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FEASIBILITY STUDY FOR
HADNOT POINT INDUSTRIAL AREA
CAMP LEJEUNE, NORTH CAROLINA

FINAL

Prepared for:

MARINE CORPS BASE
Camp Lejeune, North Carolina

Prepared by:

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EXECUTIVE SUMMARY

This report presents the findings of the focused Feasibility Study (FS) for the Hadnot Point Industrial Area (HPIA) at Camp Lejeune, North Carolina. The FS follows the initial assessment study (IAS) of HPIA, which was completed in April 1983, and was conducted concurrently with the characterization step investigation at HPIA. The database developed by the characterization step effort was utilized in the FS. The purpose of the FS is to provide information necessary for selection of a cost-effective remedial alternative for cleanup of detected contamination within the shallow aquifer at HPIA.

In the following sections, information related to the extent of contamination, objectives of the remedial action, applicable technologies, and remedial action alternatives are addressed.

EXTENT OF CONTAMINATION

The IAS identified several areas at HPIA requiring confirmation investigation of potential contamination due to base activities resulting in generation of potentially hazardous wastes. Contamination at HPIA has resulted from improper waste disposal, POL disposal, underground storage tank leakage, solvent spills, and sludge disposal.

CONTAMINATION ASSESSMENT

Thirty-five monitor wells were installed at HPIA and sampled for the purpose of assessing the extent of contamination at the site. Additionally, four water supply wells have been monitored. The results of the sampling events led to the selection of target contaminant concentrations and selection of applicable interim and long-term technologies for reducing the threat of contamination to public health and the environment.

TARGET CONCENTRATIONS

Actual cleanup criteria for remediation at HPIA cannot be established until a risk assessment study has taken place. A risk assessment would justify the need for remedial action and would serve to focus remedial action alternatives. Criteria for remediation would be developed in consideration of all realistic exposure pathways by which people, wildlife or aquatic life may be exposed to the contaminants.

No risk assessment has been performed at HPIA, and cleanup criteria could not be established for individual contaminants detected in groundwater. In lieu of cleanup criteria, drinking water standards were identified for the purpose of establishing target cleanup levels for use in developing remedial alternative cleanup goals for the FS. These target concentrations, while probably conservative, have been used to provide a level to compare contaminant groundwater concentrations for the purpose of determining the contaminants of environmental concern at HPIA.

INTERIM ALTERNATIVES

Five interim alternatives were outlined to reduce immediate health risks. The interim alternatives were considered to protect human health and the environment; their implementation will not reduce the groundwater contamination. The interim alternatives are as follows: water supply well assessment, ambient air monitoring, underground work space monitoring, continued groundwater monitoring, and cessation of continuing sources of contamination.

REMEDIAL TECHNOLOGIES

A number of currently available and demonstrated groundwater treatment technologies (long-term remedial actions) were evaluated for cleanup of contamination of groundwater at HPIA. Five remedial alternatives for remediation of contaminated groundwater were selected from the technologies based on demonstrated use, site geological and hydrogeological characteristics, and contaminant characteristics.

To select applicable remedial technologies for HPIA, a two-phase screening process was conducted. The first phase considered two factors that determine applicability to the three areas of concern: (1) waste characteristics, and (2) the degree of technological development. Technologies which were ineffectual or were otherwise limited due to contaminant characteristics and undeveloped technologies were eliminated from further consideration. Those technologies that passed the initial screening were evaluated based on site-specific characteristics for each area of concern. Technologies remaining after the site characteristics screening were subsequently used for the assembly of alternatives for each area. The remedial alternatives consist of package biological towers, carbon·adsorption, air stripping, steam stripping, and discharge to the onsite sewage treatment plant.

ALTERNATIVES SELECTION

The alternatives developed were screened based on environmental, public health, and cost criteria. This screening eliminated those alternatives which could not adequately protect human health and the environment or were an order of magnitude more costly than others in the same category.

DETAILED ALTERNATIVES ANALYSIS

An analysis of the remedial action alternatives was performed, which included technical, environmental, institutional, and public health evaluations. This included an analysis of any adverse impacts associated with the implementation of the alternative, methods for mitigating these impacts, and costs of mitigation.

The institutional requirements evaluation consisted of evaluating the effects of applicable or appropriate Federal, state, and local standards and other institutional considerations pertaining to the design, operation, and timing of each alternative.

The cost analysis was a two-step process. The initial step was to estimate the capital and operation and maintenance (O&M) costs for each alternative. To achieve this task, quantities of material requiring remediation under each alternative were estimated, and unit costs for the remedial technologies were gathered from standard cost manuals and vendor quotes. The second step was to calculate the present-worth cost of each alternative. The present-worth costs allowed the comparison of costs, in 1987 dollars, between alternatives.

SELECTION OF THE PREFERRED ALTERNATIVE

A preferred alternative was selected based on the results of the detailed analysis. The preferred alternative for HPIA is to pump groundwater directly to the onsite Hadnot Point Sewage Treatment Plant (containing two trickling filters) and to discharge effluent to the New River.

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ADI	acceptable daily intake
ARARs	applicable or relevant and appropriate requirements
BOD	biological oxygen demand
ESE	Environmental Science and Engineering, Inc.
FS	feasibility study
ft	foot
ft BLS	feet below land surface
ft/ft	foot per foot
g	gram
GAC	granular activated carbon
gal	gallon
gpd	gallons per day
gpm	gallons per minute
HPIA	Hadnot Point Industrial Area
L	liter
LEL	lower explosive limit
MEK	methyl ethyl ketone
MCLs	maximum contaminant levels
MG	million gallons
MGD	million gallon day
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
NCAC	North Carolina Administrative Code
O&M	operation and maintenance
OVA	organic vapor analyzer
PID	photoionization detector
POTW	publicly owned treatment works
RA	risk assessment
RMCLs	Recommended Maximum Contaminant Level
STP	sewage treatment plant

LIST OF ACRONYMS

TLV	threshold limit value
ug/L	micrograms per liter
USEPA	U.S. Environmental Protection Agency
VOCs	volatile organic compounds

1.0 INTRODUCTION

Under contract to Atlantic Division Naval Facilities Engineering Command, a focused feasibility study (FS) was conducted by Environmental Science and Engineering, Inc. (ESE) to determine the most appropriate method for remediating contaminated groundwater in the Hadnot Point Industrial Area (HPIA) at Camp Lejeune, North Carolina. The specific study area for which this focused FS was conducted is that portion of the overall HPIA bounded by Sneads Ferry Road to the north, Holcomb Boulevard to the west, Louis Road to the east, and Main Service Road to the south, including all utility rights-of-way (see Figure 1-1). During the course of the study, monitoring well data from the site were analyzed, cleanup standards were determined, and remediation alternatives were developed and evaluated in detail based on technical feasibility, environmental/institutional benefits, and cost criteria.

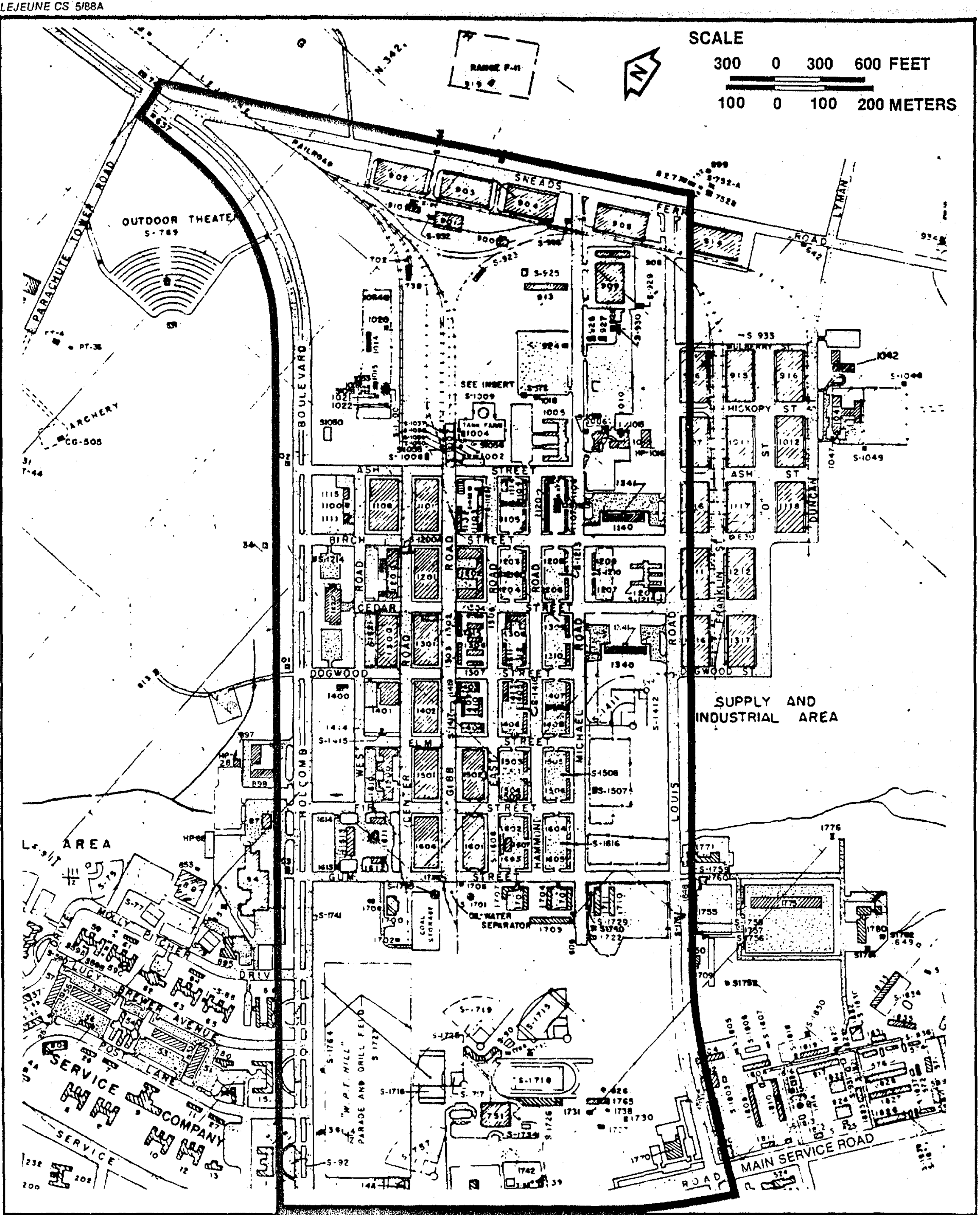

Figure 1-1
HADNOT POINT INDUSTRIAL AREA

SOURCE: Camp Lejeune, 1987.

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2.0 FOCUSED FEASIBILITY STUDY

2.1 OBJECTIVES

The objectives of the focused FS for HPIA are to:

1. Establish target drinking water criteria which comply with contaminant-specific applicable or relevant and appropriate requirements (ARARs) of Federal laws and state maximum contaminant levels (MCLs) using the contamination assessment data.
2. Evaluate currently available and demonstrated groundwater treatment technologies and develop five interim and five long-term remedial alternatives for remediation of contaminated groundwater to ensure the protection of human health and the environment.
3. Conduct a detailed evaluation of the five long-term remedial alternatives.
4. Make recommendations on appropriate long-term alternatives based on the detailed evaluation and cost estimates.
5. Identify any additional data needs for the design/implementation of the recommended interim and long-term remedial alternatives.

In conducting the FS, available groundwater treatment technologies and actions were evaluated for availability, demonstrated performance, and remediation applicability based on the contamination assessment from groundwater monitoring data from HPIA. Technologies and actions which were considered applicable to remediation of HPIA were then identified. Based on these identified technologies and actions, interim and long-term remedial alternatives were assembled. Long-term alternatives were refined to include design/operation requirements and evaluated in detail with respect to technical feasibility, environmental/institutional benefits, and order-of-magnitude cost. Included in the detailed evaluation were such factors as safety, engineering, human health and environmental protection, environmental effects, and compliance with regulations. All operations and maintenance (O&M) costs were determined based on the technologies and then adjusted to present worth for comparison purposes. The long-term alternatives were finally ranked comparatively using the technical, environmental/institutional, and present-worth cost criteria. Based on the results of the detailed evaluation, recommended alternatives in order of preference were identified. Information and data necessary to finalize the alternative selection were recommended, if applicable.

The methods used by ESE for identifying and evaluating remedial alternatives are discussed in detail in subsequent sections of the focused FS report.

