

APPENDIX E

SAMPLING AND ANALYSIS PLAN FOR LABORATORY TREATABILITY TESTING

**PILOT-SCALE TREATABILITY WORK PLAN
STEAM ENHANCED EXTRACTION
SITE 13
NAVAL AIR STATION ALAMEDA
ALAMEDA, CALIFORNIA**

**APPENDIX E
SAMPLING AND ANALYSIS PLAN FOR
LABORATORY TREATABILITY TESTING**

Contract Number: N62474-94-D-7430
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Submitted to:

EFA WEST (Code 0222)
Naval Facilities Engineering Command
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Submitted by:

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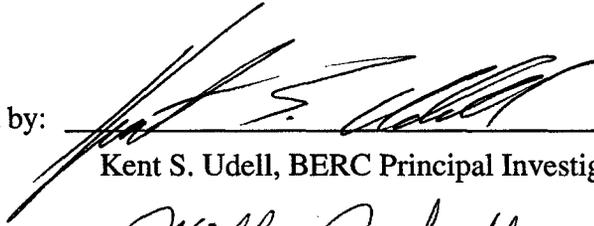
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SAMPLING AND ANALYSIS PLAN FOR
LABORATORY TREATABILITY TESTING**

Revision 1

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Approved by:



Kent S. Udell, BERC Principal Investigator

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Approved by:



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APPENDIX E

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1. INTRODUCTION

Steam enhanced extraction (SEE) of volatile chemicals is an innovative technology for in-situ remediation of contaminated soils. Laboratory treatability tests of SEE conducted at the Berkeley Environmental Restoration Center (BERC) Laboratory of the University of California, Berkeley have shown effective removal of hydrocarbons such as JP-5 fuel and coal tar liquids from soils. These tests and field pilot studies, combined with modeling of steam behavior, show that hydrocarbons can be removed from vadose and phreatic zone soils by several mechanisms. One mechanism is reduction of hydrocarbon liquid viscosity, and which then enhances flow and recovery of the hydrocarbon as an organic liquid phase. A second mechanism is the displacement of soluble/volatile hydrocarbon constituents in the aqueous phase ahead of the steam condensation front. Another mechanism is the temperature-enhanced volatilization of the more volatile constituents that can be recovered from the gas phase. These mechanisms also enhance the breakup of the hydrocarbon mass in soil and promote dissolution of the more soluble constituents into the aqueous phase. Together, these mechanisms provide for an effective remediation of chemicals that have been released into soils

This Sampling and Analysis Plan is designed to evaluate the effectiveness of SEE for treating an oily material present in saturated and unsaturated subsurface soils at Site 13 within the Alameda Naval Air Station in Alameda, California. This material is known to contain benzene, ethylbenzene, toluene, xylenes (BETX) and polycyclic aromatic hydrocarbon (PAHs) as well as other unknown components that extend to higher molecular weight fractions. Although SEE is not expected to completely remove the low solubility/low vapor pressure components in the higher molecular weight range, reductions in the concentrations of the more volatile compounds may be sufficient to reduce potential health risks to acceptable values. The sampling and analysis plan for the laboratory treatability test is also designed to evaluate the ability of the SEE process to mitigate the low pH conditions and elevated metal concentrations found in some soil samples.

This sampling and analysis plan describes a short-duration laboratory treatability test to evaluate the ability of SEE to remove mobile hydrocarbons from the oily material matrix at Site 13 and to assess the process effect on pore water pH. The one-dimensional experiment (that is, linear flow in a column) is to be run under conditions that represent displacement and volatilization mechanisms. Other hydrocarbon removal mechanisms, such as decreased viscosity/mobilization and upward migration of hydrocarbons from the saturated zone, will be studied in a subsequent three-well treatability field test. Because heat losses occur mainly at the periphery of the steam zone under field conditions, the column experiment will be run under adiabatic conditions to simulate volatile hydrocarbon behavior in the heated zone. Pressure cycling of steam will be operated to a maximum of 10 psig, a value that simulates the expected long-term operating pressure in the field. Additionally, the one-dimensional column experiment will treat a homogenized blend of site soils to overcome possible heterogeneities in soil and oily material distribution in the soil samples.

The laboratory treatability test is primarily intended to determine the extent of hydrocarbon component removal by SEE from the oily material present in Site 13 soils. The criteria for evaluating the hydrocarbon removal will include specific constituents such as BETX and PAHs, and categories of carbon ranges corresponding to kerosene, diesel, Bunker C and motor oil. The extractability of BETX and PAHs from untreated and steam-treated soils will be evaluated using The US EPA's Toxicity Characteristic Leaching Test (TCLP); the extractability of metal constituents will be evaluated using Cal EPA's Wet Extraction Test

(WET). If SEE removes at least one-half of either the volatile BTEX compounds or the PAH compounds, SEE will be considered to be a potentially significant removal mechanism for hydrocarbons under field conditions.

2. EXPERIMENTAL PROCEDURE

2.1 ONE-DIMENSIONAL EXPERIMENTAL APPARATUS

As shown in Figure 2-1, the apparatus for the one-dimensional (column) treatability study consists of a 4 ft long by 2 inch diameter borosilicate glass tube packed with soils from Site 13 that contain oily material. The sand pack is heated by a total of four heater tapes (6.5Ω) wrapped around the exterior of the cylinder's radial surface and insulated to maintain nearly adiabatic conditions at the exterior of the borosilicate cylinder; a 100Ω heater is attached to each of the end plates at both the inlet and outlet to avoid any end effects such as condensation and holdup of constituents. Both stainless steel end plates have channels engraved on their inner surface and are covered with stainless steel screens in order to promote uniform steam and constituent spreading across the sample cross section.

The SEE laboratory treatability test will be operated in a pressure cycling mode to simulate soil conditions experienced in the field. This mode employs pressure cycling, and the resulting temperature cycling facilitates volatilization of the lower vapor pressure constituents. However, while the ability to vary the pressure in the field is possible by the resistance inherent in the large (practically infinite) volume of soil at depth, the laboratory column has a finite length and therefore has a limited capacity for steam injection to cause pressure buildup in the soil column. The laboratory column study is therefore designed with a solenoid-controlled pressure valve at the end of the column to allow for control of the maximum column pressure, and that allows cycling over a pressure range that will be experienced in the field. Additionally, the water used in the steam generator for the laboratory treatability study is deaerated to preclude degassing and air bubble formation in the column during the cycling, which may introduce artifacts into the experimental results. Such degassing/ air void creation is not expected to be a significant factor in the larger and three dimensional environment of field conditions.

The experimental design uses a pair of metering pumps to deliver a constant mass flow rate of distilled water to a steam generator for steam injection, a timer-controlled solenoid valve used in pressure cycling, and an effluent collection jar cooled in an ice bath to minimize the loss of constituents from the effluent. Thermocouples are mounted at the steam inlet tubing, both the upstream and downstream ends of the soil sample, and the outlet tubing. Teflon tubing is used to carry all fluids into and out of the system and is long enough to allow effluent to cool to near room temperature before collection. During pressure cycling, when the effluent flow rate is too high to condense all of the steam in the effluent tube, an ice bath condenser stage is added to the outlet tubing between the outlet of the borosilicate column and the effluent collection jar.

2.2 SOIL SAMPLE PREPARATION

Soil samples will be collected with a suitable sampling device from three locations at Site 13; shallow samples will be collected with hand corers and deeper samples will be collected from borings with split-spoon samplers or with a Geoprobe. Soil samples will be

preliminarily categorized based on the visible extent of oily materials present. For example, light brown (B) colored samples are characterized as being relatively uncontaminated soils taken primarily from above the capillary fringe. Samples consisting of partially saturated oily sands and clays may be more gray (G) in color. Product (P) samples are those saturated with oils and water. One sample from each category will be sent to an outside laboratory for the analyses shown in Table 2-1. Samples to be mixed for treatability evaluations will be chilled to reduce hydrocarbon vapor pressure and mixed in a clean borosilicate tray to uniformly distribute the oily material within the mixed (M) sample. Prior to packing the cylinder, a sample of the mixed soil sample will also be sent for analysis as shown in Table 2-1. To estimate the variability associated with sampling and analysis for leaching tests, duplicate samples of the unmixed and mixed soil will be sent for PAH as well as both TCLP analyses. PAH and metals analyses will be performed for the compounds listed in Tables 2-2 and 2-3.

Table 2-1. Sample Size and Required Detection Limits
for Analytical Testing of Soil

TEST DESCRIPTION	EPA Analytical Method NO.	SAMPLE SIZE	REQUIRED DETECTION LIMIT
Total Extractable Hydrocarbon (TEH) as Kerosene, Diesel, Motor Oil, or Bunker C	8015	50 g	100ppm (all fractions)
(Total Volatile Hydrocarbon (TVH) as gasoline)	8015		1ppm
BTEX	8020	5 g	5ppb
PAH-8100 List	8270	30 g	1ppm
EPA Priority Pollutant Metals	6010/7471	10 g	0.05-3ppm
Sulfate Anions	375	20 g	1ppm
Chloride Anions	325	20 g	1ppm
pH	9045	10 g	—
CAC Title 26 WET for Metals	6010/7471	100 g	0.05-1ppm
TCLP for PAH	8270	100 g	100ppb
Zero Headspace TCLP for BTEX	8020	50 g	0.5ppb

Table 2-2. Analytes Detected by EPA Method No. 8270 (PAHs underlined).

ACID COMPOUNDS	BASE/NEUTRAL COMPOUNDS		
	N-Nitrosodimethylamine	Hexachlorocyclopentadiene	<u>Phenanthrene</u>
Phenol	Aniline	2-Chloronaphthalene	<u>Anthracene</u>
2-Chlorophenol	Bis(2-chloroethyl)ether	2-Nitroaniline	Di-n-butylphthalate
Benzyl Alcohol	1,2-Dichlorobenzene	Dimethylphthalate	<u>Fluoranthene</u>
2-Methylphenol	1,3-Dichlorobenzene	<u>Acenaphthylene</u>	<u>Pyrene</u>
4-Methylphenol	1,4-Dichlorobenzene	2,6-Dinitrotoluene	Butylbenzylphthalate
2-Nitrophenol	Bis(2-chloroisopropyl)ether	3-Nitroaniline	3-3'-Dichlorobenzidine
2,4-Dimethylphenol	N-Nitroso-di-n-propylamine	<u>Acenaphthene</u>	<u>Benzo(a)anthracene</u>
Benzoic Acid	Hexachloroethane	<u>Dibenzofuran</u>	<u>Chrysene</u>
2,4-Dichlorophenol	Nitrobenzene	2,4-Dinitrotoluene	Bis(2-ethylhexyl)phthalate
4-Chloro-3-methylphenol	Isophorone	Diethylphthalate	Di-n-octylphthalate
2,4,5-Trichlorophenol	Bis(2-chloroethoxy)methane	4-Chlorophenyl-phenylether	<u>Benzo(b)fluoranthene</u>
2,4,6-Trichlorophenol	1,2,4-Trichlorobenzene	<u>Fluorene</u>	<u>Benzo(k)fluoranthene</u>
2,4-Dinitrophenol	<u>Naphthalene</u>	4-Nitroaniline	<u>Benzo(a)pyrene</u>
4-Nitrophenol	4-Chloroaniline	N-Nitrosodiphenylamine	<u>Indeno(1,2,3-cd)pyrene</u>
4,6-Dinitro-2-methylphenol	Hexachlorobutadiene	Azobenzene	<u>Dibenzo(a,h)anthracene</u>
Pentachlorophenol	2-Methylnaphthalene	4-Bromophenyl-phenylether	<u>Benzo(g,h,i)perylene</u>
		Hexachlorobenzene	

Table 2-3. Metal Analysis Compounds.

COMPOUND	TEST METHOD
Mercury	7471
Antimony	
Arsenic	
Beryllium	
Cadmium	
Chromium (total)	
Copper	6010
Lead	
Nickel	
Selenium	
Silver	
Thallium	
Zinc	

The soil mixture containing oily material will be packed into the borosilicate cylinder by alternately adding a few centimeters of soil and lightly compacting the matrix with a wooden dowel to reduce void spaces in the pack. Packing will continue until enough material is in the cylinder to require a slight compression with the end cap when it is bolted in place. This compression will further minimize voids created during settling of the sand pack. To minimize end effects, 1.5 inches of clean sand will be packed at both the inlet and outlet ends of the sand pack.

2.3 PRE-STEAMING LEACHABILITY STUDY

Before steam injection is initiated, the sand pack will be flooded with distilled, de-ionized and de-aerated water, and sealed. After a period of five days to approach thermodynamic equilibrium conditions at room temperature, the water will be drained and sent for analysis as shown in Table 2-4. (PAH analysis will be performed for the compounds listed in Tables 2.) These analyses will be the baseline concentrations for the assessment of the leachability of the constituents from the affected soils.

Table 2-4. Leachability Effluent Analysis Schedule.

TEST DESCRIPTION	EPA NO.	SAMPLE SIZE	REQUIRED DETECTION LIMIT
TEH (Kerosene, Diesel, Motor Oil, Buncker C)	8015	100 mL	1ppm (diesel), 10-25ppm (oil)
TVH-BTEX	8015/8020	80 mL	0.5ppb
PAH-8100 List	8270	100 mL	100ppb
Sulfate Anions	375	50 mL	0.5ppm
Chloride Anions	325	50 mL	0.5ppm
pH	9040	10 mL	—

2.4 STEAM INJECTION PROCEDURE

A constant steam flow rate of 40 g/hr of steam will be supplied to the inlet of the sand pack. Steam will be injected for a period of 115 hours allowing for 8 soil pore volumes of steam condensate and displaced water to be collected. To minimize sample degradation, an ice bath will be placed on effluent collection bottles. Over the five days of steaming, effluent samples will be collected once every 12 hours. As each sample bottle is filled, it will be sealed with a Teflon cap and placed in a refrigerator at 4 °C (± 2 °C) or an ice bath prior to transport to the analytical laboratory. Each of the ten effluent samples will be sent for analysis as shown in Table 2-5; analyses for PAHs are included in EPA Method No. 8270, as listed in Table 2-2.

Table 2-5. Effluent Analysis Schedule.

TEST DESCRIPTION	EPA NO.	SAMPLE SIZE	REQUIRED DETECTION LIMIT
TEH (Kerosene,Diesel,Motor Oil,Buncker C)	8015	100 mL	1ppm (diesel), 10-25ppm (oil)
TVH-BTEX	8015/8020	80 mL	0.5ppb
PAH-8100 List	8270	100 mL	100ppb
Sulfate Anions	375	50 mL	0.5ppm
Chloride Anions	325	50 mL	0.5ppm
pH	9040	10 mL	—

During the steam injection phase of the treatability study, the pressure in the sand pack will be cycled from atmospheric pressure to 10 psig using a timer on a solenoid valve at the outlet end of the borosilicate cylinder; the cycling time is approximately one hour. When the valve is closed during constant steam injection, the pressure within the soil matrix builds up causing an increase in temperature. When the solenoid valve reaches the trigger pressure, the valve is then opened and pressures return to ambient conditions. The higher temperature and decrease in pressure results in enhanced volatilization of the more volatile constituents. This cycling process will serve to vaporize contaminants trapped in less accessible regions such as dead end pores. Pressure cycling has been used in previous field demonstrations of steam enhanced extraction.

2.5 POST-STEAMING LEACHABILITY STUDY

At the end of steam injection phase of the study, the sand pack will be slowly cooled to ambient temperature and again flooded with distilled, de-ionized and de-aerated water and sealed. After a period of five days to allow thermodynamic equilibrium conditions to re-establish at room temperature, the water will be drained and sent for analysis as was shown in Table 2-4. The comparison between the pre-steam and post-steam concentrations of analyzed compounds in the drained water will provide a direct measure of the impact of steam injection on the reduction of leachable constituents and thus, the degree of reduction of risk for future exposure through groundwater pathways.

After the leachability test water sample has been drained from the sand pack, the borosilicate cylinder will be chilled for 24 hours in order to reduce the vapor pressure of the hydrocarbon constituents. The soil within the borosilicate cylinder will be removed and separated into samples, one from each foot of the sand pack. All samples will be sent for analysis as was shown in Table 2-1. To estimate the variability of the sampling and analysis, duplicate samples from each section of the soil will be sent for PAH as well as both TCLP analyses. A comparison of BTEX and PAH concentrations in soil and TCLP leachate concentrations from soil before and after steam extraction will provide additional information on the potential for steam enhanced extraction to reduce the risk of future exposure to site soils.

3. QUALITY ASSURANCE/QUALITY CONTROL

This one-dimensional laboratory treatability test will follow the quality assurance and quality control (QA/QC) procedures outlined in the Contractor Quality Control Plan. In addition, all water used during steam injection will first be distilled and then boiled to reduce the amount of dissolved gases. All tubing used to carry water and effluent will be polytetrafluoroethylene (PTFE) to lower the risk of water or effluent contamination by interaction with the tubing material. In order to minimize the opportunity of system contamination throughout the experiment, the system will remain closed except for the necessary supply of water to the metering pumps and sample bottle changing.

All sample bottles will be prepared by washing with nonphosphate detergent followed by multiple tap water and then distilled water rinses. After washing, the bottles will be oven dried and sealed with Teflon caps prior to use. While sampling for effluent, bottles will be kept in an ice bath to keep the effluent temperature low and minimize potential evaporation. All full sample bottles will be capped with a Teflon cap, labeled according to the convention described in Table 3-1, and placed in a refrigerator or cooler containing ice to maintain temperatures at 4 °C (± 2 °C).

Table 3-1. Sample Naming Convention.

SAMPLE TYPE	NAMING CONVENTION
Pre-Steamng Soil	B-S, G-S, P-S, M-S
Pre-Steamng Leachability Effluent	Pre-LE
Effluent from Steam-cycling Experiment	1-E...10-E
Post-Steamng Leachability Effluent	Post-LE
Steam-treated Soil	S-1, S-2, S-3, etc.

Soil samples will be sent to the analytical laboratory at several different times, and within specified holding times. All pre-steaming soil samples will be packed and sent to the laboratory for analyses as soon as they are prepared. The steam treated soil samples will be sent to the laboratory at the conclusion of the final leachate study. All liquid effluent and *leachability test samples* will be sent to the laboratory within 18 hours of when they are collected. They will be tested for pH within 24 hours of when the sample is collected.

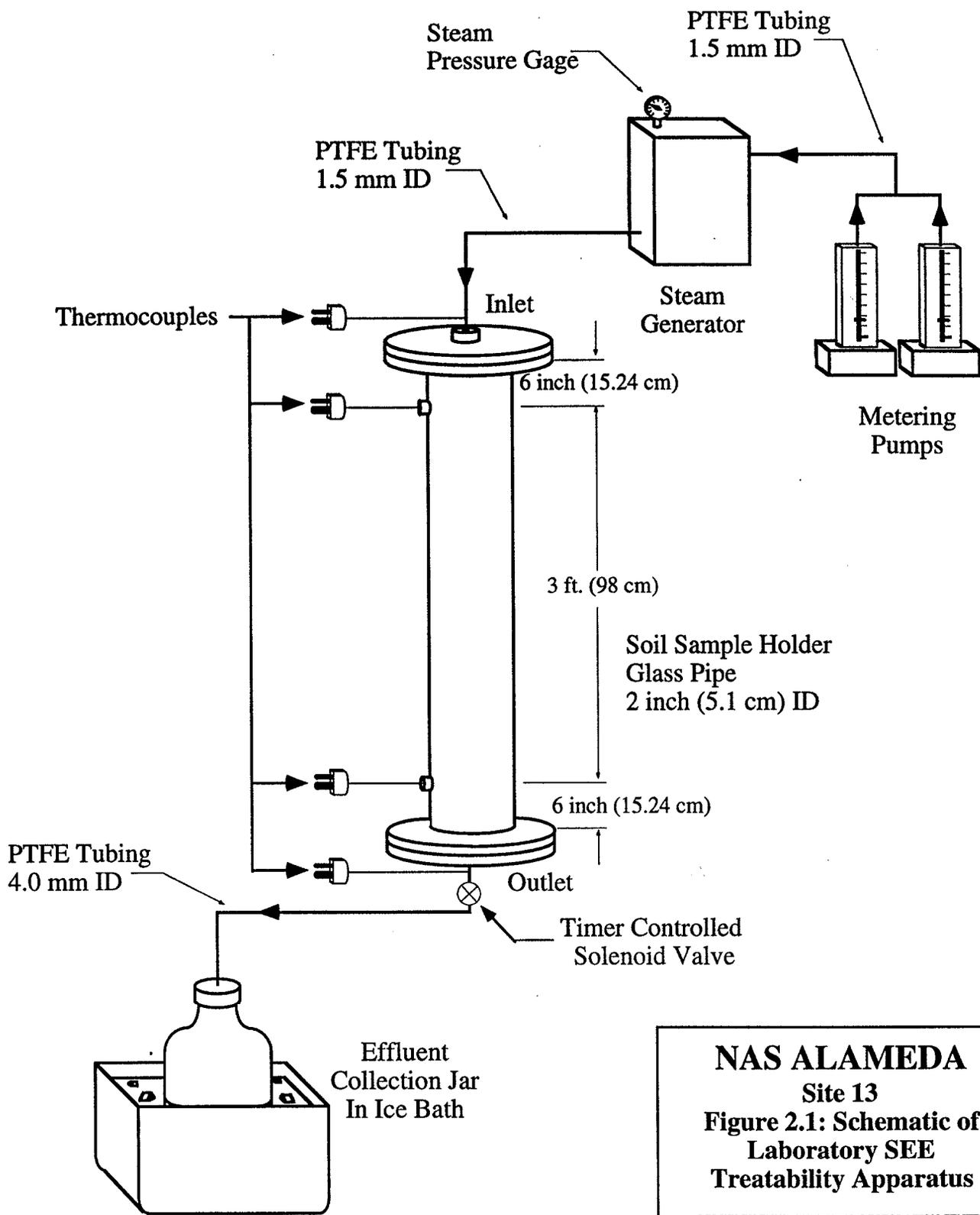
After sampling has been completed, soil and effluent samples will be packed in coolers with foam and ice. A control blank filled with distilled water as used in the metering pumps will be placed in each cooler along with the first sample. As such, the control blank should indicate any cross-contamination in the sample preparation, storage and transportation. Coolers will be sealed with custody tape and sent along with a chain of custody form within the prescribed holding times given in Tables 3-2 and 3-3.

Table 3-2. Sample Holding Time Schedule For Soil Samples

SOIL ANALYSIS SAMPLES	
TEST DESCRIPTION	HOLDING TIME
TEH (Kerosene, Diesel, Motor Oil, Bunker C)	14 days extract / 40 days analysis
TVH-BTEX	14 days analysis
PAH-8100 List	14 days extract / 40 days analysis
EPA Priority Pollutant Metals	28 days Hg / 6 mo all others
Sulfate Anions	28 days
Chloride Anions	28 days
pH	-
CAC Title 26 WET for Metals	14 days extract / 6 mo analysis
TCLP for PAH	21 days extract / 40 days analysis
Zero Headspace TCLP for BTEX	14 days extract / 14 days analysis

Table 3-3. Sample Holding Time Schedule for Effluent Samples

EFFLUENT ANALYSIS SAMPLES	
TEST DESCRIPTION	HOLDING TIME
TEH (Kerosene, Diesel, Motor Oil, Bunker C)	7 days extract / 40 days analysis
TVH-BTEX	14 days analysis
PAH-8100 List	7 days extract / 40 days analysis
Sulfate Anions	28 days
Chloride Anions	28 days
pH	24 hrs



NAS ALAMEDA
Site 13
Figure 2.1: Schematic of
Laboratory SEE
Treatability Apparatus

APPENDIX F

SAMPLING AND ANALYSIS PLAN FOR THREE-WELL TREATABILITY TEST

**PILOT-SCALE TREATABILITY WORK PLAN
STEAM ENHANCED EXTRACTION
SITE 13
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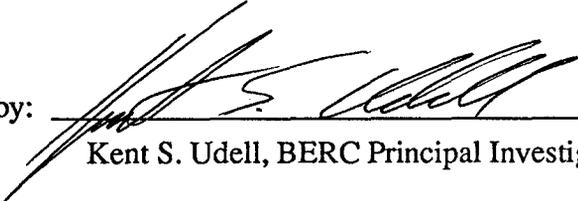
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Revision 1

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Date:

3/20/96

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APPENDIX F

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APPENDIX F

SAMPLING AND ANALYSIS PLAN FOR THREE-WELL TREATABILITY TEST

This appendix presents the sampling and analysis plan (SAP) for the three-well treatability test at Site 13 to test the application of steam enhanced extraction (SEE) for the removal of hydrocarbons from the subsurface and provide data to make a decision whether to proceed to the 15-well pilot scale test. The SAP describes the field activities, sampling, and analyses that will be performed during implementation and operation of the test to achieve the following objectives:

- Provide more detailed information regarding the vertical distribution of hydrocarbons in the planned treatment zone and assess baseline concentrations and leachability of hydrocarbons prior to treatment;
- Identify the hydraulic conductivity of the subsurface waste-bearing zone;
- Monitor the performance of the SEE system and the above-ground treatment equipment to identify potential difficulties in above-ground fluid treatment;
- Assess the ability of SEE to remove subsurface hydrocarbons through multiple mechanisms including mobilization of free phase hydrocarbons and steam distillation;
- Assess the concentration and leachability of hydrocarbons left in place after the application of steam; and
- Characterize wastes for disposal purposes.

The tasks that will be performed to achieve these objectives are described in Section 9 of the Work Plan, *Implementation Plan*.

1. CONE PENETROMETER TESTING

Cone Penetrometer Testing (CPT) with laser induced fluorescence will be used at a minimum of the 20 locations shown on Figure 1-1 to characterize the existing vertical distribution of hydrocarbons in the planned treatment zone and select final injection/extraction well locations and design. The planned locations for soundings CPT-1 through CPT-18 are shown on Figure 1-1. Soundings CPT-19 and CPT-20 will be installed within the finally selected treatment area. The locations of these soundings will be selected on the basis of the results of laser induced fluorescence conducted at locations CPT-1 through CPT-18. The soundings will be performed to a maximum depth of 30 feet below ground surface (bgs), or approximately 10 feet below the deepest expected contamination.

Small diameter borings will also be drilled adjacent to several CPT sounding locations to collect soil samples for correlation with the laser induced fluorescence results, for grain size

analyses to be used in the design of the injection/extraction wells, and to assess baseline chemical concentrations prior to treatment. CPT, sample collection, and laser induced fluorescence methods are described below.

1.1 CONE PENETROMETER TESTING

CPT methods are described in SOP No. 10.2; as summarized in Table 1-1, readings obtained at each CPT location will include the cone tip resistance, friction ratio, sleeve friction resistance, and differential pore pressure ratio to obtain information regarding subsurface lithology and water pressure in the formation. At each location, CPT soundings will be obtained to a maximum of 30 feet below ground surface or to a depth of 10 feet below the bottom of the hydrocarbon bearing zone, whichever is deeper. The bottom of the hydrocarbon bearing zone will be determined by visual observation of oily materials. Laser induced fluorescence will be used to confirm the vertical hydrocarbon extent. Groundwater samples will not be collected. Upon completion of each sounding and measurement of laser induced fluorescence, each CPT location will be backfilled with a neat cement grout containing no more than five percent bentonite.

1.2 LASER-INDUCED FLUORESCENCE

As summarized in Table 1-1, laser-induced fluorescence will be used to identify petroleum hydrocarbons by their PAH constituents. A continuous profile of petroleum hydrocarbon concentrations at each CPT location will be obtained by measuring the fluorescent response of the polynuclear aromatic hydrocarbons (PAHs) to excitation by ultra-violet light throughout the total depth of CPT sounding. In situ measurements of the PAH levels will be obtained using an in situ fluorometer equipped with two optical fibers, a timing circuit fiber, and the downhole irradiation fiber. The PAH levels can be used to infer petroleum hydrocarbon levels.

1.3 INSTALLATION OF SOIL BORINGS

A portable, hydraulically driven soil coring system will be used to install small diameter borings adjacent to CPT soundings to collect confirmation soil samples for correlation with the laser induced fluorescence results, grain size analyses, or assessment of baseline chemical concentrations within the finally selected treatment area. The borings will be identified with the same number as the adjacent CPT sounding followed by a "B" and installed to a total depth equal to the depth of the adjacent CPT location. This method utilizes two nested sampling rods that are driven simultaneously. The small-diameter inner rod is used to obtain and retrieve sample cores. The larger rod serves as a temporary drive casing to prevent caving into the boring. Upon completion of soil sample collection, each boring will be backfilled with a neat cement grout containing no more than five percent bentonite. No soil cuttings will be produced using this drilling method. Upon completion of sampling, each boring will be backfilled with a neat cement grout containing no more than five percent bentonite.

1.4 SOIL SAMPLING

Soil samples will be collected continuously from ground surface to total depth in 1-1/2 inch diameter by six-inch long precleaned stainless steel or brass tubes using a sample barrel attached to the inner rod which is advanced during drilling. All recovered soils will be

logged in the field under the supervision of a registered geologist, using the Unified Soil Classification System (USCS).

Upon retrieval, each sample will be prepared for potential analysis. Each end of the sample liner will be covered with Teflon sheeting and the liner will then be capped with a polyethylene lid, labeled, immediately placed in a cooler and handled as described in Section 14.

1.5 LABORATORY ANALYSES

Laboratory analyses that will be conducted on soil samples from the small diameter borings are summarized in Table 1-2. Analytical methods are specified in Table 1-3 and the metals to be analyzed are specified in Table 1-4. Borings CPT-1B through CPT-3B are located adjacent to the planned injection/extraction wells. Three soil samples from within the contaminated zone and one sample of five feet below the contaminated zone in each of these borings will be collected and submitted for grain size analysis. These depth intervals represent the planned screened intervals of the injection/extraction wells. The information obtained from this analysis will be used to select the screen and filter pack size for the injection/extraction and groundwater monitoring wells as described in Section 2.5.

One sample from Borings CPT-1B through CPT-6B will also be analyzed for total petroleum hydrocarbons as gasoline, diesel, and motor oil (TPHg, TPHd, and TPHmo) to correlate the analytical results with the results of laser induced fluorescence. These soil samples will also be analyzed for pH to establish the pH of soils within the planned treatment area prior to injection of steam.

The locations of CPT soundings CPT-19 and CPT-20 will be selected once the results of laser induced fluorescence conducted at locations CPT-1 through CPT-18 have been reviewed and the location of the treatment area has been finalized. These soundings will be conducted within the area bound by the injection extraction wells. Soil samples from Borings CPT-19B and CPT-20B will be laboratory analyzed to assess baseline chemical conditions within the treatment area prior to injection of steam. As summarized in Table 1-2, a soil sample from the vadose zone, top of the contaminated zone, middle of the contaminated zone, bottom of the contaminated zone, and five feet below the bottom of the contaminated zone will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo; PAHs; benzene, toluene, ethylbenzene, and xylenes (BTEX); and pH. With the exception of the vadose zone sample, each of these samples will also be analyzed for metals. The leachability of hydrocarbons in the contaminated zone will be assessed by conducting Toxicity Characteristic Leachability Procedure (TCLP) analyses for BTEX on soil samples from within this zone.

2. INJECTION/EXTRACTION AND GROUNDWATER MONITORING WELLS

The anticipated locations of the injection/extraction wells and groundwater monitoring wells to be installed for the three-well treatability test are shown on Figure 2-1, these locations may be adjusted on the basis of data obtained through CPT and laser induced fluorescence described in Section 1 of this SAP. The injection/extraction wells will be located in an equilateral triangle in the area where hydrocarbons are identified at the greatest depth in the soil and where the greatest hydrocarbon concentrations are identified. Depending on the

depth of the hydrocarbons, the spacing of the wells may be adjusted to approximately 15 feet longer than the greatest depth of hydrocarbon concentration.

Based on available information, the injection/extraction wells will be located in an equilateral triangle and spaced approximately 35 feet apart. One groundwater monitoring well will be placed approximately 15 feet outward from each injection/extraction well. A fourth groundwater monitoring well will be located approximately 35 feet radially outward from the injection/extraction well located in the southwest portion of the treatment area; this is in the approximate down gradient direction from the treatment area. Planned methods for the installation and sampling of these wells are described below.

2.1 INSTALLATION OF SOIL BORINGS

A truck mounted drilling rig equipped with eight-inch outside diameter hollow-stem augers will be used to drill initial soil borings to a maximum depth of 30 feet bgs for soil sample collection. Drill cuttings will be contained in 55-gallon drums or a covered roll-off bin and appropriately labeled as described in Section 12 for subsequent disposal.

2.2 SOIL SAMPLING

At each injection/extraction well and groundwater monitoring well location, soil samples will be collected continuously from ground surface to total depth using a two-inch diameter split spoon sampler lined with six-inch long precleaned stainless steel or brass tubes. This soil sampling procedure is described in SOP 3.2. All recovered soils will be logged in the field and recorded on the boring logs under the supervision of a registered geologist using the USCS.

Upon retrieval, each sample will be prepared for potential analysis. Each end of the sample liner will be covered with Teflon sheeting and the liner will then be capped with a polyethylene lid, labeled, and handled as described in Section 14.

2.3 INJECTION/EXTRACTION WELL CONSTRUCTION

Upon completion of soil sampling at each injection/extraction well location, the augers will be removed from the boring and it will be reamed to a 12-inch diameter using reverse circulation drilling techniques. During reaming, water will be added to the boring to maintain hydrostatic pressure in the boring and control potentially heaving sands.

The injection/extraction wells will be constructed as indicated on Figure 2-2. Well construction methods are described in SOP 8.1 and in more detail below. Upon completion of drilling, the prefabricated well will be placed into the boring. The design includes two screened intervals; the uppermost interval will be screened in both the vadose zone and the water table with the bottom of the screened interval at a depth approximately equal to the bottom of the zone of contamination. The deeper screened interval will consist of a five foot long screen located beneath the contaminated zone.

The screens will be separated by a five foot long section of blank casing. Two steel plates will be installed at the bottom of the blank interval to allow injection into each screened interval separately and to minimize the transfer of heat between the two screened intervals. The appropriate size of the screen openings will be selected using the procedures described

in Section 2.5. A temperature observation well will also be placed in the boring before the well completion materials are installed.

To complete the wells, clean imported silica sand will be poured into the annulus between the casing and the boring and will extend to 6 inches above the top of the deepest screened interval; the appropriate size of the filter pack material will be selected using the procedures described in Section 2.5. A four foot thick seal of hydrated 3/8 inch bentonite pellets will then be placed opposite of the blank casing to within six inches of the bottom of the upper screened interval. Above this, clean imported sand will be placed to six inches above the top of the uppermost screened interval. These well completion materials will be placed through a tremie pipe.

After the uppermost filter pack has been installed, a sanitary seal consisting of 3/8 inch diameter bentonite pellets will be placed and hydrated. The remainder of the annular space will be filled with a cement grout containing no more than five percent bentonite. A six inch concrete pad will be constructed around the well head. A water tight locking cap will temporarily be placed on the well head until pumping and steam injection equipment is installed and the well is hooked up to the treatment system.

2.4 GROUNDWATER MONITORING WELL CONSTRUCTION

Upon completion of soil sampling at each groundwater monitoring well location, a monitoring well will be installed in each boring. The groundwater monitoring wells will be constructed as indicated on Figure 2-3. Well construction methods are described in SOP 8.1 and in more detail below.

The casing will consist of two-inch diameter blank carbon steel. The screened interval will be constructed of 304 stainless steel installed from 25 feet bgs to four feet bgs. The appropriate size of the screen openings will be selected using the procedures described in Section 2.5. The upper limit of the screen is approximately two feet higher than the highest depth to groundwater observed at Site 13 and will allow for monitoring of free phase hydrocarbons. The bottom of the casing will be completed with welded or threaded bottom plug.

The casing and screen will be installed directly into the boring before the augers are removed. To complete the wells, clean imported silica sand will be placed in the boring through a tremie pipe as the augers are gradually removed from the boring. The appropriate size of the filter pack materials will be selected using the procedures described in Section 2.5. The top of this filter pack will extend to approximately 0.5 foot above the top of the screened interval. A two foot thick seal of hydrated 3/8 inch bentonite pellets will then be placed opposite of the blank casing. The remainder of the annular space will be filled with a neat cement grout containing no more than five percent bentonite. A six inch concrete pad will be constructed around the well head.

At each groundwater monitoring well location gas pressures of up to 10 pounds per square inch (psi) may be experienced in response to the injection of steam. To prevent escape of steam from the groundwater monitoring wells, a water tight locking cap capable of withstanding pressure will be placed on the well head.

2.5 DETERMINATION OF SCREEN AND FILTER PACK SIZE

A grain size analysis will be performed on four soil samples from Borings CPT-1B through CPT-3B and a grain size curve will be prepared for each sample. The filter pack and screen slot size for the injection/extraction and groundwater monitoring wells will be selected on the basis of these results. A filter pack material will be selected with a uniformity coefficient of 2.5 or less with a 70 percent retained size equal to the 70 percent retained size of the finest sample multiplied by a factor of 6 to 10, depending on the nature of the water bearing materials (Driscoll, 1986). The screen slot size will be selected to retain 90 percent of the filter pack material.

2.6 WELL DEVELOPMENT METHODS

At least 48 hours after completion, the injection/extraction and groundwater monitoring wells will be developed by the drilling contractor using a surge block and bailer. Well development procedures are described in SOP 8.2. A field geologist will observe the field activities and monitor water quality parameters during development. The water quality parameters to be monitored include temperature, pH, and specific conductance. Purging will continue until all three parameters have stabilized to within plus or minus 10 percent and the purge water is relatively free of sediment or there is no observable change in the amount of sediment in the purge water. A minimum of three well volumes of liquid will be removed and purge water will be contained on-site in DOT-approved 55-gallon drums and appropriately labeled as described in Section 12 for appropriate disposal.

2.7 LABORATORY ANALYSES

Laboratory analyses that will be conducted on soil samples from the injection/extraction wells and the groundwater monitoring wells are summarized in Table 2-1. Analytical methods are specified in Table 1-3. At each injection/extraction well location, a soil sample from the vadose zone, top of the contaminated zone, middle of the contaminated zone, bottom of the contaminated zone, and five feet below the bottom of the contaminated zone will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, PAHs, BTEX, and pH. With the exception of the vadose zone sample, each of these samples will also be analyzed for metals. The leachability of hydrocarbons in the contaminated zone will be assessed by conducting TCLP analyses for BTEX on soil samples from within this zone. At each groundwater monitoring well location, three soil samples from within the contaminated zone within each boring will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, and BTEX. The results of these analyses will be used to assess baseline conditions prior to injection of steam.

Laboratory analyses that will be performed on groundwater samples from each injection/extraction and groundwater monitoring well prior to the start up of the three-well treatability test are summarized in Table 2-2. Analytical methods are specified in Table 1-3. A groundwater sample from each well will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, PAH, BTEX, and metals.

3. WATER LEVEL AND GAS PRESSURE MEASUREMENTS

Pressure transducers will be permanently installed in each groundwater monitoring well to monitor water levels and gas pressures within the vadose zone. The leads to the transducers will be fed through the threaded well cap placed at the well head and the openings in the cap will be sealed to prevent leakage from the well. This measurement technique will allow monitoring of water levels and gas pressures at steam pressures with an electronic data logger. Water levels are measured to the nearest 0.01 foot; gas pressures are obtained to the nearest 0.5 psi.

4. GROUNDWATER SAMPLING METHODS

Prior to start up of the three-well treatability test, groundwater samples will be collected from the injection/extraction and groundwater monitoring wells. The groundwater monitoring wells will also be sampled at day fifteen and at the completion of the three-well treatability test.

Groundwater sampling methods are described in SOP 9.1. Prior to sampling, the well will be purged using a submersible or gas driven bladder pump. The pump and discharge line will be constructed of nonreactive materials to prevent contamination of the samples. A minimum of three and a maximum of 5 well volumes of liquid will be removed from the well prior to sampling. The pH, specific conductance, and temperature of the purge water will be closely monitored, and purging will continue until all three parameters have stabilized. If a well does not recharge fast enough to permit purging three well volumes, the well shall be pumped or bailed dry and sampled as soon as the water level has recovered to 80 percent of the original level. The purged water will be stored on-site in 55-gallon DOT-approved drums and appropriately labeled as described in Section 11.

Groundwater samples will be obtained directly from the pump discharge line into the appropriate sampling container for each analytical method. Samples for analysis of volatile organic compounds will be collected in 40 milliliter glass vials with Teflon lined lids. No head space will be present in the sample container when it is capped. All groundwater samples will be labeled and handled as described in Section 13.

5. HYDRAULIC TESTING

Aquifer testing conducted prior to the three-well treatability test will consist of single step drawdown test conducted in one injection/extraction well, followed by a constant rate discharge pumping test conducted in each of the three injection/extraction well. The step drawdown test will be conducted to determine the optimal pumping rate for the constant rate discharge test. The tests will be conducted in accordance with the procedures described in SOP 11.1 and as described below.

Prior to the start up of the step drawdown test or constant rate pumping tests, water levels will be continuously recorded for 48 hours, using a pressure transducer and electronic data logger, in the wells to be monitored during the test to establish normally occurring water level fluctuations. Water level data will be collected at 10 minute intervals in each well monitored. A submersible pump will then be placed in each well to be tested a minimum of one hour before the start up of the test. Static water levels will be manually measured in each well to be monitored at the start up of the test.

