water blanks contained concentrations of iron and zinc well below what was detected in the groundwater samples.

All analytical results for QA/QC samples is presented in **Appendix F** and a discussion of QA/QC samples is provided in **Appendix G.**

EPA Sample Spikes

EPA provided the sampling crew with laboratory spiked samples during their audit of the sampling program. These samples are meant as a blind test of the analytical laboratory. ESE has not received the sample spike values from EPA at the time this report was prepared. As this data becomes available it will be presented. Analytical results of the samples provided to ESE are presented in **Appendix F** as EPA-3 and EPA-4.

Drilling Mud Blank

One sample of the drilling mud used in the drilling of the monitor wells was collected during the field effort. There was a field error in the collection of the mud blank. A mud blank should be collected prior to use of the mud. The mud blank in question was collected after the mud had been circulated through a contaminated zone rendering it useless. This data is presented in **Appendix F** as MB-001

5.5 CASTLE HAYNE AQUIFER PUMP TEST

An aquifer pump test was performed on the Castle Hayne aquifer at HPIA. Existing Water Supply Well No. 642 was selected as the pumped well because it was the closest active well to HPIA which was not actually within the zone of deep groundwater contamination. Use of this well eliminated the need to dispose of large quantities of contaminated groundwater generated during the test. In addition, the existing well log for Well 642 indicated that the subsurface materials were typical of those encountered throughout HPIA. This ensured that the aquifer parameters quantified by the pump test would be representative of HPIA as a whole. Three observation wells provided drawdown data for analyses. These three wells included an existing USGS observation well, located 90 feet from the pumping well; observation well No. 642-1, located 200 feet from the pumping well; and observation well No. 642-2, located 300 feet from the pumping well.

The sequence of geologic materials at HPIA begins with an interval of sands approximately 30 feet thick, which overlies a clay and sandy clay layer. The clayey interval is discontinuous throughout the area and variable in thickness. Each of the boring logs for all monitor and observation wells installed in the northern area of HPIA was reviewed to determine the thickness of the clay-rich layer underlying the shallow aquifer. Variability of thickness was noted across the area, and an average value of 17 feet was used in all calculations. Below the clayey interval, the remainder of the material of interest consists of sand and limestone with minor amounts of silt, silty sand, and rock.

The presence of water within this sequence of geologic materials creates two aquifers separated by the clayey interval. From the surface of the shallow groundwater (which occurs at a depth of 12 feet BLS in Well 642), to the top of the clayey interval, an unconfined aquifer (surficial aquifer) is present in the near-surface sands. The regional literature indicates that the clayey interval acts as a semi-confining unit retarding flow between the unconfined aquifer above and a semi-confined aquifer (Castle Hayne) present in the sand and limestone below. The Castle Hayne aquifer was assumed to extend to the base of the freshwater system, a depth of approximately 300 feet below mean sea level (NEESA, 1983).

5.5.1 Well Construction

The wells used for the pump test and analyses provided data concerning the Castle Hayne aquifer. A construction log of pumping well No. 642 was provided to ESE by Camp Lejeune. The well is similar to other supply wells at Camp Lejeune, which are approximately 6-inch inside diameter (ID) and 200 feet deep. These wells are screened to produce water from the intermittent sand and limestone zones.

Wells No. 642-1 and 642-2 were constructed under the direction of ESE, specifically to monitor the Castle Hayne aquifer during the pump test. The wells were drilled at distances of 200 feet and 300 feet, respectively, from the pumping well. These distances were determined after review of the available geohydrologic information for the sand and limestone aquifer. As a common practice, pump test observation wells are installed at distances related to multiples of the aquifer thickness. The greater the distance from the pumped well that an observation well is installed, the more the aquifer parameters derived from that observation well are representative of the aquifer as a whole. However, at some distance from the pumped well, drawdown may no longer be measurable in the observation well. Review of the data for the sand and limestone aquifer, conducted with the USGS in Raleigh, NC, strongly suggested that drawdown at distances greater than two times the aquifer thickness (i.e., two times 200 feet) would not be measurable. As a result, two observation wells were installed at distances equal to 1.0 and 1.5 times the aquifer thickness. Each observation well was drilled to a depth of 200 feet and screened continuously from 100 feet to 200 feet (i.e., similar to the existing water supply wells). Well No. 642-1 is designated Well 1; Well No. 642-2 is designated Well 2.