2.2 SITE GEOHYDROLOGY

A total of 35 monitor wells have been installed in HPIA. Of this total, 29 have been completed in the shallow aquifer [25 feet (ft) deep], three have been completed to an intermediate depth (75 ft), and three are deep (150 ft) wells. Figure 2-1 shows locations of the monitor wells. Additionally, two wells were installed to a depth of 200 ft to monitor drawdown during a pump test. The lithology of the area is primarily silty-sand and sandy-clay layers, with isolated, non-continuous clay lenses. At a depth averaging 60 feet below land surface (ft BLS), the lithology grades to gravelly sand, shell, cemented clastics, and limestone layers. The surface of the shallow groundwater lies within the silty-sand and sandy-clay at depths ranging from 6.85 ft BLS in the northern sections to 14.74 ft BLS in the wells in the southern section. The groundwater flow is to the south of the area, with a slight deflection to the west in the vicinity of Shallow Monitor Well No. 19. Figure 2-2 shows the potentiometric surface of the shallow aquifer at HPIA. The average hydrologic gradient over the area is 0.0027 foot per

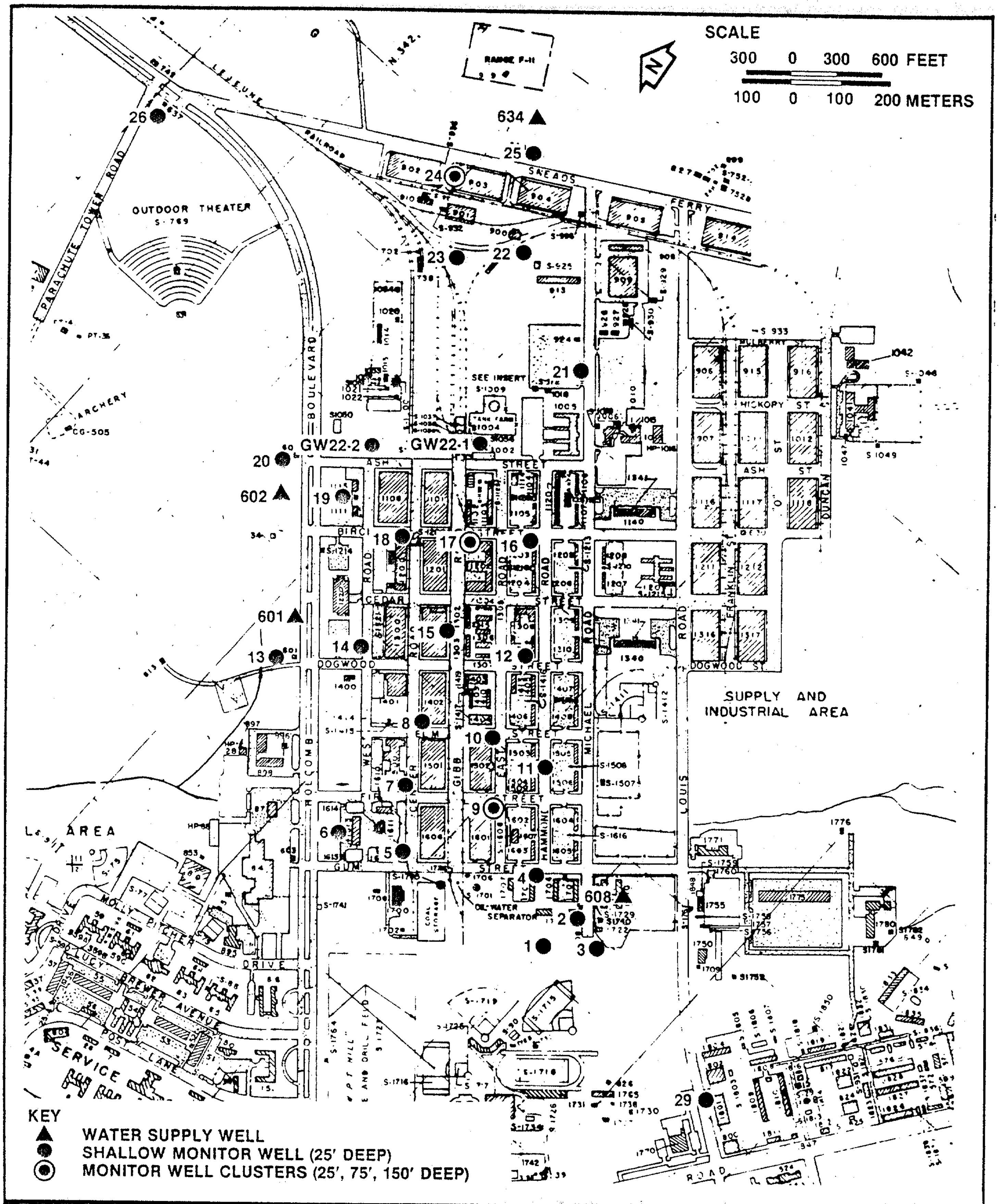

Figure 2-1
LOCATION OF MONITOR WELLS AT HADNOT POINT INDUSTRIAL AREA INSTALLED AFTER SOIL GAS INVESTIGATION
SOURCE: ESE, 1988.

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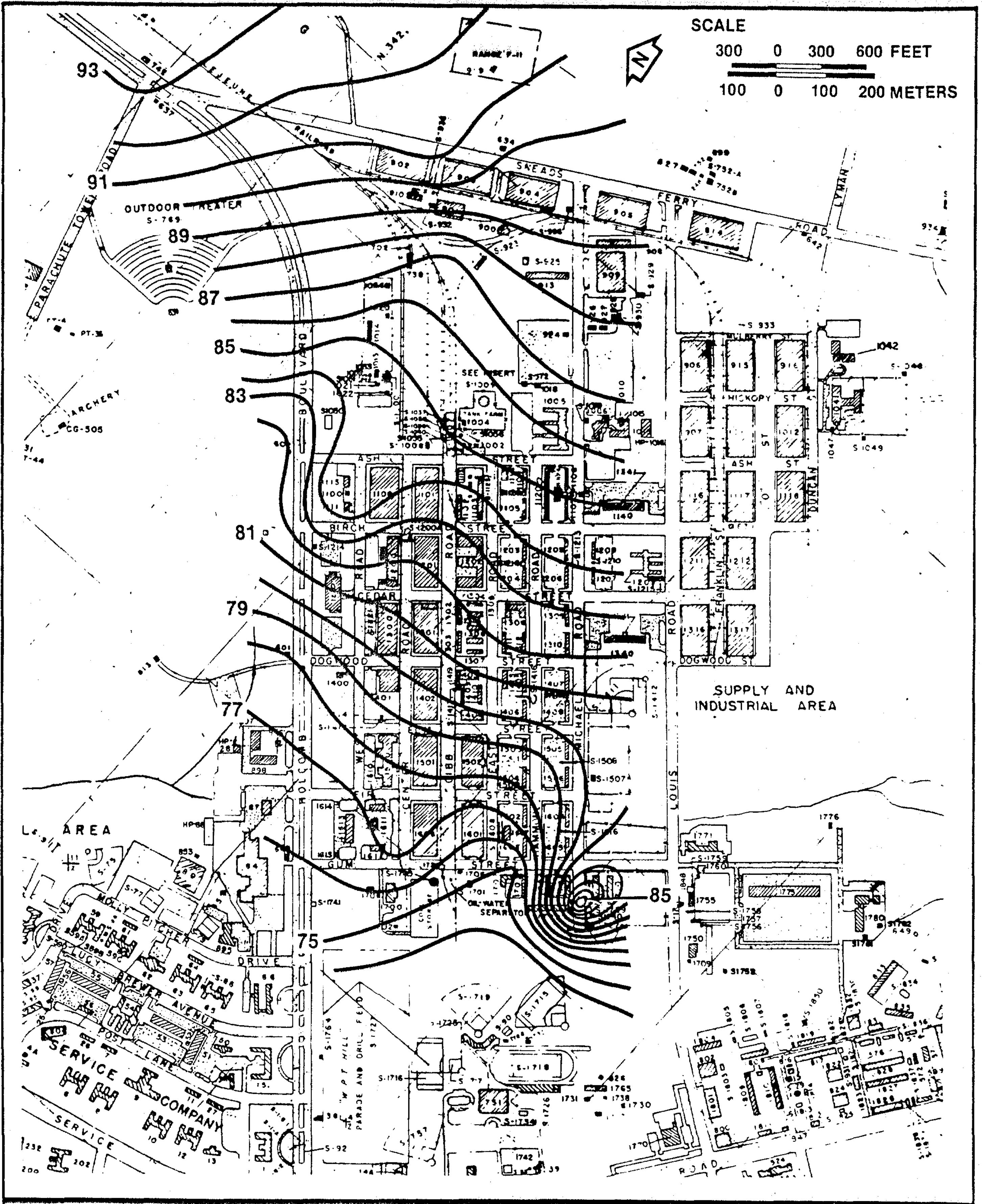

Figure 2-2
POTENTIOMETRIC SURFACE, SHALLOW AQUIFER
HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE, 1988.

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foot (ft/ft); it ranges from 0.0041 ft/ft in the northern area to 0.0023 ft/ft in the southern area.

2.3 CONTAMINATION ASSESSMENT

Samples collected by ESE personnel from the 35 monitor wells installed at HPIA were shipped to ESE's Gainesville laboratory and analyzed for the presence of 35 volatile organic compounds (VOCs) (EPA Method 8240), lead (EPA Method 6010), and oil and grease (EPA Method 413.2). The shallow monitor wells were sampled in January, March, and May 1987. The results of the analyses are presented in Appendix A in a summary table which indicates the concentration of the parameters detected in the shallow monitor wells. A total VOC isopleth map which denotes the shallow contaminated plume areas in HPIA is shown in Figure 2-3.

The intermediate and deep monitor wells were sampled in August 1987. No compounds were detected above detection limits in the intermediate monitor wells. Methyl ethyl ketone (MEK) was the only compound detected in any of the three deep monitor wells. It was detected at a concentration of 140 micrograms per liter (ug/L) in deep Well No. 9 and 290 ug/L in deep Well No. 17. Due to the limited number of data points, a total VOC isopleth map could not be developed for the deep zone of the aquifer.

In addition to the monitor wells, potable water supply wells (200 ft deep) in the area were sampled on six occasions, twice by ESE personnel and four times by Camp Lejeune personnel. Water supply Well 602 was sampled in July 1984 by ESE. Analytical results indicated the groundwater contained VOCs (see Table A-2), and the well was immediately closed by base personnel. Water supply Wells 601, 602, 608, 634, and 637 were sampled on December 5 and 12, 1984 by Camp Lejeune personnel. VOCs were detected in three of the four wells (see Table A-2), and all wells were subsequently closed. Sampling by Camp Lejeune on December 19, 1984

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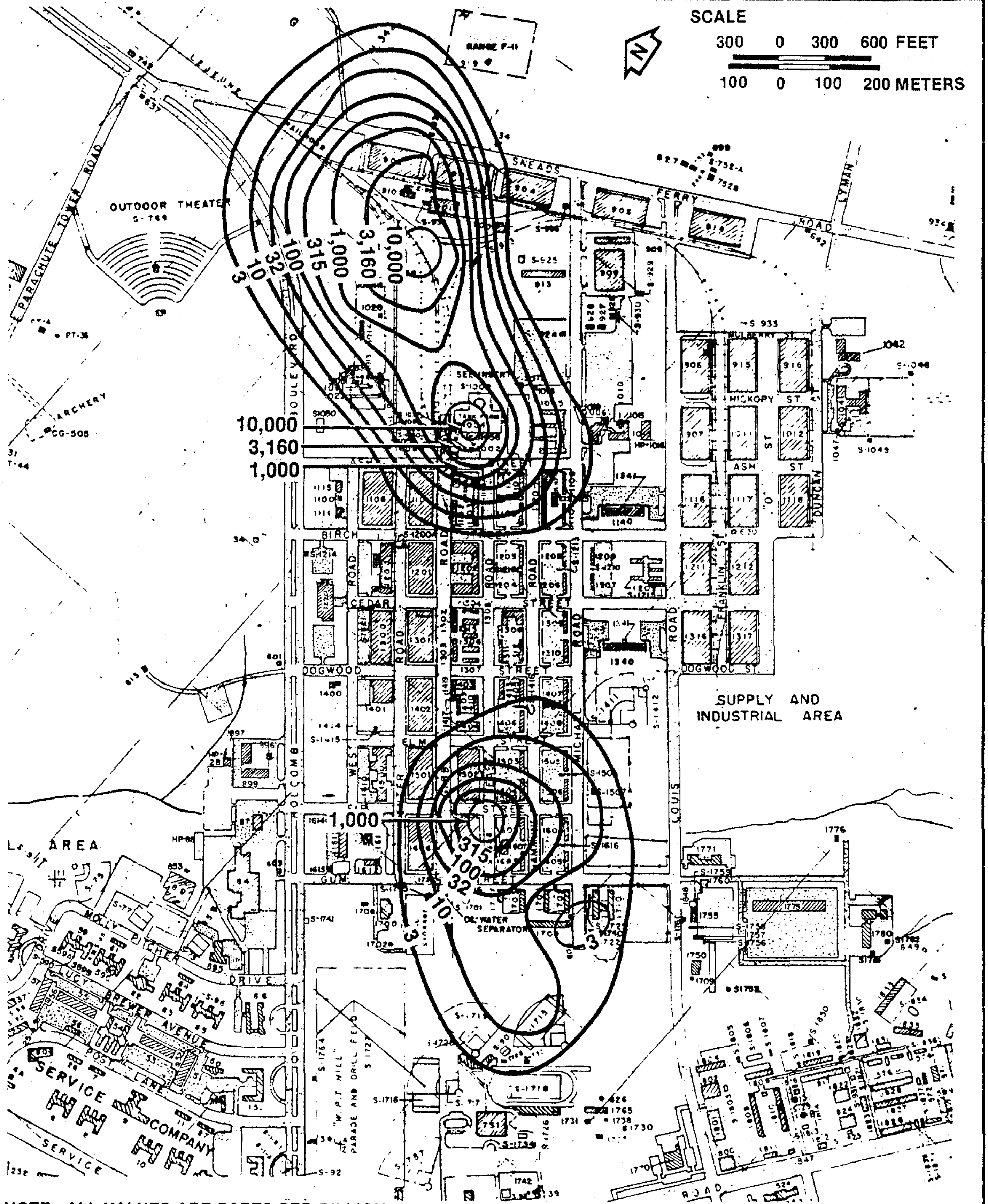

NOTE: ALL VALUES ARE PARTS PER BILLION.

Figure 2-3
TOTAL VOLATILE ORGANIC COMPOUND ISOPLETH MAP — HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE, 1988.

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and in January 1985 also detected VOCs. Water supply Wells 601, 602, 608, and 634 were sampled by ESE in November 1986.

Samples were analyzed for 137 different chemical parameters. Appendix A lists parameters and their concentrations in a summary table which shows the compounds detected in the water supply wells for each of the three sampling events (July 1984, January 1985, and November 1986).

2.4 DRINKING WATER STANDARDS

Drinking water criteria have been evaluated for the compounds detected (above detection limits) in the sampled wells using contaminant-specific criteria. The developed criteria are applicable to drinking waters; however, they are not necessarily appropriate for the groundwater at Camp Lejeune. A risk assessment (RA) at the site is necessary to determine which standards can be considered ARARs for the development of cleanup criteria at HPIA. For the purposes of the FS, drinking water standards were developed as conservative target cleanup levels for compounds detected in monitor wells. These values are subject to change after an RA has been performed.

The groundwater at Camp Lejeune is classified as a GA Water (as specified by the North Carolina Department of Natural Resources and Community Development). It contains less than 250 milligrams per liter (mg/L) chloride and occurs at depths greater than 20 ft BLS. Because no complete set of drinking water standards exists for the chemicals detected in the groundwater at Camp Lejeune, several sources were identified for the development of contaminant-specific criteria. State and National MCLs, if existing, were evaluated first before referring to other sources. Thirty-one MCLs for toxic and deleterious substances in Class GA Waters currently specified in Subparagraphs (1) through (31) of the North Carolina Administrative Code (NCAC), Title 15, Subchapter 2L, Section .0202(b) were selected first. Next, National Primary Drinking

Water Regulations, found in the Federal Register, Vol. 50. No. 219, were selected; these consist of MCLs and Proposed Recommended Maximum Contaminant Levels (RMCLs). RMCLs were used as target cleanup criteria, if MCLs did not exist (except for RMCLs with a value of zero). The next source evaluated was the Ambient Water Quality Criteria, developed by the U.S. Environmental Protection Agency (USEPA). These numbers are based on a 10^{-5} human cancer risk, associated with the daily ingestion of 2 liters (L) of contaminated water and 6.5 grams (g) of fish in water contaminated with the particular chemical. If Ambient Water Quality Criteria did not exist, standards based on other risk assessment information were selected. Criteria for certain chemicals have been developed by USEPA Health Advisory Office of Drinking Water, and a Health Effects Assessment was developed by USEPA, which provides levels based on an acceptable daily intake (ADI) of 0.12 milligram per kilogram per day (mg/kg/day). In some cases, the USEPA's RMCL was proposed to be zero. However, this level of cleanup is considered technically impracticable, and it was considered not feasible for target cleanup criteria.