The step draw down test will be conducted by pumping the injection/extraction well for a maximum of four 4-hour steps at successively higher pumping rates. Pumping will begin at 2 gpm and will be raised 2 gpm for each successive step, i.e. the pumping rate during the fourth step of the test will be 8 gpm. The test will be halted if the well becomes dewatered below the pump intake or can not otherwise sustain the higher discharge rates during the test.

During each step, water levels will be monitored at logarithmic intervals in the injection/extraction well and the nearest groundwater monitoring well using pressure transducers and electronic data loggers. Water level data will also be obtained to monitor water level recoveries in each well once the pump has been shut off and the test has been completed. These water levels will be monitored until they recover to within 95 percent of static. Manual water level measurements will also be obtained at 15 minute intervals during each step and recovery to provide back up of the electronic measurements.

Data obtained from the step drawdown test will be evaluated to determine the optimal pumping rate for the constant rate discharge pumping test. A pumping rate will be selected to avoid drawdown in the pumped well to below the pump intake, to provide the largest possible radius of influence, and to facilitate drawdown in the observation wells within the time frame of the pumping test. The constant rate discharge tests will not be started until water levels have returned to static following the completion of the step drawdown test.

One constant rate discharge pumping test will be conducted in each injection/extraction well. While one well is being pumped, water levels will be monitored in the other two injection/extraction wells and in the four groundwater monitoring wells to be installed as part of the monitoring system for the three-well treatability test.

A minimum of one hour before the start up of the test, a submersible pump will be placed in the well to be pumped. Water levels will then be measured manually in each well at the start of the test. Each pumping test will be performed for a minimum of eight hours, but the duration may be extended if drawdown data indicate hydrogeologic conditions which impact data late in the test. These may include, but not be limited to, leaky strata and discharge/recharge boundaries. A registered hydrogeologist will be present in the field to review the pumping test data for quality and completeness and to make a decision about when to terminate the pumping test.

During pumping, water levels will be measured in the pumped well and in the observation wells at logarithmic intervals using a pressure transducer and data logger for the duration of the test. At the completion of the test, the pump will be turned off and water levels will be measured logarithmically during recovery. Recovery water levels will be measured until water levels return to within 95 percent of static. Manual measurements of water levels will be obtained from the pumped well and the observation wells at 15 minute intervals throughout the duration of the test and during the recovery period to provide back up for the electronic measurements. Discharge volumes will also be checked manually at 15 minute intervals during the test to ensure that a constant discharge rate is maintained throughout the test.

During each test, water levels will be measured to the nearest 0.01 foot. Manual water levels will be recorded on an aquifer test form. Flow rates will be measured with an in-line flow meter and recorded; the meter will be calibrated prior to the test to ensure accurate readings. The temperature, pH, and conductivity of the discharged water will be measured on an hourly basis during the constant rate pumping tests.

Groundwater discharged during the pumping tests will be containerized on site in a temporary tank. At the completion of testing, the containerized water will be sampled for the parameters indicated in Table 2-2. Analytical methods are specified in Table 1-3. If the water quality meets the discharge limitations for EBMUD, the water will be discharged directly to the NAS Alameda wastewater collection system; EBMUD discharge limitations are listed in Table 5-1. If the chemical concentrations identified in the water exceed the discharge limitations, the water will be treated with the effluent treatment system installed for the three-well treatability test. A maximum of 16,000 gallons of water is expected to be produced during aquifer testing.

The pumping test data will be evaluated using Aquifer Test Solver (AQTESOLV), a commercially available computer based aquifer analysis program. This program utilizes the Theis (1935), Cooper-Jacob (1946), and Neuman (1975) solutions for unconfined aquifers. Plots of the data and match curve will be printed for each pumping test and recovery period. Manual curve matching will be conducted to provide a check of the computer solutions.

6. TEMPERATURE OBSERVATION WELL INSTALLATION

To monitor temperatures at the injection point, temperature observation wells will be installed within the annular space of each of the injection/extraction wells installed during the three-well treatability test. To monitor temperature changes within the remainder of the treatment area, 13 additional temperature observation wells will be installed using the methods described below. Estimated locations for these wells are shown on Figure 2-1.

The planned well construction is shown on Figure 6-1. The wells will be installed by pushing 2-inch outside diameter carbon steel schedule 40 pipe directly into the soil to a total depth of approximately 25 feet below ground surface using van-mounted percussion insertion techniques. The casing will be completed with a two-inch NPTF cap at the bottom and the well head will be completed with a weatherproof T-Type thermocouple terminal box. T-Type shielded stainless steel thermocouple wire with beads spaced every four feet will be installed inside the casing for temperature monitoring.

7. ELECTRICAL RESISTANCE TOMOGRAPHY

Seven electrode wells will be installed in the locations shown on Figure 2-1, each containing one strand with five regularly spaced electrodes. Between each electrode well pair, ten surface electrodes will be placed for a total of 60 surface electrodes.

7.1 SURFACE RESISTIVITY SURVEY

To determine the size of the electrodes needed for the electrode wells, surface resistivity measurements will be obtained before the electrode wells are installed. For this survey, four metal stakes will be driven approximately six inches into the ground in a linear array. Each stake will be electrically connected to a data acquisition system that transmits a current of about 0.5 amps through the transmitting electrodes and measures a voltage potential through the receiving electrodes. The apparent resistivity will then be calculated from an equation based on the voltage received.

7.2 ELECTRODE WELL INSTALLATION

Electrode wells will be installed using a cone penetrometer. The cone and a hollow push rod will be pushed into the ground and a strand of five regularly spaced electrodes will be lowered into the push rod. The push rod will then be pulled from the ground leaving the cone and the electrode strand in the ground and the soil will be allowed to cave around the electrode strand. A schematic of the electrode well is shown on Figure 7-1. Following electrode well installation, ten surface electrodes will be permanently placed between well pairs. Data from the surface electrodes and the electrode wells will be used to create two dimensional vertically oriented resistivity tomographs. A minimum of one set of resistivity measurements will be made before steam injection to collect base line data, set up the measuring system, quantify measuring noise, and trouble shoot the system. Additional measurements will be obtained during operation of the three-well treatability test as described in Section 7.7.1.3 of the Work Plan.

8. OPERATIONAL MONITORING

Operational monitoring will be conducted during the three-well treatability test to monitor the performance of the steam injection/extraction system as well as to detect changes in contaminant concentrations in the groundwater as described in Section 7.7.1 of the Work Plan. This section describes the sampling and analytical methods for influent and effluent sampling and groundwater monitoring. Temperature, total flow, pressure, and electrical resistivity measurements are described in the Work Plan and are not included in this section because they do not involve sampling and analyses activities.

Influent and effluent sampling and groundwater monitoring will be conducted by a BERCC engineer or technician. The engineer or technician will ensure that the system is operating within established parameters or make adjustments to attain compliance with operating parameters. A summary of operational sampling and analyses that will be collected is presented in Table 8-1. Analytical methods are specified in Table 1-3. Operational Monitoring Points are shown on Figure 8-1.

8.1 COMPLIANCE MONITORING

During operation of the three-well treatability test, the liquid stream from the effluent treatment system will be treated with carbon adsorption canisters. Sampling of the effluent from the carbon adsorption canisters (Monitoring Point 31, Figure 8-1) will provide a demonstration that the East Bay Municipal Utility District (EBMUD) discharge requirements are being met. Discharge limitations will be set when the discharge permit is granted. For the first week of operation, effluent samples will be collected daily from this monitoring point. To demonstrate compliance with the discharge requirements, the effluent samples will be analyzed on a 24 hour turn around basis at a Navy certified laboratory for the parameters indicated in Table 8-1 using the methods identified in Table 1-3. Depending on the results of the sampling, the sampling frequency and number of analyses may be reduced after one week following consultation with the Resident Officer in Charge of Construction (ROICC) and EBMUD.

During operation of the three-well treatability test, the gaseous stream from the vapor effluent treatment system will be treated using a thermal oxidation unit and vapors from the oil/water separators and oil storage tank will be treated with carbon canisters. Sampling of the effluent from these units (Monitoring Points 32 and 34) will demonstrate compliance with Bay Area Air Quality Management District (BAAQMD) limitations which are one

pound per day of hydrocarbons and 0.05 pounds per day of benzene. The sampling frequencies and analyses are summarized in Table 8-1. Depending on the results of the sampling, the sampling frequency may be reduced after one week after consultation with the ROICC and the BAAQMD.

8.2 PERFORMANCE MONITORING

Performance monitoring will be conducted to measure the total mass of hydrocarbons removed during the three-well treatability test and to evaluate the relative hydrocarbon removal rates of the injection/extraction wells, passive surface containment system, and the actively cooled surface containment system. Samples for the measurement of the total mass of hydrocarbon removal will be laboratory analyzed to provide a high degree of accuracy. Vapor samples to assess the relative removal rates of each component will be field analyzed and liquid samples for this assessment will be laboratory analyzed.

Samples for the calculation of the total hydrocarbon mass removal will be collected from Monitoring Points 30 and 34; analyses to be performed on these samples are summarized in Table 8-1. The liquid samples collected from Monitoring Point 30 will be laboratory analyzed for TPHg, TPHd, TPHmo, and BTEX. The vapor samples from Monitoring Point 34 will be laboratory analyzed for TPHg, TPHd, and BTEX. The lower molecular weight hydrocarbons representative of motor oil would not be expected to be present in the vapor phase.

Samples for monitoring the relative performance of the injection/extraction wells, passive containment system, and actively cooled containment system will be collected from Monitoring Points 7, 8, 9, 10, 11, 12, 14, 15a, and 15b. Monitoring points for the injection/extraction wells will only be sampled when the injection/extraction well is in operation. The analytical plan for these samples is summarized in Table 8-1. Vapor samples will be collected and field analyzed for hydrocarbons with a PID. Water samples will be collected and laboratory analyzed for TPHg, TPHd, TPHmo, and BTEX. Laboratory analytical methods are specified in Table 1-3.

Hydrocarbon concentrations in the effluent streams are expected to be highest at the onset of the three-well treatability test and to decrease rapidly until they level off at a relatively constant recovery rate. To obtain data for an accurate calculation of the hydrocarbon mass removed, samples will be collected from all performance monitoring points at 4 hour intervals during the beginning of operation. For those samples that will be laboratory analyzed, samples collected at eight hour intervals will initially be analyzed on a rush turn around basis and the intermediate samples collected will be stored at the laboratory for potential analysis. The intermediate samples will only be analyzed if there is greater than a five fold difference in the hydrocarbon concentrations identified in the 8 hour samples. As the effluent concentrations level off, the sampling frequency will be adjusted to an interval sufficient to detect a five fold change in hydrocarbon concentrations.

The volume of free-phase hydrocarbons obtained will be measured weekly and the tank will be emptied when full. A sample of free phase hydrocarbons will be collected each time the tank is emptied or at the completion of the test if the tank is not filled during the three-well treatability test. The analytical plan for these samples is summarized in Table 8-1. Laboratory analytical methods are specified in Table 1-3.

8.3 LIQUID AND VAPOR SAMPLE COLLECTION METHODS

Liquid operational samples will be obtained by collecting the water directly from the sampling port into the appropriate sample container. Vapor samples for field analyses and laboratory analysis of TPHg and BTEX will be collected from the appropriate sampling ports by using a vacuum pump and Teflon tubing to fill a one-liter tedlar bag for submittal to the laboratory. Gas samples for laboratory analysis of TPHd will be collected by collecting the sample on to a 100 milligram coconut shell or 50 milligram charcoal sorbent tube at a flow rate of 0.1 to 0.2 liter per minute with personal sampling pump.

8.4 GROUNDWATER MONITORING

Groundwater quality and groundwater elevations will be monitored in the four groundwater monitoring wells installed as described in Section 2 to monitor for changes in the contaminant concentrations in the groundwater during the three-well treatability test. Monitoring frequencies are specified in Table 8-1.

During the three-well treatability test, groundwater samples will be collected from each well at the onset of operation, at day 15, and at the completion of the test. Groundwater sampling methods are described in Section 3. During each sampling event, a groundwater sample from each well will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, and BTEX as summarized in Table 8-1. Analytical methods specified in Table 1-3.

During the three-well treatability test, daily water level measurements will also be obtained from each well. The methods for obtaining these measurements are described in Section 3.

9. POST-DEMONSTRATION SAMPLING

Soil samples will also be collected and laboratory analyzed at the completion of the three-well treatability test to identify the concentrations of hydrocarbons and metals as well as the leachability of the hydrocarbons left in the soil. This sampling will only be conducted if 1) the three-well treatability test is successful at removing high concentrations of hydrocarbons either through removal of separate phase hydrocarbons or steam distillation; and 2) at least a two order of magnitude difference is observed in the hydrocarbon concentrations of the system effluent streams from the beginning to the end of the three-well treatability test. The results of laboratory results for these samples will be compared to laboratory results for soil samples analyzed during cone penetrometer testing and installation of the injection/extraction wells to evaluate the effectiveness of SEE in reducing hydrocarbon concentrations and the leachability of hydrocarbons in the subsurface.

A total of five soil borings will be drilled for collection of soil samples. The locations of the borings will be determined after information on the shape of the steam zone can be inferred from the temperature profiles and the resistivity tomographs. The borings will be located in the areas where the highest petroleum hydrocarbon levels were previously identified. Two to three of the borings will also be located in areas that appear to have been subjected to the most extensive steaming and two to three of the borings will be installed in locations that may not have been extensively steamed based on the results of the temperature monitoring and electrical resistivity tomography. If there is no visual indication of hydrocarbons in the locations initially sampled, additional borings may be installed.

9.1 INSTALLATION OF SOIL BORINGS

A portable, hydraulically driven soil coring system will be used to collect continuous soil samples to a total depth of 25 feet below ground surface for soil sample collection. This method utilizes two nested sampling rods that are driven simultaneously. The small-diameter inner rod is used to obtain and retrieve sample cores. The larger rod serves as a temporary drive casing to prevent caving into the boring. Upon completion of soil sample collection, each boring will be backfilled with a cement grout containing no more than five percent bentonite. No soil cuttings, other than the soil samples, will be produced using this drilling method.

9.2 SOIL SAMPLING

Soil samples will be collected continuously from ground surface to total depth in 1-1/2 inch diameter by six-inch long stainless steel or brass tubes using a sample barrel attached to the inner rod which is advanced during drilling; the sample tubes will be precleaned at the laboratory. All recovered soils will be logged in the field under the supervision of a registered geologist, using the USCS.

Upon retrieval, each sample will be prepared for potential analysis. Each end of the sample liner will be covered with Teflon sheeting and the liner will then be capped with a polyethylene lid, labeled, immediately placed in a cooler and handled as described in Section 14 .

9.3 LABORATORY ANALYSES

Laboratory analyses that will be conducted on soil samples from the post demonstration borings are summarized in Table 9-1. Analytical methods are specified in Table 1-3. At each boring location, a soil sample from the vadose zone, top of the contaminated zone, middle of the contaminated zone, bottom of the contaminated zone, and five feet below the bottom of the contaminated zone will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, PAHs, BTEX, and pH. With the exception of the vadose zone sample, each of these samples will also be analyzed for metals. The leachability of hydrocarbons in the contaminated zone will be assessed by conducting TCLP analyses for BTEX on soil samples from within this zone. At each groundwater monitoring well location, three soil samples from within the contaminated zone within each boring will be analyzed at a Navy certified laboratory for TPHg, TPHd, TPHmo, and BTEX. The results of these analyses will be used to assess the concentration and leachability of hydrocarbons left in place and to assess whether the injection of steam has resulted in the spread of contamination to the vadose zone or to beneath the initial hydrocarbon bearing zone.

10. DECONTAMINATION PROCEDURES

All sampling and downhole drilling equipment will be decontaminated prior to and between uses to minimize the potential for the introduction of off-site contaminants as well as cross contamination of samples. All sampling equipment will be decontaminated by washing with a solution of tap water and non-phosphate detergent such as Lacunas or equivalent. Next, the equipment will be rinsed in succession with tap water, isopropanol, and deionized water. All downhole drilling equipment will be steam-cleaned. Decontamination of drilling and downhole equipment is described in SOP 6.2. Wastewater generated during

decontamination will be contained in DOT-approved 55-gallon drums and appropriately labeled for appropriate disposal.

11. QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Flow rate, temperature, mass of waste removed, and pressure readings will be taken in a manner that is representative of UCB scientific standards. Our goals will be to 1) detect a 50 % reduction in hydrocarbon constituent concentrations, either total or leachable, from soil, 2) maintain a +/- 50% precision on all initial and final measurements of hydrocarbon mass in soil, 3) maintain a +/- 20% precision on measurements of extracted hydrocarbon mass, and 4) maintain a +/- 10% accuracy on all energy calculations. We will maintain +/- 50% numerical accuracy with calculations involving mass and energy balances. The accuracy of initial and final mass measurements is limited by the uneven distribution of oily material in a heterogeneous subsurface. The accuracy of measurements of concentrations of polycyclic aromatic hydrocarbons (PAHs) in soil is also limited by analytical interferences and extractions inherent in detecting PAHs in an oil. Maintenance of these quality goals will require calibration diligence, backup of critical data acquisition systems, and extensive subsurface temperature measurements.

Quality assurance/quality control (QA/QC) procedures that will be followed for this project are addressed in the Contractor Quality Control Plan included in Appendix C to the Work Plan. This section identifies the field QA/QC samples that will be analyzed.

Field QA/QC samples to be collected and analyzed are addressed in SOP 18.1. The following QA/QC samples will be collected during soil and groundwater sampling. The planned number of QA/QC samples for each sampling event and the planned analyses for each sample are summarized in Tables 1-2, 2-1, 2-2, 8-1, and 9-1.

- Trip blanks will be analyzed for BTEX. One trip blank will be prepared for each cooler containing soil or groundwater samples to be analyzed for BTEX. During each phase of field activity, it is expected that there will be one shipment of samples to the laboratory. Based on this, one trip blank will be analyzed for each phase of activity;
- Equipment rinseate samples will be analyzed for the same parameters as the soil or groundwater samples being analyzed. A minimum of one equipment rinseate sample per week will be prepared. Rinseate samples collected during soil sampling will be prepared by collecting the final rinseate from the soil sampling equipment. Rinseate samples collected during groundwater sample collection will be prepared by pumping ASTM Type II deionized water through the decontaminated sampling pump and then collecting the sample into the appropriate sample containers directly from the pump discharge line. Each phase of field activity is expected to last one week or less. Based on this, one rinseate blank will be collected and analyzed for each phase of activity;
- Field blanks will be analyzed for the same parameters as the samples being analyzed. A minimum of one field blank per week will be prepared from each

source of decontamination water used during each sampling event by pouring the water directly into the appropriate sampling containers. Each sampling event is expected to last one week or less and two sources of decontamination water are expected to be used. Based on this, two field blanks will be collected and analyzed for each phase of field activity;

- Field duplicates of groundwater samples will be analyzed for the same parameters as the groundwater samples. Field duplicates are collected at an approximate rate of ten percent of the groundwater samples. During each sampling event, one duplicate groundwater sample will be collected and analyzed. No duplicate soil samples will be collected.

12. WASTE DISPOSAL

Waste materials to be disposed of during the three-well treatability test include drill cuttings, decontamination fluids, purged well water, groundwater produced during hydraulic testing, recovered free phase hydrocarbons, spent carbon canisters from the effluent treatment system, and personal protective equipment. These containerized wastes will be stored at a centralized staging area established during mobilization of the field office trailer and all waste containers will be labeled as specified in Table 12-1. Disposal of these items is discussed in this section. Disposal will be arranged by UCB.

12.1 SOIL

Drill cuttings generated during well installation will be containerized and left on-site at the end of each day in DOT-approved 55-gallon drums or roll-off bins. Selection of the appropriate disposal method for the cuttings will be based on the analytical results for soil samples from the borings.

12.2 WASTEWATER

Wastewater will be generated during the decontamination of the drilling and sampling equipment; well development and groundwater sampling activities; and hydraulic testing. The wastewater will be collected and stored in DOT-approved 55-gallon drums or larger Baker tanks, and treated with the water treatment system installed for the pilot-scale treatability study. After treatment by oil/water separation and activated carbon, the wastewater will be discharged to the base water treatment plant.

12.3 FREE PHASE HYDROCARBONS

Free phase hydrocarbons will be accumulated in the oil storage tank installed as part of the effluent treatment system. The hydrocarbons contained in the tank will be pumped directly into a vacuum truck by a licensed commercial service and transported to a licensed off-site facility for recycling.

12.4 SPENT CARBON CANISTERS

Spent carbon canisters will be picked up by a licensed waste hauler and transported to a licensed facility for regeneration.

12.5 PERSONAL PROTECTIVE EQUIPMENT

Disposable personal protective equipment will be placed in 55 gallon drums when they become excessively soiled or at the end of each work day at a minimum.

13. FIELD NUMBERING

All borings and wells installed during the pilot-scale treatability study will be identified by a unique number consisting of three letters followed by a sequential number (i.e. CPT-1, CPT-2, CPT-3. . .). The letters to be used are as follows:

- CPT sounding - CPT
- Injection/extraction wells - IEW
- Groundwater monitoring wells - GMW
- Temperature monitoring wells - TMW
- Electrode wells - ELW
- Post demonstration borings - PDB

Profiles of laser induced fluorescence (Section 1) will be identified with the CPT location number.

Samples collected during the pilot-scale treatability study will be numbered with a unique alphanumeric identification as specified in SOP 17.2. Soil samples from borings will be identified with a number of the boring followed by a comma and the depth of the top of the sampling interval (i.e. IEW-1, 6.5). Groundwater samples from the injection-extraction wells will be identified with the number of the injection/extraction well (i.e. IEW-1). Operational samples will be identified by a unique sample number consisting of the monitoring point number followed by the date and time of collection (i.e. 30-4/12/96-0830).

Temperature profiles and resistivity measurements obtained during operation of the pilot-scale treatability study will be identified with the number of the temperature monitoring well followed by the date and time of the profile or measurement (i.e. TMW-1, 12-3-95, 0900). Field quality assurance samples will be submitted blindly to the laboratory by assigning a unique sample number using the prefix "FDB" followed by a sequential number as described above.

14. SAMPLE HANDLING

After collection, each sample will be labeled using indelible ink with the following information as specified in SOP 17.1:

- Project name
- Project number
- Date and time of collection
- Sample location
- Sample identification number
- Collector's name
- Preservatives used, if any

The samples will be handled and packaged in the field following the requirements of SOP 2.1. Sample containers, preservation methods, and maximum holding times are summarized in Table 14-1. The sample container will be tightly sealed as soon as possible following collection of the sample and a piece of custody tape will be placed over or around the cap.

Each sample will then be placed in a seam-sealing polyethylene bag and excess air will be removed. Samples will be placed in a cooler with crushed or cubed ice contained in a double-bagged self-sealing polyethylene bag. A VOA filled with tap water will be included in the cooler and labeled "temperature check" so that the laboratory can verify the temperature of the samples upon receipt. The samples will be picked up daily by the laboratory or delivered daily to the laboratory by field personnel using proper chain-of-custody procedures described in SOP 1.1. Documentation of final disposition of all samples collected will be provided to EFA West.

15. REFERENCES

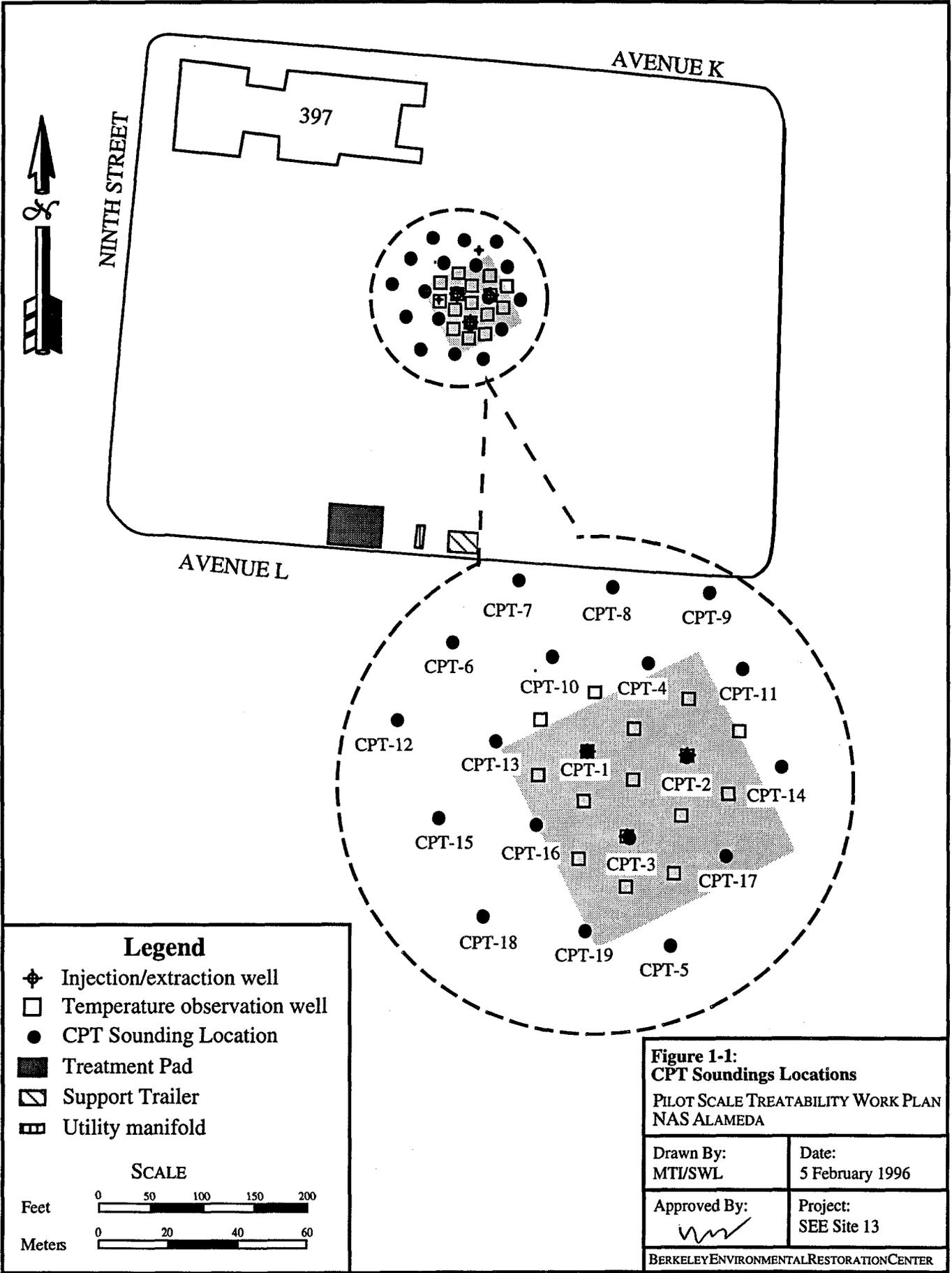
Cooper, H. H. and C.E. Jacob, 1946. "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History," Am. Geophys. Union Trans., Vol 27, pp. 526-534.

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Neuman, S. P., 1975. "Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Yield," Water Resources Research, Vol. 11, No. 2, pp. 329-342.

Theis, C. V., 1935. "The Relationship Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage," Am. Geophys. Union Trans., Vol. 16, pp. 519-524.

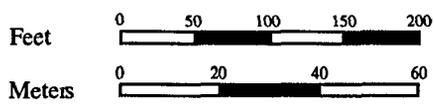
FIGURES



Legend

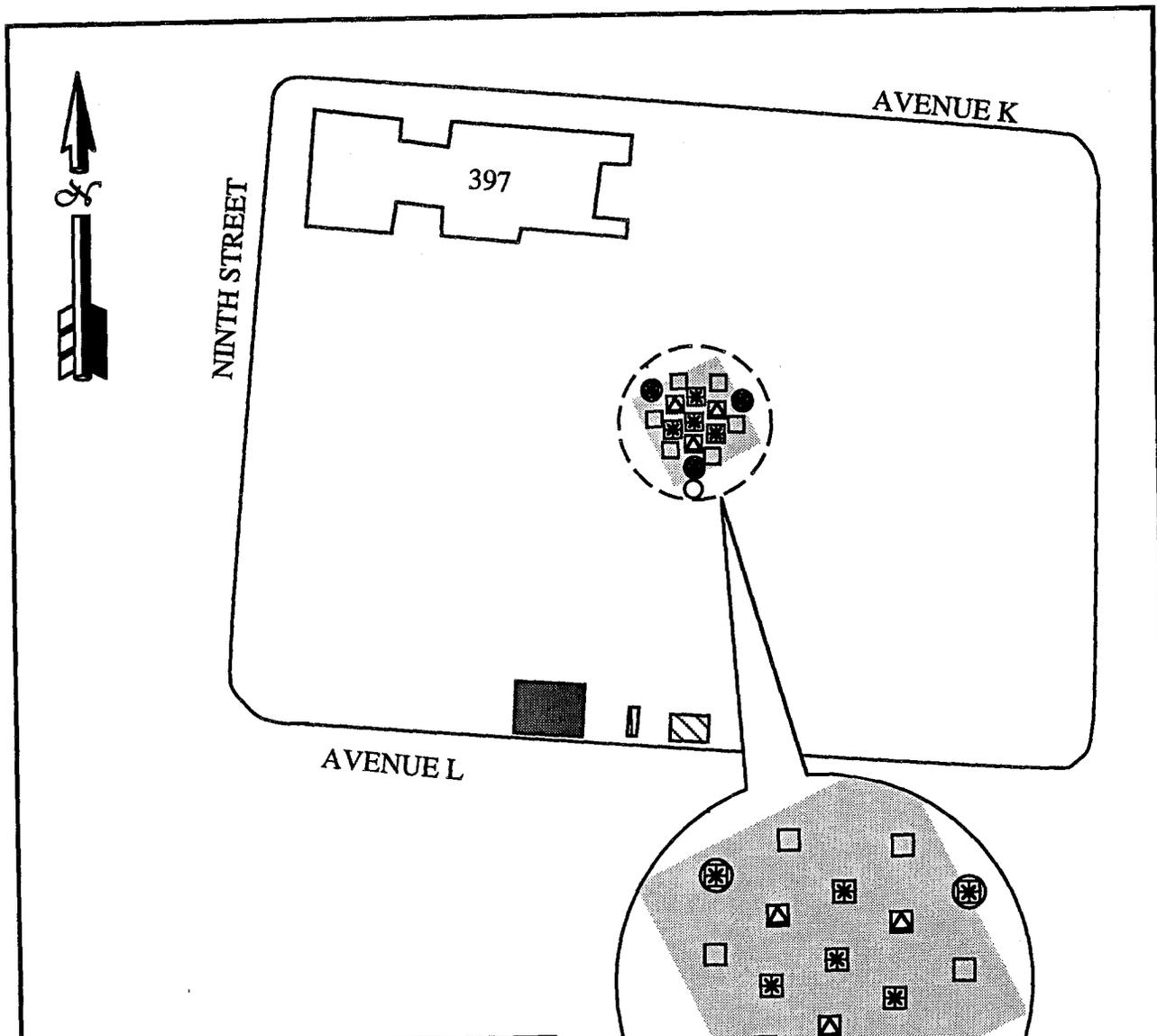
- ⊕ Injection/extraction well
- Temperature observation well
- CPT Sounding Location
- Treatment Pad
- ▨ Support Trailer
- ▤ Utility manifold

SCALE



**Figure 1-1:
 CPT Soundings Locations**
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: MTI/SWL	Date: 5 February 1996
Approved By: 	Project: SEE Site 13
BERKELEY ENVIRONMENTAL RESTORATION CENTER	



Legend

- △ Injection/extraction well
- Temperature observation well
- Groundwater monitoring well
- * Electrode well
- Treatment Pad
- ▨ Support Trailer
- ▤ Utility manifold

SCALE

Feet 0 50 100 150 200

Meters 0 20 40 60

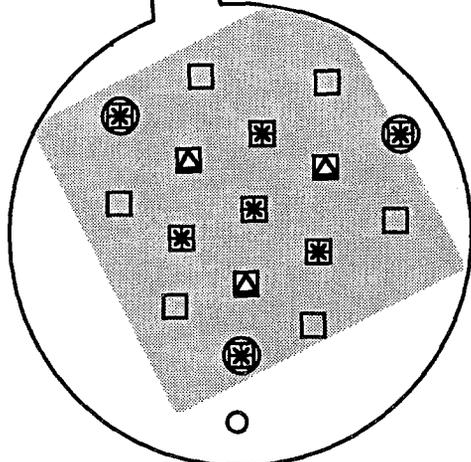
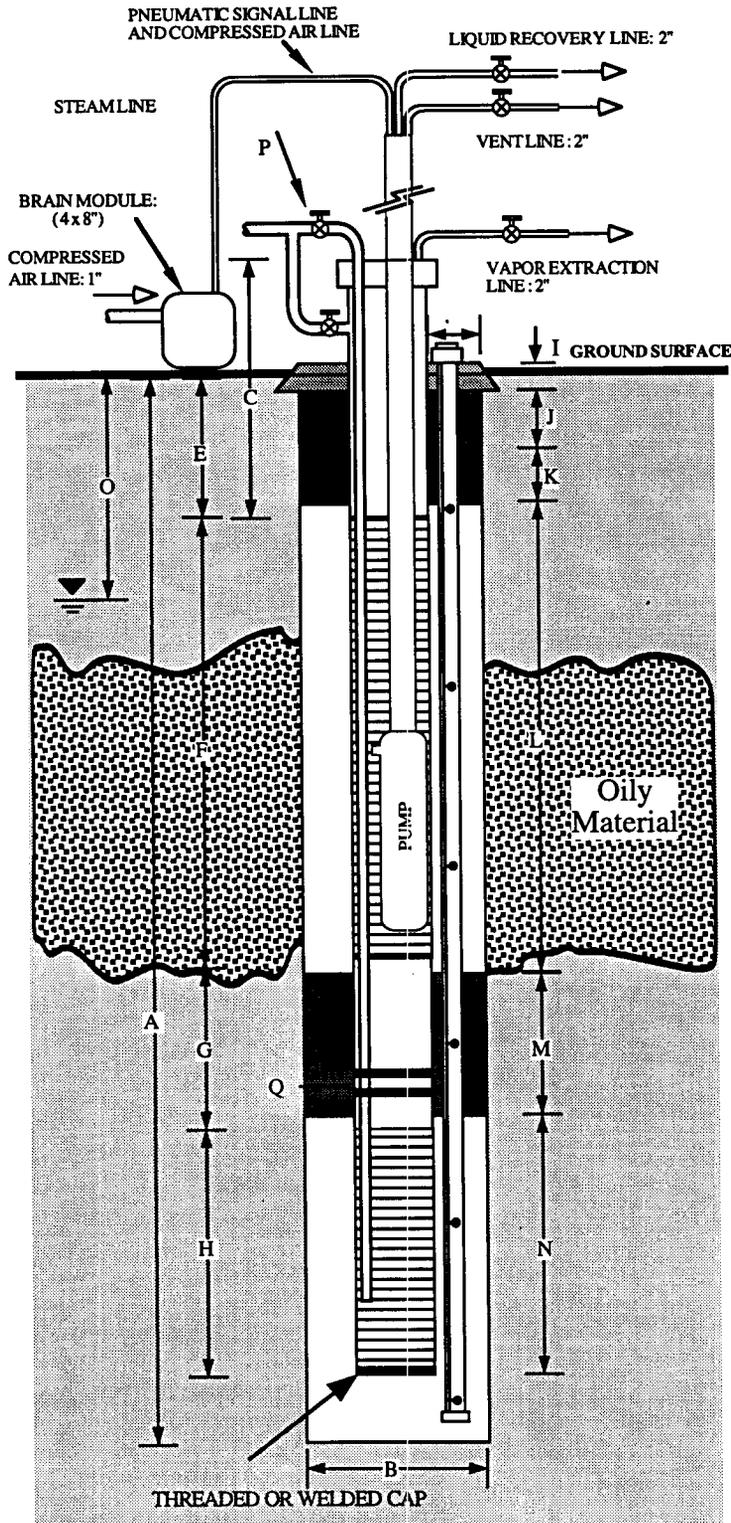


Figure 2-1:
Three Well Treatability Test Well Layout
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: MTI/SWL	Date: 15 December 1995
Approved By: 	Project: SEE Site 13

BERKELEY ENVIRONMENTAL RESTORATION CENTER

INJECTION / EXTRACTION WELL



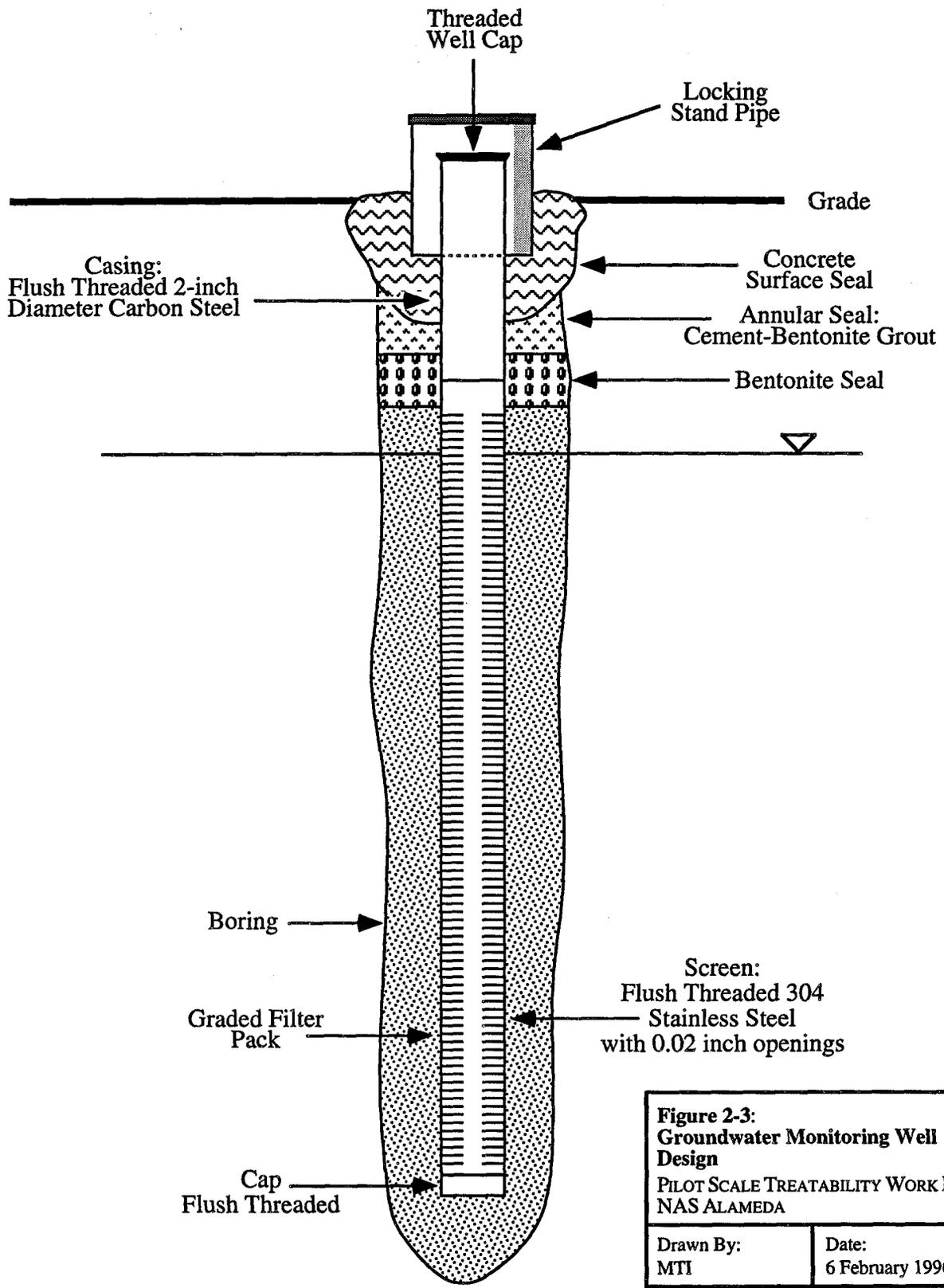
EXPLORATORY BORING

- A. Total depth --- 30 ft
- B. Diameter --- 12 in
Drilling method --- Reverse Circulation

WELL CONSTRUCTION

- C. Casing length --- 8 ft
- D. Diameter --- 8 in
- E. Depth to top of screen --- 5 ft
- F. Screen length --- 15 ft
Screen type --- continuous-slot screen
V-type slot opening
Slot size --- 0.02 in
Screen material -- 304 Stainless Steel
- G. Casing length -- 5 ft
Material --- 304 Stainless Steel
- H. Screen Length --- 5 ft
Screen type --- continuous-slot screen
V-type slot opening
Screen size -- 0.02 in
Screen material -- 304 Stainless Steel
- I. Surface seal --- 0.5 ft
Material --- Concrete
- J. Backfill --- 2 ft
Material --- Cement slurry with
5% Bentonite
- K. Seal --- 2 ft
Material --- 3/8" Bentonite pellets (hydrated)
0.5 ft above top of screen
- L. Gravel pack --- 16 ft
Material --- Silica Sand, RMC Lonestar
- M. Second Seal --- 4 ft
Material --- 3/8" Bentonite pellets (hydrated)
0.5 ft above of top screen and
0.5 ft below of bottom screen
- N. Gravel Pack --- 5.5 ft
Material --- Silica Sand, RMC Lonestar
- O. Depth to Groundwater --- 4 ft
- P. Steam Line --- 1-1/4" DIA, Carbon Steel material
24 ft from ground level
- Q. Steel Plate thickness --- 1/4 in
depth from ground surface --- 24 ft
Steel Plate is 4 inches apart
- R. Metal Flange --- 4 in