The third well used for the analyses is an existing USGS observation well. This well is 90 feet deep and assumed to be screened over the lower portion of the well. The USGS well is designated Well 3.

5.5.2 Pump Test Procedures

The pump test started at 11:36 a.m. on April 13, 1987. A pumping rate of 85 gallons per minute (gpm) from pumping well No. 642 was maintained for a period of 42.96 hours (2,577.6 minutes). Prior to the start of the test, during the pumping period, and during the recovery period, water levels were measured both with pressure transducers and hand measurements. In Situ pressure probes and a data logger were used in the Observation Wells No. 1, 2, and 3 to record water levels. Measurements of water level by the USGS wetted-tape method were also made in the three wells mentioned above and in 11 other wells in the immediate vicinity of the pump test. For the most part, the data obtained by the pressure transducers were used for the analyses. Ninety-four minutes into the test, the pressure transducer monitoring the water level in the USGS well (Well No. 3) malfunctioned, and water levels as recorded by the data logger appeared to rise in this well. Hand measurements indicated the water level continued to decline. The early-time data analyzed for Well No. 3 were recorded by the data logger; after 94 minutes, data from Well No. 3 used for the analysis were recorded by the ESE field team.

A decision was made to discontinue pumping based on observations that drawdown levels had reached a steady-state condition. At 5:32 a.m. on April 15, 1987, the pumping well was turned off and recovery of the aquifer was monitored for 10.68 hours (641.25 minutes). Recovery was terminated when recharge from a rainstorm caused water levels to rise above initial static water levels.

5.5.3 Pump Test Analysis Methods

Analyses of the drawdown and recovery data generated by the pump test were performed by ESE. All analytical techniques are most accurate if the actual field conditions parallel the assumptions utilized in the derivation of the techniques. Actual field conditions rarely are identical to these assumptions. As a result, a wide range of analytical techniques was utilized to evaluate if any one technique biased the results to a measurable extent. Drawdown data were analyzed for values of aquifer transmissivity and storage coefficient by methods developed by Theis (1935), Hantush and Jacob (1955), and Walton (1962). The data were also analyzed by the distance-drawdown method developed by Cooper and Jacob (1946). The methods of Hantush and Jacob (1955) and Walton (1962) were also used to evaluate properties of the semi-confining layer.

The first three methods interpret the aquifer parameters from logarithmic plots of the drawdown data as compared to type curves based on ideal conditions. The distance drawdown method is a semi-logarithmic straight-line data plot in which the slope of the straight line is characteristic of the aquifer.

The recovery data were analyzed by the recovery method and the residual drawdown method. These are both semi-logarithmic straight-line methods based on the equations developed by Cooper and Jacob (1946).

Pumping well efficiency was evaluated using specific-capacity data from the well. The specific capacity theoretically available from the well was estimated using empirical relationships based on the Jacob equation. The specific capacity, or amount of discharge per foot of drawdown (Q/S), available from the semi-confined aquifer at Camp Lejeune was estimated to be 4.88 gallons per minute per foot (gpm/ft). The specific capacity of the well actually observed during the pump test was 1.5 gpm/ft. The efficiency of the well is evaluated based on the following relationship:

$$\text{Well efficiency \%} = \frac{\text{Actual Q/S}}{\text{Theoretical Q/S}} \times 100$$

Evaluation of the effects of tidal fluctuations on the drawdown data was made by examining the plots of drawdown versus time, and also water-level data during the pump test from background wells. The plotted pump test data represent smooth curves which do not show any variability associated with tidal effects. The background well data indicate that the maximum total cyclic fluctuation observed was 0.2 feet. Based on adjustment to a central level, a maximum correction for tidal fluctuations would be 0.1 foot, with most corrections being less than 0.1 foot. As the plotted data do not show any variability because of tidal fluctuations, and the correction would be 0.1 foot or less, no corrections to the drawdown data were made.