Target cleanup criteria for the chemical parameters detected in the shallow monitor wells (excluding oil and grease) are listed in Appendix B, along with chemicals detected above established target criteria concentrations by monitor well. In comparison to the criteria concentrations, the analytical results of the aforementioned sampling episodes indicate several chemical parameters are present in the shallow and deep aquifer at HPIA in concentrations causing a potential human health risk. Due to the nature of the contaminants found in the deep versus the shallow portion of the aquifer and the allowable pumping rates, remediation alternatives for cleanup of the contaminated groundwater in the deep aquifer will be developed separately after collecting additional data to verify the extent of the contaminated plume area.

3.0 DESCRIPTION OF INTERIM ALTERNATIVES

Five interim alternatives for HPIA were considered to ensure the protection of human health and the environment. The main objective of these options is to reduce immediate health risks. These alternatives differ from the long-term alternatives evaluated by not reducing the groundwater contamination. For this reason, the interim alternatives have not been compared and evaluated for the selection of one best option. All five alternatives prove to be reasonable options, and each should be considered individually.

3.1 WATER SUPPLY WELL ASSESSMENT

Interim Alternative 1 involves the sampling of drinking water wells in HPIA, as well as those nearby which have the potential for contamination. Several water supply wells have been tested previously and shut down; alternative wells have been selected for drinking water use. Interim Alternative 1 entails monitoring potentially contaminated water supply wells, in addition to the routine water treatment plant effluent monitoring which currently takes place. It is recommended that water supply wells are monitored semi-annually specifically for purgeable compounds, MEK, methyl iso-butyl ketone, and xylene. Recommended water supply wells (currently operating) to be resampled include Wells No. 642 and 603. If contamination is found in any of the water supply wells, an evaluation of the water treatment plant would be required to determine if contaminants would be reduced to acceptable levels.

3.2 AMBIENT AIR MONITORING

Interim Alternative 2 involves air monitoring of areas with the potential for high levels of harmful volatile compounds. These areas may include the interiors of buildings near "hot spots" of contaminated groundwater or high levels registered during soil gas analysis (see Appendix C). Compounds which may potentially be detected during air monitoring include benzene, toluene, and xylene in the fuel farm area; and TCE, T-1,2-dichloroethene, and vinyl chloride directly south of the fuel farm. These compounds can be detected using an HNU photoionizer, an organic vapor analyzer (OVA), or detector tubes. Ambient air monitoring serves the purpose of detecting harmful pollutants which personnel working in HPIA may be exposed to on a regular basis. Sampling should be conducted during varying climatic conditions (i.e., during a dry and rainy period). In the event of compounds being detected above the threshold limit value (TLV) acceptable to humans, immediate measures, such as forced ventilation, should be taken to reduce health risks until permanent remediation measures can be taken.

3.3 UNDERGROUND WORK SPACE MONITORING

Prior to conducting or installing new underground sewer pipes or electrical cables, underground cavities and work spaces should be monitored for the presence of organic vapors and oxygen content (Interim Alternative 3). Three instruments which should be used for monitoring underground work spaces are an explosimeter, an oxygen detector, and a photoionization detector (PID). The explosimeter will determine the level of organic vapors and gases present as a percentage of the lower explosive limit (LEL). The oxygen detector will determine the oxygen percentage (which must be between 19.5 and 23.5 for breathing without supplied air), and the PID will detect organic vapor concentrations. In the possible event of oxygen or organic vapor concentrations being unacceptable, appropriate mitigation measures should be taken.

3.4 CONTINUED GROUNDWATER MONITORING

Interim Alternative 4 consists of continued monitoring of groundwater from the 35 monitor wells, as well as the abandoned drinking water wells. The wells should be monitored for the chemical parameters listed in Section 3.1. Existing monitor wells should be sampled twice per year to more accurately assess the groundwater contaminant plume characteristics.

To date, 29 shallow (25 ft), 3 intermediate (75 ft), and 3 deep (150 ft) monitor wells exist at HPIA (excluding water supply wells). In addition, water supply Wells No. 602, 608, 630, 634, 637, and 652 should be resampled.

3.5 CESSATION OF CONTINUING SOURCES OF CONTAMINATION

Interim Alternative 5 involves the evaluation and discontinuation of practices at HPIA which may result in contamination of the soil and groundwater in a particular area. Examples of practices or existing conditions which may be included in this category are outdated chemical disposal techniques, industrial operations potentially involving spillage of hazardous materials, and abandoned underground storage tanks containing fuel, oil, or hazardous chemicals (i.e., TCE). All practices involving the use of hazardous materials at HPIA should be evaluated for environmental contamination potential, and updated procedures should be instituted. In addition, locations of all underground storage tanks should be identified, and abandoned tanks should be leak tested or abandoned using approved methodologies. Any leaks identified during testing should result in removal of the stored material and cleanup of the contamination.

4.0 EVALUATION OF LONG-TERM REMEDIAL TECHNOLOGIES/ACTIONS

Available groundwater remediation response actions and technologies were evaluated to achieve the remedial response objectives (target concentrations). Table 4-1 lists the technologies evaluated in the development of remediation alternatives for the shallow zone of the aquifer underlying HPIA. Based on the parameters detected in shallow well samples above the applicable cleanup standard, five long-term alternatives capable of remediating the contaminated groundwater were developed from applicable technologies and actions. The applicable remediation technologies/actions are listed in Table 4-2. These technologies/actions were selected based on demonstrated use; site geological, hydrological, and hydrogeological characteristics; and characteristics of the contaminants. The nonapplicable technologies and reasons for exclusion are discussed in the following sections and summarized in Table 4-3.

4.1 EXCLUDED TECHNOLOGIES

4.1.1 COLLECTION

Collection by subsurface drains is generally limited to shallow depths. Although technically feasible, installation of this type of a drainage system at HPIA would be extremely difficult due to the excavation required as well as physical limitations. Costs of temporary shoring and actual dewatering during installation would be prohibitive. Actual location of appropriately sized trenches would be difficult because of the large number of physical barriers (building, etc.) in the area.

4.1.2 IN SITU TREATMENT

In situ treatment techniques have seen limited use at hazardous waste sites. Technologies such as microbial degradation, limestone treatment beds, or activated-carbon beds have many limitations and are not demonstrated technologies for groundwater treatment. Limited exposed

Table 4-1. Available Groundwater Remediation Technologies

Action	Technology
Collection	Extraction Wells Subsurface Drains
Long-term Treatment	
In Situ Treatment	Microbial Degradation Limestone Treatment Bed Activated Carbon Bed Chemical Treatment
Offsite Treatment	Sewage Treatment Plant Deep-Well Injection
Onsite Treatment	Biological Activated Sludge Trickling Filter Rotating Biological Contactor Aerated Lagoon Package Biological Tower at Pumping Point
	Physial/Chemical Ion Exchange Membrane Separation Oxidation Reduction Hydrolysis Liquid/Liquid Extraction Carbon Adsorption Air Stripping Steam Stripping Solar Evaporation Pond Spray Evaporation Wet-Air Oxidation Chemical Precipitation
No Action	Some Monitoring and Analyses may be Performed
Interim Treatment	
Containment	Barriers Slurry Wall Vibrating Beam

Table 4-1. Available Groundwater Remediation Technologies (Continued, Page 2 of 2)

Action	Technology
Containment (Continued)	Grout Curtain Sheet Piling Concrete Wall Clay Wall
Alternative Water Supply	Municipal Water System Deeper or Upgradient Wells
Contamination Assessment	Periodic Groundwater Monitoring Ambient Air Monitoring in Buildings Ambient Air Monitoring in Underground Work Space
Removal of Contamination Source	Cease Continued Sources of Contamination

Source: ESE, 1987.

Table 4-2. Applicable Groundwater Remediation Technologies

Action	Technology
Collection	Extraction Wells
<u>Long-term Treatment</u>	
Onsite Treatment	<u>Biological</u> Package Biological Tower at Pumping Point
	<u>Physical/Chemical</u> Carbon Adsorption Air Stripping Steam Stripping
Offsite Treatment	Biological Trickling Filters (HPIA STP)
<u>Interim Treatment</u>	
Alternative Water Supply	Deeper or Upgradient Wells Municipal Water Bottled Water
Contamination Assessment	Periodic Groundwater Monitoring Ambient Air Monitoring in Buildings Ambient Air Monitoring Underground Work Space
Removal of Contamination Source	Cease Continued Sources of Contamination

Source: ESE, 1987.

Table 4-3. Groundwater Remediation Technologies Excluded

Action	Technology	Reason(s)
Collection	Subsurface Drains	Impractical at the depths necessary to collect contaminated groundwater and located near highly populated area.
<u>Long-term Treatment</u>		
<u>In Situ</u> Treatment	Microbial Degradation Limestone Treatment Bed Activated Carbon Bed Chemical Treatment	Not demonstrated technology for ground treatment.
Offsite Treatment	Deep-well Injection	Prohibited in North Carolina.
Onsite Treatment	<u>Biological</u> Activated Sludge Rotating Biological Contactor Aerated Lagoon	Spatial constraints.
	<u>Physical/Chemical</u> Ion Exchange Membrane Separation Oxidation Reduction Hydrolysis Liquid/Liquid Extraction Solar Evaporation Pond Spray Evaporation Wet-Air Oxidation Chemical Precipitation	Not demonstrated technology for treatment of class of compounds (mainly volatile organics) at HPIA.
No Action		Not an acceptable solution due to concentration of contaminants and migration to water supply aquifer.

Table 4-3. Groundwater Remediation Technologies Excluded (Continued, Page 2 of 2)

Action	Technology	Reason(s)
Interim Treatment		
Containment	Barriers Slurry Wall Vibrating Beam Grout Curtain Sheet Piling Concrete Wall Clay Wall	Impractical to install at the depths required to control groundwater contamination migration.

Source: ESE, 1987.

land area in the vicinity of the shallow contaminated groundwater would cause problems in adequately treating the entire contaminated area. However, microbial degradation will be evaluated in a followup study of contaminated soil remediation technologies.

4.1.3 OFFSITE TREATMENT

4.1.3.1 Publicly Owned Treatment Works

Treatment offsite at a publicly owned treatment works (POTW) is a viable method of remediation, if the water to be treated is suitable to the particular wastewater treatment system (i.e., the contaminated water does not disrupt the POTW biological system) and the chemical contaminants can be reduced to an acceptable level at the POTW. This treatment method is practical when the treatment facility is located within a range allowing contaminated water to be transported from the area of contamination to the facility economically. Offsite treatment of contaminated groundwater at HPIA to a POTW is deemed impractical due to the existing wastewater treatment plant at Hadnot Point.

4.1.3.2 Deep-Well Injection

Offsite deep-well injection has been excluded as a remediation technology because the North Carolina General Statute (143-214.2) prohibits discharges of waste to subsurface levels by means of wells.

4.1.4 ONSITE TREATMENT AND DISPOSAL

Onsite biological treatment using conventional activated sludge, rotating biological contactors, or aerated lagoons is technologically feasible with adequate nutrient levels; however, these biological systems are considered to be maintenance intensive and result in sludge generation requiring disposal. The contaminant concentrations in the shallow groundwater may be too low to support an effective biological culture and would require costly nutrient addition. In addition, spatial constraints and limited land area would limit the installation of these types of biological systems.

Treatment technologies excluded in the physical/chemical category (see Table 4-3) are considered inappropriate for the class of compounds present in the groundwater at HPIA.

Reinjection following onsite treatment into the shallow aquifer system is not a viable option for disposal of treated groundwater during the cleanup operation in HPIA. The low permeability of the potential receptor aquifer would require, at a minimum, the installation of 40 injection wells to handle the projected 64-gallons-per-minute (gpm) treated flow. Additionally, the shallow groundwater table (10 ft BLS) and the mounding of water associated with injection wells, would result in swamp-like conditions at the injection well sites as the mounded water reached land surface. Infiltration trenches for treated water disposal are also not applicable due to the heavily developed nature of the site, which would necessitate the placement of a large-size infiltration trench to be placed far from the points of withdrawal and treatment.

4.1.5 NO ACTION

A no-action alternative is not considered feasible for the shallow aquifer due to the concentration of the contaminants in the aquifer as compared to the cleanup criteria and the evidence of migration from the shallow to the deep aquifer where potable water supply wells are drawing.

4.1.6 CONTAINMENT

Containment structures are effective means of capturing or diverting groundwater flow in the vicinity of a particular site if conditions are favorable. There is not a continuous confining layer under the shallow portion of the aquifer, making effective containment difficult (i.e., restricting further contaminant migration into the deep portion of the aquifer), if not impossible.

4.2 APPLICABLE TECHNOLOGIES

Descriptions of the selected groundwater remediation technologies are presented in this section. Also included is a summary of removal efficiencies of the technologies in removing contaminants found in groundwater at HPIA.

4.2.1 COLLECTION

4.2.1.1 Groundwater Pumping

Groundwater pumping uses a series of extraction wells to remove contaminated groundwater for treatment, followed by: (1) recharge into the same aquifer or a separate aquifer (reinjection has not been considered viable for HPIA); (2) discharge to surface water; or (3) discharge to a POTW. A well system utilizes one or more pumps to draw groundwater to the surface, forming a cone of depression in the groundwater surface. The extent and slope of the cone of depression are dependent on pumping rate and duration, local groundwater and soil factors, and the rate of recharge.