Figure 2-2: Injection/Extraction Well Design	
PILOT SCALE TREATABILITY WORK PLAN NAS ALAMEDA	
Drawn By: SC/DAS	Date: 21 February 1996
Approved By: 	Project: SEE Site 13
BERKELEY ENVIRONMENTAL RESTORATION CENTER	

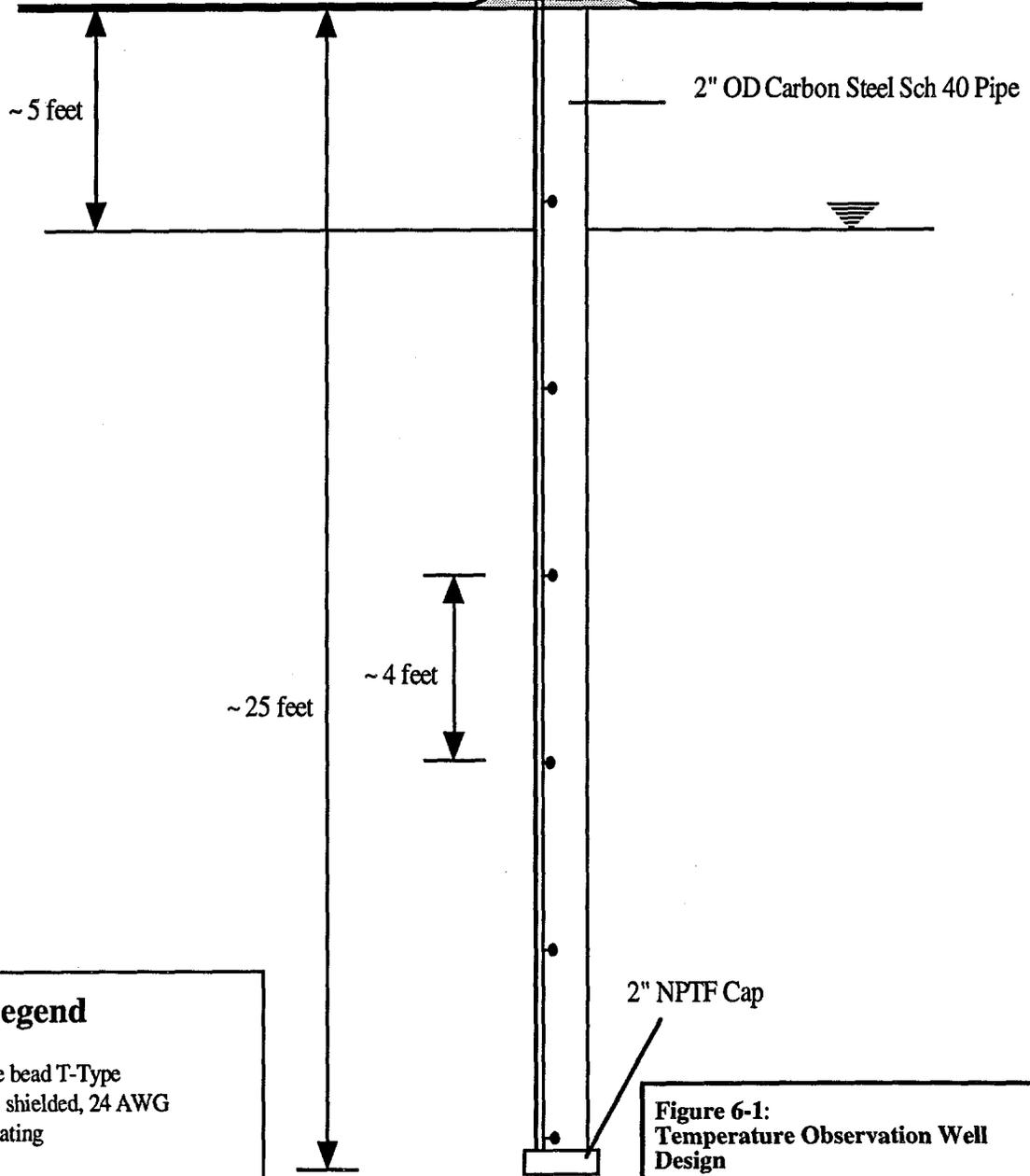


**Figure 2-3:
Groundwater Monitoring Well
Design**
PILOT SCALE TREATABILITY WORK PLAN
NAS ALAMEDA

Drawn By: MTI	Date: 6 February 1996
Approved By: <i>[Signature]</i>	Project: SEE Site 13
BERKELEY ENVIRONMENTAL RESTORATION CENTER	

T-type Thermocouple Terminal Box,
Weatherproof, 6 pairs of Connectors

Grade Level



Legend

- Thermocouple bead T-Type stainless steel shielded, 24 AWG with teflon coating
- || Bundle of Thermocouple wires

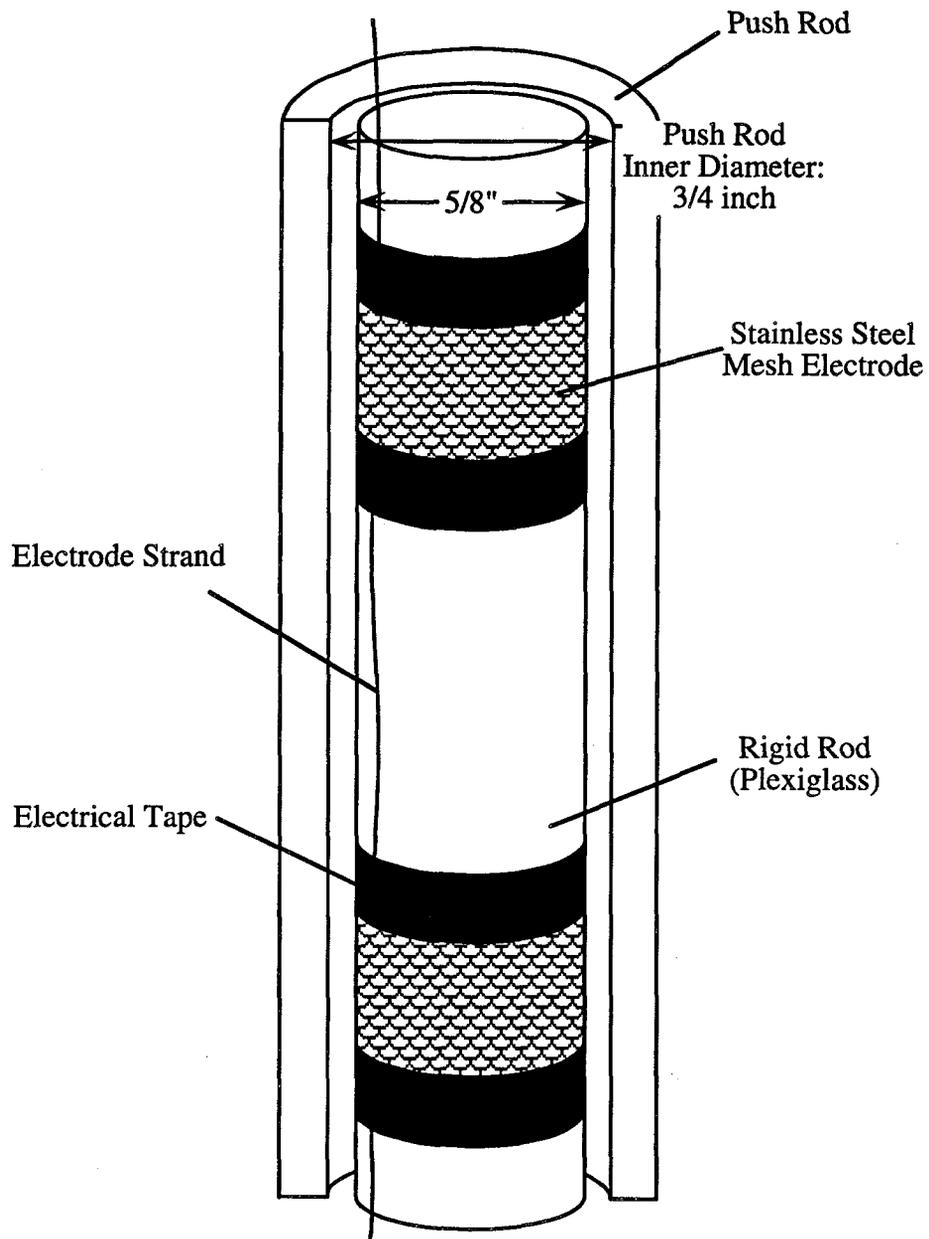
Note: The thermocouple beads and wires are attached outside the steel tubing. One bead every 5 feet.

**Figure 6-1:
Temperature Observation Well
Design**
PILOT SCALE TREATABILITY WORK PLAN
NAS ALAMEDA

Drawn By: SR	Date: 17 June 1995
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Approved By: <i>[Signature]</i>	Project: SEE Site 13
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**Figure 7-1:
Electrode Well Design**
PILOT SCALE TREATABILITY WORK PLAN
NAS ALAMEDA

Drawn By: SC	Date: 22 June 1995
Approved By: <i>[Signature]</i>	Project: SEE Site 13

BERKELEY ENVIRONMENTAL RESTORATION CENTER

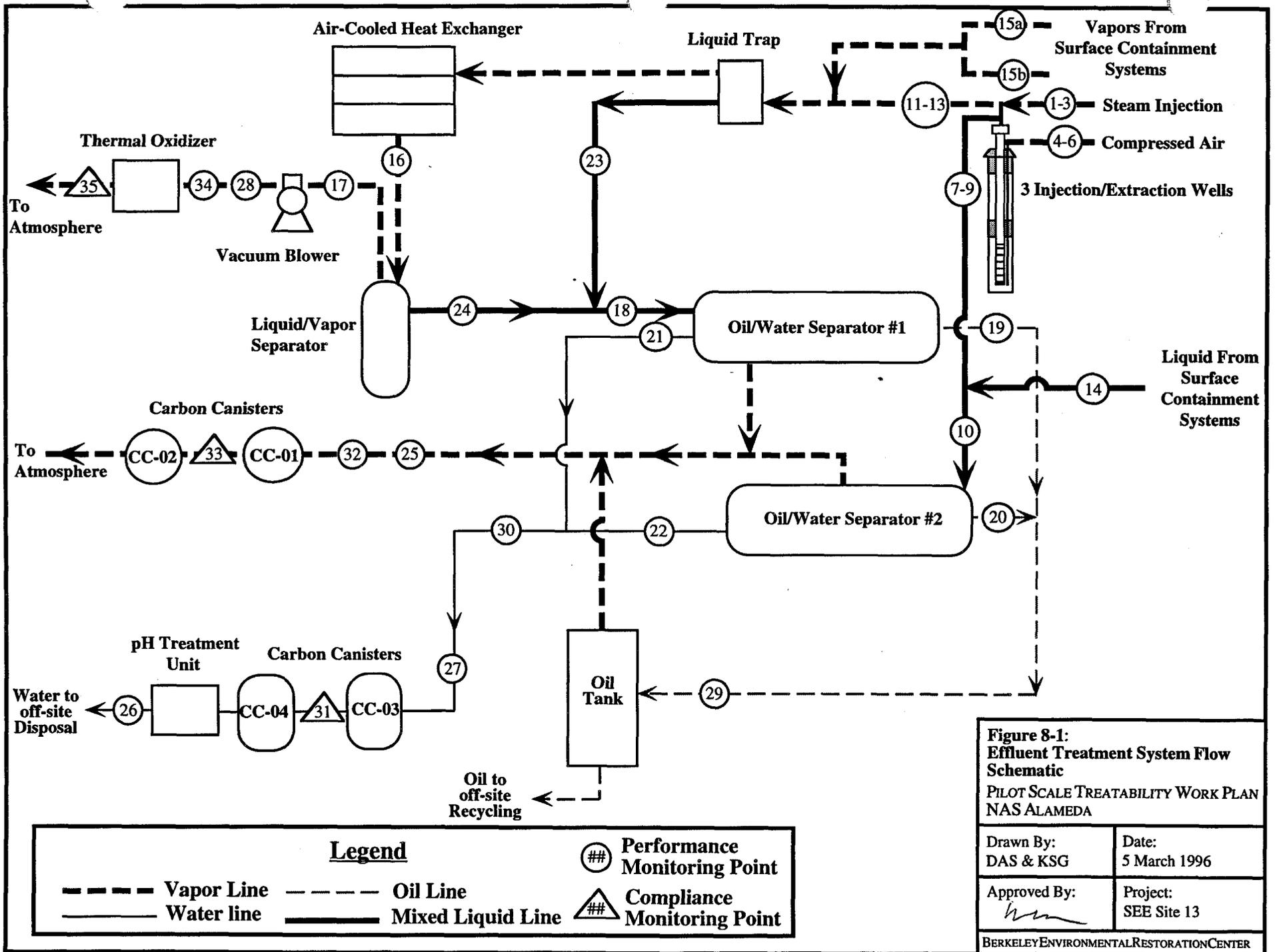


Figure 8-1:
Effluent Treatment System Flow Schematic
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: DAS & KSG	Date: 5 March 1996
Approved By: <i>[Signature]</i>	Project: SEE Site 13

BERKELEY ENVIRONMENTAL RESTORATION CENTER

Legend		##	Performance Monitoring Point
--- Vapor Line	--- Oil Line	▲	Compliance Monitoring Point
— Water line	— Mixed Liquid Line		

TABLES

Table 1-1
Summary of Required Soil Analyses, Cone Penetrometer Testing

Sampling Location	Drilling Method	Total Depth, feet	Sample Depth	Hydrogeology Suite ¹	Laser Induced Fluorescence
Day 1					
CPT-1	CPT	30	Continuous	x	x
CPT-2	CPT	30	Continuous	x	x
CPT-3	CPT	30	Continuous	x	x
CPT-4	CPT	30	Continuous	x	x
CPT-5	CPT	30	Continuous	x	x
Day 2					
CPT-6	CPT	30	Continuous	x	x
CPT-7	CPT	30	Continuous	x	x
CPT-8	CPT	30	Continuous	x	x
CPT-9	CPT	30	Continuous	x	x
CPT-10	CPT	30	Continuous	x	x
Day 3					
CPT-11	CPT	30	Continuous	x	x
CPT-12	CPT	30	Continuous	x	x
CPT-13	CPT	30	Continuous	x	x
CPT-14	CPT	30	Continuous	x	x
CPT-15	CPT	30	Continuous	x	x
Day 4					
CPT-16	CPT	30	Continuous	x	x
CPT-17	CPT	30	Continuous	x	x
CPT-18	CPT	30	Continuous	x	x
CPT-19 ²	CPT	30	Continuous	x	x
CPT-20 ²	CPT	30	Continuous	x	x

Notes:

- 1 Plots of depth, cone tip resistance, sleeve friction resistance, friction ratio, and differential pore pressure ratio will be obtained throughout each sounding to evaluate the subsurface conditions at each sounding location.
- 2 Contingency sounding, location to be selected after the completion of laser induced fluorescence and selection of the treatment area.

Table 1-2
Summary of Required Soil Analyses, Confirmation Soil Sampling

Sampling Location	Drilling Method	Total Depth, feet	Sample Depth ¹	Grain Size	Off-Site Laboratory Analyses							
					TPHg	TPHd	TPHmo	PAH	BTEX	Metals	pH	BTEX, TCLP
Day 1												
CPT-1B	Portable System	30	T	x	x	x	x					x
CPT-1B	Portable System	30	M	x								
CPT-1B	Portable System	30	B	x								
CPT-1B	Portable System	30	D	x								
CPT-2B	Portable System	30	T	x								
CPT-2B	Portable System	30	M	x	x	x	x					x
CPT-2B	Portable System	30	B	x								
CPT-2B	Portable System	30	D	x								
CPT-3B	Portable System	30	T	x								
CPT-3B	Portable System	30	M	x								
CPT-3B	Portable System	30	B	x	x	x	x					x
CPT-3B	Portable System	30	D	x								
Equipment Rinseate Blank					x	x	x	x	x	x	x	x
Field Blank, Tap Water					x	x	x	x	x	x	x	x
Field Blank, Deionized Water					x	x	x	x	x	x	x	x
Day 2												
CPT-4B	Portable System	30	T		x	x	x					x
CPT-5B	Portable System	30	M		x	x	x					x
CPT-6B	Portable System	30	B		x	x	x					x
CPT-19B ²	Portable System	30	V		x	x	x	x	x	x	x	
CPT-19B ²	Portable System	30	T		x	x	x	x	x	x	x	x
CPT-19B ²	Portable System	30	M		x	x	x	x	x	x	x	x
CPT-19B ²	Portable System	30	B		x	x	x	x	x	x	x	x
CPT-19B ²	Portable System	30	D		x	x	x	x	x	x	x	
CPT-20B ²	Portable System	30	V		x	x	x	x	x	x	x	
CPT-20B ²	Portable System	30	T		x	x	x	x	x	x	x	x
CPT-20B ²	Portable System	30	M		x	x	x	x	x	x	x	x
CPT-20B ²	Portable System	30	B		x	x	x	x	x	x	x	x
CPT-20B ²	Portable System	30	D		x	x	x	x	x	x	x	
Trip Blank									x			

Notes:

1 V = vadose zone

T = top of contaminated zone

M = middle of contaminated zone

B = bottom of contaminated zone

D = five feet below the bottom of the contaminated zone

2 Contingency sounding, location to be selected after the completion of laser induced fluorescence and selection of the treatment area.

Table 1-3
Analytical Methods

Analysis	Test Method		
	Soil ¹	Groundwater ¹	Gas ²
Total Petroleum Hydrocarbons as gasoline	8015	8015	8015
Total Petroleum Hydrocarbons as diesel	8015	8015	NIOSH 1500
Total Petroleum Hydrocarbons as motor oil	8015	8015	na
Polynuclear Aromatic Hydrocarbons	8100	8100	na
Benzene, Toluene, Ethylbenzene, and Xylenes	8020	8020	8020
Metals	6010	6010	na
Mercury	7471	7471	na
pH	9045	9040	na
BTEX-TCLP	8020	8020	na

Notes:

1 Reference: U.S.EPA SW-846, 1994

2 Reference: NIOSH Manual of Analytical Methods, August 15, 1994.

**Table 1-4
Metals to be Analyzed**

**Antimony
Arsenic
Beryllium
Cadmium
Chromium, total
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc**

Table 2-1
Summary of Required Soil Analyses, Injection/Extraction and Groundwater Monitoring Wells

Sampling Location	Drilling Method	Total Depth, feet	Sample Depth ¹	Off-Site Laboratory Analyses						
				TPHg	TPHd	TPHmo	PAH	BTEX	Metals	BTEX, TCLP
INJECTION/EXTRACTION WELLS										
Day 1										
IEW-1	8"Auger/12" Ream	30	V	x	x	x	x	x		
IEW-1	8"Auger/12" Ream	30	T	x	x	x	x	x	x	x
IEW-1	8"Auger/12" Ream	30	M	x	x	x	x	x	x	x
IEW-1	8"Auger/12" Ream	30	B	x	x	x	x	x	x	x
IEW-1	8"Auger/12" Ream	30	D	x	x	x	x	x	x	
IEW-2	8"Auger/12" Ream	30	V	x	x	x	x	x		
IEW-2	8"Auger/12" Ream	30	T	x	x	x	x	x	x	x
IEW-2	8"Auger/12" Ream	30	M	x	x	x	x	x	x	x
IEW-2	8"Auger/12" Ream	30	B	x	x	x	x	x	x	x
IEW-2	8"Auger/12" Ream	30	D	x	x	x	x	x	x	
Equipment Rinseate Blank				x	x	x	x	x		
Field Blank, Tap Water				x	x	x	x	x		
Field Blank, Deionized Water				x	x	x	x	x		
Day 2										
IEW-3	8"Auger/12" Ream	30	V	x	x	x	x	x		
IEW-3	8"Auger/12" Ream	30	T	x	x	x	x	x	x	x
IEW-3	8"Auger/12" Ream	30	M	x	x	x	x	x	x	x
IEW-3	8"Auger/12" Ream	30	B	x	x	x	x	x	x	x
IEW-3	8"Auger/12" Ream	30	D	x	x	x	x	x	x	
Trip Blank								x		
GROUNDWATER MONITORING WELLS										
Day 1										
GMW-1	8"Auger	25	T	x	x	x	x	x		
GMW-1	8"Auger	25	M	x	x	x	x	x		
GMW-1	8"Auger	25	B	x	x	x	x	x		
GMW-2	8"Auger	25	T	x	x	x	x	x		
GMW-2	8"Auger	25	M	x	x	x	x	x		
GMW-2	8"Auger	25	B	x	x	x	x	x		
Equipment Rinseate Blank				x	x	x	x	x		
Field Blank, Tap Water				x	x	x	x	x		
Field Blank, Deionized Water				x	x	x	x	x		
Day 2										
GMW-3	8"Auger	25	T	x	x	x	x	x		
GMW-3	8"Auger	25	M	x	x	x	x	x		
GMW-3	8"Auger	25	B	x	x	x	x	x		
GMW-4	8"Auger	25	T	x	x	x	x	x		
GMW-4	8"Auger	25	M	x	x	x	x	x		
GMW-4	8"Auger	25	B	x	x	x	x	x		
Trip Blank								x		

¹ V = vadose zone
T = top of contaminated zone
M = middle of contaminated zone
B = bottom of contaminated zone
D = five feet below the bottom of the contaminated zone

Table 2-2
 Summary of Required Analyses, Groundwater Sampling

Sampling Location	Off-Site Laboratory Analyses					
	TPHg	TPHd	TPHmo	PAH	BTEX	Metals
Day 1						
IEW-1	x	x	x	x	x	x
IEW-1, duplicate	x	x	x	x	x	x
IEW-2	x	x	x	x	x	x
IEW-3	x	x	x	x	x	x
Equipment Rinseate Blank	x	x	x	x	x	x
Field Blank, Tap Water	x	x	x	x	x	x
Field Blank, Deionized Water	x	x	x	x	x	x
Day 2						
GMW-1	x	x	x	x	x	x
GMW-2	x	x	x	x	x	x
GMW-3	x	x	x	x	x	x
GMW-4	x	x	x	x	x	x
Trip Blank					x	
<hr/>						
Containerized Aquifer Testing Discharge	x	x	x	x	x	x
<hr/>						

Table 8-1
Summary of Required Analyses, Operational Monitoring

Sampling Location Description	Sampling Location Number ¹	Minimum Sampling Frequency	On-Site Analyses ²	Off-Site Laboratory Analyses				
				TPHg	TPHd	TPHmo PAH	BTEX	Metals
Vapor Samples								
Influent to Vapor Phase Carbon Canisters	32	Daily ³	x					
Effluent from Vapor Phase Carbon Canisters	33	Daily ³	x					
Influent to Thermal Oxidation Unit	34	Every 4 hours ³		x	x			
Effluent from Thermal Oxidation Unit	35	Daily ³	x					x
Effluent from IEW-1	11	Every 4 hours when operating ⁴	x					
Effluent from IEW-2	12	Every 4 hours when operating ⁴	x					
Effluent from IEW-3	13	Every 4 hours when operating ⁴	x					
Effluent from Passive Surface Containment System	15a	Every 4 hours ⁴	x					
Effluent from Actively Cooled Surface Containment System	15b	Every 4 hours ⁴	x					
Liquid Samples								
Influent to Liquid Phase Carbon Canisters	30	Every 4 hours ³		x	x	x		x
Effluent from Liquid Phase Carbon Canisters	31	Daily ³		x	x	x	x	x
Effluent from IEW-1	7	Every 4 hours when operating ⁴		x	x	x		x
Effluent from IEW-2	8	Every 4 hours when operating ⁴		x	x	x		x
Effluent from IEW-3	9	Every 4 hours when operating ⁴		x	x	x		x
Effluent from Actively Cooled Surface Containment System	14	Every 4 hours ⁴		x	x	x		x
Groundwater Monitoring Wells								
GMW-1	na	Every 15 days		x	x	x		x
GMW-1, duplicate	na	Day 15						
GMW-2	na	Every 15 days		x	x	x		x
GMW-2, duplicate	na	Day 30						
GMW-3	na	Every 15 days		x	x	x		x
GMW-4	na	Every 15 days		x	x	x		x
Equipment Rinseate Blank	na	Every 15 days		x	x	x		x
Field Blank, Tap Water	na	Every 15 days		x	x	x		x
Field Blank, Deionized Water	na	Every 15 days		x	x	x		x
Trip Blank	na	Every 15 days						x
Free Phase Hydrocarbons	na	When tank is full		x	x	x	x	x

Notes:

- Figure 8-1 shows sampling locations.
- Sampling frequency to be daily during the first week of sampling. Following one week, the frequency will be reduced after consultation with the ROICC and appropriate regulatory agency, if appropriate.
- Samples to be collected every 4 hours for the first 3 days of operation. Analyze samples from every 8 hour interval. The additional samples collected will be analyzed if there is a difference in concentration of 5 times between the originally analyzed samples. Sample collection frequency will be reduced as the rate of hydrocarbon removal is reduced.
- Sampling frequency will be reduced as the rate of hydrocarbon removal is reduced.
- A PID will be used to verify compliance with benzene emission standards. A FID, CGI, or on-site GC will be used to gauge compliance with total hydrocarbon emission standards.

Table 9-1
Summary of Required Analyses, Post Demonstration Sampling

Sampling Location	Drilling Method	Total Depth, feet	Sample Depth ¹	Off-Site Laboratory Analysis						
				TPHg	TPHd	TPHmo	PAH	BTEX	Metals	BTEX, TCLP
Day 1										
PDB-1	Portable System	25	V	x	x	x	x	x		
PDB-1	Portable System	25	T	x	x	x	x	x	x	x
PDB-1	Portable System	25	M	x	x	x	x	x	x	x
PDB-1	Portable System	25	B	x	x	x	x	x	x	x
PDB-1	Portable System	25	D	x	x	x	x	x	x	
PDB-2	Portable System	25	V	x	x	x	x	x		
PDB-2	Portable System	25	T	x	x	x	x	x	x	x
PDB-2	Portable System	25	M	x	x	x	x	x	x	x
PDB-2	Portable System	25	B	x	x	x	x	x	x	x
PDB-2	Portable System	25	D	x	x	x	x	x	x	
PDB-3	Portable System	25	V	x	x	x	x	x		
PDB-3	Portable System	25	T	x	x	x	x	x	x	x
PDB-3	Portable System	25	M	x	x	x	x	x	x	x
PDB-3	Portable System	25	B	x	x	x	x	x	x	x
PDB-3	Portable System	25	D	x	x	x	x	x	x	
PDB-4	Portable System	25	V	x	x	x	x	x		
PDB-4	Portable System	25	T	x	x	x	x	x	x	x
PDB-4	Portable System	25	M	x	x	x	x	x	x	x
PDB-4	Portable System	25	B	x	x	x	x	x	x	x
PDB-4	Portable System	25	D	x	x	x	x	x	x	
Equipment Rinseate Blank				x	x	x	x	x	x	
Field Blank, Tap Water				x	x	x	x	x	x	
Field Blank, Deionized Water				x	x	x	x	x	x	
Day 2										
PDB-5	Portable System	25	V	x	x	x	x	x		
PDB-5	Portable System	25	T	x	x	x	x	x	x	x
PDB-5	Portable System	25	M	x	x	x	x	x	x	x
PDB-5	Portable System	25	B	x	x	x	x	x	x	x
PDB-5	Portable System	25	D	x	x	x	x	x	x	
Trip Blank								x		

Notes:

- 1 V = vadose zone
- T = top of contaminated zone
- M = middle of contaminated zone
- B = bottom of contaminated zone
- D = five feet below the bottom of the contaminated zone

**Table 12-1
Labeling Requirements for Waste Containers**

Information Required	Information to be Provided
Generator	U.S. Navy
Address	NAS Alameda, Alameda, California
Phone Number	510-263-3716
Generator EPA I.D. Number	CA2170023236
Contents/Composition	Drill Cuttings Decontamination Fluids Purged Groundwater Personal Protective Equipment
California Waste I.D. Number	Liquids: 223 (Unspecified Oil-Containing Waste) Soil: 611 (Contaminated Soil from Waste Clean Ups) PPE: 352 (Other Organic Solids)
Physical State	Solid Liquid
Hazardous Properties	Toxic
DOT Proper Shipping Name	Non RCRA Liquid Waste "Pending Analysis" Non RCRA Solid Waste "Pending Analysis"

The information specified above will be recorded on labels affixed to the waste containers. In addition, the containers will be spray painted with a unique identification number so that the container may be identified in the event that the label is removed.

Table 14-1
Sample Containers, Preservation Techniques, and Holding Times

Parameter	Container for Water or Gas Samples	Preservation	Maximum Holding Time
Soil and Groundwater¹			
Total Petroleum Hydrocarbons as gasoline	2-40 mL vial	< 4°C, pH<2 HCl	14 days
Total Petroleum Hydrocarbons as diesel	1 L amber glass	< 4°C	14 days
Total Petroleum Hydrocarbons as motor oil	1 L amber glass	< 4°C	14 days
Polynuclear Aromatic Hydrocarbons	1 L amber glass	< 4°C	7/40 days ²
Benzene, Toluene, Ethylbenzene, and Xylenes	40 mL vial	< 4°C, pH<2 HCl	14 days
Metals	250 mL plastic	pH<2 HNO ₃	6 months
Gas			
Total Petroleum Hydrocarbons as gasoline	1 L tedlar bag	none required	3 days
Total Petroleum Hydrocarbons as diesel	adsorbent tube	none required	3 days
Benzene, Toluene, Ethylbenzene, and Xylenes	1 L tedlar bag	none required	3 days

Notes:

1 Soil samples will be collected in brass or stainless steel sample sleeves. The only preservation required is cooling to <4° Centigrade

2 soil/water

APPENDIX G
SIMULATION RESULTS

APPENDIX G

Simulation Results

Numerical simulations were performed to characterize the expected propagation of the steam zone and movement of the oil during the implementation of the three-well treatability test of SEE at Site 13, NAS Alameda. Since the input variables to the model such as permeabilities and steam injection rates were highly uncertain, and the simulations were run with a two-dimensional geometry (vertical and radial) as an approximation to the three dimensional field, the quantitative results of these simulations are only to be considered as preliminary estimates. Also, other variables including the initial level of the water table, the specifics of the injection and extraction wells such as open intervals, flow rates, and pressures, are somewhat different than those expected at Site 13. However, overall trends such as gravitational stability and steam zone propagation are obtained through these simulations, and they are presented here to illustrate dewatering of the aquifer and removal of a relatively high volatility hydrocarbon mixture (the more volatile ends of the very low volatility Site 13 oil). This on-going effort complements the laboratory treatability tests described in Appendices B and C and serves as both a confirmatory and predictive tool in the design of the treatability study.

For this purpose, the numerical simulator Multiphase Multicomponent Non-Isothermal Organics Transport Simulator (M2NOTS), developed at the University of California at Berkeley by Adenakan and Patzek (1993) was employed. This is a fully implicit, non-linear, three-phase, multi-dimensional simulator which is capable of handling any number of hydrocarbon components which are fully partitioned into all the phases present. It is primarily used to model the multi-phase transport of multi-component organic contaminants in the subsurface. The simulations were carried out on a DEC ALPHA workstation with a run time of 3.5 days.

The discretization of the domain of interest is shown in Figure 1. The grid shows 15 elements in the vertical direction over a distance of 25 feet and 12 elements in the radial direction over a distance of 35 feet. The permeability was 2 Darcy in the horizontal direction and 0.2 Darcy in the vertical direction. The solution was only carried out for one sixth of the cylinder extending from the location of the injection well as the subsurface around it is assumed to be radially symmetric. Hence, only one sixth of the total design flow rate is entering this sector. In Figure 1, the injection well is shown on the left side of the grid and extraction well on the right.

Steam injection was simulated to occur over a three-foot interval from 19.5 feet to 22.5 feet below the ground surface. At the extraction well, a -7.8 pounds per square inch gauge (psig) was applied over a 17-foot extraction interval from 8 to 25 feet below surface. The steam injection rate was set at 240 pounds per hour (lb/hr) (only 1/6 of this, i.e., 40 lb/hr, is injected into the simulation domain) for the period of the simulation (80 days). At the extraction end, the vacuum pressure of -7.8 psig is applied. The injected steam temperature was maintained at 100°C and the initial soil temperature was assumed to be 20°C. The water table was assumed to exist at 0 feet (the top of the grid). The oil mixture simulated was composed of equal mass fractions of n-Decane, Dodecane, Tetradecane, and Hexadecane, and the oil saturation and distribution was modeled roughly as a 5-foot strip of 25 percent from 10 to 15 feet below the surface.

Representative samples of the results are displayed in Figures 2 through 4. Figure 2 shows the development of the temperature profiles over the course of the simulation; specifically after intervals of 1 day, 5 days, 10 days, 22 days, 34 days and 50 days. It can be seen how the injection of steam proceeded to heat up the entire domain and that the temperature field stabilized after approximately 34 days. (The steam zone is defined as the region where the local temperature is above or equal to the saturated temperature corresponding to the local pressure and saturations.) At day one, steam injection has warmed the soil to a 10-foot radius from the injection well. By day 10, the soil is warmed

to near steam temperature to about 25 feet from the injection well. Steam breakthrough has happened by approximately day 22. The temperatures after 50 days to the end of the simulation run remain relatively unchanged and thus are not presented.

Figure 3 shows the profiles for the water at the same time intervals. As the subsurface heats up due to the invasion of steam, it can be seen that the water is being driven towards the extraction well by the imposed steam pressure gradient. The drop in water saturation can be observed with the progression of the steam zone and can be seen to be consistent with the movement of the steam front. By day 34, most of the zone between the wells has been dewatered except a region immediately around the injection well near the ground surface and the entire domain has also reached steam temperatures. Relatively complete dewatering is also achieved after a period of 34 days.

Figure 4 shows the profiles of oil saturations during application of SEE after intervals of 1 day, 5 days, 10 days, 22 days, 34 days, and 50 days for the simulated conditions. As shown, the oil responds very quickly to the injection of steam due to liquid oil phase mobility since the oil saturations exceed the residual saturation. The simulations show oil removal by volatilization and subsequent transport to the extraction wells with the steam since the oil saturations continue to decrease after they drop below residual values. After 10 days have elapsed, oil saturation levels everywhere but near the extraction well are seen to be down around 10 percent. By day 50, the remaining oil is found near the extraction well and above the extraction well. Continued removal of oil through steam distillation is predicted until the end of the simulation.

While quantitative conclusions cannot be drawn from these simulations, operation and design information can be inferred from the general trends. The simulations show the need to control upward movement and condensation of the oil into upper zones by preheating the top region by steam injection into that location before the steam injected from below propagates through the oil-laden zone. Also, gradual dewatering of the zone by

staged decreases in the extraction well pumping level appears to be appropriate to minimize downward movement of mobile oil near the extraction well.

Reference:

Adenakan, A.E., and Patzek, T.W., and Pruess, K. (1993), "Modeling of Multiphase Transport of Multicomponent Organic Contaminants and Heat in the Subsurface, Numerical Model Formulation," *Water Resources Research*, Vol. 29, No. 11, pp 3727 - 3739, November.