5.5.4 Pump Test Conclusions

The pump test was successful in terms of evaluating the various aquifer parameters. The overall average transmissivity for the limestone aquifer was determined to be 9.6×10^3 gpd/foot. The overall average storage coefficient was estimated to be 8.8×10^{-4}. Some variation between wells was observed (as would be expected) in the variable geologic material present at HPIA, but the aquifer appears to be more transmissive at greater depths (100 to 200 feet). The values obtained by the analyses are in agreement with previously developed values for the wells in the Castle Hayne aquifer in the region.

The analyses indicate the Castle Hayne aquifer is semi-confined and is receiving recharge through a clayey layer overlying the aquifer near the surface. The hydraulic conductivity of this layer was estimated to be an average of 4.6×10^{-3} foot/day (1.6×10^{-6} cm/sec). This value of hydraulic conductivity is typical of silty sands and silty clays, material which would act more as a semi-confining layer and not a complete confining layer. The semi-confining layer exhibits the greatest leakage in the vicinity of Well No. 3.

The efficiency of the pumped Well No. 642 was evaluated. The well was found to be 31 percent efficient. This is not an efficient well. Cleaning and redevelopment of the well may increase its efficiency.

6.0 SUMMARY AND CONCLUSIONS

6.1 RECORDS SEARCH

The existing IAS report (NEESA, 1983) was reviewed, and potential sources of the contamination identified by the Verification Step efforts were noted. With the assistance of Camp Lejeune staff, a 2-person team from ESE conducted a building-by-building evaluation of all past and/or current activities that may have utilized any solvent compounds. buildings and other facilities identified in the IAS report were evaluated with extra caution. In many cases, the physical facilities of the buildings (i.e, floor drains, sumps, and unmarked pipe lines) were inspected to identify the general purpose and any interconnections. Any pits, tanks, or other drainage structures outside of the buildings were also closely investigated.

A number of potential source areas within HPIA were identified, for the most part associated with vehicle maintenance facilities. Three specific areas exhibited a higher probability of actually being the source of the observed contamination: (1) Bldgs. 901, 902, and 903; (2) Bldg. 1202; and (3) Bldgs. 1502 and 1601.

6.2 SOIL INVESTIGATION

6.2.1 Soil Gas Survey

To optimally site monitor well locations, soil gas sampling and analysis was conducted in the vicinity of all buildings that could potentially act as VOC source areas, as indicated by the records search effort.

VOCs, if present in groundwater or in the soil matrix, occupy the interstices or voids in the soil. Vapors from the interstitial space were sampled and characterized using a portable gas chromatograph (GC). Determination of contaminant concentrations to the low parts-per-billion level was made with this system. TCE was used as the indicator compound at HPIA to trace volatile plumes.

The soil gas investigation corroborated the records search efforts by verifying the presence of TCE within the unsaturated soils at the three primary sites. Limited amounts of TCE contamination were detected at sites other than the three major ones.

6.2.2 Soil Sampling and Analytical Results

Shallow soil borings were performed at HPIA to evaluate the extent of shallow (above the water table) soil contamination in three areas of concern at HPIA. These areas are located in the vicinity of Buildings 1601, 902, and 1202.

Each soil boring was advanced to the water table. Continuous split spoon sampling was conducted while vapor monitoring with an photoionization detector, and samples were selected from each boring for chemical analysis. Ten percent of the samples collected were analyzed for full Target Contaminant List (TCL) parameters. The remaining 90% were analyzed for volatile organic compounds (TCL VOAs), pesticides and PCBs, and Toxicity Characteristic Leaching Procedure (TCLP) metals.