4.2.2 BIOLOGICAL TREATMENT

Biological treatment has proven to be effective in removing several compounds detected in groundwater at HPIA. Compounds removed effectively through biological treatment include benzene, methylene chloride, toluene, trichloroethene, and vinyl chloride. Actual removal efficiencies for these compounds, as well as the other compounds detected in groundwater at HPIA, can be determined during pilot testing. Lead (detected in monitor wells at a maximum concentration of 81 ug/L) is not removed through biological treatment, and may be inhibitory to biological populations at concentrations greater than 10 mg/L. Xylene (detected at

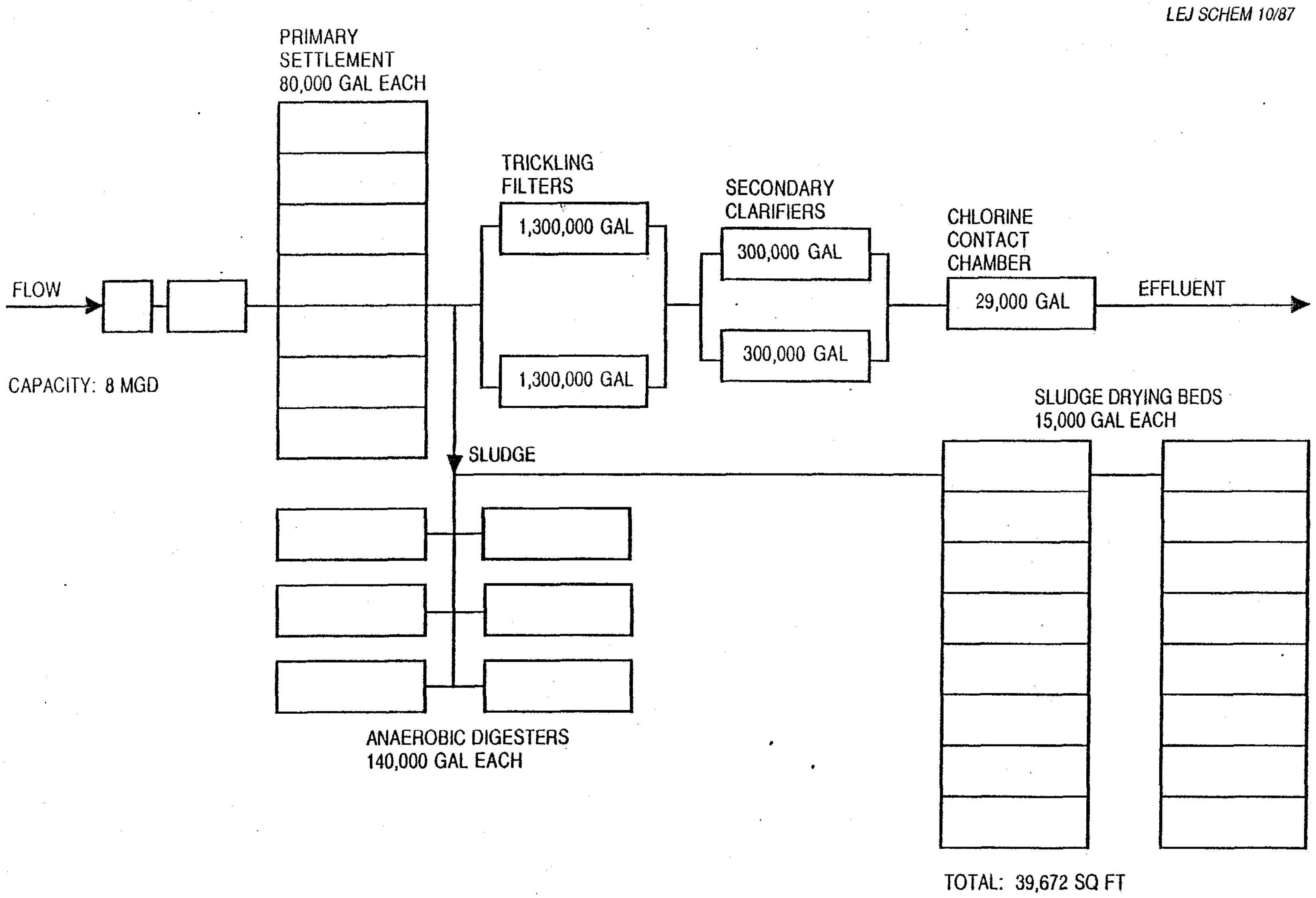

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Figure 4-1
HADNOT POINT WASTEWATER TREATMENT PLANT SCHEMATIC DIAGRAM — BLDG 22

SOURCE: Camp Lejeune, 1987.

DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND

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already being treated at the plant. However, a treatability study would be required to ensure that the present microbial populations on the trickling filters are capable of reducing the groundwater contaminants to acceptable levels. Periodic sampling and analysis of discharged groundwater would be required to monitor contaminant levels. This technology includes pumping groundwater through an underground piping system to the onsite sewage treatment plant. Installation of pipes would be required to tie into a sewer main leading to the STP.

4.2.2.2 Package Biological Tower at Pumping Point

A biological packed tower (or towers) can be used onsite at the point of groundwater pumping to reduce levels of biodegradable compounds in the water. Because groundwater is generally nutrient-depleted, nitrogen and phosphorus would need to be added to the water to achieve optimum biological activity. Usually, a ratio of biological oxygen demand (BOD) to nitrogen to phosphorus of 100:5:1 is recommended. Nitrogen and phosphorus typically are added in the forms of liquid ammonia and phosphoric acid. Other nutrients which may need to be added to the groundwater include calcium, potassium, magnesium, sulfur, manganese, iron, copper, and zinc.

This technology includes pumping contaminated groundwater with added nutrients through one or more plastic media pilot towers. The final design of the system will be based on the required contact time and concentrations of both nutrients and groundwater contaminants. Nutrients would be added in concentrations needed for optimal biological degradation, based on concentrations of organic compounds.

4.2.3 ONSITE PHYSICAL/CHEMICAL TREATMENT

Physical/chemical treatment has been proven effective in removing many of the compounds detected in HPIA groundwater. Both carbon adsorption and stripping have been demonstrated to effectively remove benzene, toluene, This technology entails pumping contaminated groundwater through a GAC adsorption system. The final design of the system will be based on the required contact time determined from the carbon 1-inch mini-column bench test results. Waste generated includes spent carbon which can be either: (1) properly disposed of offsite, (2) shipped to a regeneration facility, or (3) regenerated onsite. If the carbon is regenerated onsite, an additional waste stream contaminated with potentially high levels of organics will require proper offsite disposal.

4.2.3.2 Air Stripping

Air stripping is a mass-transfer process in which volatile organics in the liquid phase (water) are transferred to the gas phase (air). The operation is normally accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of countercurrent flow. The contaminated water stream flows down through the packing while the air flows upward and is discharged through the top. The packing material provides mixing of air and water, contact time for volatile organic chemical molecules to transfer from water to air, and a large void volume to minimize energy loss of the air system. The operating principle of the air stripping process is based on the kinetic theory of gases, which states that molecules of dissolved gases can readily move between the gas and liquid phases. Consequently, if water contains a volatile contaminant in excess of its equilibrium level, the contaminant will move from the liquid phase (water) to the gas phase (air) until equilibrium is reached. If the air in contact with the water is continuously replenished with fresh, contaminant-free air, eventually all of the contaminant will be removed from the contaminated water. The objective of the design of air-stripping equipment is to maximize the rate of mass transfer at a reasonable cost. Onsite pilot testing is normally conducted prior to developing the final design and operating conditions.

This technology includes pumping the contaminated groundwater through an air-stripping system. The final operating parameters and design of the system are generally developed after conducting pilot studies onsite. Waste generated includes air emissions (and vapor trail) contaminated with organics which may be environmentally unacceptable, thus requiring the addition of a de-mister and vapor-recovery equipment. The vapor-recovery equipment will generate additional waste contaminated with organics which will require proper offsite disposal.

4.2.3.3 Steam Stripping

Steam stripping is also a mass-transfer process which involves contacting the contaminated water with steam to remove one or more of the soluble or sparingly soluble VOCs. The VOCs in the contaminated groundwater are separated by partial vaporization. When contacted with steam in a countercurrent stripping column, the VOCs are driven into the vapor phase and discharged through the top of the column (i.e., the overheads or distillate) and condensed for disposal. The treated water is discharged through the bottom of the column and generally reused in a heat exchanger to preheat the incoming wastewater. The extent of the separation is governed by the physical properties of the organic compounds, the temperature and pressure at which the stripper is operated, and the arrangement and type of equipment used. The process can be conducted with packed or tray countercurrent towers, using either batch or continuous operation. Generally, it is more economical to use batch-operated packed towers for low flows [10,000 gallons per day (gpd) or less].

Wastewater characteristics and desired removal efficiency are used by the vendor in theoretical calculations to design the stripper.

This technology includes pumping the contaminated groundwater through a steam stripping system. The final design will be based on vendors' theoretical calculations using wastewater properties, steam pressure available, and desired removal efficiency. Waste generated includes condensed overheads with high levels of contaminants.

5.0 DESCRIPTION OF ALTERNATIVES

The aforementioned technologies have been combined into treatment alternatives for remediation of the groundwater contamination at the HPIA site. The applicable alternatives are described in the following paragraphs. All alternatives include the installation of thirty-two 4-inch recovery wells that will pump at a rate of 2 gpm (see Figure 5-1).

5.1 TRICKLING FILTER BIOLOGICAL TREATMENT

This alternative involves pumping the contaminated groundwater to the onsite STP which consists of two tickling filters as biological treatment. No pretreatment is involved before the groundwater reaches the STP in this alternative. The groundwater will be mixed in-line with the sewage the plant is currently receiving. Since the groundwater will be mixed with the current plant effluent (in an approximate ratio of 85 parts sewage to 1 part contaminated groundwater), effluent discharge and sludge disposal will continue to be handled by the STP in the same manner as currently used.

5.2 PLASTIC MEDIA BIOLOGICAL TOWER

This option involves the installation of two packaged biological towers. The towers will be placed in an area which will service all 32 recovery wells. The effluent from these two towers will be discharged onsite directly to Cogdels Creek. Since it is anticipated that nutrients will be required to sustain microbial growth in the pilot tower, an estimated cost was implemented into the overall cost of this option. The amount of nutrient added to the groundwater will ultimately be determined from theoretical models, groundwater characteristics, and pilot studies. With this alternative, it is anticipated that approximately 1 month of acclimation will be required. For this, several hundred gallons of groundwater will be extracted and recycled in a closed loop allowing microorganisms to acclimate. Sludge generated from this process will be

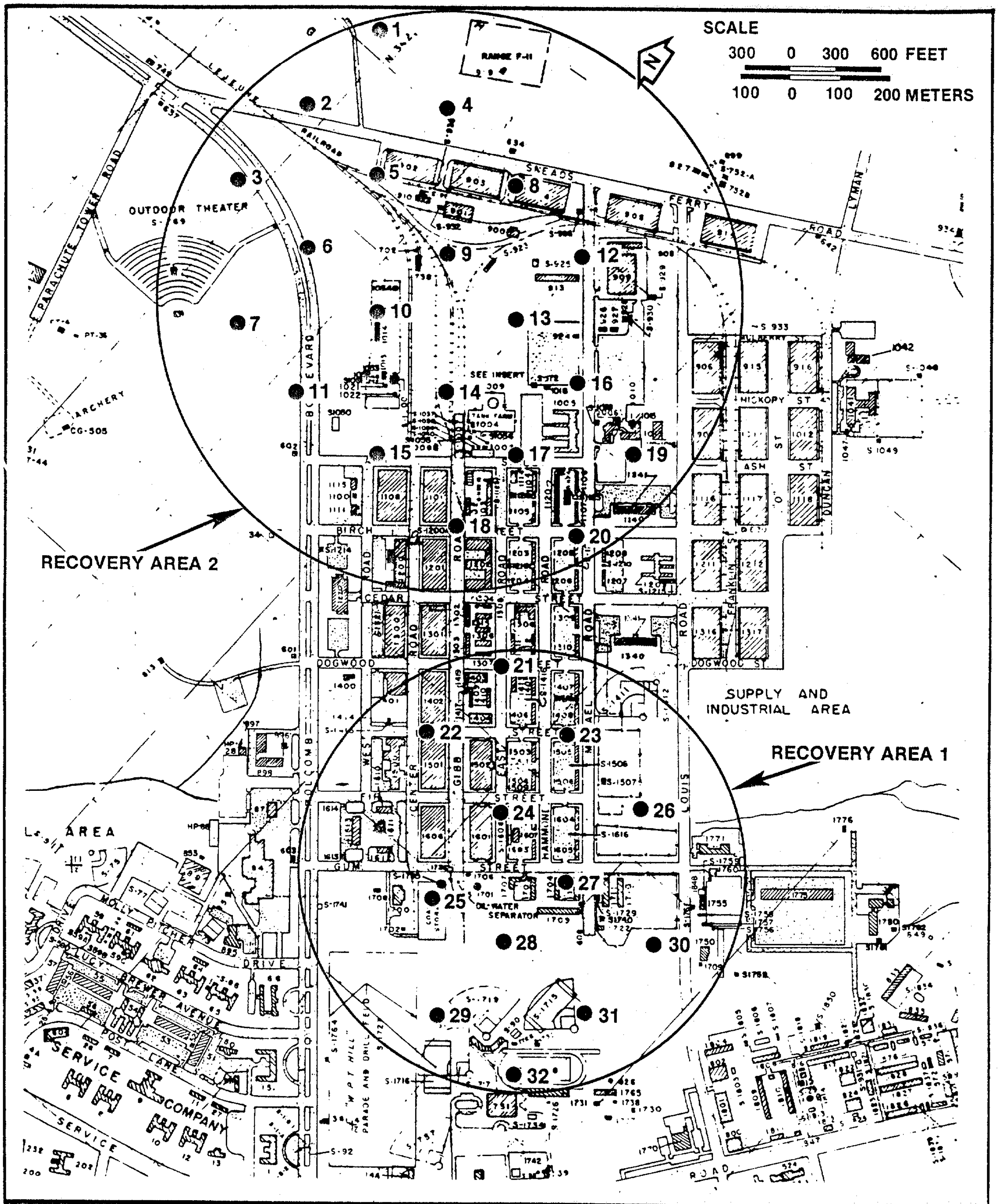

Figure 5-1
RECOVERY WELL LOCATIONS — HADNOT POINT INDUSTRIAL AREA

SOURCE: ESE, 1988.

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disposed with the sludge from the STP [after extraction procedure (EP) toxicity testing to ensure it is non-hazardous by characteristics].

5.3 CARBON ADSORPTION

This alternative involves the installation of two portable GAC units. One unit will be placed in the area of recovery Wells 1 through 20; the second unit will be placed in the area of recovery Wells 21 through 32 (see Figure 5-1). This alternative entails pumping contaminated groundwater through the two granular activated carbon adsorption systems. The final design of the system will be based on the contact time determined from 1-inch mini-column bench test results. Spent carbon waste generated can be either: (1) properly disposed of offsite, (2) shipped to a regeneration facility, or (3) regenerated onsite. If the carbon is regenerated onsite, a source of steam and cooling water will be required and an additional waste stream contaminated with high levels of organics will require proper offsite disposal. The selection of the best of the three options will be based on cost. Treated water will be discharged directly to Cogdels Creek after obtaining appropriate surface water discharge permits or waivers.