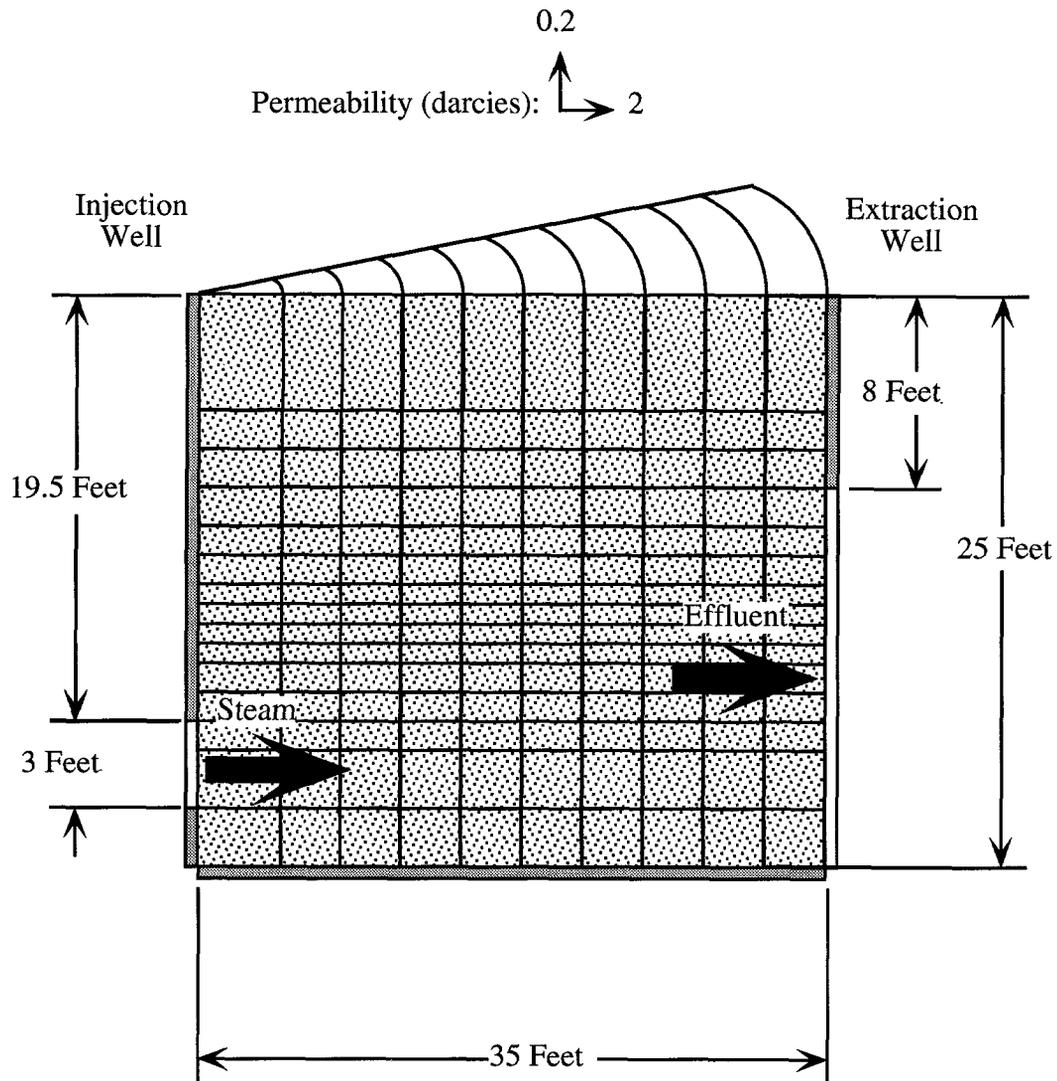


Figure 1:
Schematic for Numerical Simulation

PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: SWL	Date: 15 December 1995
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Approved By: <i>mm</i>	Project: SEE Site 13
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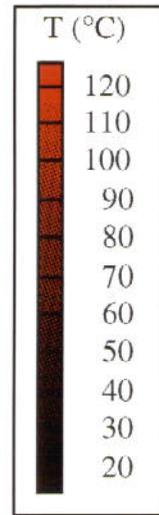
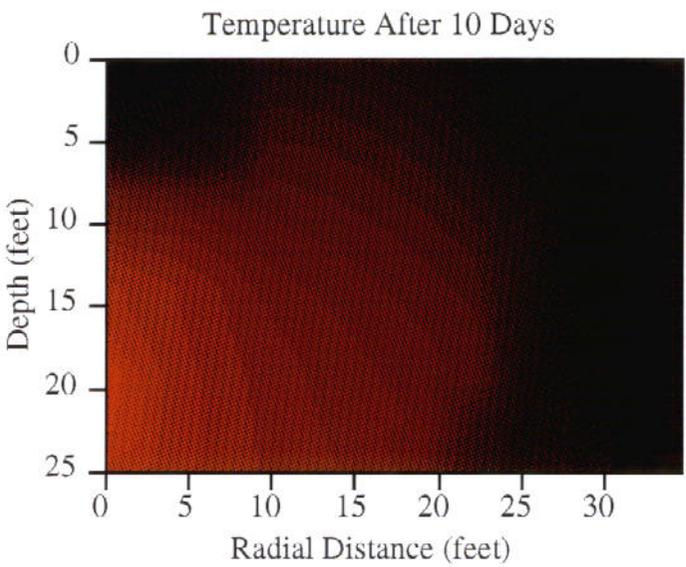
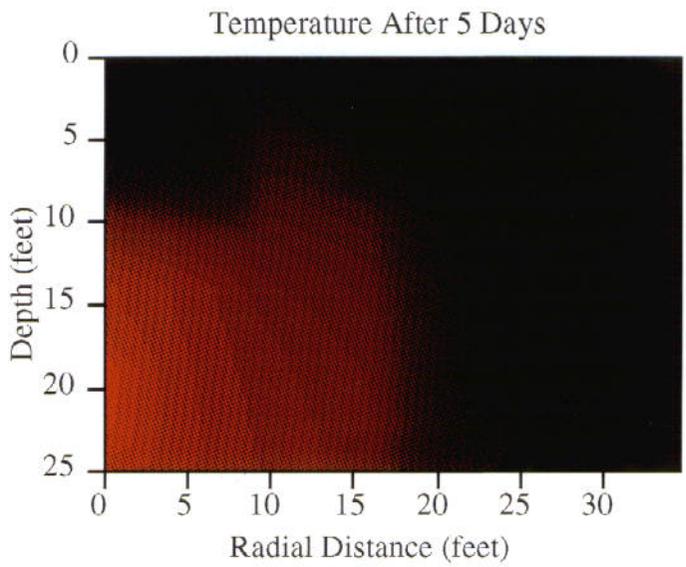
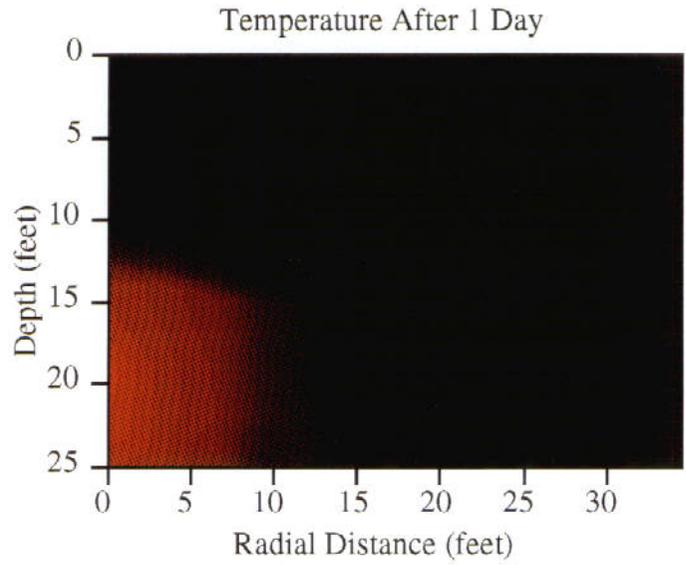


Figure 2:
Temperature Profiles -- Computer Simulation
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

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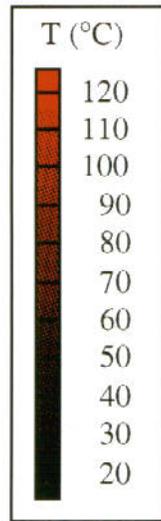
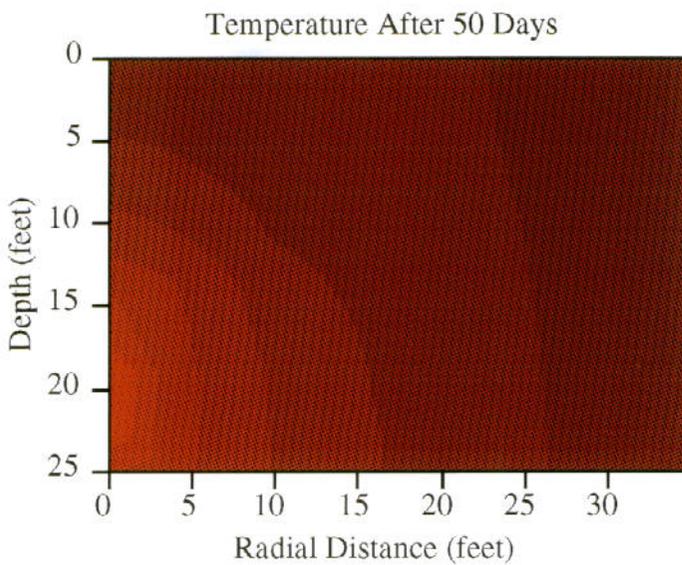
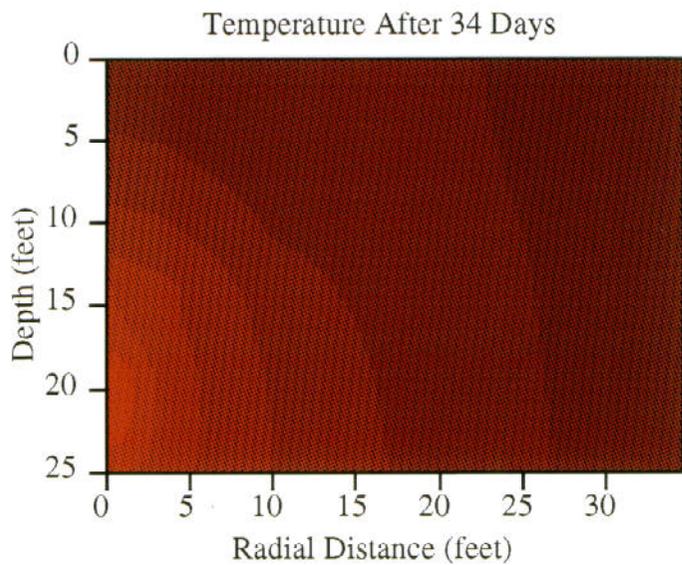
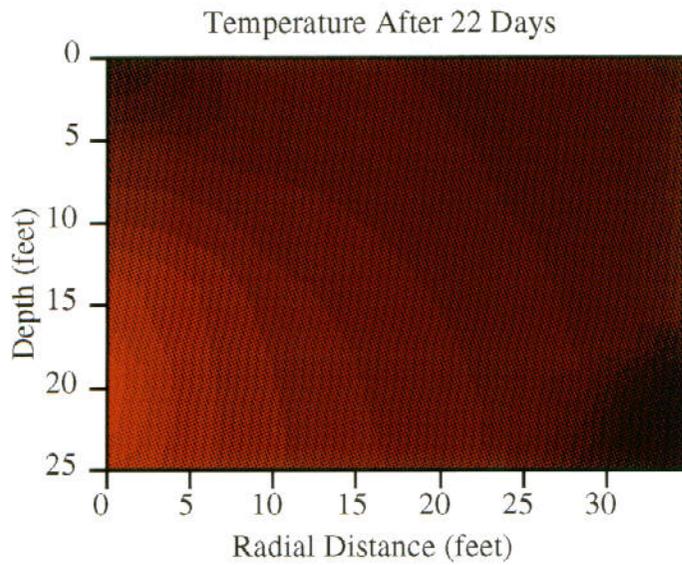


Figure 2 (con't):
Temperature Profiles -- Computer Simulation
 PILOT SCALE TREATABILITY WORK PLAN
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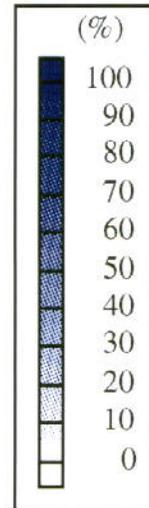
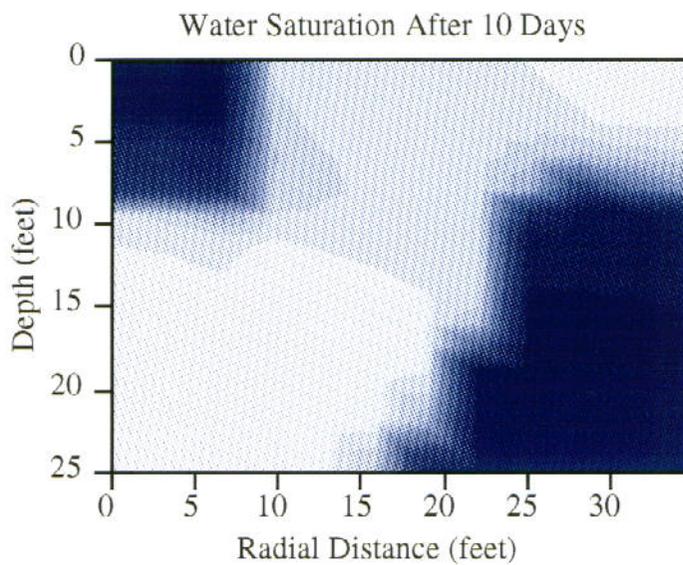
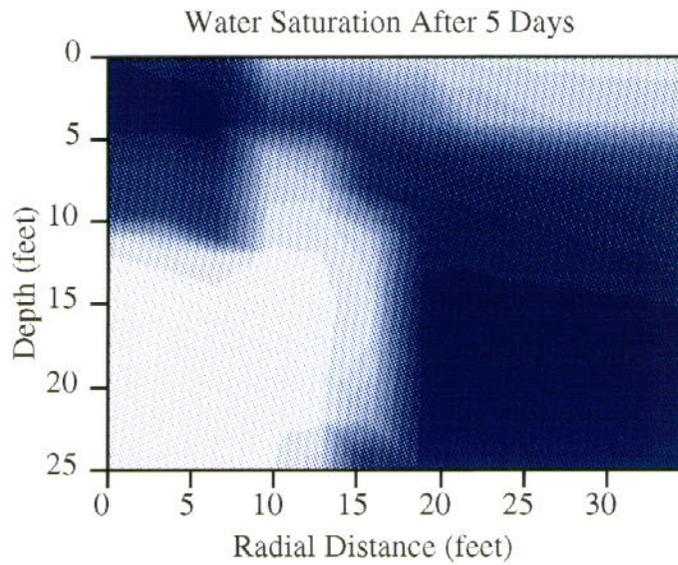
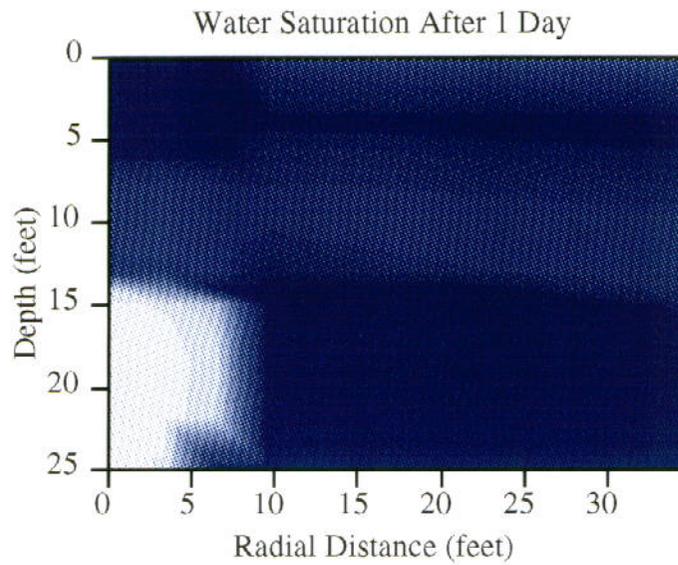
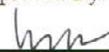


Figure 3:
Water Saturation Profiles --
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 PILOT SCALE TREATABILITY WORK PLAN
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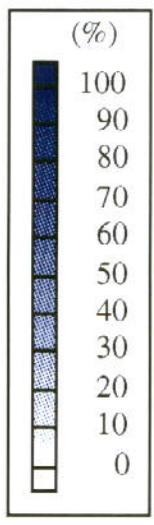
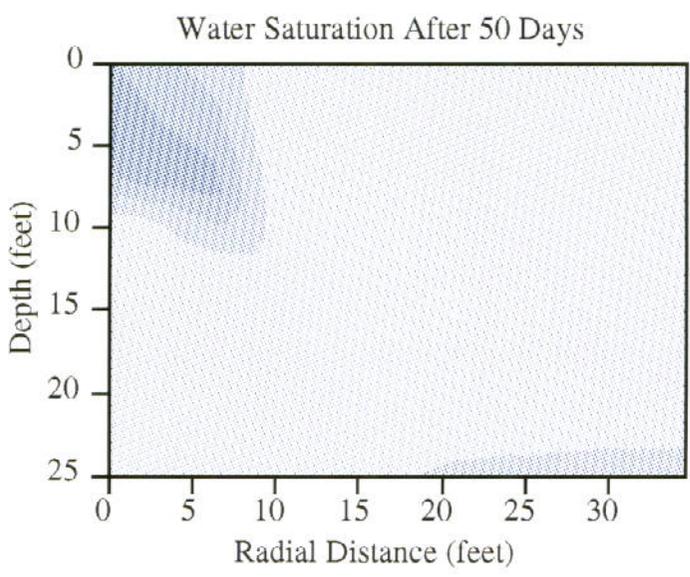
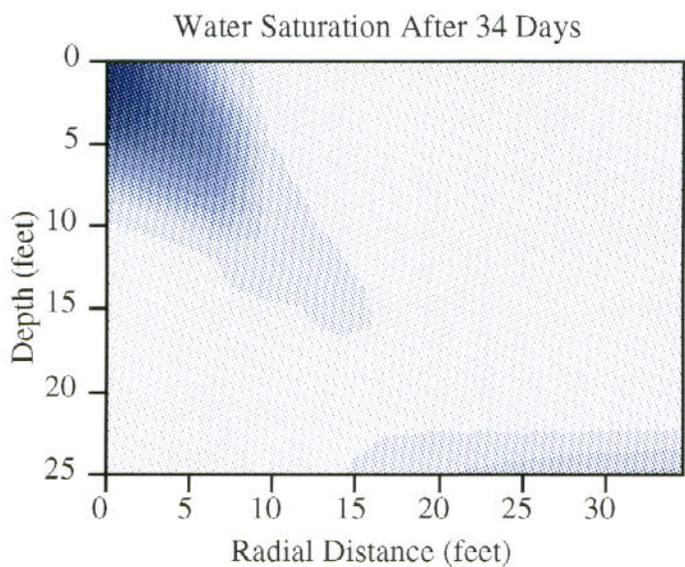
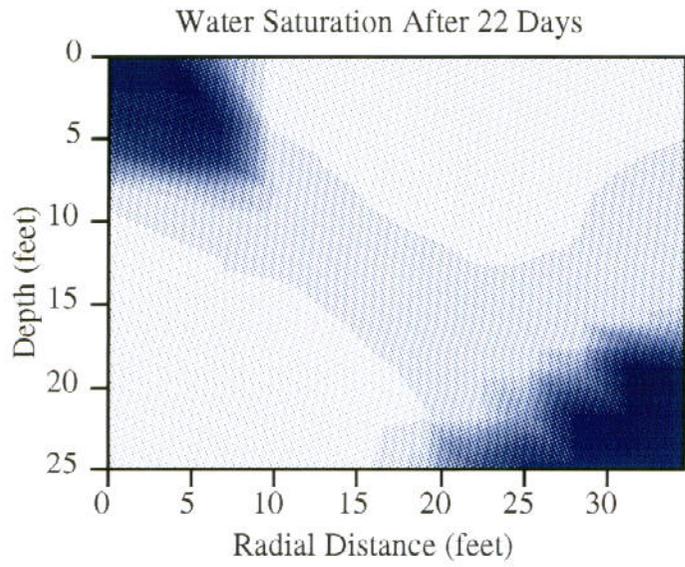


Figure 3 (cont):
Water Saturation Profiles --
Computer Simulation
 PILOT SCALE TREATABILITY WORK PLAN
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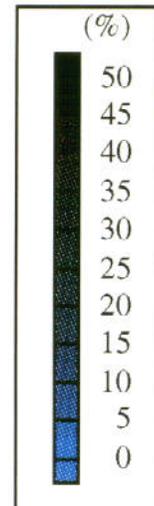
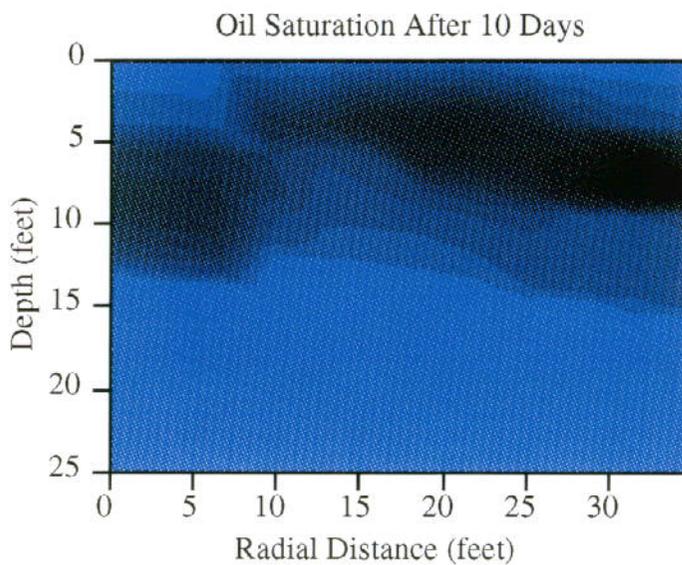
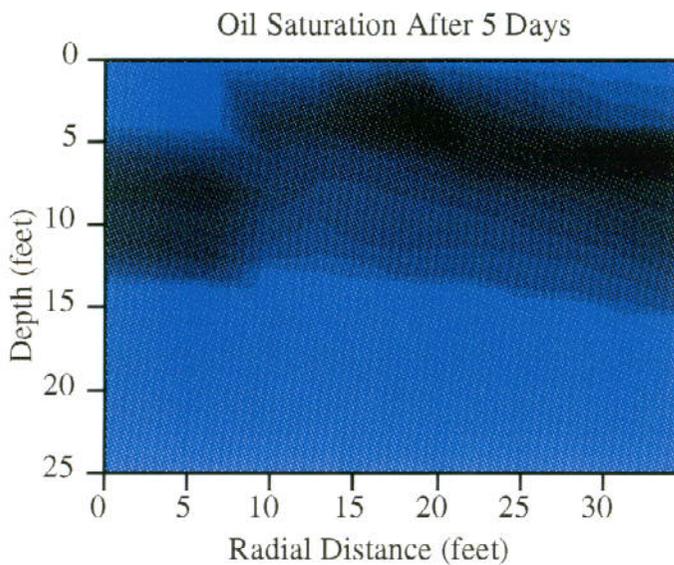
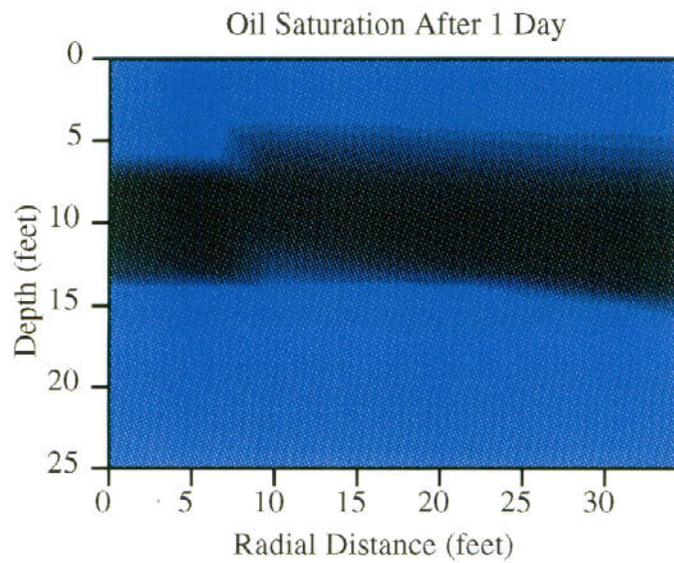


Figure 4:
Oil Saturation Profiles -- Computer Simulation
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

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Approved By: <i>[Signature]</i>	Project: SEE Site 13

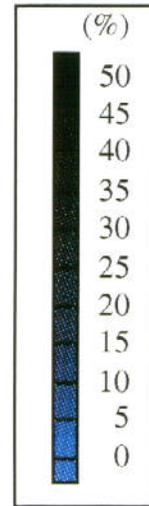
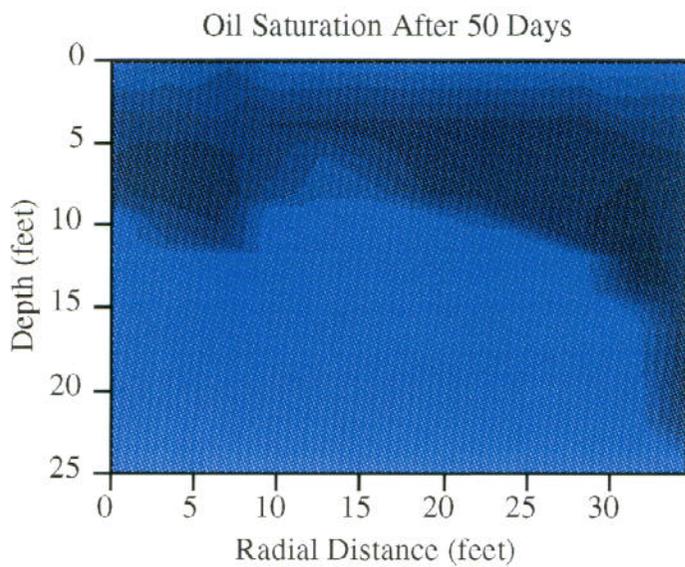
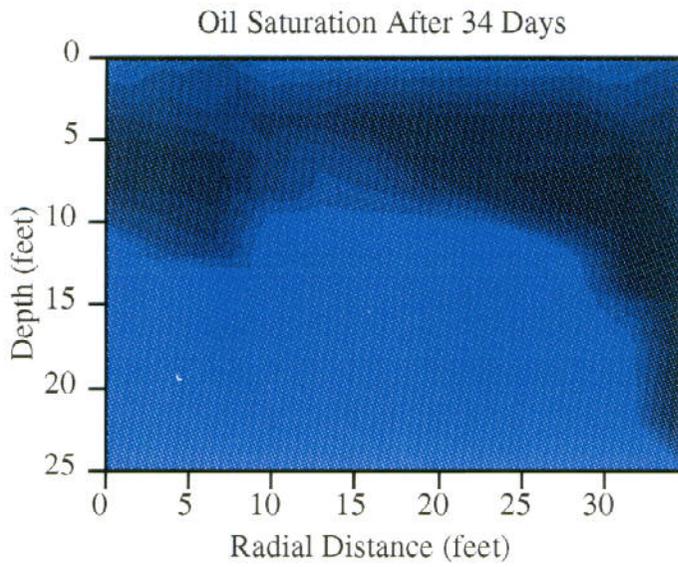
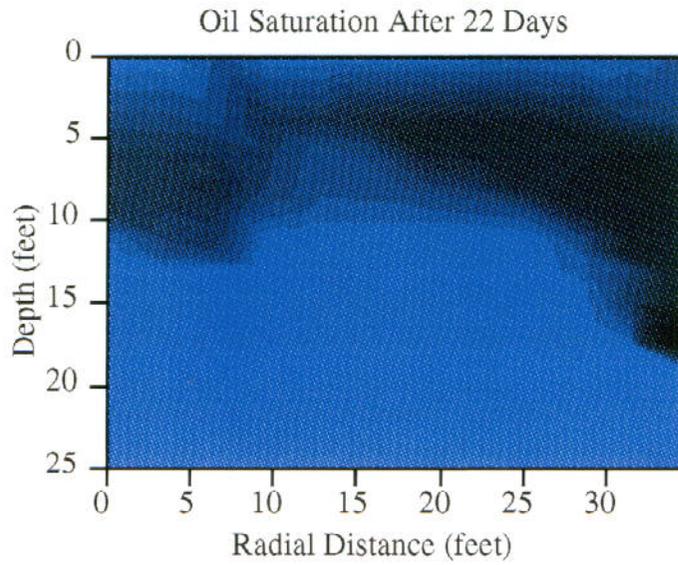
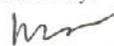


Figure 4 (con't):
Oil Saturation Profiles -- Computer Simulation
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: SWL	Date: 15 December 1995
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Approved By: 	Project: SEE Site 13
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APPENDIX H
SITE HEALTH AND SAFETY PLAN

**SITE HEALTH AND SAFETY PLAN
STEAM ENHANCED EXTRACTION
SITE 13
NAVAL AIR STATION ALAMEDA
ALAMEDA, CALIFORNIA**

Contract Number: N62474-94-D-7430
Delivery Order No. 003

Submitted to:

EFA WEST (Code 0222)
Naval Facilities Engineering Command
900 Commodore Drive
San Bruno, CA 94066-5006

Submitted by:

Berkeley Environmental Restoration Center
University of California at Berkeley
3114 Etcheverry Hall #1750
Berkeley, CA 94720-1750

Revision 1

UNCLASSIFIED
May 10, 1996

Issued to: _____

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SITE HEALTH AND SAFETY PLAN

for

STEAM ENHANCED EXTRACTION

SITE 13

NAVAL AIR STATION ALAMEDA

CONTRACT NO. N62474-94-D-7430

Delivery Order No. 003

Revision 1

UNCLASSIFIED

May 10, 1996



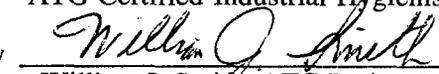
Prepared By



Michael Connor, CIH, CSP
ATG Certified Industrial Hygienist (CIH)

Date: May 10, 1996

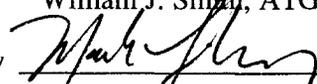
Approved By



William J. Smith, ATG Project Manager

Date: 5/10/96

Approved By



Mark Freiberg, UCB Program CH

Date: 5/10/96

Approved By



Kent S. Udell, Ph.D.
BERC Program Manager

Date: 5/14/96

HEALTH AND SAFETY PLAN COMPLIANCE AGREEMENT FORM

All field personnel will agree in writing to comply with the provisions of this HSP, with the BERC Program Health and Safety Plan, and with ATG's Corporate Health and Safety Program, before starting field work at Site 13. The following page contains the Health and Safety Compliance Agreement Form Attachment to be signed by all field personnel.

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ATTACHMENT 3-2 STEAM WORK PERMIT

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ABBREVIATIONS AND ACRONYMS

(Sheet 1 of 2)

AC - alternating current
ACGIH- American Conference of Governmental Industrial Hygienists
APR - air-purifying respirator
ALARA - as low as reasonably achievable
ANSI - American National Standards Institute
ATG - Allied Technology Group, Inc.
ATSDR - Agency for Toxic Substance and Disease Registry
BERC- Berkeley Environmental Restoration Center
CAL/OSHA- California Occupational Safety and Health Administration
CCR - California Code of Regulations
CFR - Code of Federal Regulations
CGI - Combustible gas indicator
CH₄ - methane
CIH - Certified Industrial Hygienist
CPR - cardiopulmonary resuscitation
CPT - cone penetrometer testing
CRZ - Contamination Reduction Zone
CSE - Certified Safety Executive

dBA - decibels, measured on the A-weighted scale
DRI - direct-reading instrument

ECM - Erythema chronic migraine
EPA - U.S. Environmental Protection Agency
eV- electronvolt
EZ - exclusion zone

°F - degrees Fahrenheit
FID - flame ionization detector
HEPA - High efficiency particulate air
HSP - Health and safety plan (site-specific)
HP - Health Physics

IDLH- immediately dangerous to life or health
IP - ionization potential
LEL - lower explosive limit
LEPC- Local Emergency Planning Committee
MSDS - material safety data sheet
MSHA - United States Mine Safety and Health Administration
mg/ m³ - milligrams per cubic meter of air

NAS - Naval Air Station
NH₃ - ammonia
NIOSH- National Institute for Occupational Safety and Health

ABBREVIATIONS AND ACRONYMS

(Sheet 2 of 2)

NOSCDR - Navy On-Scene Commander
NOSC - Navy On-Scene Coordinator
O₂ - oxygen
OM - O₂ meter
OSHA - United States Occupational Safety and Health Administration
OVA - organic vapor analyzer
PCB - polychlorinated biphenyls
PDS - personnel decontamination station
PEL - OSHA or CAL/OSHA Permissible Exposure Limit
PI - Principal Investigator
PID - ultraviolet photoionization detector
PM - ATG's Project Manager
PPE - Personal protective equipment
ppm - parts per million
ROICC - Resident Officer in Charge of Construction
SEE - Steam enhanced extraction
SHSO - Site Health and Safety Officer
SSP - standard safety procedure
SS - Site Superintendent
SVOC - Semivolatile Organic Compounds
SZ - Support zone
TLV - Threshold Limit Value
TWA - time-weighted average
UCB - University of California - Berkeley
VOC - Volatile organic compounds

1.0 INTRODUCTION

The purpose of this site-specific Health and Safety Plan (HSP) is to describe the necessary health and safety procedures for the three-well pilot scale treatability study of steam enhanced extraction (SEE) at Site 13, Naval Air Station, Alameda. This work, referred to as the pilot study in this HSP, has been authorized under the Partnership agreement between the U.S. Navy Engineering Field Activity West and the Berkeley Environmental Restoration Center (BERC), University of California at Berkeley (UCB). Allied Technology Group, Inc. (ATG) as a BERC contractor prepared the HSP in response to Navy Delivery Order 003. The objective of this SEE treatability test is to ascertain the SEE's viability as a cost-effective method for restoration of soils and groundwater containing low-volatility hydrocarbons at Site 13.

Work will be conducted in accordance with the Pilot-Scale Treatability Study Work Plan, Steam Enhanced Extraction, Site 13 (Work Plan); the BERC Health and Safety Plan Program, Volumes 1 and 2, Revision 2.0, dated October 16, 1995; ATG Corporate Health and Safety Program; ATG General Management Plan; and the requirements of this HSP. The field work will be conducted by UCB personnel, ATG, and subcontractors to ATG.

This HSP is intended to protect UCB and ATG employees as well as ATG's subcontractors on site. This HSP has been prepared to assure that all Occupational Safety and Health Administration (OSHA) requirements promulgated in 29 Code of Federal Regulations (CFR) 1910.120(b)(4) *Site-Specific Safety and Health Plan*, and in Title 8 of the California Administrative Code, Section 5192(b)(1) are met. This document describes the health and safety procedures that will be instituted for all field activities associated with this SEE pilot scale project. This HSP references standard safety procedures described in Section 12 of the BERC Health and Safety Plan (Program) a copy of which will be available on-site. Site standard safety procedures relevant to this project are included in BERC Health and Safety Plan (Program).

This HSP will be provided to all field personnel who may be exposed to hazardous on-site conditions, including BERC, ATG, and subcontractor personnel and site visitors. Field personnel shall read this HSP and document their agreement to comply with it on the Compliance Agreement Form shown at the front of this document.

The Site Health and Safety Officer (SHSO), with the support of ATG's Project Manager (PM), will be responsible for enforcement of this HSP. Personnel who fail to follow the HSP procedures will face disciplinary action up to dismissal from the project at Site 13. The UCB Program Certified Industrial Hygienist (CIH), in consultation with ATG's CIH, PM and SHSO, shall be responsible for resolving health and safety related questions and disputes.

This HSP focuses primarily on health and safety related issues as they pertain to site preparation and construction for the pilot scale study. This document also addresses health and safety related issues related to SEE operations. However, as SEE operations may be revised during design and construction, portions of this HSP may require update or modification.

2.PROJECT PERSONNEL RESPONSIBILITIES

This HSP applies to all field personnel working at Site 13, including subcontractors and visitors. The ATG PM and the SHSO will be responsible for implementation and enforcement of the health and safety provisions of this HSP. Their duties are described in this section along with the duties of other project personnel.

2.1 BERC PROGRAM MANAGER

Dr. Kent Udell is the BERC Program Manager. He is responsible for reviewing proposed activities and safety precautions at Site 13.

2.2 UCB PROGRAM CERTIFIED INDUSTRIAL HYGIENIST

Mr. Mark Freiberg is the UCB Program Certified Industrial Hygienist (CIH). He has the overall responsibility for the health and safety activities at BERC project work site at Site 13. He reviewed and approved this HSP. No changes may be made to this HSP without his written approval.

2.3 BERC PRINCIPAL INVESTIGATOR

Dr. Kent Udell is also the BERC Principal Investigator. As the principal investigator he is responsible for including safety precautions in proposed activities at Site 13.

2.4 ATG PROJECT MANAGER

William J. Smith, Ph.D., P.E., is ATG's Project Manager (PM). With the assistance of the Site Superintendent (SS), he is responsible for the job-related health and safety of site personnel and for managing the risks associated with project equipment and facilities.

2.5 ATG CERTIFIED INDUSTRIAL HYGIENIST

Mr. Michael Connor, CIH, CSP, is ATG's CIH. Mr. Connor is responsible for developing, establishing, and coordinating the implementation of health and safety policies and procedures for ATG managed activities on BERC projects. He prepared this HSP. Mr. Connor shall also be responsible for updating this document to reflect either changes in SEE operations or regulatory changes. Proposed changes shall only be implemented if approved by the UCB CIH (Mr. Freiberg).

ATG's CIH will be the first point of contact on health and safety related issues for field personnel. ATG's CIH will communicate with UCB's Program CIH on all matters relating to health and safety activities at Site 13 and on any decision made regarding health and safety activities. Accident/ Incident reports will be sent to ATG's CIH with a copy furnished to UCB's Program CIH.

2.6 SITE HEALTH AND SAFETY OFFICER

The SHSO for this project is Mr. Lawrence Chiu, P.E. He is the primary enforcement authority for compliance with the policies and provisions of this HSP, with the BERC Health and Safety Plan (Program), and with ATG's Health and Safety Program. Mr. Chiu shall also be responsible for conducting bi-weekly site inspections to identify and to ensure that hazards previously noted have been corrected.

2.7 ATG SITE SUPERINTENDENT

Mr. Chiu is the Site Superintendent (SS). He will direct all field activities including emergency response operations. Mr. Chiu will ensure necessary preparation and coordination for all site operations, including health and safety.

2.8 SUBCONTRACTOR MANAGEMENT AND PERSONNEL

Each subcontractor responsible for workers required to enter a hazardous waste site exclusion zone shall comply with the requirements of 29CFR1910.120, 8CCR5192, and with the requirements of the BERC Health and Safety Plan (Program) and of this HSP. Compliance with these requirements is not intended to either supersede or replace the contractor's own illness and injury prevention plans required by 8CCR3203. Responsibilities of subcontractor management and personnel are described in additional detail in Section 2.5 of the BERC Health and Safety Plan (Program).

2.9 VISITORS

Site visitors are also required to adhere to this HSP. Either the ATG Project Manager or the SHSO shall brief site visitors on site health and safety hazards when they first arrive on site. In general, site visitors will not be allowed access to contaminated areas (exclusion zones) unless they have demonstrated compliance with the medical surveillance and training requirements of this HSP. The responsibilities of visitors to Site 13 are further described in Section 2.7 of the BERC Health and Safety Plan (Program).

3. HAZARD ANALYSIS AND CONTROL PROGRAM

3.1 PROGRAM OVERVIEW

This section describes the site, summarizes the three well treatability study pilot scale SEE work tasks, and discusses the hazards associated with the field work.

3.1.1 Site Location

Site 13 is located at NAS Alameda. A "Site Location Map" is shown as Figure 3-1. NAS Alameda is located on the western end of Alameda Island. Site 13 consists of approximately 30 acres located in the southeast corner of NAS Alameda. Pacific Coast Works refinery occupied the site between 1879 and 1902 during which refinery wastes and asphaltene residues were dumped on site. The refinery consisted of pump and lubricating houses, stills, two laboratories and agitators, as well as approximately 19 above-ground iron oil storage

tanks, six underground iron storage tanks, and a storage area containing drums of oil. The U.S. Navy later surfaced the area once occupied by the refinery. A surface rupture from subsurface refinery waste vapor buildup in the 1940s led the U.S. Navy to remove contaminated soil to reduce the risk of future rupture. This required an excavation 30 by 30 feet (depth not recorded) at the bottom of which was placed a concrete slab. The excavation was then backfilled and resurfaced.

The pilot study shall take place in the area bordered by Avenues K and L and 9th and 11th streets, as shown in Figure 3-2, because this is where the highest concentrations of hydrocarbons have been found. This test location contained an oil storage area, a lubricating building, bleaching tanks and several large iron oil tanks associated with Pacific Coast Refinery.

3.1.2 Project Summary

This section provides a summary of the work needed to complete the pilot study at Site 13. The work essentially consists of drilling wells to inject steam, installing steam injection equipment into these wells, installing a surface containment system to capture steam and contaminant condensates, installing wells to monitor the effectiveness of the SEE process, injecting steam to remove subsurface contaminants and treating SEE process effluents. For the purposes of hazard analysis, these activities can be broken down into the following steps, which are anticipated to take 60 days to complete.

- Mobilization - Install field offices, to stage equipment, to clear underground utilities, and prepare for field work.
- Surveying - Map ground elevations and grading for subsequent surface containment system and drainage construction and well locations.
- Well installation and development - Install steam injection wells, groundwater monitoring wells, temperature observation wells, and electrode wells. This may occur in different phases of the field work.
- Well sampling - Test subsurface aquifers testing, and evaluate SEE pilot test effectiveness.
- Surface containment construction - collect steam and contaminant condensates for subsequent treatment and disposal.
- Treatment systems and construct above-ground piping networks - Treat and collect subsurface contaminant wastes.
- System operation for 30 days - run the pilot test.
- Post demonstration sampling - evaluate the pilot scale work
- System decommissioning - The SEE pilot work at Site 13 will produce two effluent streams requiring treatment. These are:

- Hydrocarbons and groundwater pumped from the injection/extraction wells
- Condensed vapors and cooling water from the containment systems.

Liquid and vapor effluents shall be treated separately. Figure 3-3 shows a schematic diagram of the above-ground processing equipment.

3.2 HAZARD ANALYSIS

As indicated in Section 3.1.2, there are a variety of field activities associated with the SEE pilot study each of which is associated with various hazards. Table 3-1 provides a summary of the hazards associated with each major field activity.

These hazards can generally be classified into chemical, physical and biological hazards. The chemical hazards would most likely be an issue when handling actually or potentially contaminated materials or when using products which contain hazardous ingredients (e.g. adhesives). Chemical hazards would be minimal during a number of site construction activities.

As shown on Table 3-1, physical and, to a lesser extent, biological hazards will be present during most phases of the pilot study. The physical hazards are mostly related to construction activities, although SEE activities may also pose thermal hazards from low pressure steam and hot surfaces. The site biological hazards are limited to insect bites or contact with irritant plants. The following sections describe these hazards in additional detail.

Additional potential hazards associated with the effluent treatment system may be identified after its design has been finalized. After final design, standard operating procedures which will include appropriate health and safety practices, will be developed for system use during the three-well treatability test. These procedures will address purging of tanks, separating water and hydrocarbons, sampling at monitoring wells under steam pressure, steam line operations, use of activated carbon to treat water before discharge, use of vacuum pumps, and valve operation. Examples of health and safety practices include safe distances for workers not specifically operating the system, and steps for depressurizing wells before sampling and inspection. Standard lockout/tagout procedures will be used whenever any part of the system that is normally pressurized is open to the atmosphere.

3.2.1 Chemical Hazards

Table 3-2 lists the contaminants known to be on Site 13. These contaminants can be classified into volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, and pesticides. Exposure to these substances could arise through inhalation, skin contact and ingestion. Each of these routes of exposures is discussed below. Table 3-3 contains a summary of the adverse effects of known site contaminants.

Inhalation exposure to VOCs is expected to be below applicable federal and California PELs during well installation, soil and groundwater sampling, aquifer studies and other similar activities because they would originate from small point sources (i.e. wells) and because known contamination levels are relatively low. However, higher exposures would be expected

because the high temperature of the SEE process will increase the volatility of VOCs present. On the other hand, the SEE is a closed process so that employee exposures are not normally expected. exposures could potentially be higher when the pilot study is in operation particularly if there is a leak in process lines or in the surface containment system.

Although worker exposures to VOCs are expected to be low, they will be monitored through direct reading methods during various phases of construction and operations as described in Section 10 of this HSP to ensure adequate employee protection. This HSP makes provisions for respiratory protection should air monitoring results so warrant.

Although some VOCs known to be present on site are flammable, the fire and explosion hazard is not anticipated to be significant because flammable concentrations are well above the Action Levels described in Section 10.6 of this HSP. Nonetheless, there will be periodic monitoring of the work area with a combustible gas indicator. Fire hazards will be controlled by following standard safety procedure 12.16 of the BERC Health and Safety Plan (Program).

The SVOCs are not expected to be an inhalation hazard since by definition they have low vapor pressures. However, inhalation exposure to SVOCs could occur if visible dust is generated during some field activities which require disturbance of site contaminants (e.g. drilling). Airborne dust is not expected to be an issue, except during project construction work. The latter is not a significant issue since the contaminants to be removed are subsurface. However, as discussed in Section 9 of this HSP, there are provisions to monitor airborne dust concentrations, and for dust suppression if necessary. Although exposure to SVOCs could also occur during steam leaks from the SEE process, this is expected to be low because of the low overall SVOC content and because steam exposure is self-limiting due to its temperature. Furthermore, site workers shall be required to avoid steam exposure at any time and to report steam leaks promptly.

As with SVOCs, neither metals nor pesticides are anticipated to represent significant airborne hazards. Section 3.2.1 and Table 4 of the BERC Health and Safety Plan (Program) discuss how even with visible dust, it is unlikely that the personal exposure limits (PEL as defined by OSHA or CAL/OSHA) PELs for site metals will be exceeded. This same analysis would apply to pesticides which are present in very low concentrations. Of the metals, only lead is present at concentrations of concern in surface soils. Concentrations of other metals in site soils, reported in the "Pilot-Scale Treatability Work Plan, Results of Laboratory Test for Leachable Hydrocarbons," are typical of values found in local soils.