While TCE and other volatile compounds were the primary concern during the soil gas survey, these compounds were detected in few of the soil samples collected. Quantifiable concentrations of TCE, toluene and 1,2-DCE were detected in samples collected from one soil boring (SB-5), and ethylbenzene and xylenes were detected in another. Several other compounds were detected as TICs. Semi-volatile compounds were quantified in one soil sample and were detected as TICs in eight others. Pesticides were quantified in a total of five samples collected from three boreholes.

Three metals (aluminum, calcium, and iron) were abundant in many of the soil samples analyzed in concentrations greater than 1,000 ug/kg. Many of the other metals analyzed for were also detected, but were detected in quantities that were above the instrument detection level but below the certified limit of the method. TCLP analysis of 27 samples showed detectable quantities of virtually all analytes with the exception of mercury and silver. Mercury was detected in one sample and silver was not detected in any sample. Those analytes which were detected typically were detected in quantities that were above the instrument detection level but below the certified limit of the method.

Based on these analyses, the shallow soils at the areas investigated do not appear to be heavily contaminated. Volatile compounds detected in the soil gas remain in the vapor phase and have not adhered to the soils. The hits in the sample from SB-5 were collected near the old TCE tank at Building 902 and appear to be associated with that tank.

The semi-volatile compounds detected in boring SB-6 and the volatile compounds detected in SB-14 are fuel related (diesel) and fit with the use of these areas (Buildings 902 and 1202) as vehicle repair and maintenance.

Pesticide contamination is limited and occurs in the surface soils (0-2 feet) in three of the five samples where they were detected.

Many of the metals detected were found in all samples analyzed and are therefore indicative of the soil matrix and associated clays.

6.3 GROUNDWATER INVESTIGATION

6.3.1 Monitor Well Installation

A network of groundwater monitoring wells was installed at the site to define the nature of the contaminants within the groundwater and to determine the horizontal and vertical extent of the identified contaminants. A total of 33 wells were installed during the Characterization phase (September 1986 through August, 1987); 27 shallow wells, three intermediate wells, and three deep wells. Additionally, two shallow wells were installed at the Hadnot Point Fuel Farm (Study Area 22) and one at the transformer storage yard (Study Area 21) during the Verification investigation.

In December 1990, eight groundwater monitoring wells were installed downgradient of the four areas of concern in the Hadnot Point area at Camp Lejeune. Both an intermediate and deep well were installed at each location in order to evaluate the vertical distribution of contaminants in the groundwater downgradient of specific areas of concern. The areas of concern are Building 1602, Building 902, Building 1202, and the Industrial Area Tank Farm (Site 22).

Shallow wells were completed to a depth of 25 feet. Each of the intermediate wells were screened from approximately 65 to 75 feet below grade. The deep wells were screened from approximately 140 to 150 feet below grade. All wells were developed by pumping, and well elevations and locations were surveyed.

6.3.2 Groundwater Sampling

Characterization Phase

Each of the shallow wells installed during the Characterization were sampled three times during the phase, with a period of approximately 60 days between sampling events. The intermediate and deep wells were sampled once during this phase. All samples collected were analyzed for lead, oil and grease and volatile organics (EPA Method 624).

Supplemental Characterization

Each of the groundwater monitor wells and nine water supply wells were scheduled to be sampled during the field investigation. One shallow well and one deep well could not be sampled because they could not be located after numerous attempts to find them. Water supply wells 608 and 630 were not sampled because the wells were either welded shut (608) or demolished (630).

All groundwater samples collected during this phase were analyzed for full TCL parameters.