5.4 AIR STRIPPING

This alternative involves pumping contaminated groundwater through an air stripping system. The air stripper will be placed in an area which will service all 32 recovery wells. Contaminated groundwater will be pumped initially to a 10,000-gal equalization tank. Then, water from the equalization tank will be pumped to the air stripper. Waste generated from this process will be air emissions contaminated with organics. Since it is assumed that vapor recovery will be needed to prevent the release of stripped organics into the atmosphere, a cost for vapor recovery was included. The vapor recovery equipment will generate additional waste contaminated with organics which will require proper off-site disposal or regeneration. Also, modification to the existing

HPIA air permit will be required to account for the potential for additional air releases. The effluent from air stripping will be discharged directly to Cogdels Creek after obtaining appropriate surface water discharge permits or waivers. The final operating parameters and design of the system are generally developed after conducting onsite pilot studies.

5.5 STEAM STRIPPING

This alternative involves pumping the contaminated groundwater through a steam stripping system. The location of this process will be in an area that will allow it to service all 32 recovery wells. The final design will be based on vendors' theoretical calculations using wastewater properties, steam pressure available, and desired removal efficiency. Steam will be available onsite by annexing the already existing steam line network. Waste generated will consist of condensed overheads with high levels of organic contaminants which will require proper offsite treatment. Treated water will be discharged directly to Cogdels Creek after obtaining appropriate surface water discharge permits or waivers.

6.0 DETAILED ANALYSIS OF REMAINING ALTERNATIVES

Each alternative was rated with regard to technical and environmental/institutional factors such as safety, engineering, public health risk and environmental effects (long and short term), compliance with regulations, and institutional benefits. Alternatives were developed in sufficient detail to estimate capital and O&M costs. Finally, each alternative was ranked based on the technical rating, environmental/institutional rating, and cost.

6.1 RATING CRITERIA

To assess the feasibility of each alternative, the following criteria and rating scale were applied in the technical, environmental/institutional, and cost ratings.

6.1.1 CRITERIA

Technical Feasibility--Factors considered in evaluating technical feasibility include performance, reliability, implementability, and safety. Performance is defined in terms of effectiveness and useful life. Effectiveness relates to the degree with which the alternative will prevent or minimize release of hazardous substances to current or future public health, welfare, or environmental receptors. Useful life relates to the length of time that the level of effectiveness can be maintained.

Reliability is assessed for O&M requirements and demonstrated performance. O&M requirements address labor availability, frequency, necessity, and complexity. Demonstrated performance addresses probability of failure and pilot testing. Implementability is defined in terms of ease of installation and time. Ease of installation relates to constructability, applicability to site conditions, external conditions such as permits and access to offsite disposal facilities, and equipment availability. The time to implement and the time to achieve beneficial results are also evaluated.

Safety during construction and operation as well as safety upon failure is also evaluated.

Environmental/Institutional Benefits--Factors considered in evaluating environmental/institutional benefits include short-term (construction related), institutional, long-term, and public health impacts.

Short-term impacts are defined in terms of odor, noise, air, surface water, and groundwater pollution, wildlife habitat and historic site alteration, disposal of construction material, and disruption of households, business, and services. Institutional impacts are assessed for political jurisdictions, surface/groundwater standards. air/odor/noise standards, land acquisition, land use/zoning, and local/state/Federal laws or policies. Long-term benefits are addressed for the same criteria as short-term benefits plus impacts on threatened and endangered species, use of natural resources, parks/transportation and urban facilities, and aesthetic changes.

Cost--Cost comparison involves development of preliminary capital and O&M costs for each alternative. The cost estimates are conceptual and based on 1987 dollars. These estimates are not intended to present actual "construction" cost but are based on conceptual design of treatment alternatives using the information available and direct quotes from vendors.

ASSEMBLED ALTERNATIVE: ________
BY: ________
DATE: ________

ALTERNATIVE/TECHNOLOGY

	STP	BIO TOWERS	CARBON ADSORPTION	AIR STRIPPING	STEAM STRIPPING	CRITERIA
SHORT TERM (CONSTRUCTION - RELATED)	++	O	O	O	O	Odor
	++	−	−	−	−	Noise
	+	+	O	++	++	Air Pollution
	O	O	O	O	O	Surface Water Pollution
	O	O	O	O	O	Groundwater Pollution
	++	++	++	++	++	Wildlife Habitat Alteration
	O	O	O	O	O	Historic Site Alteration
	O	O	O	O	O	Disposal of Construction Materials
	+	O	O	O	O	Disruption of Households/Businesses/Services
	27	20	19	21	21	
INSTITUTIONAL	++	++	++	++	++	Political Jurisdictions
	++	++	++	++	++	Surface/Groundwater Standards
	++	+	+	+	+	Air/Odor/Noise Standards
	++	++	++	++	++	Land Acquistion
	++	++	++	++	++	Land Use/Zoning
						Local/State/Federal Laws or Policies
	20	19	19	19	19	
LONG TERM	+	+	+	+	+	Odor
	++	O	O	O	O	Noise
	O	O	O	++	++	Air Pollution
	++	++	++	++	++	Surface Water Pollution
	O	O	O	O	O	Groundwater Pollution
	++	++	++	++	++	Wildlife Habitat Alteration
	++	++	++	++	++	Threatened and Endangered Species
	O	O	O	O	O	Use of Natural Resources
	O	O	O	O	O	Parks, Transportation, and Urban Facilities
	+	+	+	+	+	Relocation of Households/Businesses/Services
	++	O	O	O	O	Aesthetic Changes
	34	30	30	30	32	
PUBLIC HEALTH	−	−	−	−	−	Exposure Risk - Short Term
	++	++	++	++	++	Exposure Risk - Long Term
	5	5	5	5	5	
	3.19	2.74	2.70	2.78	2.85	Summary

NOTES:

Figure 6-1
ENVIRONMENTAL/INSTITUTIONAL RATING MATRIX
SOURCE: ESE, 1987.

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Remedial Response: ____________

BY: ____________

DATE: ____________

	CRITERIA	STP	BIO TOWERS	CARBON ADSORPTION	AIR STRIPPING	STEAM STRIPPING
PERFORMANCE	**Effectiveness/** Degree which action will prevent or minimize release of hazardous substances to present or future public health/welfare/ or environmental	++	++	++	++	++
	Useful Life/ Length of time that level of effectiveness can be maintained	++	++	++	++	++
RELIABILITY	**Operation & Maintenance/** Labor availability, frequency and necessity complexity	++	O	O	O	O
	Demonstrated Performance/ Proven Probability of failure Pilot test	O	O	++	++	++
IMPLEMENTABILITY	**Ease of Installation/** Constructability/ Applicability to Site Conditions/ Conditions external to site (permits, access offsite disposal areas), equipment availability	++	O	O	O	O
	Time Time to implement	++	+	+	+	+
	Time to Achieve Beneficial Results	++	+	++	++	++
SAFETY	During Installation/Operation	++	+	+	+	O
	Upon Failure	++	+	+	+	+
	Summary	3.78	2.89	3.22	3.22	3.11

Figure 6-2
TECHNICAL RATING MATRIX

SOURCE: ESE, 1987.

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Table 6-1. Cost Summary

Alternative	Operation and Maintenance		Labor		Capital
	1st YR	2nd YR+	1st YR	2nd YR	
STP	62,832	42,992	11,000	7,800	109,940
Plastic Media Biological Towers	100,318	80,478	12,820	9,620	447,551
Carbon Adsorption	533,273	513,433	12,820	9,620	415,512
Air Stripping	118,028	98,188	12,820	9,620	387,109
Steam Stripping	196,296	176,456	12,820	9,620	764,259

Source: ESE, 1987.

of the 32 recovery wells three times the first year and annually thereafter. Samples will be analyzed for the contaminants that were detected in the prior sampling episode in concentrations greater than the ARARs (i.e., lead, benzene, chloromethane, trans-1,2-dichloroethene, methylene chloride, trichloroethene, vinyl chloride, xylene, toluene, and MEK, hereafter referred to as the contaminants). Also included are costs for sampling and analysis of the influent (to treatment systems) and effluent stream (at point of discharge) assumed to be monthly for each year of operation for use in reporting in applicable permits. Parameters of analysis are the same as previously listed for recovery well samples. Actual permit specifications may require additional sampling. Based on the limited analytical information for groundwater with respect to the proposed placement of the recovery wells, a worst-case scenario was used to estimate influent concentrations of contaminant to the carbon adsorption, air stripping, and steam stripping alternatives for use in theoretical models to estimate design parameters. This worst-case scenario consisted of using the highest concentration of each parameter found in the monitor wells. Due to this assumption, it is likely that the size and costs for all three of these alternatives are conservative. Conditions pertaining to recovery wells are summarized below. Remediation will be considered complete when all contaminants have been reduced to the appropriate cleanup criteria. Specific factors considered in the ratings of each separate alternative follow.

<u>Recovery Wells</u>

Number of Wells	32
Depth	25 ft
Pumping Rate	2 gpm
Estimated Time to Achieve Cleanup	1,825 days

6.2.1 ALTERNATIVE 1--STP

As described previously, this alternative involves pumping the groundwater directly to the onsite STP which contains two trickling filters. The ratings and final ranking of this alternative will have to be reconsidered if this assumption is found to be invalid after completion of the HPIA pilot tests, denial of a request to modify existing STP operating permit, and/or if pretreatment is required. Figure 6-3 represents the estimated pipeline requirements which must be installed for transporting the groundwater to the STP.

6.2.2 ALTERNATIVE 2--PACKAGE BIOLOGICAL TOWERS

As described previously, this alternative involves pumping contaminated groundwater from the recovery wells to two onsite biological towers (see Figure 6-4 for biological tower diagram). It will be necessary to stabilize each tower with stabilization wires, since each tower is 35 ft high. Also, a clarifier will be used on the effluent of each tower to remove solids. It is assumed that the sludge from the clarifiers will be periodically removed with a vacuum truck and transported to the onsite STP sludge system for treatment. A time period of 1 month was assumed to acclimate the biological conditions in the towers to ensure adequate treatment. Both towers will be placed in an area (designated as Treatment Area 2) which will service all 32 recovery wells. The configuration of underground pipes to move groundwater to the biological towers as well as the location of the towers is represented by Figure 6-5. The ratings and final ranking of this alternative will have to be reconsidered if these assumptions are found to be invalid after completion of the HPIA pilot test or if an operating permit for the biological towers or surface water discharge permit is denied.

6.2.3 ALTERNATIVE 3--GAC ADSORPTION

This alternative involves pumping contaminated groundwater from the recovery wells to two separate carbon adsorption units. For the purposes

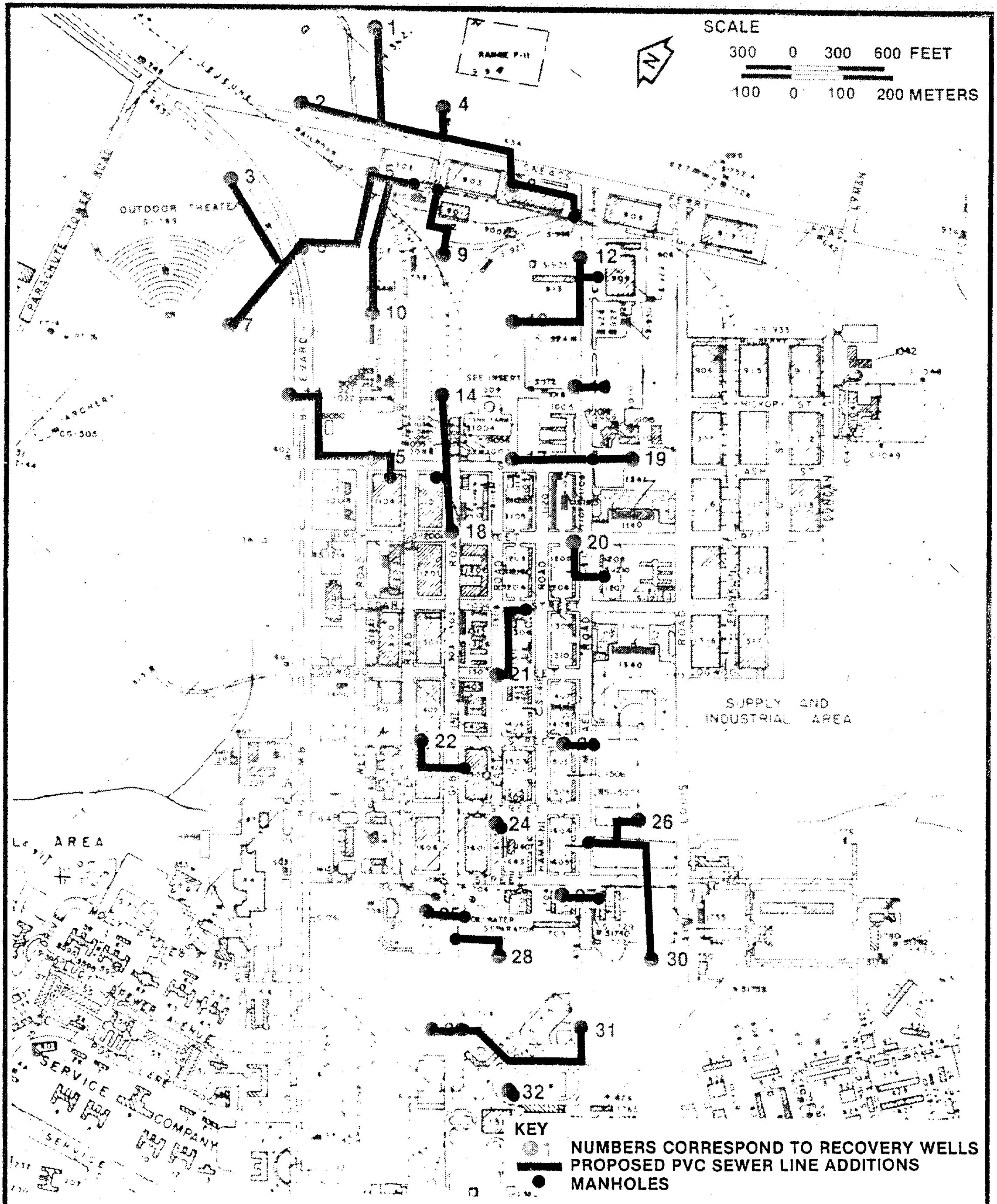

Figure 6-3
PIPING DIAGRAM FOR ALTERNATIVE 1 —
HADNOT POINT SEWAGE TREATMENT PLANT

SOURCE: ESE, 1987.