Another potential air contaminant is hydrogen sulfide (H₂S) which may originate from residual subsurface petroleum products. Although this gas is not anticipated to be a problem during drilling work on site, there is potentially more significant exposure during SEE work. H₂S is an acutely toxic gas which can be fatal at relatively low concentrations (500 ppm). Exposure to lower concentrations may cause eye and respiratory irritation. The current

CAL/OSHA PEL for this substance is 10 ppm on an 8 hour time weighted average. Although the rotten egg-like odor of H₂S is easily detectable at low concentrations, its odor is not a reliable warning because the olfactory system becomes desensitized during prolonged exposure. High concentrations, may cause loss of consciousness, dizziness and upset stomach. The chronic effects of exposure to H₂S are negligible. This potential hazard will be evaluated through periodic monitoring with a direct H₂S reading monitor.

Dermal exposure to site contaminants is more likely than inhalation, particularly during activities associated with site contaminants. Examples of these activities would be drilling, and either soil or ground water monitoring. However, the use of personal protective equipment as described in Section 8 of this HSP will minimize this hazard. Ocular exposure shall be minimized through the use of appropriate eye protection, and through dust mitigation.

Ingestion exposure to site contaminants is also expected to be low because eating, drinking and smoking is forbidden in the exclusion zone, and because personal decontamination is required when leaving the exclusion zone.

Chemical exposures are anticipated to be lower during post SEE pilot study sampling since residual contaminants are expected to be lower if the process is successful. There could also be some exposure during decommissioning of the system, although this would be mitigated either by cleaning the equipment before it is disassembled or by sealing off equipment which cannot be cleaned.

The other possible source of chemical exposure is the use of products which contain hazardous ingredients. This is most likely to be an issue during site construction (e.g. adhesives for containment system liners). As required in CAL/OSHA's Hazard Communications Standard (8CCR5194), Material Safety Data Sheets for all products used on site shall be submitted for either ATG CIH or SHSO review. Furthermore, employees required to use such products shall wear the appropriate personal protective equipment and shall be trained on the hazards associated with the product's hazardous ingredients. This training may take place during tailgate safety meetings.

3.2.2 Physical Hazards

As shown in Table 3-1, there are a number of physical hazards associated with the pilot study. Table 3-1 references the corresponding standard safety procedures for these hazards. These procedures originate from Section 12 of the BERC Program Health and Safety Plan (Program).

3.2.2.1 Material Handling

Work on and around a drill rig involves a number of physical hazards associated with rotating machinery, pinch points and overhead loads. These hazards shall be minimized by using qualified drill rig operators, by guarding all nip and pinch points, by daily inspection of the equipment before it is used and by the use of hard hats. Either the ATG Project Manager or the SHSO shall review these hazards with field personnel during tailgate safety meetings. Section 12.4 of the BERC Health and Safety Plan (Program), the project standard safety procedure for the drill rig shall be reviewed during the site specific health and safety training.

3.2.2.2 Drilling Operations

Work on and around a drill rig involves a number of physical hazards associated with rotating machinery, pinch points and overhead loads. Additionally, reflected water spray or overspray during auger decontamination with low pressure steam (<300 psi) or hot water (<1,000 psi) may pose an eye hazard. This shall be mitigated through the use of face shields in addition to other PPE requirements. These hazards shall be minimized by using qualified drill rig operators, by guarding all nip and pinch points, by daily inspection of the equipment before it is used and by the use of hard hats. Either the ATG Project Manager or the SHSO shall review these hazards with field personnel during tailgate safety meetings. Section 12.4 of the BERC Health and Safety Plan (Program), the project standard safety procedure for the drill rig shall be reviewed during the site specific health and safety training.

3.2.2.3 Use of Heavy Equipment

Work around heavy equipment poses a number of physical hazards including the potential for collisions between the equipment and pedestrian workers. Site personnel shall be instructed to maintain eye contact with equipment operators whenever there is heavy equipment use around the site. Section 12.5 of the BERC Health and Safety Plan (Program) provides additional details on working safely around heavy equipment.

3.2.2.4 Noise

Elevated noise levels are anticipated in areas of drilling operations where other heavy equipment also may be in operation. The use of hearing protection will be required during operations associated with noise levels in excess of 85 dBA (decibels measured on the A-weighted scale). Noise levels shall be measured with a Type 2 sound level meter (as defined in ANSI S1.4) whenever there is reason to suspect levels exceed 85 dBA.

All work will be done in compliance with the requirements of 29 CFR 1910.95, "Occupational Noise Exposure," 29 CFR 1926.52, "Occupational Noise Exposure," and SCBA Article 105. BERC field staff or ATG workers may request the SHSO to perform a noise survey, as needed. Section 12.14 of the BERC Health and Safety Plan (Program) contains the hearing conservation program for the project.

3.2.2.5 Heat Stress

Heat stress is a potential hazard during warm months due to physical exertion associated with construction activities while wearing personal protective clothing. When ambient temperatures reach 70 degrees Fahrenheit (° F) and workers are wearing personal protective clothing, work-rest cycles will be scheduled on a regular basis and liquids with electrolytes will be available to replenish body fluids. The PM and SHSO shall establish the work rest cycles as necessary. This shall be discussed during tailgate safety meetings.

Because the incidence of heat stress depends upon a variety of factors, all workers, even those not wearing personal protective equipment (PPE), will be observed and instructed to report any symptoms of heat stress.

Section 12.15 of the BERC Health and Safety Plan (Program) contains the standard safety procedures for handling heat stress-related hazards. It shall be reviewed during the site specific training.

Cold stress is not anticipated to be a hazard for this project.

3.2.2.6 *Electrical Hazards*

Electrical hazards other than utilities as discussed in Section 4.5.1 are not expected during the treatability study. Should they be encountered, they will be handled in accordance with Section 12.6 of the BERC Health and Safety Plan (Program).

3.2.2.7 *Slip, Trip, and Fall Hazards*

Slip, trip, and fall hazards may be present at Site 13. Such hazards will be identified and reviewed by the SHSO at the daily health and safety meeting before field work begins. Slip, trip, and fall hazards are discussed in Section 12.17 of the BERC Health and Safety Plan (Program).

3.2.2.8 *Underground and Above-Ground Utilities*

As explained in Section 3 of this HSP, the Navy will conduct a utility survey before site work begins. A minimum distance of 20 feet from overhead utilities will be maintained at all times. There will be no drilling unless all nearby underground utilities have been identified. ATG's PM and the SHSO shall coordinate the necessary arrangements to either disconnect or de-energize power lines wherever possible. Section 11.3 of this HSP describes standard safety procedures when working around utilities.

3.2.2.9 *Steam*

The use of low pressure steam during SEE operations poses a potential thermal hazard through skin contact with either hot metal or steam. This hazard will be minimized by insulating steam lines, and valves and fittings. Uninsulated steam lines or other hot surfaces shall be either guarded or barricaded. Live steam lines shall be labeled. Steam leaks are generally not expected to be a problem as system pressure shall be monitored. Furthermore, site workers will be instructed on the recognition of steam leaks through sound (hissing), visible steam plumes, and condensate collection. System leaks will be identified during periodic site inspections. Steam leaks shall be reported to the SS promptly. Work will not be conducted on live steam lines. Repair or maintenance to the SEE equipment shall be in accordance with lock out and tag out practices described in Section 12.6 of the BERC Health and Safety Plan (Program). Attachment 3-1 contains a copy of the lockout and tagout form to be used during this project. Attachment 3-2 contains a copy of the steam work permit to be used when working on steam equipment. Section 11.5 discusses site specific procedures for work around SEE operations. Section 12.20 of the BERC Health and Safety Plan (Program) addresses work around steam and effluent recovery lines. These procedures will be reviewed with site personnel when steam is brought to the site, and periodically during installation and operation of the pilot study SEE.

3.2.2.10 Other Construction Related Hazards

As shown in Table 3-1, site work is associated with a number of physical hazards which have been addressed in the standard safety procedures discussed in Section 12 of BERC Health and Safety Plan (Program). The PM, SS or SHSO shall review these procedures with BERC and ATG site personnel. Contractors shall be expected to have addressed hazards they routinely encounter in their own illness and injury prevention plans.

3.3.3 Biological Hazards

Site 13 does not currently have flora and fauna that would present a biological hazard. However, the ATG Project Manager or the SHSO shall inspect the site before field work begins to ensure the absence of such hazards. This shall be discussed during the site specific training. Additionally, the SHSO shall conduct routine inspections of the site to ensure there are no biological hazards present. Section 12.24 of the BERC Health and Safety Plan (Program) contains the standard safety procedures for biological hazards.

4. TRAINING REQUIREMENTS

Work in the exclusion zones of the project will require completion of a 40 hour hazardous waste class. Site supervisors shall also have completed an appropriate 8 hour supervisor course. This general training shall be updated annually. These training requirements are described in detail in Section 4 of the BERC Health and Safety Plan (Program).

Site specific training is also required for all site personnel. The content of this training will depend on the activities to be conducted. Site mobilization will essentially require site orientation training whereas site drilling, well sampling and aquifer testing shall require more extensive training. Similarly, SEE operations will require training specific to the hazards of the operation. Attachment 4-3 contains an example of a tailgate health and safety form to record topics covered. The following is an outline of the site specific training:

- Site roles and responsibilities
- Site hazards
- Site controls
- Site personal protective equipment
- Site decontamination procedures
- Applicable standard safety procedures (See Table 3-1)
- Emergency preparedness
 - Communications
 - Location of emergency facility
 - Evacuation/muster points

Personnel without site specific training shall not be permitted into exclusion zones. Visitors are required to adhere to this training requirement.

5. MEDICAL SURVEILLANCE

All BERC, ATG, and sub-contractor personnel that will be working either with contaminated materials or in an exclusion zone shall participate in an annual medical surveillance program in accordance with federal and state requirements. A California licensed and certified physician shall clear workers to wear respiratory devices and protective clothing as required.

Field personnel shall receive pre-placement examinations and annual re-evaluations to update clearances. Documentation of examinations shall be provided to the Navy five working days prior to the Preconstruction Meeting. The SHSO shall communicate medical restrictions to the affected employee whose work tasks shall be revised to be consistent with terms of the restrictions. Employees leaving their positions shall also be provided with an exit physical, if they have not had an annual re-examination in the preceding six months. Medical surveillance requirements for field personnel are further described in Section 5 of the BERC Health and Safety Plan (Program).

6. SITE CONTROL

Figure 6-4 shows the layout of test wells within the project area. Site control procedures specified in Section 6 of the BERC Health and Safety Plan (Program), and include exclusion zone (EZ), contamination reduction zone, support zone and site security. The EZ is the project area where there is actual or potential contamination of equipment and personnel. Personal protective equipment as described in Section 8 of this HSP shall be worn in the EZ. Visitors will not be permitted to enter the EZ without the authorization of the SHSO. Entry to the EZ shall be restricted to the minimum number of personnel, and only under the buddy system. Either the ATG PM or SHSO will also establish a site log-in, log-out procedure for work in the EZ.

The specific location of the EZ will vary according to task. For example, the exclusion zone (EZ) will extend at least 10 feet from all drilling and sampling activities and will be marked by cones, barricade tapes or other equivalent methods. These EZs shall be terminated when boreholes have been either covered or backfilled. On the other hand, the exclusion zone for the SEE pilot process shall be designated with a cyclone fence around the equipment once the it has been built and installed.

The contamination reduction zone (CRZ) will be immediately adjacent to and upwind from the EZ. This area shall be used to enter and exit the EZ. The CRZ shall be used to clean contaminated tools and equipment and to doff personal protective equipment. In the case of drilling activities, the CRZ shall be marked by cones. A more permanent CRZ shall be built during site preparation activities. This may consist of a bermed pad with plumbed water supply. Its location will be reviewed with site workers at the appropriate time.

The support zone (SZ) will be situated in a clean, uncontaminated area outside the CRZ, where exposure to either hazardous materials or conditions is minimal. Contaminated equipment, samples, or personnel are not permitted in the SZ. The office trailer shall be installed in the SZ.

7. PERSONAL PROTECTIVE EQUIPMENT

The variety of tasks associated with the pilot study will require different levels of personal protective equipment (PPE). Attachment 7-4 shows a list of all personal protective equipment and monitoring equipment required for work at Site 13 at NAS Alameda.

PPE requirements for site mobilization and construction activities which do not require contact with site contaminants shall consist of the following:

- Hard hat
- Safety glasses with side shields
- Long-sleeved shirts
- Cotton or leather gloves
- Foot wear with steel toe and shank
- Hearing protection (if noise levels exceed 85 dBA)

This PPE shall be modified as needed during certain specific activities. For example, appropriate eye and skin protection shall be worn when welding.

The PPE required in exclusion zones associated with either drilling work or other activities with actual or potential exposure to site contaminants will consist of the following modified level D ensemble:

- Hard hat
- Safety glasses with side shields
- Polyethylene coated Tyvek suits
- Nitrile gloves with surgical inner gloves
- PVC or neoprene boots with steel toe and shank

This ensemble will be upgraded to Level C if air monitoring results so indicate, as discussed in Section 9 of this HSP. The respiratory protection to be used shall consist of full-face air purifying respirators fitted with organic vapor/ HEPA combination filters. Respirator use shall be consistent with Section 7.5 of the Health and Safety Plan (Program). In addition to this PPE, face shields shall also be worn when pressure washing augers.

The anticipated PPE during operation of the SEE process shall be similar to that required during construction work. Work around steam lines may require additional protection, such as welding gloves. Additional personal protection equipment will include:

- Welding gloves for turning steam valves
- Apron or jacket when checking water or oil levels within hot water treatment units
- Eye and face protection when opening hot, but depressurized water treatment units for monitoring or inspection

These will be specified in the steam work permit discussed in section 11.5 of this HSP.

The SHSO shall review these PPE needs on a periodic basis in accordance with the guidelines shown in Section 7 of the BERCC Health and Safety Plan (Program). PPE requirements shall be reviewed during tailgate safety meetings as necessary.

8. DECONTAMINATION

The pilot study will require different levels of decontamination which will depend on exposure to site contaminants. Consequently, decontamination for drilling, well sampling and possibly SEE equipment maintenance will be more rigorous than for site construction or for normal SEE operations. Furthermore, decontamination facilities will also differ in that initial drilling work will require temporary arrangements whereas SEE operation will have more permanent facilities.

8.1 DECONTAMINATION PROCEDURES

The following decontamination stations shall be used in the designated CRZ for decontamination during drilling, and well sampling activities:

- 1) Segregated equipment drop. Drop equipment used on site (hand tools, monitoring equipment and sampling containers, radios, clipboards, etc.) on plastic drop cloths or in containers with plastic liners.
- 2) Boot cover, outer glove, and outer garment wash and rinse. Scrub boots, outer gloves, and outer garment with decontamination solution or detergent water. Rinse off decontamination solution or detergent water using copious amounts of water. Repeat as necessary.
- 3) Removal station for boot covers and outer gloves. Remove duct tape around boots and gloves and deposit in container with plastic liner.
- 4) Removal station for outer garment. With assistance of a helper, remove protective garment and deposit it in container with plastic liner.
- 5) Hand and face wash and rinse. Wash hands and face.

These procedures may be modified during well sampling, and aquifer testing. For these activities there will be a fixed designated equipment drop at the site and more permanent hand washing facilities will be installed.

Decontamination, other than good personal hygiene practices, is not required for site mobilization and site construction except as discussed above. These activities are not associated with contact with site contaminants. The same applies to normal SEE operations. However, decontamination would be required during either maintenance or repair of contaminated equipment.

8.2 DISPOSAL PROCEDURES

Used but clean disposable protective clothing will be double-bagged and placed in drums for disposal as ordinary waste. Disposable sampling tools and visibly contaminated protective equipment shall be double bagged and disposed of appropriately based on analytical results from soil or groundwater samples. Wash and rinse waters will be collected in drums and disposed of based on analytical results. Drill cuttings will be containerized and analyzed. Disposal of cuttings will be also be based on analytical results.

The disposal of effluents and condensates is addressed in the Work Plan.

8.3 DECONTAMINATION DURING MEDICAL EMERGENCIES

If prompt life-saving first aid or medical treatment is required, decontamination procedures will be omitted as needed. Protective clothing and equipment shall be cut away before transportation to the emergency facility. On-site personnel will accompany contaminated victims to the medical facility to advise on matters involving decontamination. This is not anticipated to be a significant issue since the pilot study field work is not expected to be associated with significant exposure to contaminants. Section 8.4 of the Health and Safety Plan (Program) provides additional details on emergency decontamination procedures.

9. EXPOSURE MONITORING

The purpose of exposure monitoring is to ensure that personnel are adequately protected and to verify that site chemical hazards have been properly evaluated. Figure 9-5 list exposure guidelines for chemical hazards known to occur in the project area. The exposure monitoring necessary during the SEE pilot study shall consist of use of a photoionization detector (PID) fitted with a 10.2 eV bulb, a direct reading H₂S monitor, a combustible gas indicator (CGI) and an MIE PDM-3 MINIRAM aerosol monitor. This equipment shall be used by individuals trained on the equipment's use and limitations. The equipment shall be calibrated in accordance with the manufacturer's instructions. The ATG Project Manager or the SHSO are responsible for ensuring the necessary monitoring is conducted by trained personnel.

The PID shall be used to evaluate potential exposures to aromatic VOCs. PID readings shall be evaluated against criteria shown in Section 9.1.1 of this HSP. Respirators listed shall be donned when the results exceed the criteria. Wells and other borings shall be monitored every five feet of depth. The results shall be noted in the boring log. When VOCs are detected at the borehole, worker breathing zones shall be monitored. Respirator use may be discontinued when results fall below the criteria shown in Section 9.1.1. The use of respiratory protection shall be noted in the daily work log as with the location of the elevated results. Repeated need for respiratory protection shall be discussed with the ATG CIH to determine whether additional monitoring is required. PID monitoring during SEE operations shall be used when personnel are working within five feet of wells or steam leaks.

The direct-reading H₂S monitor shall be used to monitor potential exposures to this gas in accordance with the guidelines shown in Section 9.1 of this HSP. This instrument shall be used during SEE operations to survey work areas or areas near steam leaks.

The CGI shall be used to verify that there are no flammable gases present at ignitable concentrations. As discussed in Section 4 of this HSP, such concentrations are not anticipated. Nonetheless, the work areas shall be monitored periodically to ensure there is no fire or explosion hazard associated with the site contaminants.

The MIE PDM-3 MINIRAM aerosol monitor shall be used to evaluate airborne dust exposures. If site activities generate visible dust, wet control measures shall be implemented.

9.1 ACTION LEVELS

This section describes the criteria against which air monitoring results shall be evaluated. These levels are as measured in worker breathing zones and as sustained for a period of five consecutive minutes. Respiratory protection may be downgraded when results fall below the specified criteria for five consecutive minutes

9.1.1 Total Organic Vapors

Normal Background Levels	=	Level D protection
Above Background Levels		
>0 to 5 ppm	=	Level C protection. Increase monitoring frequency (every 15 minutes).
>5 to 500 ppm	=	Suspend work and evaluate hazards with ATG CIH
>500 ppm	=	Stop work; evacuate site; call ATG CIH

9.1.2 Hydrogen Sulfide

Normal Background Levels	=	Level D protection
Above Background Levels		
>0 to 5 ppm	=	Increase monitoring frequency (every 15 minutes)
>10 ppm	=	Stop work; evacuate site; call ATG CIH

9.1.3 Total Particulate Matter

< 5 mg/m ³	=	Level D
5 to 10 mg/m ³	=	Level C, respirators equipped with HEPA filters

9.1.4 Oxygen Content

20.8%	=	Normal background level
20.8 to 19.5%	=	Continue investigation with continuous air monitoring
<19.5%	=	Stop work; call ATG Program CIH

9.1.5 Explosive Atmospheres

0 to 10% LEL	=	Normal background levels
> 10% LEL	=	Stop work; evacuate site; call ATG Program CIH

During operations with live steam, the CGI and PID will be used to check all work areas within the exclusion zone before initiating work activities. When activities within the work zone involve only monitoring, CGI and PID readings will be taken near each monitoring point once each day or when emissions are observed.

If H₂S was observed during the drilling operation at concentrations greater than 50 ppm, then H₂S will be monitored during the steaming operation at the same frequency as CGI and PID measurements. Otherwise, H₂S will be monitored only if observed in the extracted vapors at concentrations greater than 50 ppm.

10. EMERGENCY RESPONSE

The following sections discuss general first aid procedures, hospital and evacuation route, emergency resources, emergency response telephone numbers, and accident/incident reporting. The site superintendent directs emergency response operations.

The ATG SS or the SHSO shall be notified of fires spills or leaks to assess the situation and determine the response. All personnel not trained in spill control shall evacuate the area. If necessary, the Base Fire Department shall be called for fire or emergency response. The location and type of fire suppression equipment at the project site will be determined during site construction.

10.1 SITE EMERGENCIES

Major site emergencies such as chemically related injury or fatality, uncontrolled effluent steam releases, fires and explosions shall require the site to be evacuated. This shall be announced by five long blasts of the alarm. Employees shall muster at the entrance to Site 13 unless otherwise directed. A map of the muster point shall be posted on site. Drains or other offsite pathways shall be diked off with either soil or sorbent materials. Uncontrolled steam releases shall be controlled by shutting off steam to the site. The Base Fire Department shall be contacted to extinguish major site fires.

Minor site emergencies include small spills (less than 50 gallons or 50 pounds) of contaminated materials or effluents, small steam leaks, or small fires. Personnel shall report these emergencies without delay. Either the SS or the SHSO shall direct response actions, the first being to isolate the affected work area. Small spills shall be contained with sorbent materials. Small steam leaks shall be repaired after shutting off steam to the affected area and after the equipment has cooled off sufficiently. Small fires shall be put out with fire extinguishers. First aid incidents shall be handled as described in Section 10.2. Emergency decontamination procedures are described in Section 8.3.

The SHSO shall investigate all site emergencies after they have been mitigated to determine whether responses were satisfactory and to determine appropriate corrective actions. This may result in modifications to this HSP. These modifications shall be submitted for approval by the UBC Program CIH before they are implemented.

10.2 GENERAL FIRST AID PROCEDURES

Dermal Exposure: Wash with soap immediately and rinse with copious amounts of clean water. Watch for signs of skin irritation. Seek medical attention at first signs of irritation.

Inhalation: Move victim to fresh air. Give artificial respiration if necessary. Observe victim for signs of shock. Seek medical attention immediately.

Ingestion: CALL POISON CONTROL CENTER. Seek immediate medical attention. If possible, a sample of ingested material will be collected and transported to hospital with the victim.

10.3 HOSPITAL AND EVACUATION ROUTE

During site mobilization, ATG personnel will conduct a pre-emergency run to Alameda Hospital - 2070 Clinton Avenue - 510-523-4357 emergency room, and 510-522-3700 hospital. The purpose of this is to (1) familiarize personnel with the route to the hospital; and (2) notify the hospital of the planned site activities and potential medical needs. An emergency route to the East Gate is shown in Figure 10-6. A "Hospital Route Map" is shown in Figure 10-7.

To reach the Alameda Hospital, exit the NAS site through the East Gate. Cross Main Street, continuing East on Atlantic Avenue. turn right onto Webster Street, then left on to Central Avenue. take Central and then a 90 degree right turn onto Sherman Street. Turn left onto Clinton Avenue Emergency room entrance in on the right hand side of Clinton Avenue, between chestnut Street and Willow Street.

10.4 EMERGENCY RESOURCES

Before work begins at each site, contact will be made with local authorities and emergency services to establish communication channels during an event of emergency and to familiarize the project personnel with the communication procedure and services. Pertinent emergency information will be included at the daily tailgate safety meetings.

From a base telephone (found in all government offices)

On base calls: Dial "3" plus the last 4 digits of an on-base number

Off base calls (local): Dial "9" plus the 7 digit number

Off base calls (long distance): Dial "91" plus the area code and 7 digit number,

Public Agencies

Fire (Base) (510) 263-4300
(Alameda City) 911 or (510) 522-2423
Ambulance (510) 263-4444
Police (Alameda City) 911 or (510) 522-2423
OSHA (415) 744-6670
Cal/OSHA (Oakland) (510) 568-8602

CONFIDENTIAL RECORD

PORTIONS OF THIS RECORD ARE CONSIDERED
CONFIDENTIAL AND ARE NOT FOR PUBLIC VIEWING

PRIVATE CITIZEN'S HOME PHONE NUMBER HAS BEEN
REDACTED IN ACCORDANCE WITH THE PRIVACY ACT

QUESTIONS MAY BE DIRECTED TO:

**DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
NAVAL FACILITIES ENGINEERING COMMAND
SOUTHWEST
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132**

TELEPHONE: (619) 532-3676

Key Project and BERC Personnel

Program Manager (Kent S. Udell) (510) 642-0922
(510) 643-1300

Program CIH (Mark Freiberg) (510) 643-8676
pager (510) 430-5038

Project Manager (William Smith) (510) 490-3008

Project Superintendent (Lawrence Chiu) (510) 490-3008
pager (800) 690-3573

Site Health and Safety Officer (Lawrence Chiu) (510) 490-3008
pager (800) 690-3573

Occupational Health Physician (Thomas Gamsky, M.D.) (510) 643-7116

Navy Contact [Resident Officer in Charge of Construction (ROICC)] (Wayne Coffey) (510) 302-3354

Base Health and Safety Office (510) 263-3395

Agency for Toxic Substance and Disease (404) 639-0615

Registry (ATSDR)

Navy On-Scene Coordinator (NOSC) (510) 263-3276

Navy On-Scene Commander (NOSCDR) (510) 263-3003

Local Emergency Planning Committee (LEPC) (510) 263-3050

Regional Poison Control Center (510) 476-6600

Medical Care Facilities

Hospital Name: Alameda Hospital
Hospital Address: 2070 Clinton Avenue
Alameda, CA
Alameda Hospital Telephone: (510) 522-3700
Alameda Emergency Room (510) 523-4357
Base Medical: (510) 263-4444

Regulatory Agencies:

California State Office of Emergency Services (510) 646-5908

Fish and Game (800) 952-5400

Regional Water Board (510) 464-1255

CHEMTREC (800) 424-9300

Poison Control Center (800) 356-3129

Underground Services Alert (800) 642-2444

Base Hot Work Permits (510) 263-3279

10.5 ACCIDENT/INCIDENT REPORTING

Accidents and incidents shall be reported on the form contained in Attachment 10-5, "Accident/Incident Report Form," in accordance with BERC's Health and Safety Plan and ATG's Corporate Health and Safety Program. The accident/incident form will be forwarded to ATG's CIH. Reportable events that may occur on a BERC project work site include:

- Injuries - injuries to personnel of any magnitude
- Toxic agent exposure - any exposure of inadequately protected personnel to toxic agents
- Personnel radiation contamination - personnel exposures to radiation contamination
- Back injuries - back injuries that require treatment by a clinic or chiropractor
- Near miss - incident in which an injury could have occurred and which requires either preventive or corrective action to prevent re-occurrence
- Tool or equipment failure - failure that results or could result in serious injury
- Vehicle accidents - any magnitude collision or malfunction
- Property damage - ATG, client or private property
- Fire or explosion - any magnitude
- Fatality - any accident that results in the death of an employee, client, or visitor at the BERC project work site.

11. STANDARD SAFETY PROCEDURES

This section describes certain standard safety procedures relevant to the SEE pilot study. This section is not intended to either supersede or replace safety procedures described in the BERC Health and Safety Plan (Program). Particularly relevant to this HSP are the following site safety procedures:

Materials Handling	12.1
Compressed Gas Cylinders	12.2
Vehicle Traffic	12.3
Drilling	12.4
Trenching and Excavation	12.5
Control of Hazardous Energy	12.6
Hand Tools	12.7
Power Tools	12.8
Ladders	12.9
Forklift Operations	12.10
Cranes	12.11
Use of Torches	12.12

Fire Prevention	12.16
Slip, Trip and Fall Hazards	12.17
Portable Electric Equipment	12.19
Steam and Effluent Recovery Lines	12.20

11.1 SITE ENTRY PROCEDURES

All field personnel shall attend a site orientation meeting before work starts at the site. Thereafter, an on-site health and safety meeting will be held at the beginning of each work day to discuss pertinent health and safety issues. Attachment 3 contains a Safety Meeting Sign-Off Sheet for persons who attended the meeting.

11.2 STANDARD WORK PRACTICES

Standard health and safety work practices in exclusion zones at Site 13 NAS Alameda include the following:

- Contact with potentially contaminated substances should be avoided. Field personnel shall not walk through puddles, pools, mud, etc., and shall avoid, whenever possible, kneeling on the ground, leaning, or sitting on equipment on the ground.
- Containers (such as drums) will be moved only with the proper equipment and will be secured to prevent dropping or loss of control during transport.
- Equipment will not be placed on potentially contaminated surfaces, including but not limited to the ground.
- Portable eyewash stations will be located near individual work sites.
- Eating, drinking, chewing tobacco, smoking, and carrying matches or lighters, and using cosmetics are prohibited in EZ and CRZ, or where the possibility for the transfer of contamination exists.
- During rest periods, all personnel will be required to wash their hands and faces before eating, drinking, smoking, or applying cosmetics.
- All field team members should make use of all their senses to alert them to potentially dangerous situations in which they should not become involved, i.e., presence of strong and irritating or nauseating odors.
- Site personnel will observe each other for signs of toxic exposure and heat or cold stress. Indications of adverse health effects include but are not limited to the following:
 - Changes in complexion and skin discoloration
 - Changes in coordination
 - Changes in demeanor
 - Excessive salivation and papillary response
 - Changes in speech patterns
- Site personnel will inform each other of non-visual effects of illness, such as the following:
 - Headache

- Dizziness
 - Nausea
 - Blurred vision
 - Cramps
 - Irritation of eyes, skin, or the respiratory tract
- Spills should be prevented to the greatest extent possible. In the event that a spillage occurs, contain liquid if possible.
 - Splashing of the contaminated materials shall be avoided.

All hazardous wastes generated during ATG's and/or subcontractor activities should be disposed of as directed by the SHSO.

11.3 WORK WITH UTILITIES

The following practices shall be observed when working in areas with underground and overhead utilities are as follows:

- The utility locations shall be communicated to all site workers during the initial daily health and safety meeting. Utilities will be marked or access otherwise restricted to avoid the risk of accidental contact.
- Overhead or above-ground electric lines should be considered "live" or "active" until a reliable source, such as base electrician or personnel from the relevant operating company, has documented them to be otherwise.
- Clearance will be adequate for the movement of vehicles and for the operation of construction equipment.
- Drill rigs or vehicle superstructures will be erected at least 20 from overhead electrical lines until the line is de-energized, grounded, or shielded and a competent electrician has certified that arcing cannot occur between the work place and superstructure.
- Overhead transmission and distribution lines will be carried on towers and poles that provide safe clearance over roadways and structures.
- Workers will be instructed to use care in working under or around utilities, to avoid hot surfaces, loud noises, pressurized gases or air, leaking pipelines, discharging steam or hot liquids and must work to prevent accidental contact with breakage.

The following clearances will be maintained between equipment and energized power lines:

<u>Voltage</u>	<u>Working Clearance</u>	<u>Equipment Clearance</u>
Less than 50 kV	10 feet	4 feet
50 to less than 345 kV	10 feet, plus 4 inches per each extra kV	10 feet

11.4 WORK WITH STEAM

The project policy shall be to avoid unnecessary work on either hot surfaces or steam lines. If such work is unavoidable, work shall be delayed until a steam work permit, shown as Attachment 2, has been obtained. The SHSO will issue this permit upon request after inspection of the work area to evaluate the thermal hazards and to verify that they have been adequately controlled. Work in and around hot surfaces may require protective equipment as described in Section 7 of this HSP. The completed permit will be posted in the work area. Use of steam work permits shall be discussed in the site-specific training as described in Section 4.

There will be a first aid-trained person familiar with burn treatment on site during work on hot surfaces.

11.5 LOCKOUT/TAGOUT PROCEDURES

These procedures are based on the conceptual design of the three-well treatability test. These procedures will be reviewed and revised, if necessary, when the Final Design is completed. A sample lockout/tagout form is shown as Attachment 1.

These requirements apply to electrical equipment and valves on steam lines, valves on the vapor collection system, and valves on the treatment system.

Work on electrical equipment and valves may be performed only after the following conditions have been met:

- It has been determined that it is necessary to work on electrical equipment or valves, and the SHSO has approved of the operation.
- Involved personnel have received instructions on the work techniques and hazards involved in the particular task to be performed.
- Suitable barriers, barricades, equipment guards, and danger tags are in place for protection of personnel.
- Equipment has been locked out and tagged out as specified by the SHSO.

Section 12.6 of the BERC Health and Safety Plan (Program) details specific lockout and tagout procedures for the project.

11.6 RECORD KEEPING

The health and safety record keeping requirements are an important component of UCB Health and Safety Program and ATG's Health and Safety Program. The following list highlights the record keeping requirements for BERC field staff and ATG's employees and site-specific activities. The items will be retained by ATG for 30 years after each covered employee has ended employment with BERC or ATG, respectively.

- Medical surveillance results for each of BERC's or ATG's employees
- Names, addresses, and phone numbers of examining and consulting physicians and clinics
- A copy of respirator fit test results
- A copy of training certificates for initial 40 hours of project work site training, SHSO training, 8 hours of supervisor's health and safety training, 8 hours of annual refresher training, CPR and first aid training, and any other training received
- A copy of employee CPR and Red Cross certificates
- The following records will be retained by ATG for 30 years after close-out of delivery order 3 at a BERC project work site managed by ATG:
 - Copies of UCB's and ATG's Health and Safety Programs
 - Records of site visits by ATG's employees and subcontractors
 - A copy of pages from logbooks on field calibration of health and safety monitoring equipment for air sampling and other field issues related to health and safety.
 - All health and safety survey reports
 - Accident/incident reports

TABLE 3-1

Hazard Analysis Summary
SEE Pilot Scale Study

Activity	Hazards	Hazard Control
Mobilization	Vehicle traffic	SSP 12.3
	Materials handling	SSP 12.1
	Slip, trip and fall	SSP 12.17
Utility clearance	Vehicle traffic	SSP 12.3
	Materials handling	SSP 12.1
	Slip, trip and fall	SSP 12.17
Surveying	Vehicle traffic	SSP 12.3
	Materials handling	SSP 12.1
	Slip, trip and fall	SSP 12.17
Site drilling and sampling	Exposure to subsurface contaminants	See HSP
	Drilling work	SSP12.4
	Heat stress	SSP 12.15
	Noise	SSP12.14
	Slip, trip and fall	SSP 12.17
	Low Pressure Steam Rinse	SSP 12.20
Surface containment construction	Materials handling	SSP 12.1
	Use of handtools	SSP 12.7
	Use of power tools	SSP 12.8
	Use of torches	SSP 12.12
	Compressed gases	SSP 12.3
	Use of portable electric equipment	SSP 12.19
	Use of cranes and forklifts	SSP 12.10 and 12.11
	Heat Stress	SSP 12.15
	Fires	SSP 12.16
	Slip, trip and fall	SSP 12.17
Noise	SSP 12.14	
Treatment system construction	Materials handling	SSP 12.1
	Use of handtools	SSP 12.7
	Use of power tools	SSP 12.8
	Use of torches	SSP 12.12
	Compressed gases	SSP 12.3
	Use of portable electric equipment	SSP 12.19
	Use of cranes and forklifts	SSP 12.10 and 12.11
	Heat Stress	SSP 12.15
	Fires	SSP 12.16
	Slip, trip and fall	SSP 12.17
Noise	SSP 12.14	

TABLE 3-1 (CONT'D)

Hazard Analysis Summary
SEE Pilot Scale Study

Activity	Hazards	Hazard Control
SEE Operation	Exposure to subsurface contaminants	See HSP
	Low pressure steam	SSP 12.20
	Steam and effluent recovery lines	SSP 12.20
	Hazardous energy	SSP 12.6
Post SEE operations sampling	Exposure to subsurface contaminants	See HSP
	Slip, trip and fall	SSP 12.17
SEE decommissioning	Use of handtools	SSP 12.7
	Use of power tools	SSP 12.8
	Use of torches	SSP 12.12
	Residual contaminants	See HSP

TABLE 3-2
Site 13 Contaminants
Alameda NAS

VOLATILE ORGANIC COMPOUNDS (VOC)	Max. Conc.	Min. Conc.	Unit	Depth(ft) of Max. Conc.
Benzene	1	ND	mg/kg	6.5-7
1,2-Dichloroethene	0.005	ND	mg/kg	11-11.5
Ethylbenzene	1.8	ND	mg/kg	11-11.5
Methylene Chloride	0.16	ND	mg/kg	11-11.5
Methyl Ethyl Ketone	0.0 05	ND	mg/kg	7-7.5
Toluene	1.6	ND	mg/kg	2-2.5
Xylene	4.1	ND	mg/kg	11-11.5

SEMIVOLATILE ORGANIC COMPOUNDS (SVOC)	Max. Conc.	Min. Conc.	Unit	Depth(ft) of Max. Conc.
Anthracene	0.1	ND	mg/kg	11-11.5
1,2-Benzanthracene	0.39	ND	mg/kg	11-11.5
Benzo(a)pyrene	0.52	ND	mg/kg	12-12.5
Benz(e)acephenanthrylene	1.1	ND	mg/kg	11-11.5
Benzo(g,h,i)perylene	1.4	ND	mg/kg	11-11.5
Benzo(k)fluoranthene	0.51	ND	mg/kg	12-12.5
Chrysene	2.3	ND	mg/kg	0.5-1
Fluorene	0.79	ND	mg/kg	11-11.5
Fluoranthene	0.8	ND	mg/kg	11-11.5
Indeno(1,2,3-cd)pyrene	0.69	ND	mg/kg	11-11.5
2-Methylnaphthalene	17	ND	mg/kg	11-11.5
Naphthalene	5.4	ND	mg/kg	11-11.5
N-Nitrosodiphenylamine	2.7	ND	mg/kg	11-11.5
Pentachlorophenol	1	ND	mg/kg	4-4.5
Phenanthrene	1.8	ND	mg/kg	14-14.5
Pyrene	1.9	ND	mg/kg	11-11.5

TABLE 3-2 (CONT'D)

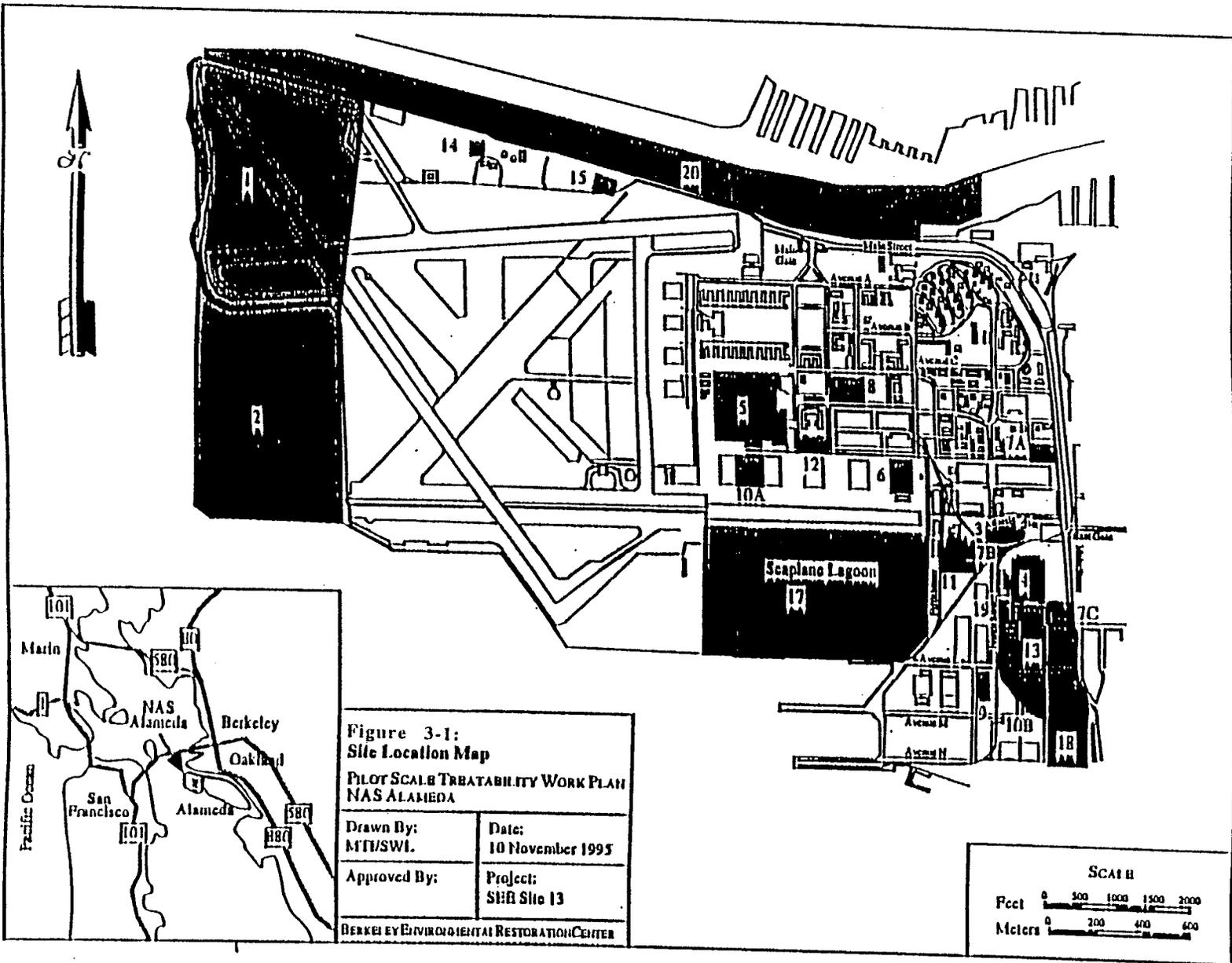
**Site 13 Contaminants
Alameda NAS**

Metals	Max. Conc.	Min. Conc.	Unit	Depth(ft) of Max. Conc.
Arsenic	0.077	ND	mg/L	
Barium	1.9	0.37	mg/L	
Beryllium	0.0084	0.0054	mg/L	
Chromium	1.1	0.13	mg/L	
Cobalt	0.25	0.14	mg/L	
Copper	0.32	0.042	mg/L	
Lead	0.18	0.054	mg/L	
Manganese	12	2.7	mg/L	
Nickel	1.7	0.19	mg/L	
Selenium	0.18	0.097	mg/L	
Vanadium	0.76	0.11	mg/L	
Zinc	0.86	0.12	mg/L	