6.3.3 Analytical Results

Surficial Aquifer

The sampling and analysis program has delineated the extent of contamination within the surficial aquifer at the HPIA. Two nodes of VOC and\or petroleum hydrocarbon contamination were found to exist. The northern node consists of two separate sources of contamination--one centered near the maintenance facility associated with Bldg. 901, and another centered at the Hadnot Point Fuel Tank Farm (Site 22). Contaminant isopleth modeling suggests that these two source areas may have effectively coalesced into one larger node of contamination. The southern node is centered near the maintenance facility associated with Bldgs. 1601 and 1709.

When looking at the type of contamination at each of the nodes, fuel related compounds, as would be expected, constitute the bulk of the contamination at the tank farm, where a layer of floating product has been identified. The contamination centered near building 901 consists primarily of 1,2-DCE and TCE with minor secondary contamination by fuel related compounds. The contamination at Building 1601 also consists of 1,2-DCE and TCE, but there is a strong fuel related component. Wells within the remainder of the plume are contaminated primarily by solvents. A comparison of the Characterization and supplemental Characterization data indicates that the strength of the VOC plume has increased based on the source strength at the center of each node. The horizontal extent of the plume has remained generally the same.

Semi-volatile compounds were detected in only six of the shallow wells tested. These compounds occurred in areas with high VOC contamination and were compounds commonly associated with diesel fuels or oils.

Pesticide contamination was limited to one compound in one well and reflects the soil data in that any pesticides present are typically contained in the upper portion of the soil column.

Metals in the shallow groundwater also reflect the soils data. High concentrations of basic metals typically associated with clays were in all samples. Part of this may be attributed to the unfiltered samples which are collected and analyzed. Release of metals adsorbed to the clays or contained in the clay minerals themselves can be achieved through the acidification of the sample during preservation. The shallow wells at the HPIA are all set into a silty clayey sand which extends to a depth of approximately 30 feet across the site. Four metals (chromium, iron, manganese, and sodium) were detected in concentrations above the primary or secondary drinking water standard in the majority of the wells tested. Lead was also in concentrations over the standards in one third of the wells.

Castle Hayne Aquifer

Low concentrations of VOCs (1-50 ug/L total) were detected in all of samples collected from the intermediate depth wells. These compounds consisted of 1,2-DCE and the four fuel related compounds (benzene, toluene, ethylbenzene, and xylenes) although vinyl chloride was detected in well HPGW30-2. Most of the fuel related compounds were detected as TICs only.

Semi-volatile compounds were detected in four of the intermediate depth wells. These compounds are typically associated with diesel fuels and oils, although a phthalate compound was detected as a TIC in three of the wells. Two of the wells contained naphthalene at levels greater than 50 ug/L.

No pesticides were detected in any of the samples collected from the intermediate depth wells.

Metals concentrations decreased significantly in the samples collected from the intermediate depth wells as compared to the shallow wells. This may be attributed to fewer clay minerals in the monitored zone. The intermediate wells are set into a lithological layer composed of sand, shells, and cemented clastics. The rise in the calcium concentrations reflects this change in lithology. Iron remained in concentrations above the standards in all of the intermediate depth wells sampled, and manganese and thallium each exceeded the standards in one well.

Deep Wells

Fuel related VOCs (total 107 ug/L) were detected in one sample collected from a deep well (HPGW32-3). These compounds were also detected in the sample collected from the intermediate depth well at this location. No shallow well exists in this cluster, but the cluster is located within the shallow plume originating from the fuel tank farm area. Solvents were detected as TICs in one other well.

One semi-volatile compound was detected as a TIC in two of the samples collected from the deep wells. No pesticides were detected in any of the samples collected from the deep wells.

Metals concentrations were also decreased in the samples collected from the deep wells as compared to the shallow wells. The deep wells are set into similar materials as the intermediate depth wells; a lithological layer composed of sand, shells, and cemented clastics. Elevated calcium concentrations also occur in these wells. Iron remained in concentrations above the standards in all but one of the deep wells sampled, but these concentrations are up to 300 times less than those seen in the shallow well samples. Manganese barely exceeded the standard in one well.