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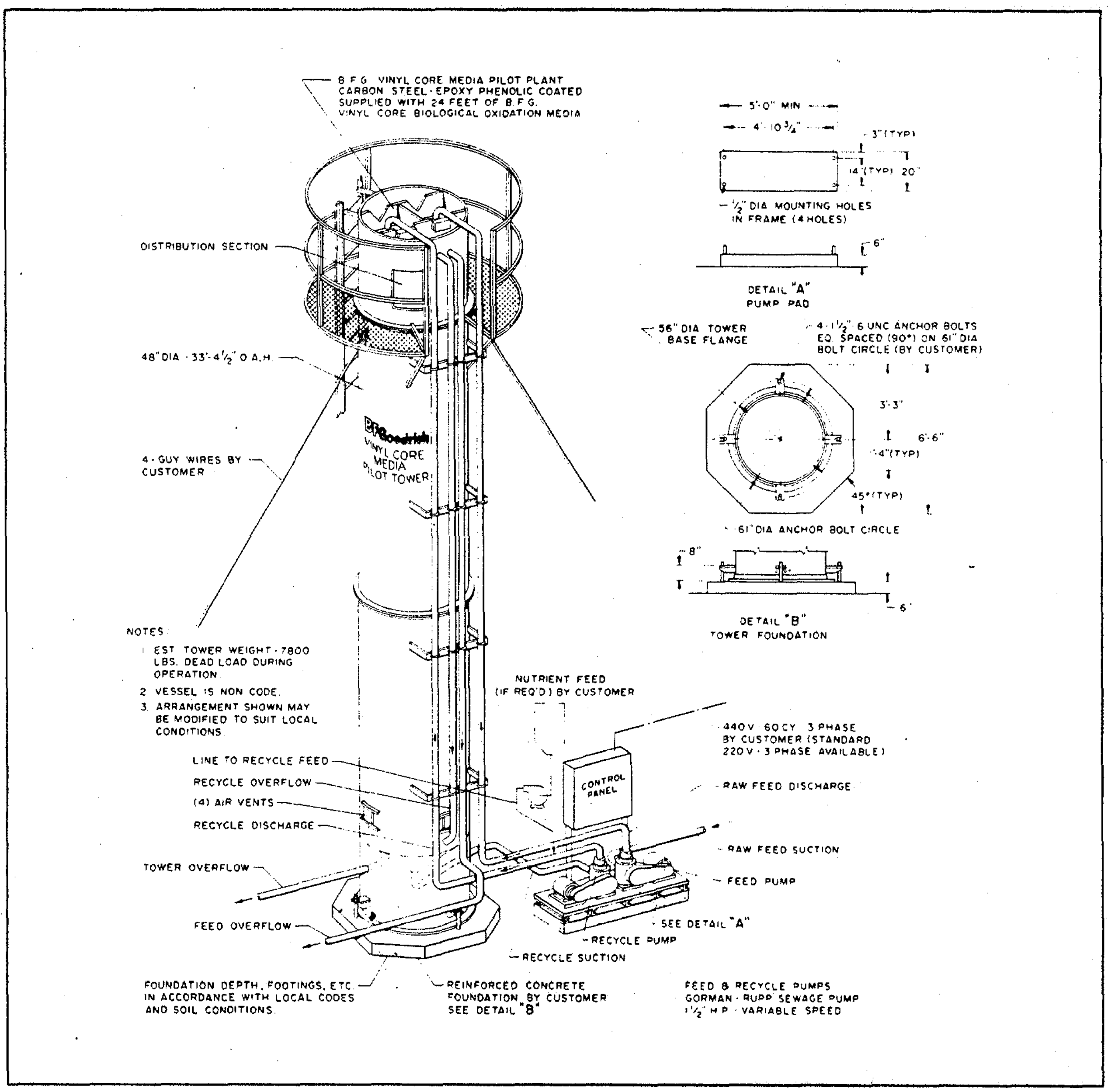

Items supplied with the pilot tower BFGoodrich (to be returned with tower)

1 Tower with ladder and catwalk.
2 Gorman Rupp pumps—1½ H.P. each.
2 G.E. 2 H.P. motors.
2 Fixed-speed sheaves.
2 Driven sheaves.
2 Vari-speed belts.
1 Gear reductor with motor (for distributor).
1 Timing belt (for distributor).
8 Brass floodjet nozzles. (More supplied if required).
4 Bronze hose couplers.
1 100′ length 2″ Radial Flex Hose.
1 50′ piece of 4″ hose.
1 Pump control panel.
1 Pump and motor pad with separate motor/pump mounting plates.
2 Red rubber gaskets.

Items not supplied with pilot tower

Metering nutrient pumps and reservoirs.
Automatic sampling.
Tower and pump pad foundation.
Guy wire (recommend ½″ cable).
Pilot clarifiers or filters.

Figure 6-4
BIOLOGICAL TOWER DIAGRAM

SOURCE: B.F. Goodrich, 1981.

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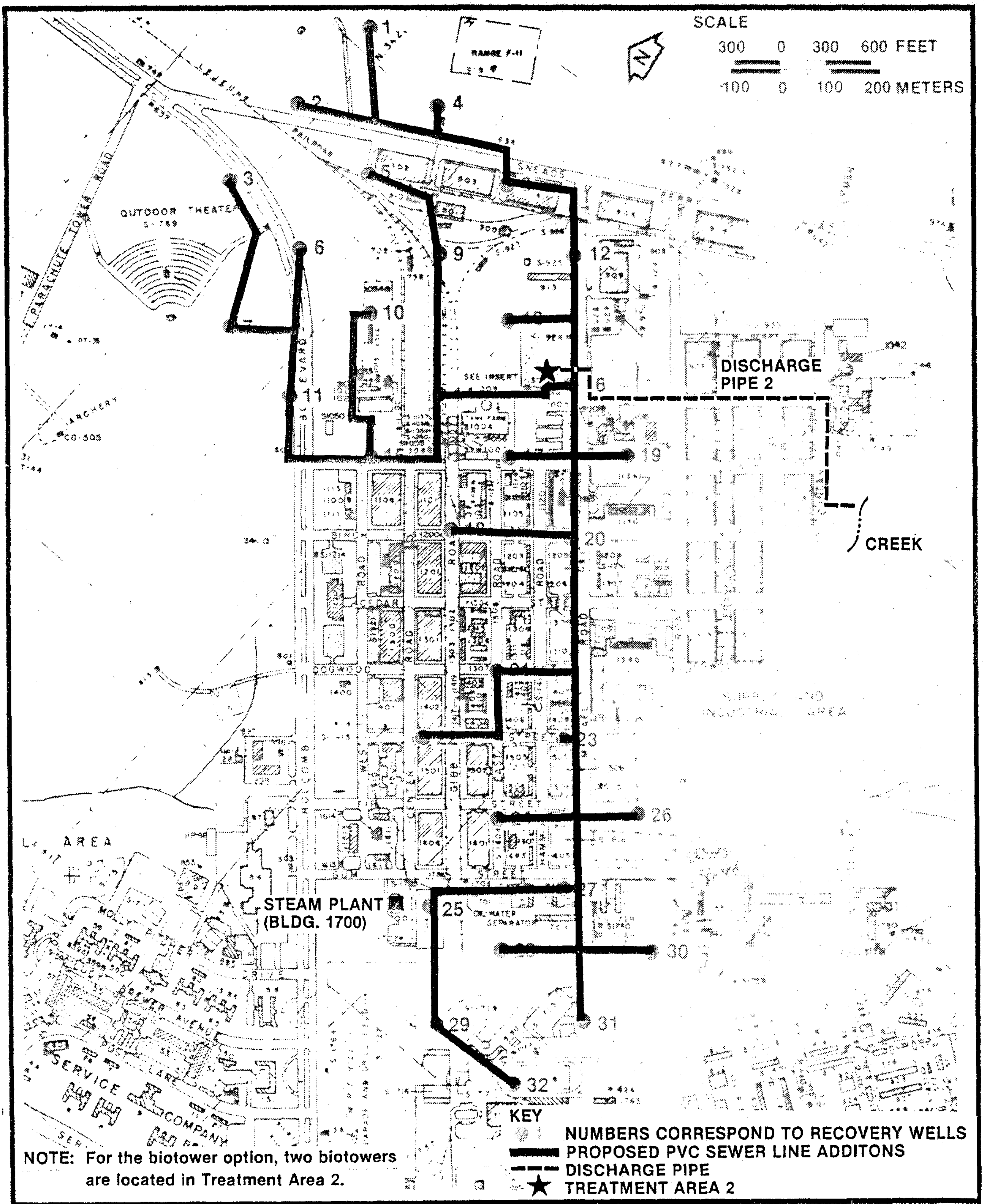

NOTE: For the biotower option, two biotowers are located in Treatment Area 2.

KEY
● 1 NUMBERS CORRESPOND TO RECOVERY WELLS
▬ PROPOSED PVC SEWER LINE ADDITONS
--- DISCHARGE PIPE
★ TREATMENT AREA 2

Figure 6-5
PIPING DIAGRAM FOR ALTERNATIVE 2 — (PACKAGE BIOLOGICAL TOWERS), ALTERNATIVE 4 (AIR STRIPPING), AND ALTERNATIVE 5 (STEAM STRIPPING)
SOURCE: ESE, 1988.

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of cost, offsite regeneration of spent carbon was assumed. The location of the units and the configuration of underground pipes are illustrated in Figure 6-6. The ratings and final ranking of this alternative will have to be reconsidered if this assumption is found to be invalid after completion of the HPIA pilot test or if an operating permit for the carbon adsorption or surface water discharge permit is denied.

6.2.4 ALTERNATIVE 4--AIR STRIPPING

This alternative involves pumping groundwater from the recovery wells to an air stripping system. The air stripping system will consist of one air stripper 25 ft in height and be placed in an area which will service all 32 recovery wells. Stabilization wires will be required. The air stripper will be equipped with a vapor recovery system consisting of activated carbon. For the purposes of cost, offsite regeneration was assumed. The network of underground pipes required to move water from the recovery wells to the air stripper as well as air stripper location is illustrated in Figure 6-5. The final ranking of this alternative will have to be reconsidered if this alternative is found to be invalid after completion of the HPIA pilot test or if an operating permit for the air stripper or surface water discharge permit is denied.

6.2.5 ALTERNATIVE 5--STEAM STRIPPING

This alternative involves pumping groundwater from the recovery wells to a steam stripper. The network of underground pipes necessary to carry water from the recovery wells to the steam stripper as well as steam stripper location is illustrated in Figure 6-5. For the purpose of cost, steam currently generated in HPIA was assumed available for use (at current base usage cost) and condensed overheads were assumed to be transported offsite for incineration. The steam stripper will be placed in a location which will service all 32 recovery wells. The final ranking of this alternative will have to be reconsidered if this alternative is found to be invalid after completion of the HPIA pilot

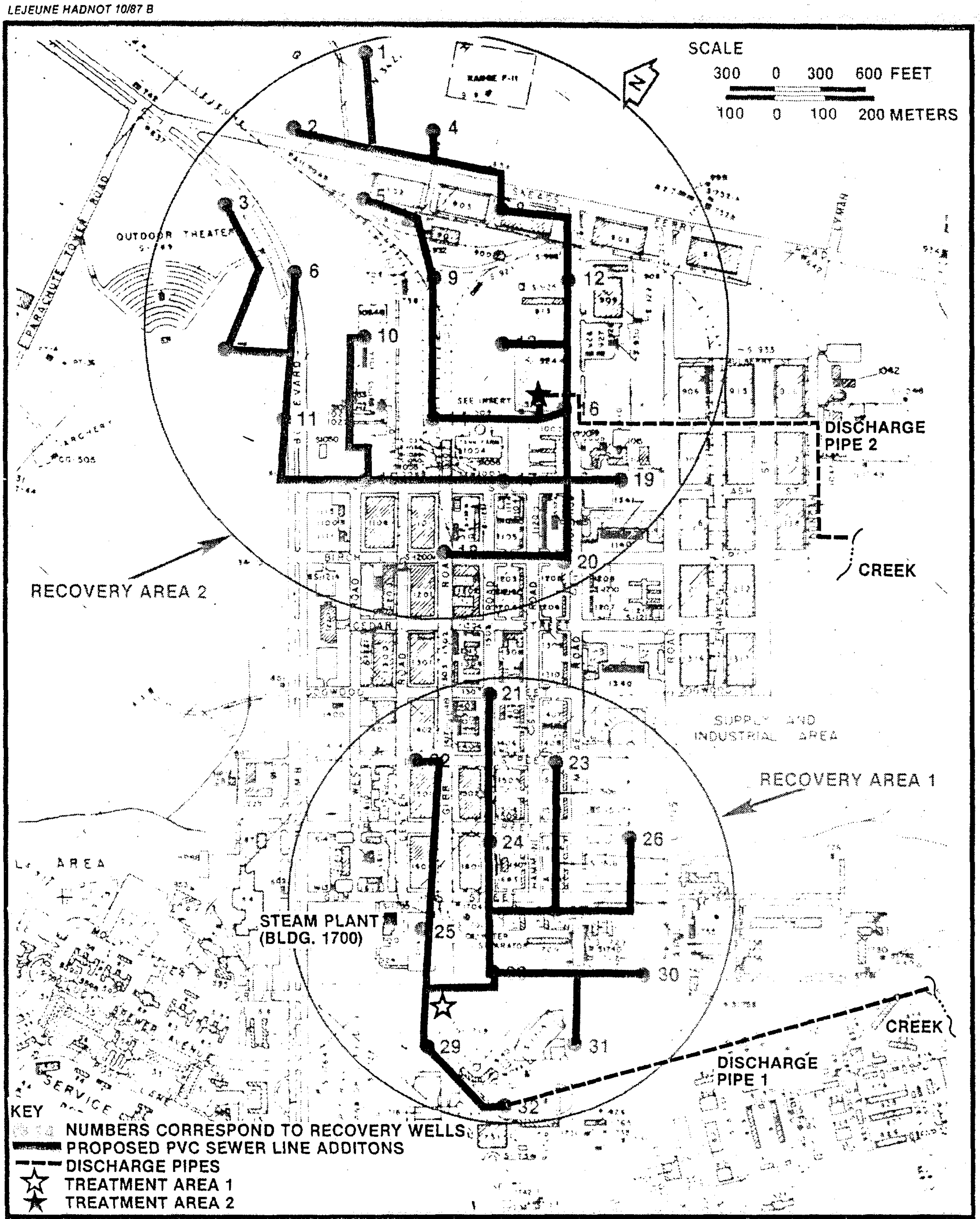

Figure 6-6
PIPING DIAGRAM FOR ALTERNATIVE 3 —
GRANULAR ACTIVATED CARBON ADSORPTION

SOURCE: ESE, 1988.