Pesticides	Max. Conc.	Min. Conc.	Unit	Depth(ft) of Max. Conc.
Beta-BHC	0.0035	ND	mg/kg	10.5-11
4,4'-DDD	0.014	0.0045	mg/kg	13.5-14
4,4'-DDE	0.035	0.0037	mg/kg	12.5-13
4,4'-DDT	0.16	ND	mg/kg	0.5-1
Heptachlor Expoxide	0.0054	ND	mg/kg	0.5-1
Toxaphene	2.5	0.4	mg/kg	10.5-11

FIGURE 3-1

SITE LOCATION MAP

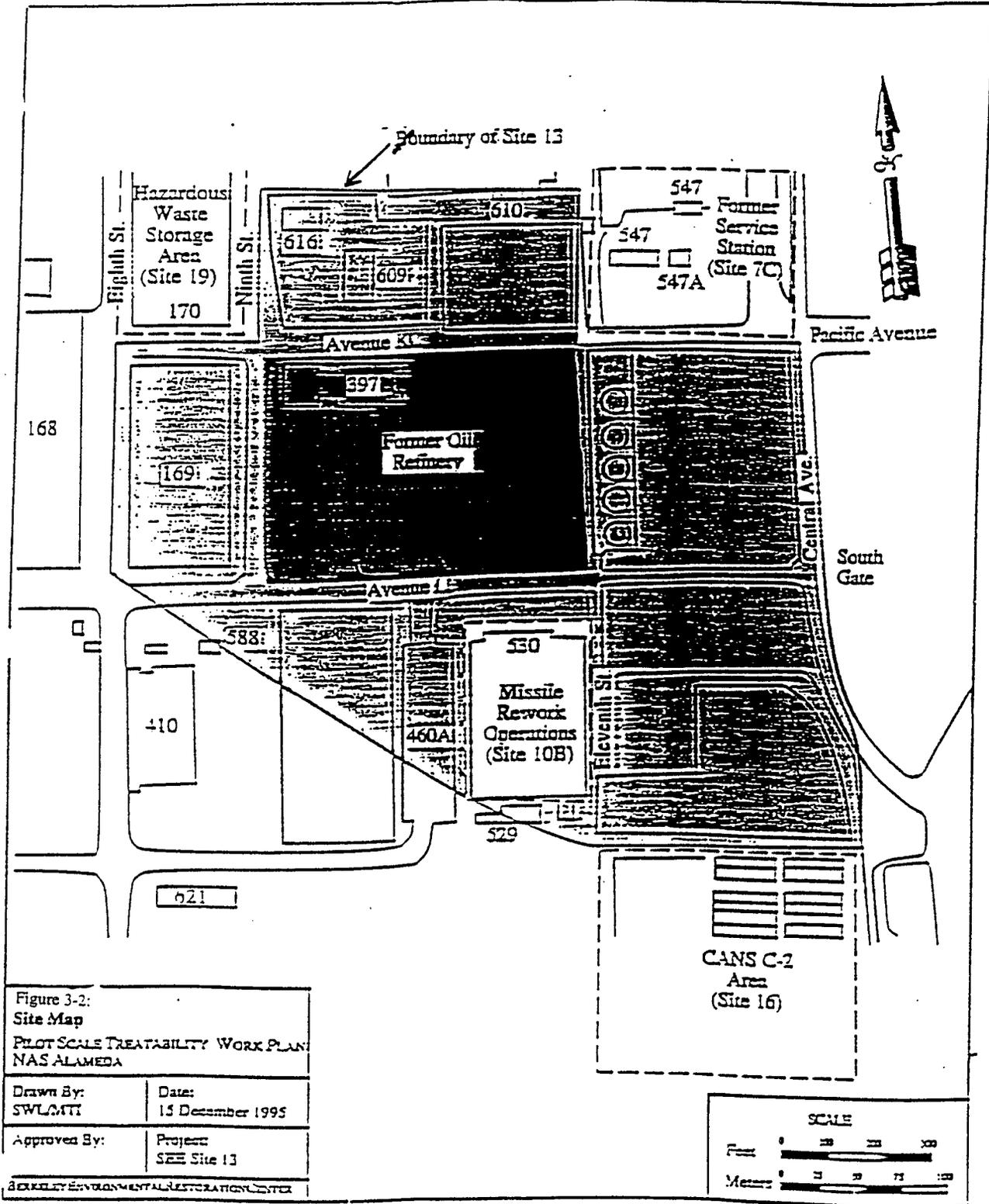


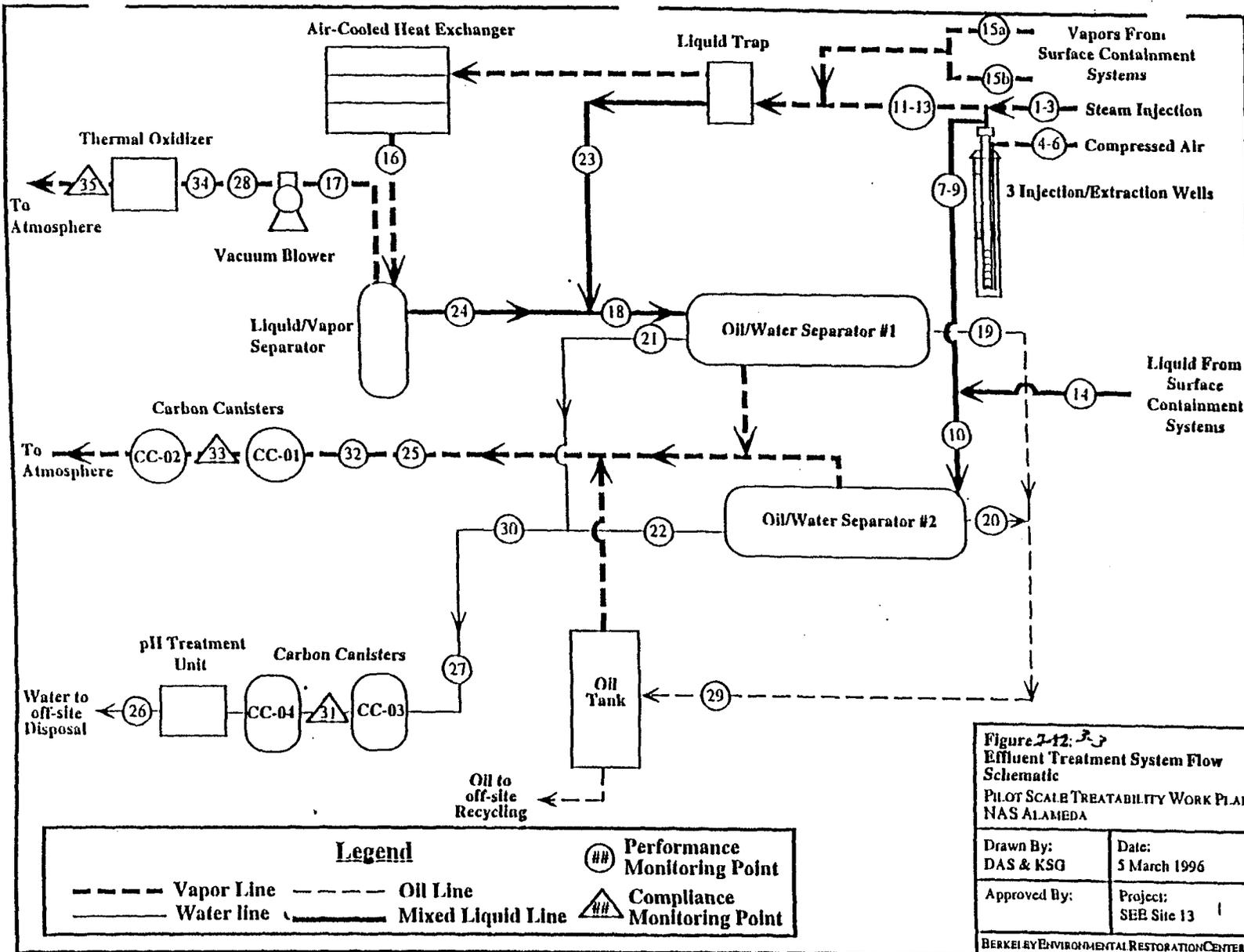
**Figure 3-1:
Site Location Map**
**PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA**

Drawn By: MFI/SWL	Date: 10 November 1995
Approved By:	Project: SHE Site 13

BERKELEY ENVIRONMENTAL RESTORATION CENTER

FIGURE 3-2
SITE 13 MAP





EFFLUENT TREATMENT SYSTEM FLOW SCHEMATIC

FIGURE 3-3

Figure 3-3: Effluent Treatment System Flow Schematic
 PILOT SCALE TREATABILITY WORK PLAN
 NAS ALAMEDA

Drawn By: DAS & KSG	Date: 5 March 1996
Approved By:	Project: SEB Site 13
BERKELEY ENVIRONMENTAL RESTORATION CENTER	

FIGURE 3-4
THREE-WELL TREATABILITY
TEST WELL LAYOUT

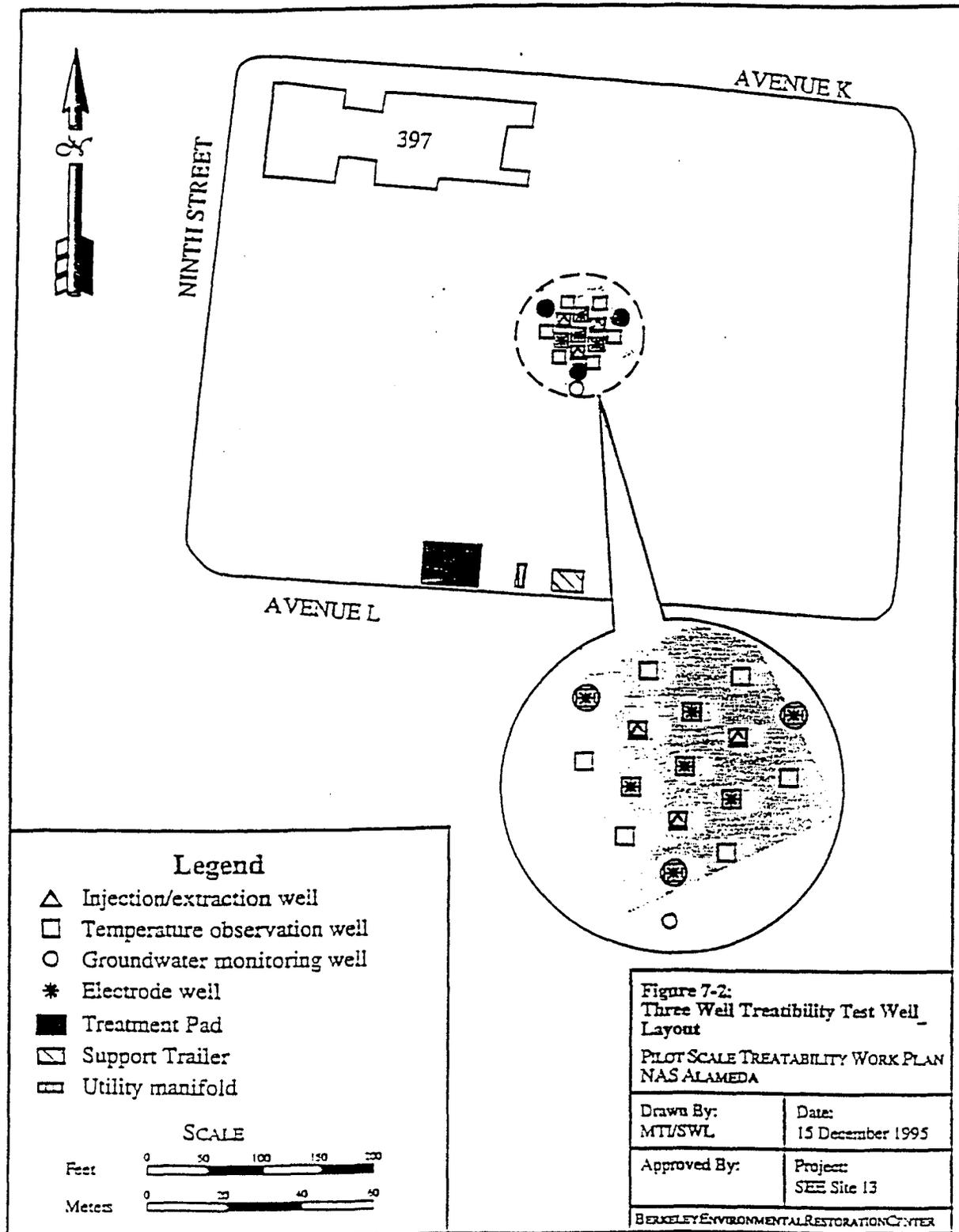


FIGURE 3-5
Pesticide Health and Safety Profile
Site 13
Alameda, NAS

Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
1,2,3,4,5,6-Hexachloro- cyclohexane (Beta-BHC)	0.5 mg/m ³ (Germany)	N/A	N/A	N/A	Unk	Suspect liver CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
4.4'-DDD	N/A	N/A	N/A	N/A	Unk	Suspect liver CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
4.4'-DDE	N/A	N/A	N/A	N/A	Unk	Suspect liver CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
4.4'-DDT	1 mg/m ³	N/A	1 mg/m ³	N/A	500 mg/m ³	Chronic neurotoxin Suspect CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Heptachlor epoxide	N/A	N/A	N/A	N/A	Unk	Chronic hepatotoxin Suspect liver CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Toxaphene (chlorinated camphene)	0.5 mg/m ³	N/A	0.5 mg/m ³	1 mg/m ³ ceiling	200 mg/m ³	Convulsant Suspect liver CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.

FIGURE 3-5
Metals Health and Safety Profile
Site 13
Alameda, NAS

Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
Arsenic	0.5 mg/m ³ as As or as inorganic compounds	NA	0.01 ppm	NA	5 mg/m ³ as As as inorganic compounds	Skin and mucous membrane irritant Human CNG Repro Tox	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Barium	0.5 mg/m ³	NA	0.5 mg/m ³	NA	1,100 mg/m ³	Low toxicity irritant	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Beryllium	0.002 mg/m ³ 0.005 mg/m ³ Ceiling	NA	0.002 mg/m ³	NA	4 mg/m ³	Skin and mucous membrane irritant Suspect lung CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Chromium	1.0 mg/m ³ (Cr) 0.5 mg/m ³ (CrIII) 0.001 mg/m ³ (Cr VI)	NA	0.5 mg/m ³ (Cr) 0.5 mg/m ³ (CrIII) 0.05 mg/m ³ (Cr VI)	NA	250 mg/m ³ as Cr	Cr and Cr III. low toxicity Cr IV skin and respiratory irritants Suspect lung CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Cobalt	0.1 mg/m ³	NA	0.02 mg/m ³	NA	20 mg/m ³ as Co	Skin and respiratory sensitizer	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Copper	1 mg/m ³ as Dust 0.1 mg/m ³ as Fume	NA	1.0 mg/m ³	NA	100 mg/m ³ as Cu	Low toxicity	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Lead	0.05 mg/m ³	NA	0.05 mg/m ³	NA	100 mg/m ³	Systemically toxic. Affects CNS, nervous system, kidneys and repro system Suspect kidney CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.

CNS stands for central nervous system (brain), CNG for carcinogen.

FIGURE 3-5
Metals Health and Safety Profile
Site 13
Alameda, NAS

Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
Manganese	5 mg/m ³	NA	0.2 mg/m ³	NA	500 mg/m ³	Chronic CNS toxin	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Nickel	1 mg/m ³	NA	1 mg/m ³	NA	10 mg/m ³	Skin sensitizer Suspect lung CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Selenium	0.2 mg/m ³	NA	0.2 mg/m ³	NA	1 mg/m ³ as Se	Skin, mucous membrane and eye irritant. Chronic CNS toxin. Causes hair loss	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Vanadium	0.1 mg/m ³ as V ₂ O ₅ fume 0.5 mg/m ³ as V ₂ O ₅ dust	NA	0.05 mg/m ³ as V ₂ O ₅	NA	35 mg/m ³ as V	Eye and respiratory irritant	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Zinc	15 mg/m ³ as ZnO Total Dust 5 mg/m ³ as ZnO Respir Fract	NA	10 mg/m ³	NA	N/A	Low toxicity	Odor Thresh: Unk. Eye Irr Lvl: Unk.

FIGURE 3-5
SVOC Health and Safety Profile
Site 13
Alameda, NAS

Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
Anthracene	N/A	N/A	N/A	N/A	Unk.	See Note 1	Odor Thresh: Unk. Eye Irr Lvl: Unk.
1,2-Benzanthracene (Benzo(a)anthracene)	N/A	N/A	N/A	N/A	Unk.	See Note 1 Suspect CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Benzo(a)pyrene (Benzo(d,e,f)chrysene)	N/A	N/A	N/A	N/A	Unk.	See Note 1 Suspect CNG Suspect MTG Suspect TERA	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Benz(e)acephenanthrylene (Benzo(b)fluoranthene)	N/A	N/A	N/A	N/A	Unk.	See Note 1 Suspect CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Benzo(g,h,i)perylene	N/A	N/A	N/A	N/A	Unk.	See Note 1	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Benzo(k)fluoranthene	N/A	N/A	N/A	N/A	Unk.	See Note 1 Suspect CNG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Chrysene (Benzo(a)phenanthrene)	0.2 mg/m ³	N/A	None	N/A	Unk.	See Note 1 Suspect CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Fluoranthene	N/A	N/A	N/A	N/A	Unk.	See Note 1 Suspect CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.

CNG stands for carcinogen, MTG for mutagen, TERA for teratogenic agent.

Note 1: There is limited tox information on each individual polyaromatic hydrocarbon. Collectively, they are known or suspect lung, kidney and skin CNS. They may also cause skin photosensitization. Except for naphthalene, PAHs generally have low acute toxicity.

SVOC Health and Safety Profile
 Site 13
 Alameda, NAS

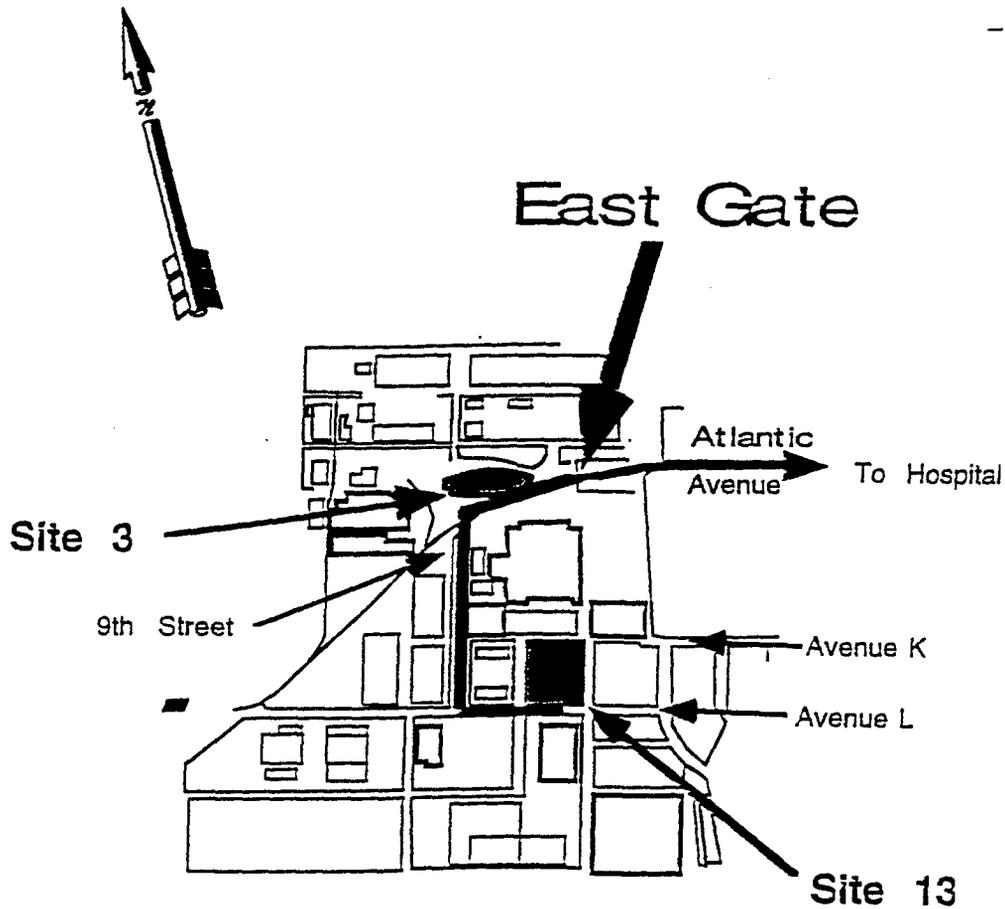
Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
Fluorene	N/A	N/A	N/A	N/A	Unk.	See Note 1	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Indeno(1,2,3-cd)pyrene	N/A	N/A	N/A	N/A	Unk.	See Note 1	Odor Thresh: Unk. Eye Irr Lvl: Unk.
2-Methylnaphthalene (Beta-Methylnaphthalene)	N/A	N/A	N/A	N/A	Unk.		Odor Thresh: Unk. Eye Irr Lvl: Unk.
Naphthalene	10 ppm	N/A	10 ppm	15 ppm	250 ppm	May cause headaches, nausea and confusion. Also an eye and respiratory irritant. May cause hemolysis and kidney damage	Odor Thresh: Unk. Eye Irr Lvl: 15 ppm.
N-Nitrosodiphenylamine	N/A	N/A	N/A	N/A	Unk.	Suspect bladder CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Pentachlorophenol	0.5 mg/m ³	N/A	0.5 mg/m ³	N/A	2.5 mg/m ³	Eye and respiratory irritant. Kidney and liver toxin.	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Phenanthrene	N/A	N/A	0.2 mg/m ³	N/A	700 mg/m ³	See Note 1 Suspect CNG Suspect MTG	Odor Thresh: Unk. Eye Irr Lvl: Unk.
Pyrene	0.2 mg/m ³	N/A	N/A	N/A	Unk.	See Note 1	Odor Thresh: Unk. Eye Irr Lvl: Unk.

FIGURE 5
 VOC Health and Safety Profile
 Site 13
 Alameda, NAS

Contaminant (Synonyms)	OSHA PEL		ACGIH TLV		IDLH	TOX SUMMARY	WARNING PROPERTIES
	8-HR TWA	15-MIN STEL	8-HR TWA	15-MIN STEL			
Benzene	1 ppm	5 ppm	0.3 ppm	N/A	500 ppm	CNS depressant (headaches, nausea and confusion). Leukemogenic agent. Suspect TERA	Odor Thresh: 12 ppm Eye Irr Lvl: 3,000 ppm
1,2-Dichloroethene	200 ppm	N/A	200 ppm	N/A	1,000 ppm	CNS depressant (headaches, nausea and confusion). May Cause liver and kidney damage	Odor Thresh: 17 ppm Eye Irr Lvl: Unk.
Ethylbenzene	100 ppm	125 ppm	100 ppm	125 ppm	800 ppm	Skin and respiratory irritant	Odor Thresh: 2.3 ppm Eye Irr Lvl: 1,000 ppm
Methylene Chloride (Dichloromethane)	500 ppm	1000 ppm	50 ppm	500 ppm	2,300 ppm	CNS depressant. Skin and respiratory irritant. Suspect liver CNG	Odor Thresh: 250 ppm Eye Irr Lvl: Unk.
Methyl Ethyl Ketone (2-Butanone)	200 ppm	N/A	200 ppm	300 ppm	3000 ppm	Skin, eye and respiratory irritant. May cause neuropathy. Suspect TERA	Odor Thresh: 5 ppm Eye Irr Lvl: 200 ppm
Toluene (Methyl benzene)	200 ppm	300 ppm	50 ppm	N/A	500 ppm	CNS depressant. Repro Tox	Odor Thresh: 2.9 ppm Eye Irr Lvl: 300-400 ppm
Xylene	100 ppm	150 ppm	100 ppm	150 ppm	900 ppm	Skin, eye and respiratory irritant.	Odor Thresh: 1.1 ppm Eye Irr Lvl: 200 ppm

CNG stands for carcinogen, MTG for mutagen, TERA for teratogenic agent, CNS for central nervous system (brain).

**FIGURE 10-6
EMERGENCY ROUTE TO EAST GATE**



Evacuate Through East Gate

From Site 3 to East Gate

1. Proceed a few hundred feet east on Atlantic Avenue to guard house.

From Site 13 to East Gate

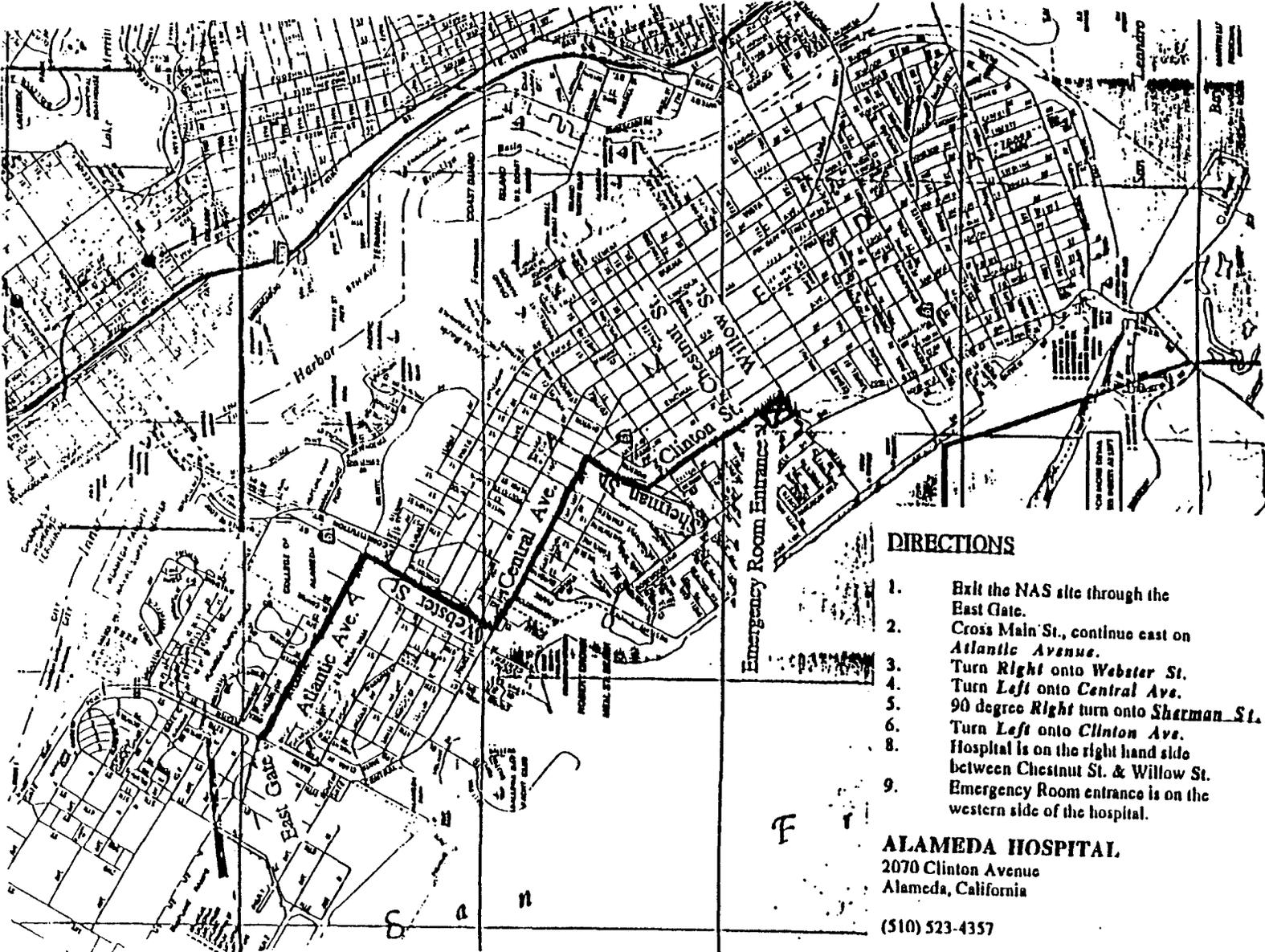
1. Proceed west on Avenue L 1 block to 9th Street.
2. Turn right on 9th Street and proceed 3 blocks north to Atlantic Avenue.
3. Turn right on Atlantic Avenue and proceed a few hundred feet east to guard house.

Figure 2-1:
Emergency Route to East Gate
TREATABILITY STUDY WORK PLAN
NAS ALAMEDA

Drawn By: WJS Date: 9 February 1996

Approved By: _____ Project: Intrinsic Bioremediation

BERKELEY ENVIRONMENTAL RESTORATION CENTER



DIRECTIONS

1. Exit the NAS site through the East Gate.
2. Cross Main St., continue east on Atlantic Avenue.
3. Turn Right onto Webster St.
4. Turn Left onto Central Ave.
5. 90 degree Right turn onto Sherman St.
6. Turn Left onto Clinton Ave.
8. Hospital is on the right hand side between Chestnut St. & Willow St.
9. Emergency Room entrance is on the western side of the hospital.

ALAMEDA HOSPITAL.
2070 Clinton Avenue
Alameda, California

(510) 523-4357

FIGURE 10-7
EMERGENCY HOSPITAL ROUTE

ATTACHMENT 3-1

LOCKOUT/TAGOUT FORM

(Steam, Water and Fluid Lines)

Job: _____

Device: _____

Location: _____

Authorized Person: _____

PREPARATION FOR SHUTDOWN

1. Determine line types and shutoff location.
2. Determine if there is more than one energy source.
2. Determine magnitude of compressed air or gas.
4. Notify affected employees in the area that equipment will be under lockout for maintenance.
5. Disconnect and shutoff main steam, water or fluid lines to equipment.

LOCKOUT/TAGOUT

6. Lock and tag main supply (i.e. chaining through valve handle with lock) in the OFF position with a bleeder open on the load side.
7. Drain fluids from shutoff valves to equipment.
8. Repair equipment.

RETURN TO SERVICE

9. Be sure all connections are made and any unused tools and equipment are removed.
10. Remove lock if necessary to verify machine is repaired. The maintenance employee cannot leave the immediate area, while verifying the machine is repaired.
11. Remove tag from machine.
12. Notify employees in the area that the equipment is available.

Authorized Person: _____ Site Supervisor: _____

ATTACHMENT 4-3

TAILGATE HEALTH AND SAFETY FORM		
Site Supervisor:		SHSO:
Meeting Held By:		Date:
SUMMARY OF WORK LOCATION AND ACTIVITIES		
<i>Site Hazards Evaluation</i>	<i>Circle</i>	<i>Circle</i>
Toxic Vapors	Yes	No
Explosivity	Yes	No
Equipment	Yes	No
Steam	Yes	No
Physical Hazards (<i>Specify</i>)	Yes	No
Personal Protective Equipment (<i>Specify</i>)	Yes	No
Decontamination Procedures (<i>Specify</i>)	Yes	No
EMERGENCY INFORMATION		
First Aid Location	Yes	No
Hospital Route Location	Yes	No
Emergency phone number and phone location	Yes	No
SIGNATURES		
Team Member	Signature	Date

ATTACHMENT 7-4

FIELD EQUIPMENT LIST

This is a list of required equipment for use on site. This list may be modified according to site conditions and activities.

Personal Protective Equipment (Mobilization and general construction)

- Hard hat
- Safety glasses with side shields
- Long sleeved shirts
- Cotton or leather gloves
- Foot wear with steel toe and shank
- Hearing protection (if noise levels exceed 85 dBA)
- Traffic vests

Personal Protective Equipment (Drilling and work with site contaminants)

- Hard hat
- Safety glasses with side shields
- Polyethylene coated Tyvek suits
- Nitrile gloves with surgical inner gloves
- PVC or neoprene boots with steel toe and shank
- Full face respirators with OV/HEPA cartridges (See Section 9 of HSP)

Decontamination Equipment

- plastic liners
- six mil polyethylene drop cloths
- containers (20-30 gallons)
- decontamination solution or detergent water
- pressurized spray unit (Hudson sprayer)
- water
- 5 to 6 long-handle, soft-bristle scrub brushes
- bench, or other seating
- wash basins or buckets
- hand soap, wash basins and towels

MONITORING EQUIPMENT:

- PID with 10.2 eV lamp
- CGI/Oxygen meter
- Hydrogen sulfide monitor
- MIE PDM-3 MINIRAM aerosol monitor
- Calibration gases and equipment

MISCELLANEOUS EQUIPMENT:

- First aid kit
- Eyewash and/or shower
- Absorbent material
- Fire extinguishers (10 ABC rated)
- Hand-held alarm horns

ATTACHMENT 10-5
ACCIDENT/INCIDENT REPORT FORM

ATG ACCIDENT/INCIDENT REPORT FORM

(Sheet 1 of 2)

SITE SUPERINTENDENT REPORT OF ACCIDENT/INJURY
(USE FOR ON-SITE ACCIDENTS OR EXPOSURES ONLY)

To: Michael Connor., CIH,
ATG Certified Industrial Hygienist

From: ATG's Site Health and Safety Officer

Telephone Number ____ / ____ - ____

Project No.: _____

Site Name: _____ Exact Location of Accident/Injury _____

Name of Injured/Ill Employee(s): _____

Date and Time of Accident/Injury: _____

Description of Accident/Injury: _____

Nature of Illness or Injury and Part of Body Involved: _____

Probable Disability (check one):

- Fatal
- Lost work days (No. of days: ____)
- Restricted activity (No. of days: ____)
- First aid only

ATTACHMENT 10-5
ACCIDENT/INCIDENT REPORT FORM (CONT'D)

ATG ACCIDENT/INCIDENT REPORT FORM

(Sheet 2 of 2)

Corrective Action(s) Taken by Reporting Unit:

Corrective Action That Remains to be Taken (By whom and by when):

ATG Project Manager: _____

ATG Site Superintendent: _____

Signature: _____

Date: _____

cc: Mark Freiberg, UCB Program CIH

APPENDIX I
ENVIRONMENTAL PROTECTION PLAN

APPENDIX I

Environmental Protection Plan

There are no buildings on this five-acre site, and the surface is mostly fill materials with a sparse presence of grasses and weeds. There does not appear to be any burrows, nests, or scat to indicate the presence of any on-site fauna. Because this is a demonstration project site, it will be up to the discretion of the EFA-West to restore and/or reseed this area.

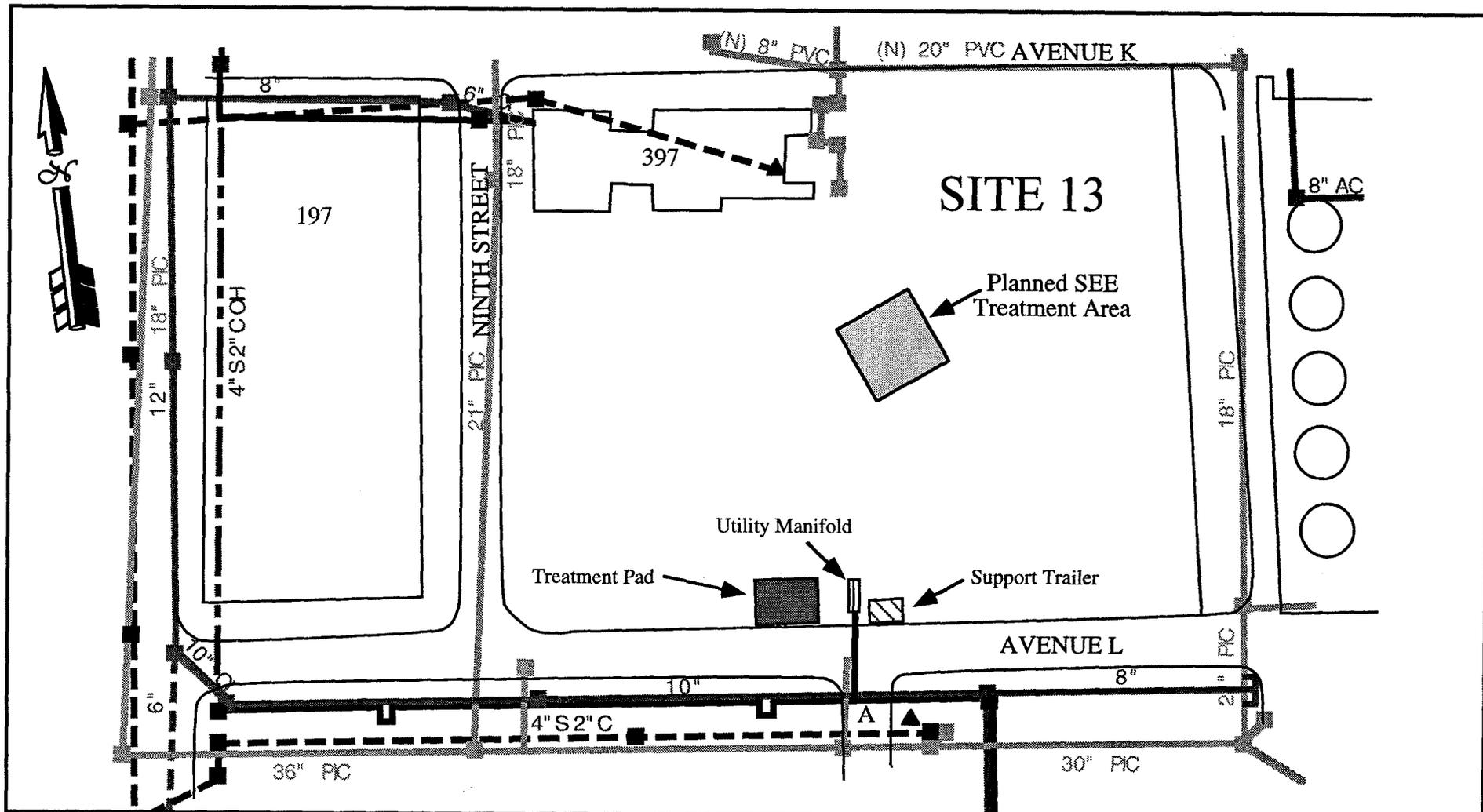
Before work activities commence, a standard six-foot cyclone fence will be installed around the perimeter of Site 13 and an exclusionary zone will be identified and marked around the entrance of the site to protect project workers as well as people walking in this area. A 50-foot by 40-foot concrete bermed pad was recently installed adjacent to Avenue L for waste stream treatment and collection from the vapor and liquid extraction system. The steam manifold, which is part of the Steam Enhanced Extraction (SEE) system (a contained system), was also recently installed by the NAS Alameda Department of Public Works directly adjacent to the concrete pad. Additionally, a trailer supporting the contractor's work force, will be placed within the fenced area.

Fugitive dust emissions during grading operations will be controlled by light watering of affected areas as directed by the construction site superintendent or as directed by the Resident Officer In Charge of Construction (ROICC) based upon wind velocity and site observations. The graded surfaces will be covered with two types of surface covering (plastic and corrugated metal) as outlined in the Work Plan. The grading of the test site will provide a sloped surface of one-quarter-inch rise per foot of run for proper drainage of the surface covering. Runoff will be drained via a pipe located in the trench at the base of the surface covering and drained into a sump pump. The runoff will then be pumped periodically at intervals and end up at the waste stream treatment and collection pad. After the injection/extraction wells have been installed, any residual soil from the soil borings will be placed in roll-off bins or drums and covered as necessary.