Water Supply Wells

Solvent contamination was detected in four water supply wells in 1984. Contamination in these wells included solvents and fuel related compounds. These wells were taken off line upon the discovery. VOC contamination in these wells has dropped since they were taken off line. With the end of pumping from these locations, contamination is no longer being drawn into this zone. VOC contamination in the worst well (WS602) has dropped from a total of approximately 2,400 ug/L in 1984 to less than 60 ug/L. Samples collected from four additional wells continue to show very low concentrations (1-3 ug/L) of solvent compounds as TICs.

Iron and manganese continue to be elevated above standards in some of the wells tested.

6.4 AQUIFER TESTING

An aquifer pumping test was conducted at HPIA in April, 1987 to determine site-specific aquifer characteristics for the Castle Hayne aquifer, and to evaluate the interconnection between this unit and the surficial aquifer. Water supply well 642 was selected for the pumping test because it was the closest, active well to HPIA that was not within the zone of deep contamination. The three observation wells included in the pumping test were a USGS well and two observation wells.

Drawdown data from the pumping test was analyzed by a number of analytical methods. The methods of Theis (1985), Hantush (1955), and Walton (1962) were employed to analyze drawdown data for values of transmissivity and storage coefficient. The distance drawdown method of Cooper and Jacob (1946) was also used to analyze drawdown data. Additionally, the methods of Hantush and Jacob (1955) and Walton (1962) were used to evaluate properties of the semi-confining layer.

6.5 GEOHYDROLOGY

The installation of the shallow monitor well network identified the presence of interlayered sands, silts, and clays in the shallow subsurface. This mixed sequence of materials appears to extend to a depth of approximately 100 feet at which point a more permeable unit of sand and limestone dominates the lithology. All potable groundwater at Camp Lejeune is obtained from this sand/limestone interval (Castle Hayne aquifer).

Groundwater flow at the HPIA is generally toward the New River. Horizontal hydraulic gradients in the surficial aquifer at HPIA were determined from the potentiometric surface map. In general, the horizontal hydraulic gradient in the surficial aquifer at HPIA is approximately 0.003 feet/ft. Specifically, the northern and southern portions of HPIA exhibit a horizontal hydraulic gradient of 0.003 feet/ft. However, the west-central portion of HPIA exhibits a horizontal hydraulic gradient of approximately 0.004 feet/ft (ESE, 1991). al. (1989) and ESE (1988).

Hydraulic gradients were also calculated for the deep and intermediate zones. Due to there being fewer measured points in these zones, the gradients are calculated from one end of the site to the other between well clusters 4 and 24. The calculated gradient for the intermediate zone was 0.0015 ft/ft and for the deep zone the gradient was 0.0021 ft/ft. All gradients were calculated using the February 1991 data.

Vertical flow gradients were determined at monitoring well cluster locations by comparing water level measurements taken from shallow, intermediate, and deep monitoring wells. The shallow monitoring wells are approximately 25 feet deep, the intermediate monitoring wells are approximately 75 feet deep, and the deep monitoring wells are approximately 150 feet deep.

The vertical gradient between the shallow zone and the deeper zones (intermediate and deep wells) is in the downward direction and increases as you move upgradient across the site. This downward gradient is most pronounced in cluster 24. The occurrence of this downward gradient is most likely a result of pumping from the lower zones for potable uses and provides the hydrologic mechanism to carry contaminants from the shallow zones to the lower zones.

In general, the water levels within the intermediate and deep well of each well cluster are nearly the same with the exception of cluster 24 which shows an upward gradient. This data reflects the fact that the intermediate and deep zones behave hydrologically as one unit.

The Castle Hayne aquifer was found to have an average transmissivity of 9.6×10^3 gpd/ft and an average storage coefficient of 8.8×10^{-4}. The hydraulic conductivity of the semi-confining bed separating the shallow and deep aquifer zones was found to be approximately 4.6×10^{-3} ft/day. The overall average leakance of this semi-confining bed was determined to be 1.1×10^{-3} day^{-1}.

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