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test or if an operating permit for the steam stripper or surface water discharge permit is denied.

7.0 SUMMARY AND RECOMMENDATIONS

Short-Term Interim Actions--No ranking system was used for the five proposed interim measures because they are all equally recommended.

Long-Term Actions--The results of the capital, O&M, labor, technical, and environmental/institutional rankings are presented in Table 7-1. The alternatives are ranked first by category, and then the rankings for each alternative were added to obtain the total ranking. Only first-year O&M and labor costs were used for comparison ranking. The results of the detailed analyses were used to recommend preferred alternatives. The alternatives not recommended, including reasons, are discussed in Sections 7.1 and 7.2, followed by a discussion on the recommended alternatives.

7.1 ALTERNATIVES NOT RECOMMENDED

7.1.1 ALTERNATIVE 2--PACKAGED BIOLOGICAL TOWERS

The use of two plastic media biological towers is not recommended based on total ranking (compared to other alternatives). The total ranking was poor due to its high capital cost and low technical and environmental/institutional rankings (caused by the potential release of organics during operation and time required to acclimate system and achieve beneficial results).

7.1.2 ALTERNATIVE 3--GAC

The use of two carbon adsorption units to treat contaminated groundwater is not recommended based on total ranking (compared to other alternatives). The total ranking was poor due to the high O&M costs required to operate the system (which was primarily due to the high rate of carbon usage and cost to replace carbon) and a low environmental/institutional ranking (which was due to the possible release of organics when carbon units are changed).

Table 7-1. Alternative Ranking Summary*

Alternative	First Year Cost+	Technical Rating	E/I Rating	Total
Onsite STP	183,772 (1)	3.78 (1)	3.15 (1)	1
Plastic Media Biological Towers	560,989 (3)	2.89 (4)	2.70 (4)	4
Carbon Adsorption	961,605 (4)	3.22 (2)	2.67 (5)	5
Air Stripping	517,957 (2)	3.22 (2)	2.74 (3)	2
Steam Stripping	973,375 (5)	3.11 (3)	2.81 (2)	3

*Total Ranking = Based on the sum of the individual rankings from each category.

+Includes Capital Cost and first year Operations and Maintenance.

Source: ESE, 1988.

7.1.3 ALTERNATIVE 5--STEAM STRIPPING

The use of a steam stripper is not recommended based on its total ranking (compared to other alternatives). The ranking of this alternative was poor due to high O&M costs (which are primarily due to steam cost) and high capital cost (which is primarily due to engineering cost to design the steam stripper).

7.2 RECOMMENDED ALTERNATIVES

7.2.1 ALTERNATIVE 1--STP

The alternative to send contaminated groundwater to the onsite STP received the best ranking. This was due to low capital and O&M costs, and high rankings in technical and environmental/institutional categories. This alternative is based on the assumption that the request to modify the current operating permit for the STP is granted and that pilot-scale testing verifies that the onsite STP can effectively treat the proposed waste matrix. If these assumptions prove to be invalid, this alternative should be reevaluated.

7.2.2 ALTERNATIVE 4--AIR STRIPPING

The alternative to treat the contaminated groundwater at HPIA by air stripping had the second highest ranking. Although air stripping could not be considered a close second compared to Alternative 1, it did rank fairly well in all categories addressed (no worse than a ranking of 3 in any category). This alternative is based on the assumptions that a request to operate an air stripping process is approved and the pilot-scale tests show the process to be effective in treating the waste matrix. If these assumptions prove to be invalid, this alternative will have to be reevaluated.

7.3 ADDITIONAL RESPONSE ACTIONS

Prior to determining the final alternative for remediation of the shallow aquifer at HPIA, additional data must be obtained to confirm actual concentrations of contaminants present at the installed recovery well locations. These data, in addition to data obtained concurrently from the existing monitor well network, will determine the actual influent loadings to the final treatment system. Because some of these recovery wells must be installed in areas of HPIA not currently monitored by wells, the groundwater quality data from the recovery wells are required to augment the existing knowledge of the contaminant status of the shallow aquifer at HPIA. If these samples are not obtained, a possibility exists that the selected treatment system may be improperly sized for the actual influent loads, and/or additional contaminants incompatible with the selected technology may be recovered.

Once influent loadings have been determined, a more accurate waste matrix can be identified and used to design and cost the selected alternative for final evaluation. Specific cleanup criteria must be developed through an RA study for the determination of target contaminant cleanup concentrations. Pilot tests will then need to be performed on the actual waste matrix to effectively determine the degree of treatment that each alternative can achieve.

APPENDIX A

ANALYSES FOR SHALLOW MONITOR WELLS AND WATER SUPPLY WELLS

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune

Parameter (Units)	Concentration by Well Number and Monitoring Period*																	
Well No.:	22GW1			22GW2			1			2			3			4		
Monitoring Period:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lead, Total (ug/L)	33.0	29.0	78.0	28.0	--	--	27.0	--	--	--	--	--	40.0	--	--	29.0	--	--
Oil & Grease (mg/L)	7	11	9	0.8	--	--	0.7	--	--	0.7	--	--	0.8	0.2	--	0.3	0.3	--
Benzene (ug/L)	12,000	10,000	13,000	--	--	--	43	3.9	--	12	--	--	1.4	--	--	25	3.2	1.6
Chloroform** (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (ug/L)	--	--	--	--	--	--	--	--	--	5.0	--	--	--	--	--	--	--	--
1,1-Dichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.9	2.2	4.4
Ethylbenzene (ug/L)	1,800	--	--	--	--	--	12	--	--	--	--	--	8.2	9.0	--	--	--	--
Methylene Chloride (ug/L)	--	--	--	7.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene (ug/L)	15,000	18,000	24,000	--	--	--	100	12	--	38	--	--	--	--	--	35	8.2	--
1,1,1-Trichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	13	--	--	--	--
Trichloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.4	--	7.7
Trichlorofluoromethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl Chloride (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total (ug/L)	9,000	--	--	--	--	--	62	--	--	28	--	--	--	--	--	--	--	--
Methyl Ethyl Ketone (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 2 of 6)

Parameter (Units)	Concentration by Well Number and Monitoring Period*																	
Well No.:	5			6			7			8			9			10		
Monitoring Period:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lead, Total (ug/L)	--	--	--	--	--	--	--	29.0	--	--	--	--	130	92.0	70.0	29.0	--	--
Oil & Grease (mg/L)	0.9	--	--	0.2	--	--	3	0.2	--	0.1	--	--	32	11	6	0.4	--	--
Benzene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloroform** (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (ug/L)	--	--	--	--	--	--	--	--	--	7.2	--	--	--	--	--	--	--	--
1,1-Dichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	740	--	2,700	--	--	--
Ethylbenzene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	1,100	--	--	--	--	--
Methylene Chloride (ug/L)	--	--	--	--	--	--	--	--	--	20	--	--	--	--	--	--	--	--
Tetrachloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	5,000	6,100	--	7.4	8.6	--
Trichlorofluoromethane (ug/L)	--	--	--	--	--	--	--	--	--	14	96	--	--	--	--	--	--	--
Vinyl Chloride (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	4,500	--	4,000	--	--	--
Methyl Ethyl Ketone (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 3 of 6)

Parameter (Units)	Concentration by Well Number and Monitoring Period*																	
Well No.:	11			12			13			14			15			16		
Monitoring Period:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lead, Total (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	46.0	--	--	45.0	41.0	--
Oil & Grease (mg/L)	0.3	0.6	--	0.2	--	--	0.2	--	--	0.2	--	--	--	--	--	0.2	3	--
Benzene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloroform** (ug/L)	3.2	2.2	2.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene (ug/L)	13	7.2	6.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methylene Chloride (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethene (ug/L)	--	--	--	--	3.6	--	--	--	--	--	--	--	--	--	--	-	--	--
Toluene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene (ug/L)	49	34	24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.1	--	--	--
Vinyl Chloride (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methyl Ethyl Ketone (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 4 of 6)

Parameter (Units)		Concentration by Well Number and Monitoring Period*																	
	Well No.:	17			18			19			20			21			22		
	Monitoring Period:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lead, Total (ug/L)		--	--	--	--	--	--	--	--	--	46.0	33.0	--	--	--	--	27.0	--	--
Oil & Grease (mg/L)		--	3	--	--	2	--	0.2	2	--	--	3	--	0.2	2	--	1	2	--
Benzene (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloroform** (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene (ug/L)		--	--	--	--	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methylene Chloride (ug/L)		--	--	--	--	--	--	--	--	--	--	3.4	--	--	--	--	--	--	--
Tetrachloroethene (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene (ug/L)		--	--	--	--	--	--	6.0	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl Chloride (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methyl Ethyl Ketone (ug/L)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 5 of 6)

Parameter (Units)	Concentration by Well Number and Monitoring Period*														
Well No.:	23			24			25			26			29		
Monitoring Period:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lead, Total (ug/L)	38.0	--	--	--	--	--	--	--	--	31.0	--	--	--	52.0	--
Oil & Grease (mg/L)	0.6	3	--	0.1	2	--	0.2	0.3	--	0.2	2	--	0.2	--	--
Benzene (ug/L)	--	--	--	2.0	--	--	--	--	--	--	--	--	--	--	--
Chloroform** (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane (ug/L)	--	--	--	12	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene (ug/L)	830	6,100	7,100	6,400	4,300	4,000	--	--	--	--	--	--	--	--	--
Ethylbenzene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methylene Chloride (ug/L)	--	300	--	--	--	--	--	2.9	--	--	6.5	--	--	--	--
Tetrachloroethene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene (ug/L)	830	13,000	4,300	57	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl Chloride (ug/L)	--	--	--	190	--	250	--	--	--	--	--	--	--	--	--
Xylene, Total (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methyl Ethyl Ketone (ug/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A-1. Summary of Materials Detected in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 6 of 6)

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*Dates for monitoring periods are as follows:
1 = January 1987
2 = March 1987
3 = May 1987

**Chloroform = total trihalomethanes [bromodichloromethane + dibromochloromethane + tribromomethane + trichloromethane (chloroform)].

Note: -- = below detection limit.

Source: ESE, 1988.

Table A-2. Detected Target Analytes, Potable Wells--Hadnot Point Industrial Area

Parameter (Units)	Concentration by Well Number				
	601	602	608	634	637
<u>Detected in July 1984</u> <u>Analyzed by ESE</u>					
Benzene (ug/L)	NA	380	NA	NA	NA
1,2-Dichloroethane (ug/L)	NA	46	NA	NA	NA
Trans-1,2-Dichloroethene (ug/L)	NA	7.8	NA	NA	NA
Ethylbenzene (ug/L)	NA	8	NA	NA	NA
Trichlorofluoromethane (ug/L)	NA	3	NA	NA	NA
Toluene (ug/L)	NA	10	NA	NA	NA
<u>Detected on December 5, 1984</u> <u>Analyzed by JTC Environmental Consultants</u>					
Benzene (ug/L)	--	120	3.7	--	--
Trans-1,2-Dichloroethene (ug/L)	88	630	5.4	--	--
Trichloroethene (ug/L)	210	1,600	110	--	--
Toluene (ug/L)	--	5.4	--	--	--
Tetrachloroethene (ug/L)	5.0	24	--	--	--
Vinyl Chloride (ug/L)	--	18	--	--	--
<u>Detected on December 12, 1984</u> <u>Analyzed by JTC Environmental Consultants</u>					
Benzene (ug/L)	--	720	4.0	--	--
Trans-1,2-Dichloroethene (ug/L)	99	380	2.4	2.3	--
Trichloroethene (ug/L)	230	540	13	--	--
Tetrachloroethene (ug/L)	4.4	--	--	--	--
Methylene Chloride (ug/L)	10	--	14	130	--

Table A-2. Detected Target Analytes, Potable Wells--Hadnot Point Industrial Area (Continued, Page 2 of 3)

Parameter (Units)	Concentration by Well Number				
	601	602	608	634	637
Detected on December 19, 1984 Analyzed by JTC Environmental Consultants					
Benzene (ug/L)	NA	230	NA	NA	NA
Trans-1,2-Dichloroethene (ug/L)	NA	230	NA	NA	NA
Trichloroethene (ug/L)	NA	340	NA	NA	NA
Toluene (ug/L)	NA	12	NA	NA	NA
Detected in January 1985 Analyzed by JTC Environmental Consultants					
1,2-Trans-dichloroethene (ug/L)	8.8	NA	NA	700	--
Trichloroethene (ug/L)	26	NA	NA	1,300	--
Tetrachloroethene (ug/L)	--	NA	NA	10	--
Detected in November 1986 Analyzed by ESE					
Barium, Total (ug/L)	21.8	31.3	43.4	18.5	NA
Nitrogen, $NO_2 + NO_3$ (as N) (mg/L)	0.042	--	--	--	NA
Nitrogen, NO_2 (as N) (mg/L)	0.042	--	--	--	NA
Iron, Total (ug/L)	12,800	15,200	3,600	2,830	NA
Chloride (mg/L)	68.3	23.0	9.5	7.9	NA
Manganese, Total (ug/L)	97.6	134	67.8	19.5	NA
Sodium, Total (mg/L)	9.25	12.3	6.53	5.48	NA
Sulfate (mg/L)	5,170	92	12	--	NA
Color, True (PCU)	104	48	9	10	NA

Table A-2. Detected Target Analytes, Potable Wells--Hadnot Point Industrial Area (Continued, Page 3 of 3)

Parameter (Units)	Concentration by Well Number				
	601	602	608	634	637
Detected in November 1986 Analyzed by ESE (Continued)					
Residue, Diss (mg/L)	358	524	270	226	NA
Turbidity (FTU/NTU)	17.0	18.0	10.0	11.0	NA
Chromium, Total (ug/L)	7.7	14.1	6.8	6.1	NA
Copper, Total (ug/L)	10.4	556	574	21.7	NA
Mercury, Total (ug/L)	0.6	0.5	0.7	0.6	NA
Zinc, Total (ug/L)	3,200	93.8	99.1	17.2	NA
Benzene (ug/L)	--	50	--	--	NA
1,2-Dichloroethane (ug/L)	--	9.2	--	--	NA
Trans-1,2-Dichloroethene (ug/L)	--	14	8.5	2.9	NA
Trichloroethene (ug/L)	--	2.2	66	--	NA
Bis(2-Ethylhexyl) Phthalate (ug/L)	1.3	--	--	--	NA

Note: ug/L = micrograms per liter.
mg/L = miiligrams per liter.
FTU/NTU = formazin turbidity unit and nephelometric turbidity unit.
NA = not analyzed.
PCU = platinum-cobalt units.
-- = below detection limits.