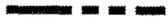
The locations of known underground utilities at Site 13 (provided by EFA-West) are shown in Figure 1. A survey to locate all utilities should be conducted before the work commences as it is reported that there is an active water line (PVC pipe) transversing the site. Therefore, any kind of environmental impact from this water line affecting the site condition is premature until all information has been gathered to make an accurate assessment of the situation. The locations of all utilities (steam, electric power line, sanitary, and storm) will be clearly marked with either paint, caution flags, or tape on stakes or temporary barricades, as appropriate, to the activities at the location and the element of risk. Existing water, sanitary, and storm sewer lines will not be removed or rerouted nor will any associated vaults or drains be removed or interfered with.

The existing above-ground power lines (adjacent to Avenue L) will remain intact, and the contractors will use this power source for the two on-site trailers. Should unanticipated rerouting or removal of utilities be considered necessary during this project, all such activities will proceed only with the knowledge and approval of the ROICC and the Contracting Officer.

Groundwater monitoring wells at the site will be protected during the three-well treatability test. As necessary, each groundwater monitoring well will be completely sealed with plastic, or a corrugated metal cover will be placed over the well head. Each location will be marked with grade stakes and caution flags.



LEGEND

-  UNDERGROUND STEAM LINE
-  OVERHEAD STEAM LINE
-  ELECTRIC POWER LINE
-  SANITARY SEWER LINE
-  STORM DRAIN LINE
-  TREATMENT PAD
-  SUPPORT TRAILER
-  UTILITY MANIFOLD

SCALE

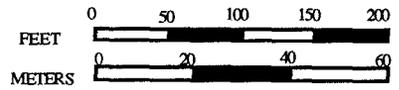


Figure 1: Utility System	
PILOT SCALE TREATABILITY WORK PLAN NAS ALAMEDA	
Drawn By: YHF	Date: 15 December 1995
Approved By: <i>MLH</i>	Project: SEE Site 13
BERKELEY ENVIRONMENTAL RESTORATION CENTER	

APPENDIX J
SUPPLEMENTAL INFORMATION

**AN ANALYSIS OF OPTIMAL CYCLING TIME AND ULTIMATE
CHLORINATED HYDROCARBON REMOVAL FROM HETEROGENEOUS
MEDIA USING CYCLIC STEAM INJECTION**

By

Michael T. Itamura
Graduate Student Researcher

Kent S. Udell
Professor

Berkeley Environmental Restoration Center
Department of Mechanical Engineering
University of California, Berkeley

Abstract

A numerical and theoretical study of chlorinated hydrocarbon removal from porous media using cyclic steam injection is presented. The porous medium modeled is a high permeability fracture, adjacent to a thick, contaminated low permeability zone. Two-dimensional computer simulations were run for different initial saturations of TCE and PCE until aqueous phase concentration levels were below 1 ppb ($\mu\text{g}/\text{kg}$). The two-dimensional simulations provided interesting details of the steam-water contaminant redistribution and volatilization rates during various steam cycling modes. To generalize the results of numerical simulations, theory is developed to estimate optimal cycle times and the effectiveness of cyclic steam injection in reducing aqueous concentrations to drinking water standards. The analytic predictions of optimal cycle times and ultimate rates of contaminant concentration reduction compared well with those of the numerical simulations.

To be presented at the 1995 ASME International Mechanical Engineering Congress and Exposition, San Francisco, California, November 12-17, 1995.

Nomenclature

C	concentration [kg/m ³]
c_p	constant-pressure specific heat [J/kg-K]
Fo	Fourier Number []
H	Henry's constant [Pa-m ³ /kg]
\bar{H}	dimensionless Henry's constant []
h_{ig}	heat of vaporization [J/kg]
k	permeability [m ²]
k_r	relative permeability []
m	mass [kg]
P	pressure [Pa]
R	gas constant [J/kg-K]
s_w	water saturation []
T	temperature [K]
t	time [sec]
X	mass fraction []
ϕ	porosity []
Γ	mass fraction ratio of i in water phase to i in vapor phase []
λ	root to fourier series []
λ_{eff}	effective thermal conductivity [J/m-K]
μ	dynamic viscosity [N-sec/m ²]
ρ	density [kg/m ³]
Subscripts	
i	contaminant I
o	original state
s	surface
v	vapor phase
w	water phase
∞	at infinite time

Introduction

Conventional methods used for cleaning up *in situ* subsurface spills of Dense Non-Aqueous Phase Liquids (DNAPL's) include vacuum extraction for the vadose zone and ground water pumping for regions below the water table. Unfortunately, these conventional technologies tend to become ineffective for contaminants not found in pumped fluid flow paths leading to the extraction wells. Since many DNAPL's are only minimally soluble in water and the aqueous phase molecular diffusivities are so low, immobile DNAPL's located below the water table and in large low permeability zones are almost impossible to remove within a lifetime. Since their paths of downward migration of DNAPL's are usually different than the fractures supporting fluid flow during pumping, DNAPL contamination of fractured bedrock or clay is a particularly problematic situation. The technology of steam enhanced extraction [1], where steam is injected into the subsurface to heat the contaminated regions and either evaporate or displace separate phase contaminants, offers hope that such environmental hazards can finally be cleaned up.

Background

Steam enhanced extraction with cyclic steam injection for use in removing volatile and semi-volatile contaminants from the subsurface has been applied to two field sites. The first was conducted on a pilot scale in San Jose in the summer of 1988. After a period of 140 hours of constant-rate steam injection, a series of vacuum extraction and steam injection periods followed. The depressurization periods were on the order of only one to three hours in duration but showed promise as a method of removing contaminants from heated low permeability regions [2].

At the Lawrence Livermore National Laboratory, steam enhanced extraction was used at full-scale to clean-up a gasoline spill. There were two high permeability zones, one above and the other below the water table. Steam was injected in two different passes. The first steam injection period lasted 35 days. At the end of the first steam pass, recovery

rates were averaging 45 gallons per day. Three months later, after a higher capacity effluent waste treatment system had been installed, recovery rates increased to over 200 gallons per day. Two weeks into the second pass of steam injection, with the recovery rates having dropped to 80 gallons per day, steam was turned off while a vacuum was still pulled at the extraction well. The recovery rate peaked at 130 gallons per day two days later and then dropped to 110 gallons per day two days after that. When steam was turned on again at this point, recovery rates dropped off to 50 gallons per day. This cycling of steam on and off was done one more time with similar results [3].

The mechanisms for the removal of a DNAPL in a porous media using steam injection/vacuum extraction have been identified as a piston-like displacement of liquids and a thermally enhanced evaporation/advection mechanisms [4,5]. Cyclic steam injection after steam breakthrough introduces another mechanism; *in situ* boiling of heated liquids in and around the steam zone [1]. This third mechanism is important should there be significant permeability differences in the layers composing the contaminated region. In both laboratory experiments and field studies, steam has been found to preferentially enter the high permeability regions, initially bypassing contaminated low permeability zones. Thicker low-permeability regions take a longer time for the steam to heat, thus increasing the time necessary for steam injection to clean out the contaminants [2,3,6,7]. Similarly, for a fractured bedrock system, steam should be able to remove contaminants from accessible fractures relatively quickly. However, once sufficient time has passed for conduction to heat the low permeability zones, depressurization provides a means to remove contaminants from the inaccessible fractures and the adjacent bulk bedrock.

A schematic of a typical situation encountered during the latter stages of steam enhanced extraction operations is shown in Figure 1. Here the liquid contaminant has been removed from the high permeability zones above and below the contaminated low permeability layer. Conductive heat transfer, augmented by some enthalpy flux carried with any steam that might flow into the low permeability zone, will eventually heat the layer

to temperatures near those of the adjacent high permeability zones. During this time, compounds with boiling points lower than that of water will boil from the medium, leaving residual contamination in the aqueous phase and adsorbed to the solid surfaces. For negligible fluid flow through the low permeability region, recovery would be limited by diffusion. DNAPLs' with boiling points greater than that of water will be particularly difficult to remove since the mass transfer rates would remain low and the residual liquid contaminant mass remains high. However, cyclic steam injection following steam breakthrough increases recovery rates since liquid water and separate phase contaminant will boil when the system is de-pressurized. The energy required for the phase change comes from the solid matrix and liquid during the cooling associated with the de-pressurization of the steam-water system. Consider the thermodynamics involved in bringing an otherwise closed reservoir system from steam conditions (115°C) to that of a 50 kPa vacuum. The temperature corresponding to the equilibrium vapor pressure of water at a 50 kPa vacuum is 82°C. If the reservoir temperature is at 115°C when the 50 kPa vacuum is applied, then a 33°C temperature drop must occur before a uniform pressure distribution can be established. Depending of the heat capacity of the solid matrix material, the porosity and the water volumetric fraction of the pore space, about 10% of the liquid water present must evaporate to satisfy the energy and mass balances. This evaporation will continue to occur uniformly until the temperature of the reservoir has dropped to 82°C, cooler if any air is present. A large pressure gradient caused by the evaporation can form in the lower permeability zones which can drive out mobile liquid water and contaminant from otherwise inaccessible zones into the higher permeability zones leading to extraction wells. After the system has been de-pressurized and partially de-watered, steam injected in latter cycles will clear out contaminant that had migrated into the higher permeability zones, and re-charge the energy released during the previous depressurization cycle. The decrease in the water saturation resulting from de-pressurization also increases the steam permeability,

providing for a more effective heating of the lower permeability zones during subsequent steam injection cycles.

Numerical Simulation

Simulations of the effectiveness of constant rate steam injection and cyclic injection were carried out using a coupled air-water heat and mass transfer computer code originally developed by Preuss [8], and extended to non-isothermal transport of multiple component liquid contaminants by Adenekan and Patzek [9]. The code structure was further modified to improve robustness and allow simulations using various computational platforms. The code can model three-dimensional multi-phase transport of multi-component organic contaminants in the subsurface in response to constant or cyclic steam injection.

Simulations were run for two different contaminants and with two different initial saturations. Both TCE and PCE simulations were run at uniform initial saturations of 30% and 85%. The simulations were run until the remaining hydrocarbon concentrations were less than 10^{-10} of the initial concentration.

The system considered was a two-dimensional region, 40 cm wide, and 80.2 cm high, divided into 68 control volumes (see Figure 2). The control volumes of the top row were 0.2 cm high and 10 cm wide and the node control volumes in the lower sixteen rows were 5 cm high and 10 cm wide. The permeability of the top row of nodes, roughly corresponding to a fracture, was $45 \times 10^{-12} \text{ m}^2$ and the bulk permeability of the lower rows of nodes was $0.35 \times 10^{-12} \text{ m}^2$. The permeability was isotropic within each grid block. The left-most block of the high permeability zone contained the injection well and the right-most high permeability node contained the extraction well. All other boundaries were closed and treated as adiabatic (perfectly insulated). The steam injected at the injection node was held at 103°C , 115 kPa, and 90% quality. The extraction well was maintained at a 61 kPa vacuum. Gravity was neglected for these simulations.

The computed NAPL saturation, temperature, and water saturation fields are plotted in Figures 3-5. The white color in the NAPL saturations represent zero saturation and the

light gray in the zero time image represents the initial 30% TCE saturation. As the steam enters the system, a region cleared of TCE develops in the upper right corner and progresses downward. Ahead of the clean zone, a band of high saturation of TCE develops. The maximum saturation in this band varies with time from 70% to 85%. At 50 hours, the high saturation band has propagated to the far end of the system. At this point in time, the steam is migrating into the lower permeability region, evaporating the TCE, and carrying it out to the extraction face.

The temperature plots are very similar in shape to the concentration plots. The region that has been cleared of TCE is the hottest. There is a sharp temperature gradient, corresponding to the steam condensation front, in the region that is occupied by the maximum TCE saturation wave in the system. The water saturation plots clearly show that water saturation maxima is located at the steam condensation front.

The TCE saturation at three different nodes is shown in Figure 6. The nodes are labeled A, B, and C in Figure 2. For Node A, located in a low permeability zone two rows from the high permeability nodes, the NAPL-phase saturation drops to zero within the first hour of the simulation. For Node B, located in the middle of the low permeability zone, the NAPL-phase saturation rises quickly to 83% at two hours after the start of steam injection and then drops to zero over the next 6 hours. For Node C, found at the bottom of the low permeability zone, the TCE remains at the initial 30% saturation for almost 15 hours before rising to a maximum saturation of 78% at 27 hours. The TCE is slowly removed after that; the separate phase TCE finally evaporating at the 76 hour mark.

The temperature profiles for those same three nodes are shown in Figure 7. As expected, the temperature of Node A changes almost immediately to that of saturated steam. The temperature of the Node B rises to 88°C after the separate phase TCE completely evaporates from that node. The small oscillations in the temperature histories are due to numerical instabilities encountered when the rows of nodes surrounding that particular node experience a high rate of TCE evaporation. The temperature of Node C increases to

near 70°C after 28 hours and remains constant for almost 50 hours. It levels off at 70°C because the pressure at that node corresponds to the vapor pressure of TCE at 70°C. After the liquid TCE is gone from the node, the temperature of that node finally begins to rise again. The temperature of the bottom node does not reach 96°C until the adjacent bottom row nodes are void of liquid TCE.

Figure 8 shows the water saturation for Nodes A, B, and C. Node A maintains an almost uniform water saturation of 13% throughout the simulation. The water saturation for Node B varies significantly with time. The oscillation at early time seems to be a numerical artifact of the rapidly changing NAPL phase at those times. As the steam front passes node B, the saturation maintains a steady 30% until dropping to near 13% as the NAPL phase completely disappears in the far end of the system. Node C maintains the initial water saturation of 10% for most of the simulation, only dropping a few percent when the steam front approached the node.

Cyclic Steaming

For an initial saturation of 30% TCE, 60% air, and 10% water, removal of 99% of the initial TCE was predicted by continuous steam injection in 96 hours. Subsequent predictions of cyclic steaming were begun at 22 hours after the start of steam injection. To accomplish this using the simulator, the source term for the steam was removed but the vacuum at the extraction node was maintained. The amount of TCE remaining in the system is plotted in Figure 9 for continuous steam injection and for three different cycle times. At the start of the first vacuum cycle, the TCE recovery rate, shown in Figure 10, immediately rose by a factor of 3.5 over the next hour. At ten hours into this vacuum cycle, the recovery rates had dropped back down to the level that it was just before the start of the vacuum cycle. After 22 hours of vacuum, the recovery rates had dropped to 1/3 of the rate of the continuous steam case at that time, but the total TCE mass removed up to that point was 78% versus 70% for continuous steam. At the end of this vacuum cycle, the

system temperature was almost uniformly 50°C. Once steam was re-injected after 44 hours, the recovery rates initially dropped off to zero. At this time, most of the steam was going into re-heating and repressurizing the system. Four hours after the re-start of steam injection, the TCE recovery rates began to increase rapidly; approaching the rates that were seen during the steam only run. The second 22-hour vacuum cycle removed all of the remaining separate phase TCE. The average temperature of the system after the second vacuum cycle was 63°C. Compared with the steam only case, it took 98% of total clean-up time but only 58% of steam injection time. The Fourier number (equation 6) for a 22 hour cycle is 3.64.

When shorter 10 hour ($Fo = 1.65$) and 6 hour ($Fo = 0.99$) cycle times were simulated, the total clean-up time was reduced considerably. As before, the steam/vacuum cycling began after the initial 22 hours of continuous steam simulation. For the 10 hour cycle time, the separate phase TCE was removed at 65 hours -- using only 68% of the total time used by steam only and 44% of the steam time used by the 22 hour cycle case. Using the cycle time of 6 hours, the savings are just a little bit better -- shaving an additional 9 hours off the total time and 6 hours off the steam time required for clean-up to 1 part per billion.

The NAPL saturation, temperature, and water saturations during the first three hours of vacuum extraction and then the first three hours of the re-start of steam injection for a 10 hour cycle time are plotted in Figures 11-13. In Figure 11a, the start of vacuum extraction (22 hours), the TCE spreads from the bottom of the system out towards the extraction well. When steam is injected again (32 hours) as shown in Figure 11b, the remaining separate phase TCE is partially pushed back into the system. There is however, a noticeable decrease in the overall saturation between the system at the start of the vacuum cycle and three hours into the next steam injection cycle (35 hours).

Figure 12 shows how quickly the temperature in the system comes to equilibrium as the steam is turned off and then on again. At 25 hours, the temperature of the system is

almost uniform and at 35 hours, the temperature field is almost identical to the one at 22 hours. The water saturations show a similar pattern to that of the TCE concentrations in that the saturation wave is removed during the first few hours of vacuum extraction and it re-forms during the first few hours of steam injection.

The TCE phase saturations for the 10 hour cycle time at the three nodes discussed earlier are plotted in Figure 14. The big difference between the cycle phase saturations and those of Figure 6 is that the saturation only peaks at 50% (vs. 78%) and is removed completely at 68 hours instead of 76 hours. The dip in the TCE saturation caused by the vacuum extraction is easily seen at the 22, 42, and 62 hour times at Node C. The temperature of the three nodes are plotted in Figure 15. The temperatures for Nodes A and B drop quickly when vacuum extraction begins and rise when steam injection begins again. The temperature maxima are fairly constant but the minimum temperature at the end of the vacuum cycles rise during each successive cycle. Node C takes much longer to get rise to steam temperatures but this is expected as the presence of the highly volatile liquid TCE remains at that node until the third vacuum cycle. After this time, the temperature at that node rises to nearly 100°C during the following steam injection period.

Additional computer runs were performed for an initial concentration of TCE of 85%. Similar results were achieved compared with the earlier series of TCE runs. Since the amount of TCE in the system was much higher, it is not surprising that the total time for removal of separate phase TCE took 180 hours. This time, a cycle time of 22 hours saved 50 hours of total clean-up time and 55 hours of steam time. Savings of even more time was achieved when a cycle time of 10 hours was used.

PCE, which has a boiling temperature of 121°C takes much longer to remove than the more volatile TCE. For 30% initial concentration of contaminant, the simulations predicted 162 hours to remove 99% of the PCE and 184 hours to reduce residual contamination levels to the 1 ppb level. Using a 44-hour cycle time, the time to remove 99% of the PCE increased to 195 hours and the time to the 1 ppb level increased to 221

hours but there still was a savings of 52 hours of total steam time over continuous steam. Table 1 shows the relative economics for all four systems and cycle times considered.

Theoretical Analysis of Optimal Cycle Time

The thermodynamics of cyclic steam injection can be easily modeled in a one-dimensional framework. Of interest here are the optimal cycle time and the rates at which the contaminant can be removed by cyclical depressurization. The time scale for evaporation or condensation process to occur can be estimated from the coupling of the flow and energy transport equations[10]. Starting with Darcy's Law

$$\dot{m}_v = -\rho_v \frac{kk_{rv}}{\mu_v} \frac{\partial P}{\partial x}, \quad (1)$$

an energy balance,

$$\frac{\partial}{\partial x} \left(\lambda \frac{\partial T}{\partial x} \right) - \frac{\partial}{\partial x} (\dot{m}_v h_v) = \overline{\rho c_p} \frac{\partial T}{\partial t} \quad (2)$$

and the Clayperon equation to relate the saturation temperature gradient to a pressure gradient,

$$\left. \frac{\partial P}{\partial T} \right|_{sat} = \frac{\rho_g h_{fg}}{T} \quad (3)$$

a relationship for the energy balance can be written as:

$$\frac{\partial}{\partial x} \left(\lambda_{eff} \frac{\partial T}{\partial x} \right) = \overline{\rho c_p} \frac{\partial T}{\partial t} \quad (4)$$

where the effective thermal conductivity of the system [11] is

$$\lambda_{eff} = \lambda + \frac{kk_{rv}}{\mu_g T} \rho_g^2 h_{fg}^2 \quad (5)$$

If the effective thermal conductivity is assumed to remain constant during the pressurization or de-pressurization processes, then equation (4) is the familiar Fourier equation. Although evaporation or condensation can change the water content, thus altering the relative permeability, the assumption of a constant effective thermal

conductivity is reasonable for small (<10%) changes in water mass or temperature (<30°C).

We model our system as a one-dimensional slab with a step change in surface temperature corresponding to a step change in the imposed pressure, with a no-flux condition at the low permeability zone centerline at L. Analytical solutions to this problem are available in the literature [12], and have been graphically presented by Heisler [13]. The temperature at the middle of the slab is:

$$\frac{T - T_s(P)}{T_o - T_s(P)} = 2 \sum_{n=0}^{\infty} \frac{(-1)^n}{\lambda_n} e^{-\lambda_n^2 Fo} \quad (6)$$

where $\lambda_n = (2n+1)\pi/2$, $Fo = \alpha t/L^2$, and $\alpha = \frac{\lambda_{eff}}{\rho C_p}$.

The time necessary for the temperature of the center of the slab to change to 90% of the difference between the initial temperature and the surface temperature is obtained from a value of the Fourier Number equal to 1. From this condition, we approximate the optimal steam/vacuum cycle time. The optimal cycle time for different bulk permeabilities and for different layer thicknesses is plotted in Figure 16. For permeabilities less than $1 \times 10^{-15} \text{ m}^2$ (1 mDarcy), the effective thermal diffusivity λ_{eff} , approaches the actual thermal diffusivity λ since the vapor flow becomes insignificant even with large pressure gradients.

Theoretical Analysis of Ultimate Cleanup Levels

The very rapid drop in contaminant mass predicted by the simulations during the depressurization cycle after the separate phase had been removed is of great interest since the goal of drinking water standard concentrations are very quickly met. The potentially high residual concentration of contaminants in aqueous phase is of concern since the boiling of volatile contaminants is likely to increase contaminant contact with water and leave the water with concentration near the solubility limit. This residual concentration might leave the site with long-term pumping needs if not removed as a part of the

processing. From the simulations, it appears that depressurization provides a mechanism for removing *in situ* dissolved phase contaminants to drinking water standards. To support that observation, an equilibrium model of the contaminant removal rate during depressurization is developed.

To determine the rate at which dissolved water phase contaminant i can be removed from liquid water, we begin with a partially saturated porous media at steam temperature. The total mass of i present in the system is equal to the mass of water times the mass fraction of i in the water phase (X_i).

$$m_i = m_w X_{i,w} \quad (7)$$

The change in the mass of i in the system can be found by taking the derivative of equation 7. This change in the total mass of i is also equal to the mass fraction of i in the vaporized water multiplied by the rate of water evaporation.

$$\frac{d}{dt} m_i = \frac{d}{dt} (m_w X_{i,w}) = X_{i,vap} \frac{d}{dt} m_w \quad (8)$$

We relate the concentration of i in the vapor phase to that in the liquid phase through the linear relationship of Henry's law. A common representation of Henry's law is:

$$P_{i,v} = H C_{i,w} \quad (9)$$

where $P_{i,v}$ is the partial pressure of contaminant i in the vapor phase, $C_{i,w}$ is the concentration of i in the water phase, and H is the Henry's constant.

Re-writing Equation 9 in terms of a non-dimensional Henry's Law we arrive at:

$$X_{i,v} \rho_v = \bar{H} X_{i,w} \rho_w \quad (10)$$

where \bar{H} is the non-dimensional Henry's Law constant which is equal to the ratio of the mass concentration of i in the vapor phase to the mass concentration of i in the water phase. Equation 10 can be transformed into Equation 11 where the dimensionless Henry's

constant has been replaced by Γ ($\Gamma = \rho_v/\rho_w \bar{H}$) which is the ratio between the mass fraction of i in the water phase to the mass fraction of i in the vapor phase.

$$X_{i,w} = \Gamma X_{i,v} \quad (11)$$

Substituting Equation 11 into Equation 8 and re-arranging terms yields:

$$\left(\frac{1-\Gamma}{\Gamma}\right) X_{i,w} \frac{d}{dt} m_w = m_w \frac{d}{dt} X_{i,w} \quad (12)$$

For a given pressure drop, only a certain fraction of the mass of water will evaporate due to thermodynamic limitations. From the analytic expression for the temperature at the center of the slab (Equation 6), an exponential decay of m_w from the initial water mass, m_{w0} , to the final water mass, $m_{w\infty}$ is expected. The mass remaining, to leading terms in the Fourier series of Equation 6, is given by

$$m_w = m_{w\infty} + (m_{w0} - m_{w\infty}) e^{-\frac{\pi^2 Fo}{4}} \quad (13)$$

The solution to Equation 12 is:

$$\frac{C_{i,w}}{C_{i,w0}} = \left(\frac{1 + \left(\frac{m_{w0} - m_{w\infty}}{m_{w\infty}} \right) e^{-\frac{\pi^2 Fo}{4}}}{1 + \left(\frac{m_{w0} - m_{w\infty}}{m_{w\infty}} \right)} \right) \left(\frac{1-\Gamma}{\Gamma} \right) \quad (14)$$

This equation is plotted in Figure 17 for various values of the dimensionless mass fraction ratio Γ , the water mass fraction removed, $(m_{w0} - m_{w\infty})/m_{w0}$, and the Fourier Number.

At large time, when most of the evaporation has taken place, the concentration in the water phase reduces to:

$$\frac{C_{i,w\infty}}{C_{i,w0}} = \left(\frac{m_{w\infty}}{m_{w0}} \right)^{\left(\frac{1-\Gamma}{\Gamma} \right)} \quad (15)$$

Equation 15 is plotted in Figure 18 for different values of Γ and mass fraction removed. As shown in Figure 18, aqueous phase TCE concentrations can change by orders of magnitude for even small amounts of water evaporation. This is due to the large exponential provided by $(1-\Gamma)/\Gamma$. For TCE, Γ would be approximately 0.003 at 20°C, and decreases with an increase in temperature since the vapor pressure of TCE rises more quickly with temperature than its solubility in water. For a value of Γ of 0.002, a 1% reduction of water mass by evaporation will cause a drop of two orders of magnitude in aqueous contaminant concentration. Removal of 2% and 5% of the water will drop TCE concentrations by five and twelve orders of magnitudes respectively. Limitations in flow paths for water vapor to leave lower permeability regions may prevent concentration levels from dropping as fast as is theoretically possible. However, the expectation that the boiling process occurs on the pore level in a manner determined by the local heat transfer from solid particles to the water vapor interface gives rise to the hope that, once separate phase contaminants have been removed, concentration levels can be reduced to drinking water standards very quickly.

The value of Γ for several different chemicals at 20 °C are listed in table 2. Also listed in the table are the mass fraction of the contaminant in the water and in the liquid phase. Reasonable large values of the mass fraction of the contaminant in the vapor phase are realized for many of the contaminants because, even though the vapor pressures are small relative to the total pressure, the large difference in the molecular weight of the contaminant molecules compared with that of the water vapor molecules or the oxygen and nitrogen molecules in the air. Combining this effect with the low solubility of many of the contaminants in water leads to the low values of Γ which range from a low of 0.0011 for PCE to a high of 0.024 for Dichloromethane.

The temperature effect on Γ for common contaminants cannot be explored without additional data on the temperature dependence on their solubility in water. Clearly the vapor pressures for all of the chemicals will rise with increasing temperatures but it is the behavior of the solubility of the contaminant in water that will determine the magnitude of Γ at high temperatures. Since, for many of the chemicals listed in Table 2, the mass fraction of the contaminant in the vapor phase is already significant (over 25%), a rise in the vapor pressure can only increase the mass fraction by a factor of four, whereas there is a much smaller limitation on the growth of the mass fraction in the liquid phase with an increase in temperature.

The limiting conditions for Γ in Equation 15 are $\Gamma = 0$ (corresponding to a substance that is soluble in water but with a negligible vapor pressure) and $\Gamma = \infty$ (corresponding to a substance with a non-negligible vapor pressure but is nearly insoluble in water). For the case of when Γ approaches 0, we expect that the contaminant concentration should increase inversely proportional to the amount of water removed. Equation 15 is reduced to $C_{i,\infty}/C_{i,0} = m_{i,0}/m_{i,\infty}$. For the second limiting condition of $\Gamma = \infty$, in which all of the contaminant mass should be driven off immediately, Equation 15 becomes $C_{i,\infty}/C_{i,0} = (m_{i,\infty}/m_{i,0})^\infty$, which means that evaporating a little water will drive off the remaining contaminant in solution. For the case that the contaminant behaves exactly like the water ($\Gamma = 1$), Equation 15 reduces to the trivial solution of $C_{i,0} = C_{i,\infty}$ or the concentration remains constant.

The amount of water that will evaporate in the porous media as a result of a pressure change can be solved using the Clapeyron equation combined with energy balances resulting in the following relationship for the fraction of water mass removed.

$$\frac{\Delta m}{m_0} = \frac{T^2 R}{\rho_w s \phi h_{fg}^2} \left[(1 - \phi) \rho_w C_p + \phi s_w \rho_w C_p \right] \ln \left(\frac{P_1}{P_0} \right) \quad (15)$$

where R is the gas constant, P_0 and P_1 are the final and the initial pressures and T is taken at steam temperatures. This equation is plotted in Figure 19 for two values of porosity and

different values of water saturation for a depressurization from some absolute pressure to a final pressure of 50,000 Pa absolute (0.5 atmosphere vacuum). The curves are not straight since, as the temperature and pressure drops, the rate of change in the temperature decreases slower than the rate of change of the pressure. As can be seen, in a system with 40% porosity, a change of pressure of 1.5 atmospheres to 0.5 atmosphere can result in a loss of at least 10% of water mass in a system. For the 30% initial TCE simulation run, a vacuum extraction cycle pulled out 20% of the water in the system.

Discussion

Using the Fourier number equal to 1 to estimate the optimal steam/vacuum cycle time, we found a time of 6 hours for the conditions of the system. This would correspond approximately to the time required for the effluent rates to begin to drop off after the initial high rates following the start of steam injection. For the 30% TCE case presented, a cycle time of 6 hours was superior compared with the larger cycle times or with constant steaming. The simulations predicted only a few cycles to completely remove the contaminant from the system so it is impossible to pinpoint the optimal Fourier Number for quickest clean-up.

For the Lawrence Livermore National Laboratory site, the corresponding optimal cycle time would have been 10 days. This is based on a 6 meter thick low permeability zone and the thermal properties of the soil to be those of sand. The LLNL site was operated with a cycle time of 5 days. It may be that a larger cycle time would have resulted in a greater quantity of gasoline recovered within the operational time limits of the second steam pass where cyclic steam was effectively applied. More field data are needed to fully investigate the optimal cycle time in a real heterogeneous system.

Conclusions

Steam enhanced extraction using cyclic steam injection after steam breakthrough of a simple two-dimensional numerical system was presented. In the simulation, both TCE and PCE, located initially in a low permeability region were effectively removed. Cyclic

steam injection always shortened the total steam injection time although the total time for clean-up varied depending on time chosen for the steam cycling. A modified Fourier Number of 1 gave a good estimate of the optimal cycle time for the numerical system and a reasonable estimate of the actual operation at the Lawrence Livermore Laboratory field site.

Acknowledgments

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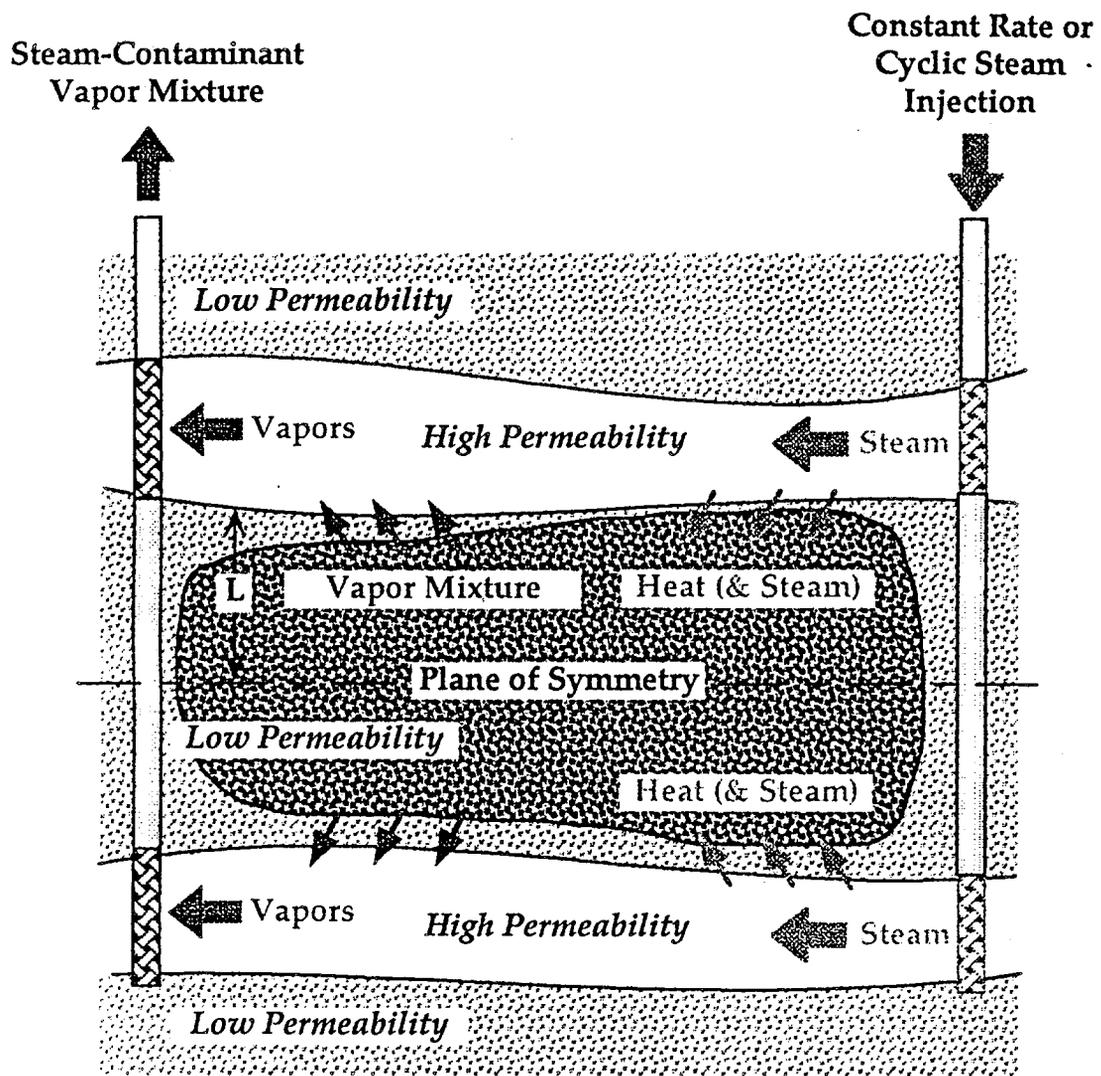


Figure 1 Schematic of volatile contaminant removal from a low permeability region bounded on two sides by high permeability zones.

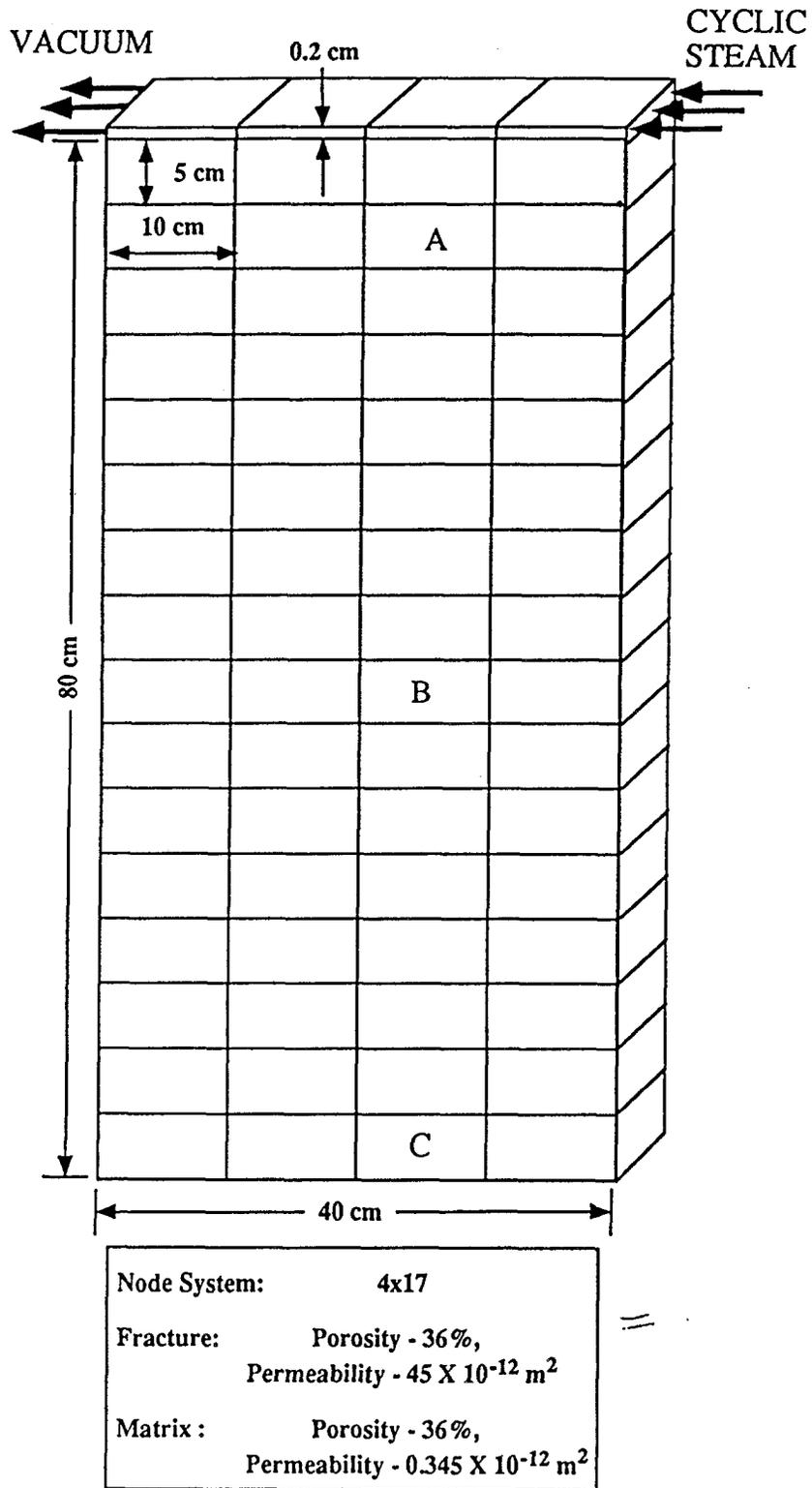
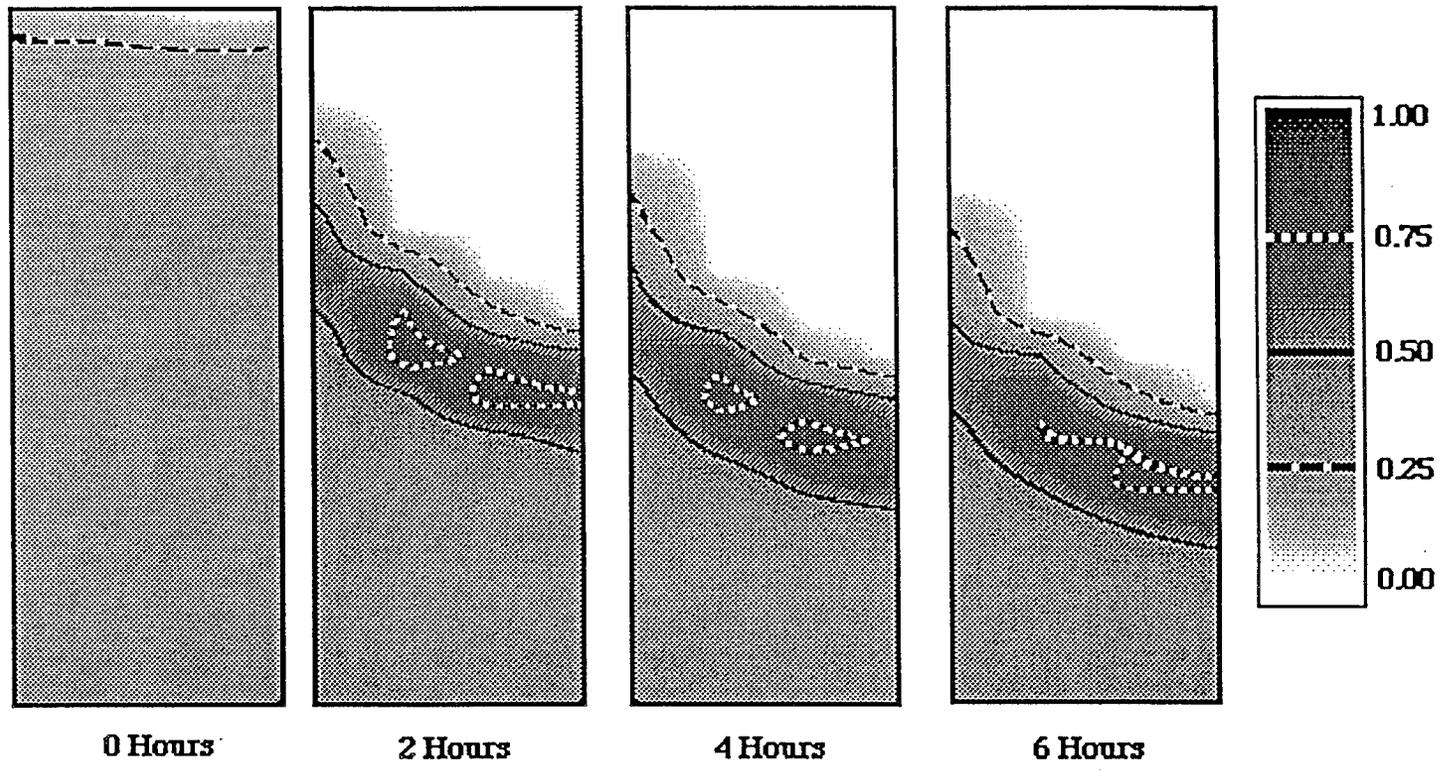
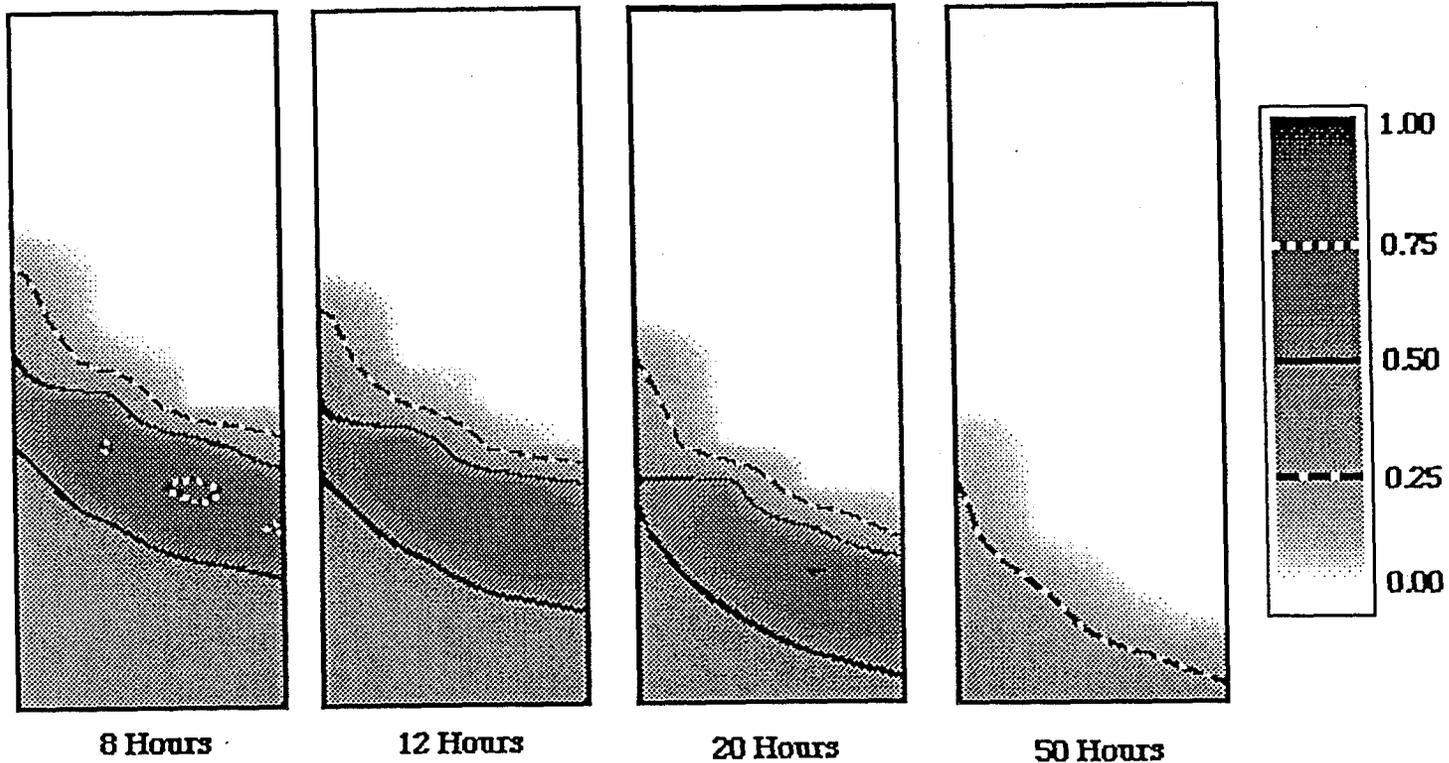


Figure 2 Control volume layout for numerical simulations of contaminant removal from heterogeneous media by cyclic steam injection and vacuum extraction.