Source: ESE, 1988.

APPENDIX B

MATERIALS DETECTED ABOVE ARAR IN SHALLOW MONITOR WELLS

Table B-1. Summary of Materials Detected Above Drinking Water Standard in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune

Parameter	Drinking Water Standard ug/L	Drinking Water Standard Source+	Average* Concentration (ug/L) Above ARAR by Well Number 22GW1	22GW2	1	2	3	4	5	6	7	8	9	10
Lead, Total	50	1	--	--	--	--	--	--	--	--	--	--	97.3	--
Benzene	5	2(MCL)	11,666	--	15.63	--	--	9.933	--	--	--	--	--	--
Trihalomethanes, Total++	100	1	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (Methyl Chloride)	1.9	3	--	--	--	--	--	--	--	--	--	2.4	--	--
1,1-Dichloroethane	4,200	4	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene	70	2(RMCL)	--	--	--	--	--	--	--	--	--	--	1,146.6	--
Ethylbenzene	680	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
Methylene Chloride	1.9	3	--	2.433	--	--	--	--	--	6.666	--	--	--	--
Tetrachloroethene	8.0	5	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	2,000	2(RMCL)	19,000	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	200	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene (TCE)	5.0**	2(MCL)	--	--	--	--	--	--	--	--	--	--	3,700	5.333
Trichlorofluoromethane	32,300	3	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl Chloride	1.0***	2(MCL)	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total	440	6	3,000	--	--	--	--	--	--	--	--	--	2,833.3	--
Methyl Ethyl Ketone	172	6	--	--	--	--	--	--	--	--	--	--	--	--

Table B-1. Summary of Materials Detected Above Drinking Water Standard in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 2 of 4)

Parameter	Drinking Water Standard		Average* Concentration (ug/L) Above ARAR by Well Number											
	ug/L	Source+	11	12	13	14	15	16	17	18	19	20	21	22
Lead, Total**	50	1	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	5	2(MCL)	--	--	--	--	--	--	--	--	--	--	--	--
Trihalomethanes, Total++	100	1	--	--	--	--	--	--	--	--	--	--	--	--
Chloromethane (Methyl Chloride)	1.9	3	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	4,200	4	--	--	--	--	--	--	--	--	--	--	--	--
T-1,2-Dichloroethene	70	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	680	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
Methylene Chloride	1.9	3	--	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethene	8.0	5	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	2,000	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	200	2(RMCL)	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene	5.0	2(MCL)	35.66	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	32,300	3	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl Chloride	1.0	2(MCL)	--	--	--	--	--	--	--	--	--	--	--	--
Xylene, Total	440	6	--	--	--	--	--	--	--	--	--	--	--	--

Table B-1. Summary of Materials Detected Above Drinking Water Standard in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 3 of 4)

	Drinking Water Standard		Average* Concentration (ug/L) Above ARAR by Well Number				
Parameter	ug/L	Source+	23	24	25	26	29
Lead, Total**	50	1	--	--	--	--	--
Benzene	5	2(MCL)	--	--	--	--	--
Trihalomethanes, Total++	100	1	--	--	--	--	--
Chloromethane (Methyl Chloride)	1.9	3	--	--	--	--	--
1,1-Dichloroethane	4,200	4	--	--	--	--	--
T-1,2-Dichloroethene	70	2(RMCL)	4,677	4,900	--	--	--
Ethylbenzene	680	2(RMCL)	--	--	--	--	--
Methylene Chloride	1.9	3	100	--	--	2.166	--
Tetrachloroethene	8.0	5	--	--	--	--	--
Toluene	2,000	2(RMCL)	--	--	--	--	--
1,1,1-Trichloroethane	200	2(RMCL)	--	--	--	--	--
Trichloroethene	5.0	2(MCL)	6,043	19	--	--	--
Trichlorofluoromethane	32,300	3	--	--	--	--	--
Vinyl Chloride	1.0	2(MCL)	--	146.6	--	--	--
Xylene, Total	440	6	--	--	--	--	--
Methyl Ethyl Ketone	172	6	--	--	--	--	--

Table B-1. Summary of Materials Detected Above Drinking Water Standard in 25-ft Shallow Monitor Wells, Hadnot Point Industrial Area, Camp Lejeune (Continued, Page 4 of 4)

Notes: Oil and grease excluded from table.
MCL = maximum contaminant level.
RMCL = Recommended maximum contaminant level.
ARAR = Legally applicable or relevant and appropriate standard, requirement, criteria, or limitation.
Total Trihalomethanes = Bromodichloromethane + dibromochloromethane + tribromomethane (bromoform) + trichloromethane (chloroform).
-- = Below detection limit.

*Average of concentrations from Monitoring Periods 1 (January 1987), 2 (March 1987), and 3 (May 1987).
+Source of ARARs:
1 = North Carolina Administrative Code (NCAC), Title 15, Subchapter 2L, Feb. 11, 1985.
2 = <u>Federal Register</u>, Vol. 50, No. 219, National Primary Drinking Water Regulations, Proposed RMCLs and MCLs, Nov. 13, 1985, pp.46880-47022.
3 = Ambient Water Quality Criteria for Halomethanes, USEPA, 1980.
4 = Health Effects Assessments [based on acceptable daily intake (ADI) of 1.2×10^{-1} mg/kg/day], USEPA, 1984.
5 = Ambient Water Quality Criteria for Tetrachloroethylene, USEPA, 1980.
6 = Lifetime Health Advisory, Health Advisory Office of Drinking Water, USEPA, 1985.
**State of NC drinking water standard = 2.8 ug/L.
++In shallow wells, total trihalomethanes - chloroform.
***State of NC drinking water standard = 0.18 ug/L.

Source: ESE, 1988.

APPENDIX C

SOIL GAS DATA

Table 1. Soil Gas Data For Building 1202.

Sample ID	TCE* (nl/l)+
1202-1	<10
1202-2	53
1202-3	<10
1202-4	<10
1202-5	<10
1202-6	<10
1202-7	<10
1202-8	<10
1202-9	<10
1202-10	1760
1202-11	8200
1202-12	37
1202-13	24000
1202-14	64
1202-15	36
1202-16	15
1202-17	14700
1202-18	13200
1202-19	36770
1202-20	116

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 2. Soil Gas Data For Building 1601.

Sample ID	TCE* (ng/l)+
1601-1	<10
1601-2	10
1601-3	41400
1601-4	18130
1601-5	79
1601-6	33
1601-7	43
1601-8	43
1601-9	10
1601-10	<10
1601-11	<10
1601-12	2630
1601-13	10
1601-14	<10
1601-15	<10
1601-16	7440
1601-17	703000
1601-18	68000
1601-19	22450
1601-20	20

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 3. Soil Gas Data For Buildings 1502 and 1602.

Sample ID	TCE* (nl/l)+
1502-1	16
1502-2	33
1502-3	13
1502-4	16
1502-5	30
1502-6	<10
1502-7	10
1502-8	13
1502-9	14
1502-10	15
1502-11	<10
1602-1	29
1602-2	10
1602-3	53

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 4. Soil Gas Data For Buildings 1300 and 1100.

Sample ID	TCE* (nl/l)+
1300-1	295
1300-2	<10
1100-1	<10
1100-2	<10
1100-3	10
1100-4	<10
1100-5	152
1100-6	<10
1100-7	<10
1100-8	<10
1100-9	<1000
1100-10	<2000

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 5. Soil Gas Data For Building 915.

Sample ID	TCE* (nl/l)+
915-1	<10
915-2	<10
915-3	<10
915-4	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 6. Soil Gas Data For Buildings 1709 and 1710.

Sample ID	TCE* (nl/l)+
1709-1	<10
1709-2	35
1709-3	53000
1709-4	<10
1709-5	<10
1709-6	<10
1709-7	<100
1709-8	<10
1709-9	<1000
1709-10	<10
1709-11	<10
1709-12	<10
1709-13	<10
1709-14	<10
1709-15	<10
1710-1	<10
1710-2	<1000
1710-3	<10
1710-4	<10
1710-5	<1000
1710-6	<1000
1710-7	<100000

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 7. Soil Gas Data For Buildings 1300, 1302, 1101, and 1102.

Sample ID	TCE* (nl/l)+
1300-1	295
1300-2	<10
1300-3	<10
1300-4	<10
1300-5	<10
1300-6	<10
1300-7	46
1300-8	404
1302-1	<10
1302-2	1250
1302-3	<10
1302-4	25
1101-1	<10
1101-2	<10
1101-3	<10
1102-1	442
1102-2	<10
1102-3	<10
1102-4	800

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 8. Soil Gas Data For Storage Lot 201.

Sample ID	TCE* (nl/l)+
201-1	<10
201-2	<10
201-3	<10
201-4	<10
201-5	<10
201-6	<10
201-7	<10
201-8	<10
201-9	250
201-10	<10
201-11	<10
201-12	<10
201-13	<10
201-14	<10
201-15	<10
201-16	<10
201-17	<10
201-18	<10
201-19	<10
201-20	<10
201-21	<10
201-22	<10
201-23	<10
201-24	<10
201-25	<10
201-26	<10
201-27	<10
201-28	<10
201-29	<10
201-30	<10
201-31	<10
201-32	<10
201-33	<10
201-34	<10
201-35	<10
201-36	<10
201-37	<10
201-38	13

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 8 (continued). Soil Gas Data For Storage Lot 201.

Sample ID	TCE* (nl/l)+
201-39	<10
201-40	<10
201-41	<10
201-42	<10
201-43	<10
201-44	<10
201-45	<10
201-46	<10
201-47	<10
201-48	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 9. Soil Gas Data For Storage Lot 203.

Sample ID	TCE* (nl/l)+
203-1	<10
203-2	<10
203-3	<10
203-4	<10
203-5	<10
203-6	<10
203-7	<10
203-8	<10
203-9	<10
203-10	<10
203-11	<10
203-12	<10
203-13	<10
203-14	<10
203-15	<10
203-16	<10
203-17	<10
203-18	<10
203-19	<10
203-20	<10
203-21	<10
203-22	<10
203-23	<10
203-24	<10
203-25	<10
203-26	<10
203-27	<10
203-28	440
203-29	<10
203-30	<10
203-31	<10
203-32	<10
203-33	<10
203-34	<10
203-35	1067
203-36	<10
203-37	18
203-38	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 9 (continued). Soil Gas Data For Storage Lot 203.

Sample ID	TCE* (nl/l)+
203-39	<10
203-40	<10
203-41	<10
203-42	<10
203-43	4423
203-44	<10
203-45	24
203-46	<10
203-47	<10
203-48	<10
203-49	<10
203-50	<10
203-51	<10
203-52	<10
203-53	<10
203-54	<10
203-55	<10
203-56	<10
203-57	<10
203-58	<10
203-59	750
203-60	<10
203-61	<10
203-62	<10
203-63	<10
203-64	<10
203-65	<10
203-66	<10
203-67	<10
203-68	<10
203-69	<10
203-70	16
203-71	<10
203-72	<10
203-73	9103
203-74	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 10. Soil Gas Data For Area of Well 652.

Sample ID	TCE* (nl/l)+
652-1	<10
652-2	<10
652-3	<10
652-4	<10
652-5	<10
652-6	<10
652-7	<10
652-8	<10
652-9	<10
652-10	<10
652-11	<10
652-12	<10
652-13	<10
652-14	<10
652-15	<10
652-16	<10
652-17	<10
652-18	<10
652-19	<10
652-20	<10
652-21	<10
652-22	<10
652-23	<10
652-24	<10
652-25	<10
652-26	<10
652-27	<10
652-28	<10
652-29	<10
652-30	<10
652-31	<10
652-32	<10
652-33	<10
652-34	<10
652-35	<10
652-36	<10
652-37	<10
652-38	<10
652-39	<10
652-40	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 11. Soil Gas Data For Area of Well 653.

Sample ID	TCE* (nl/l)+
653-1	<10
653-2	<10
653-3	<10
653-4	12
653-5	<10
653-6	<10
653-7	<10
653-8	<10
653-9	<10
653-10	<10
653-11	<10
653-12	<10
653-13	<10
653-14	<10
653-15	<10
653-16	<10
653-17	<10
653-18	<10
653-19	<10
653-20	10
653-21	<10
653-22	<10
653-23	<10
653-24	<10
653-25	<10
653-26	<10
653-27	<10
653-28	<10
653-29	<10
653-30	<10
653-31	<10
653-32	<10
653-33	<10
653-34	<10
653-35	<10
653-36	<10
653-37	<10
653-38	<10
653-39	<10
653-40	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 12. Soil Gas Data For Drive-In Treater (Building S-769) Area.

Sample ID	TCE* (nl/l)+
S-769-1	<10
S-769-2	<10
S-769-3	<10
S-769-4	<10
S-769-5	<10
S-769-6	<10
S-769-7	<10
S-769-8	<10
S-769-9	<10
S-769-10	<10
S-769-12	<10
S-769-13	<10
S-769-14	<10
S-769-15	<10
S-769-16	<10
S-769-17	<10
S-769-18	<10
S-769-19	<10
S-769-20	<10
S-769-21	<10
S-769-22	<10
S-769-23	<10
S-769-24	<10
S-769-25	<10
S-769-26	<10
S-769-27	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.

Table 13. Soil Gas Data For Buildings 901, 902, and 913.

Sample ID	TCE* (nl/l +
901-1	570
902-1	<10
902-2	<10
902-3	1497
902-4	<10
902-5	<10
902-6	<10
902-7	<10
902-8	<10
902-9	<10
902-10	<10
902-11	<10
902-12	<10
902-13	<10
902-14	<10
902-15	<10
913-1	<10
913-2	<10
913-3	<10
913-4	<10
913-5	<10
913-6	<10
913-7	<10
913-8	<10
913-9	<1000
913-10	<1000
913-11	<10
913-12	<10
913-13	<10
913-14	<10
913-15	<10
913-16	<10

Note: * TCE = Trichloroethene
+ nl/l = nanoliter per liter (parts per billion)

Source: ESE, 1987.