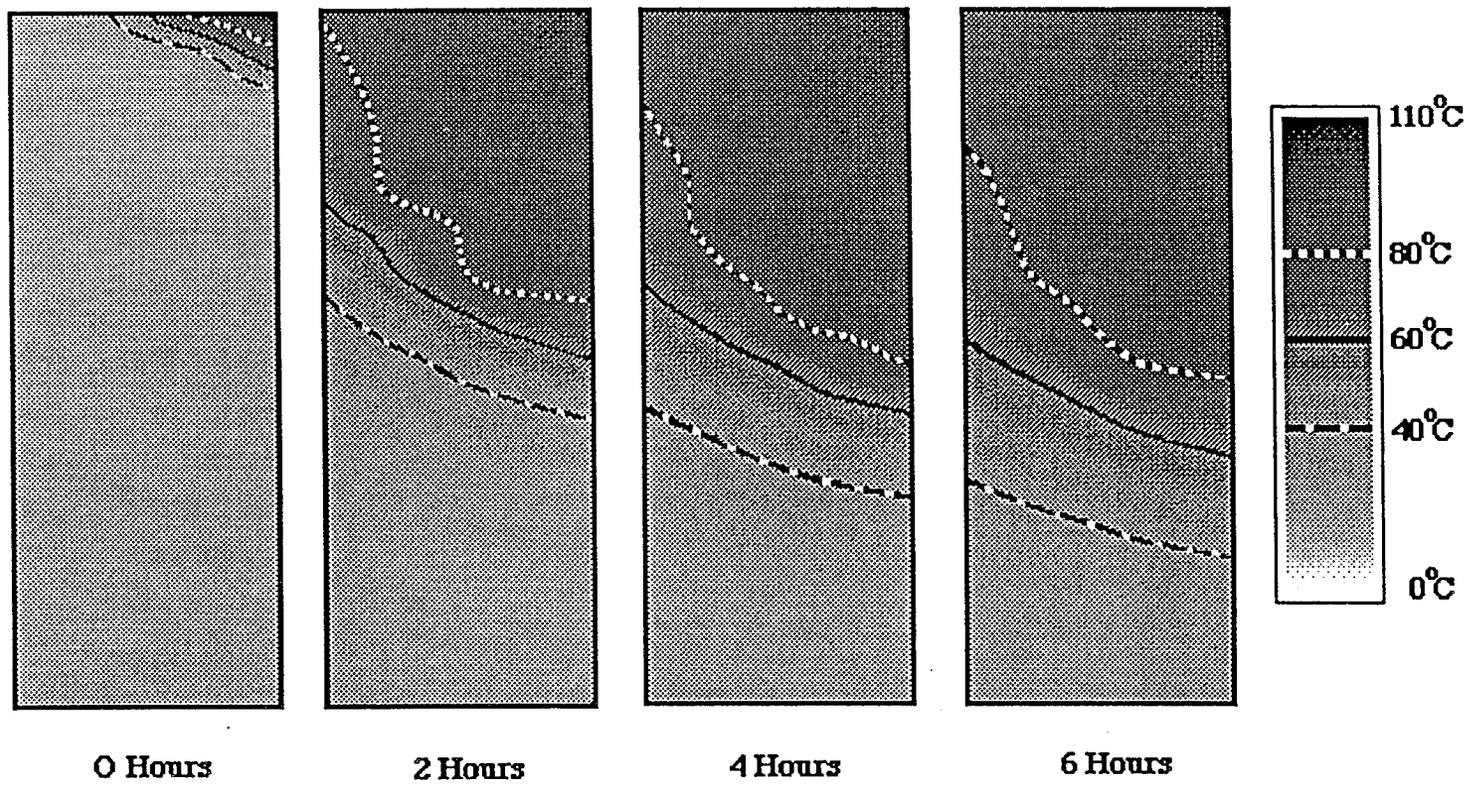
TCE Saturation Profile – 30% Initial TCE Saturation

Figure 3a.



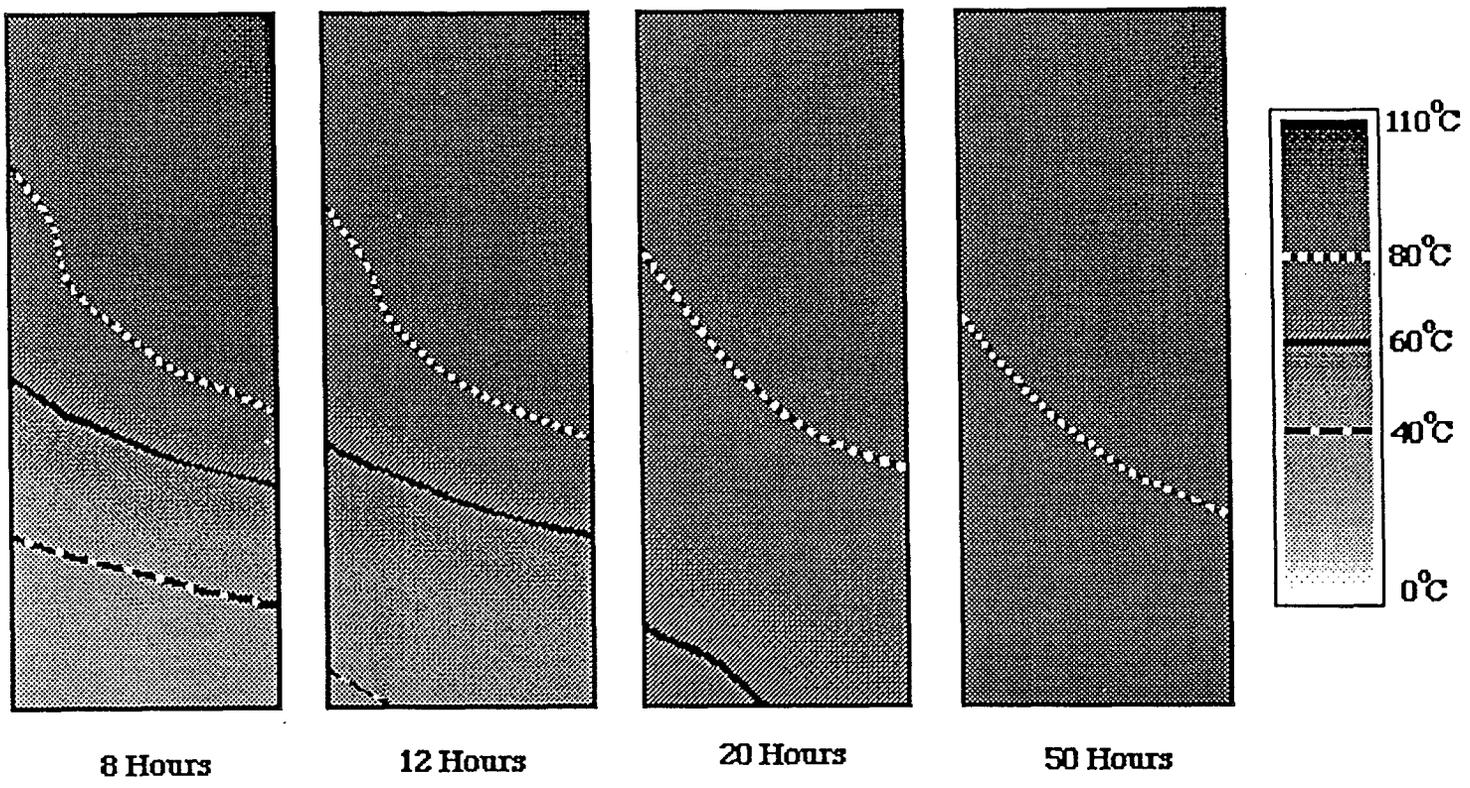
TCE Saturation Profile - 30% Initial TCE Saturation

Figure 3b.



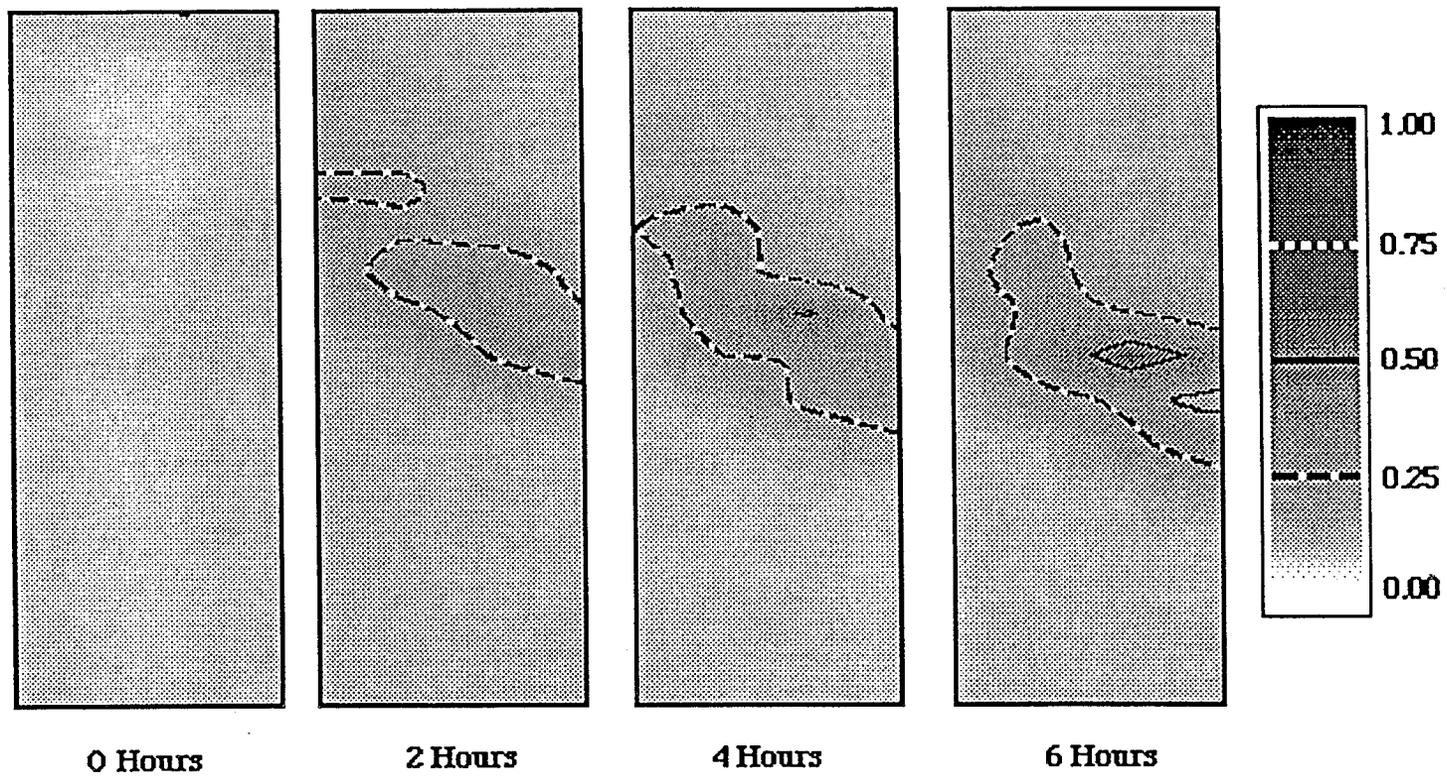
Temperature Profile - 30% Initial TCE Saturation

Figure 4a.



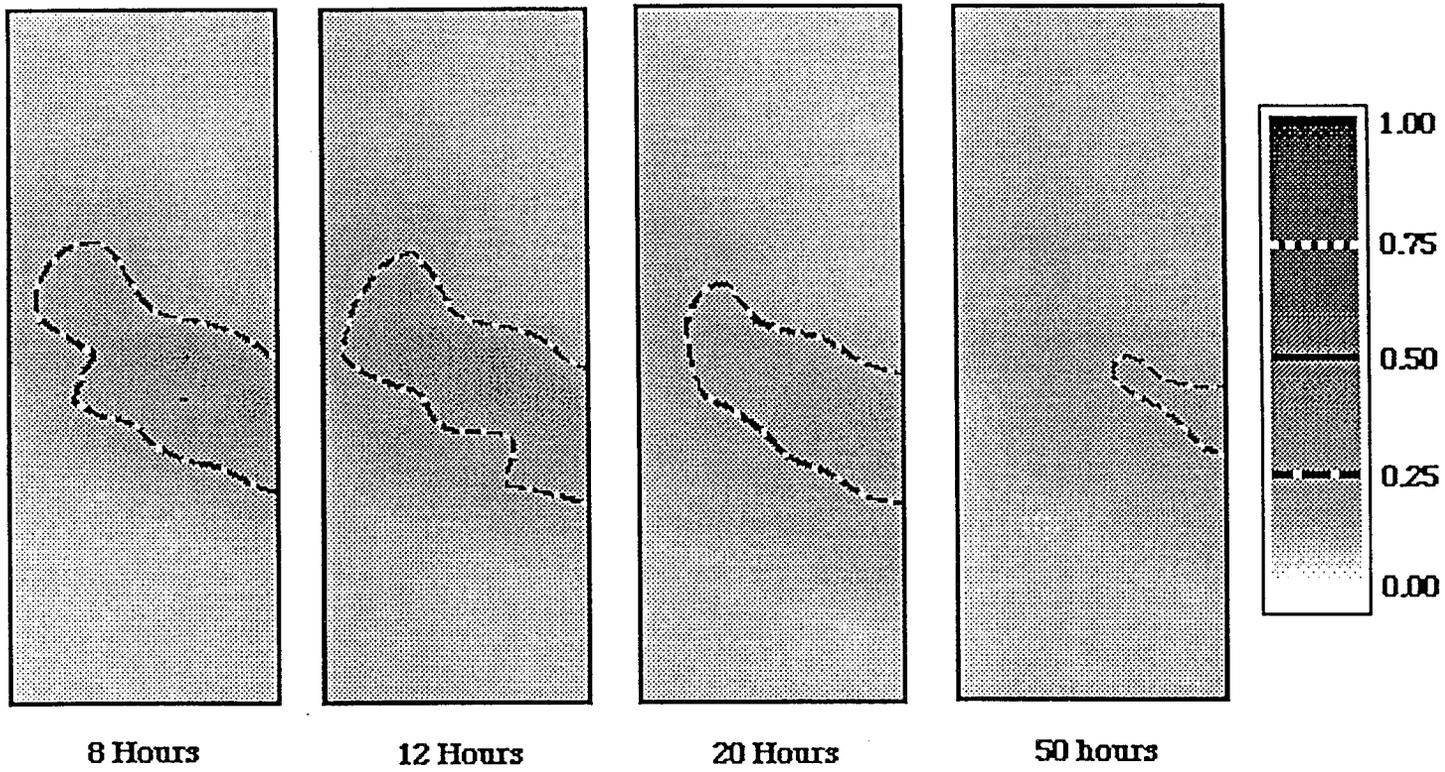
Temperature Profile - 30% Initial TCE Saturation

Figure 4b.



Water Saturation Profile – 30% Initial TCE Saturation.

Figure 5a



Water Saturation Profile – 30% Initial TCE Saturation.

Figure 5b.

TCE Phase Saturation

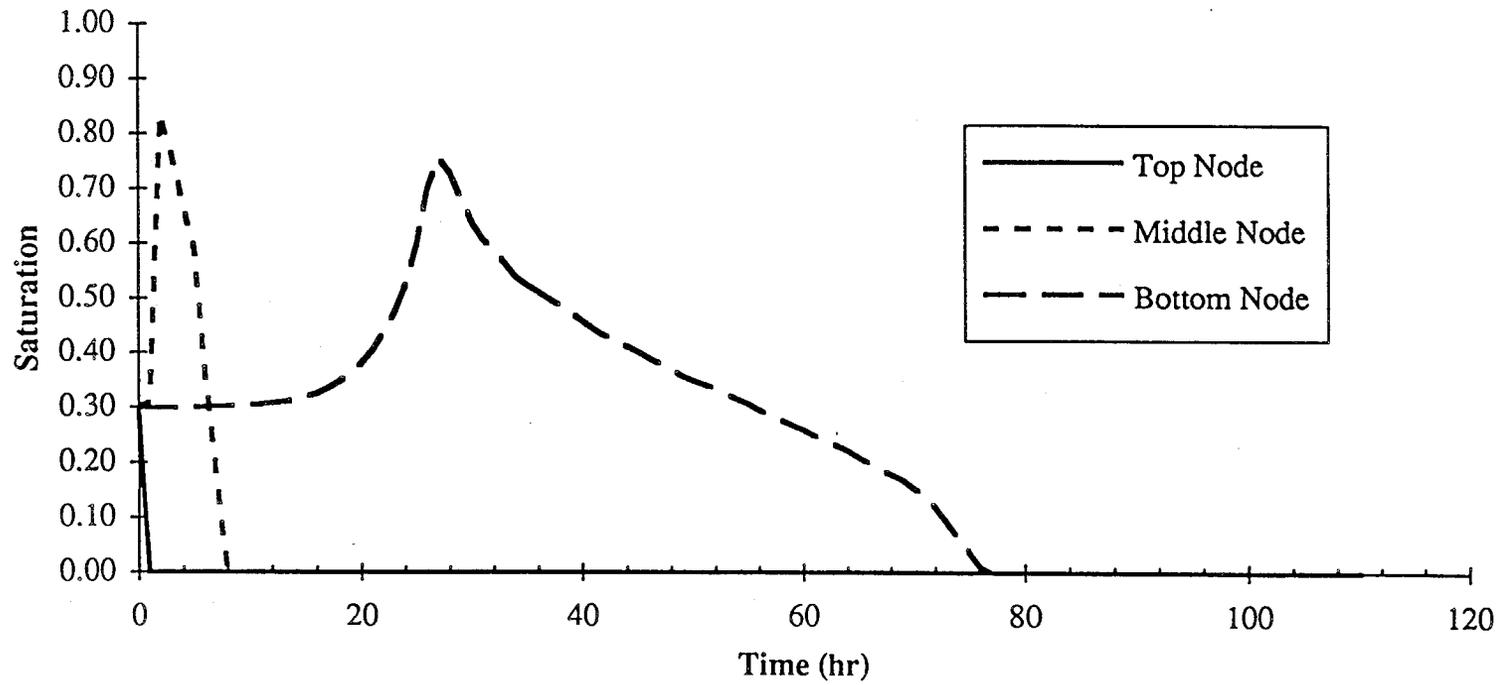


Figure 6. TCE saturation profiles for three nodes during computer simulation.

TCE Simulation Temperatures

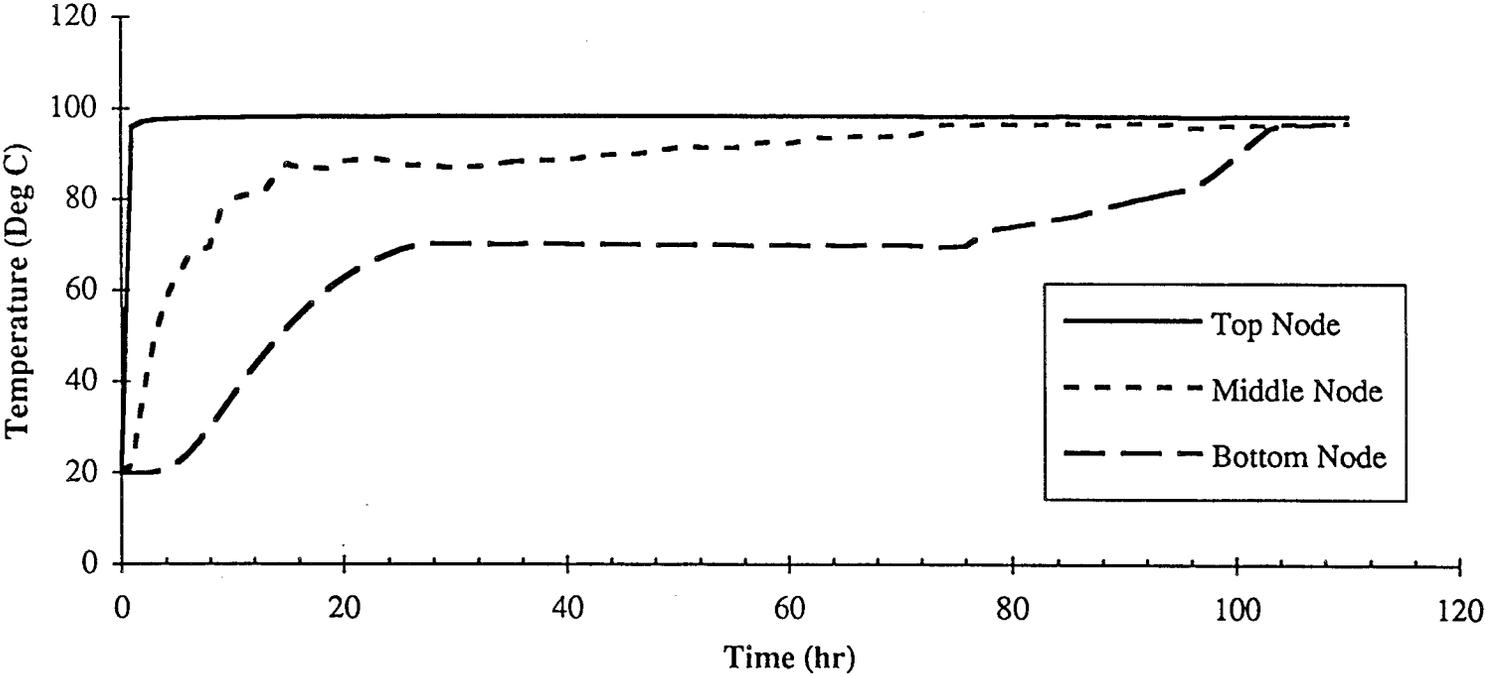


Figure 7. Temperature at three nodes during the computer simulation.

Water Phase Saturation

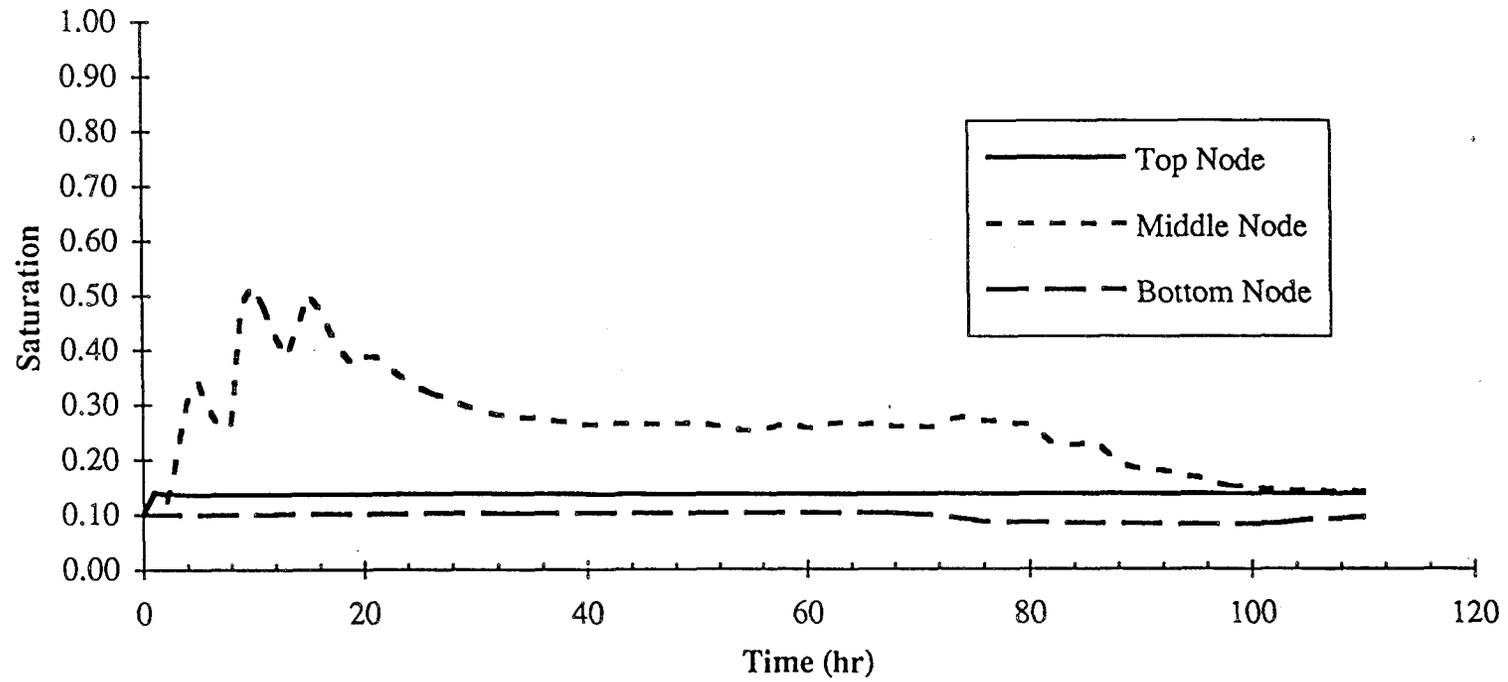


Figure 8. Water phase saturation at three nodes during the computer simulation.

30% initial TCE saturation -- Computer Simulation

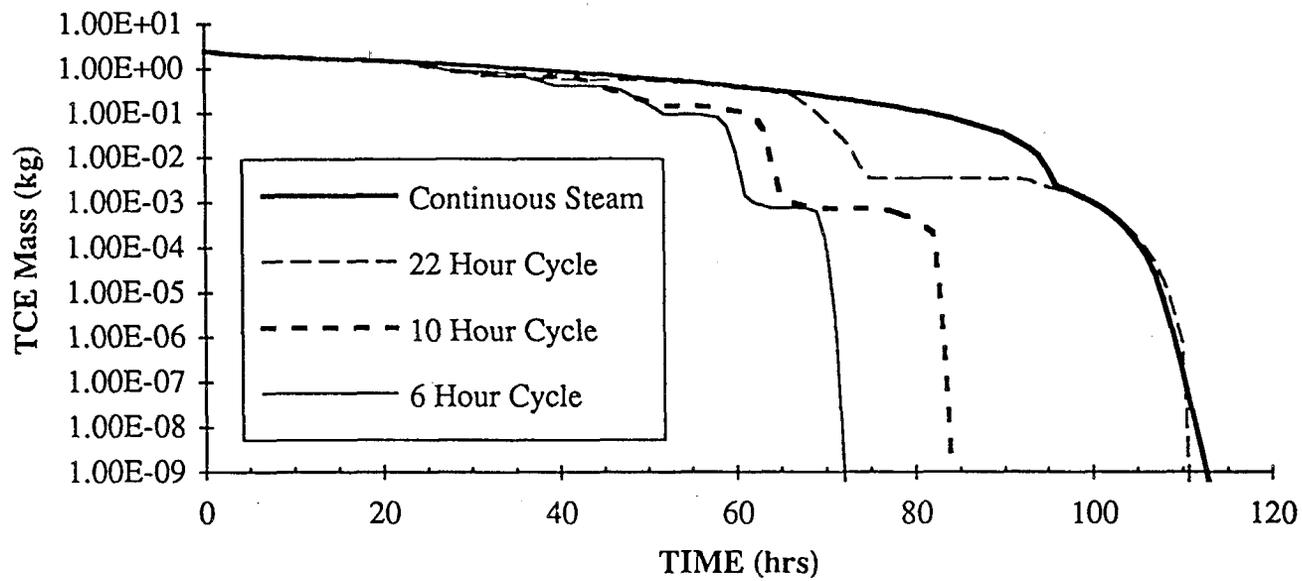


Figure 9. Total TCE mass in system as a function of time for various vacuum/steam cycle times beginning at 22 hours.

30% initial TCE saturation -- Computer Simulation

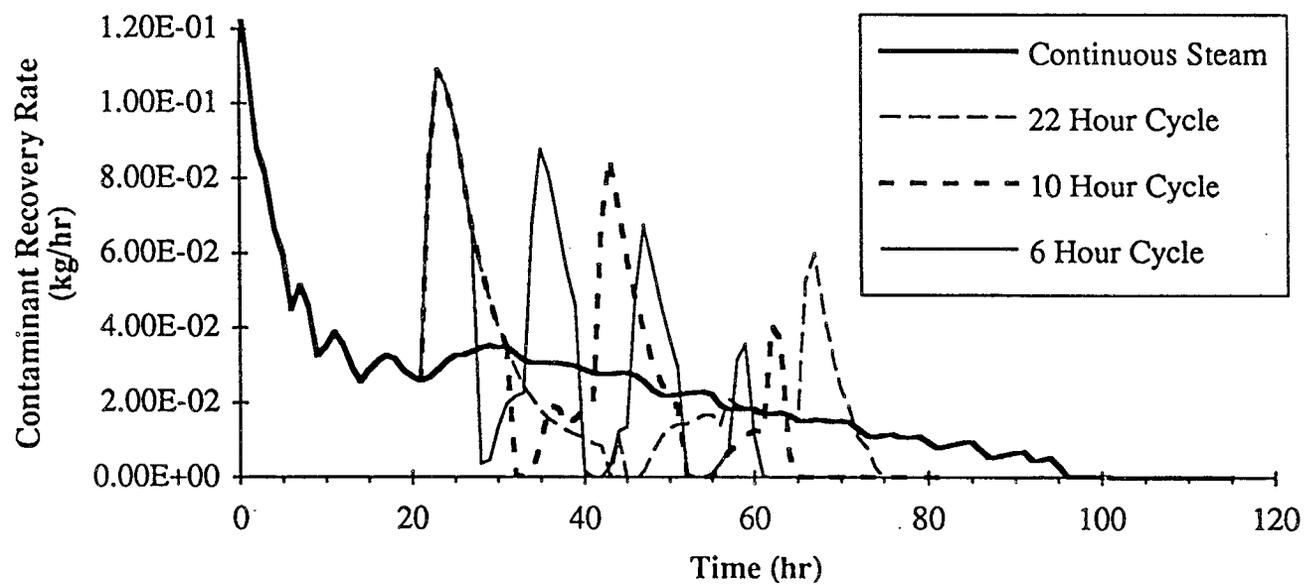
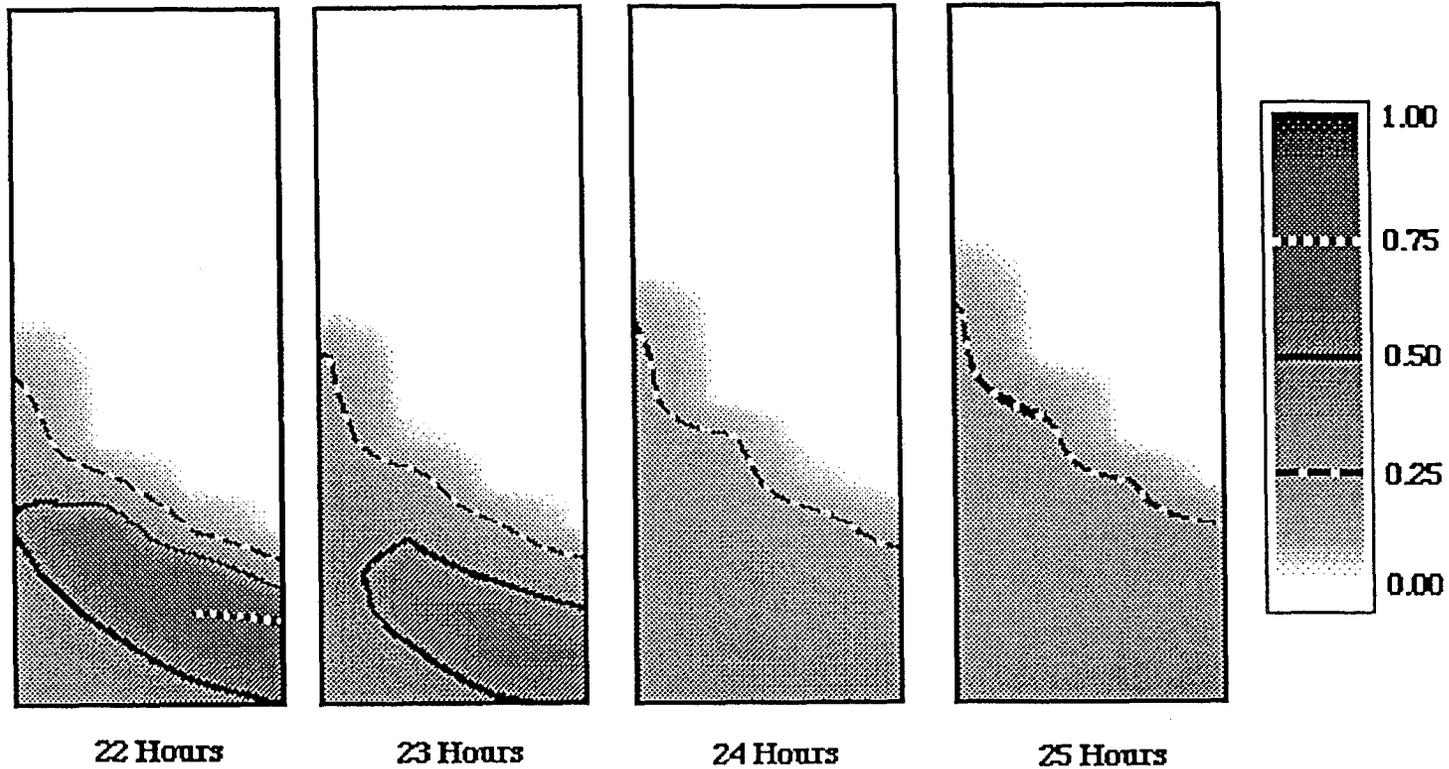
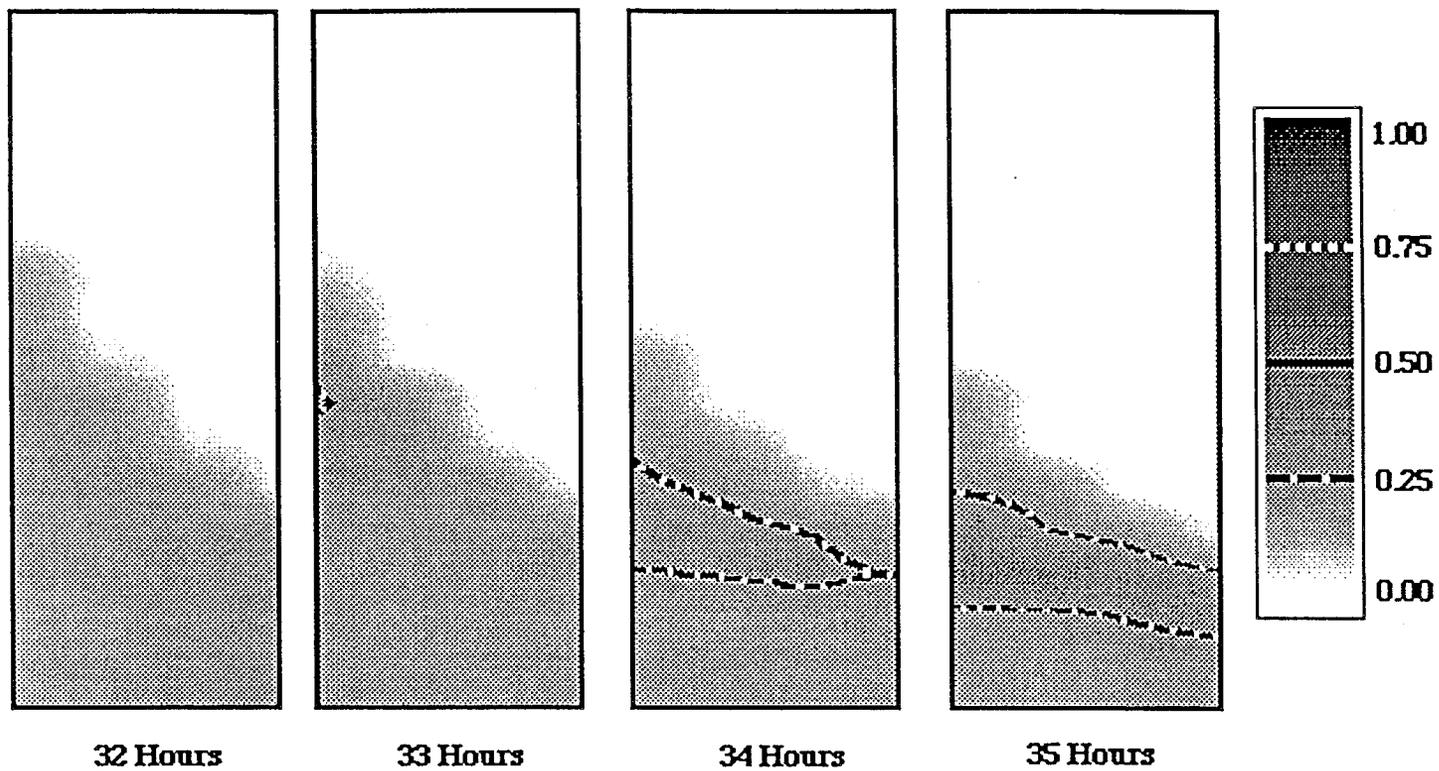


Figure 10. Contaminat removal rate for computer simulation for various steam/vacuum cycle times starting at 22 hours



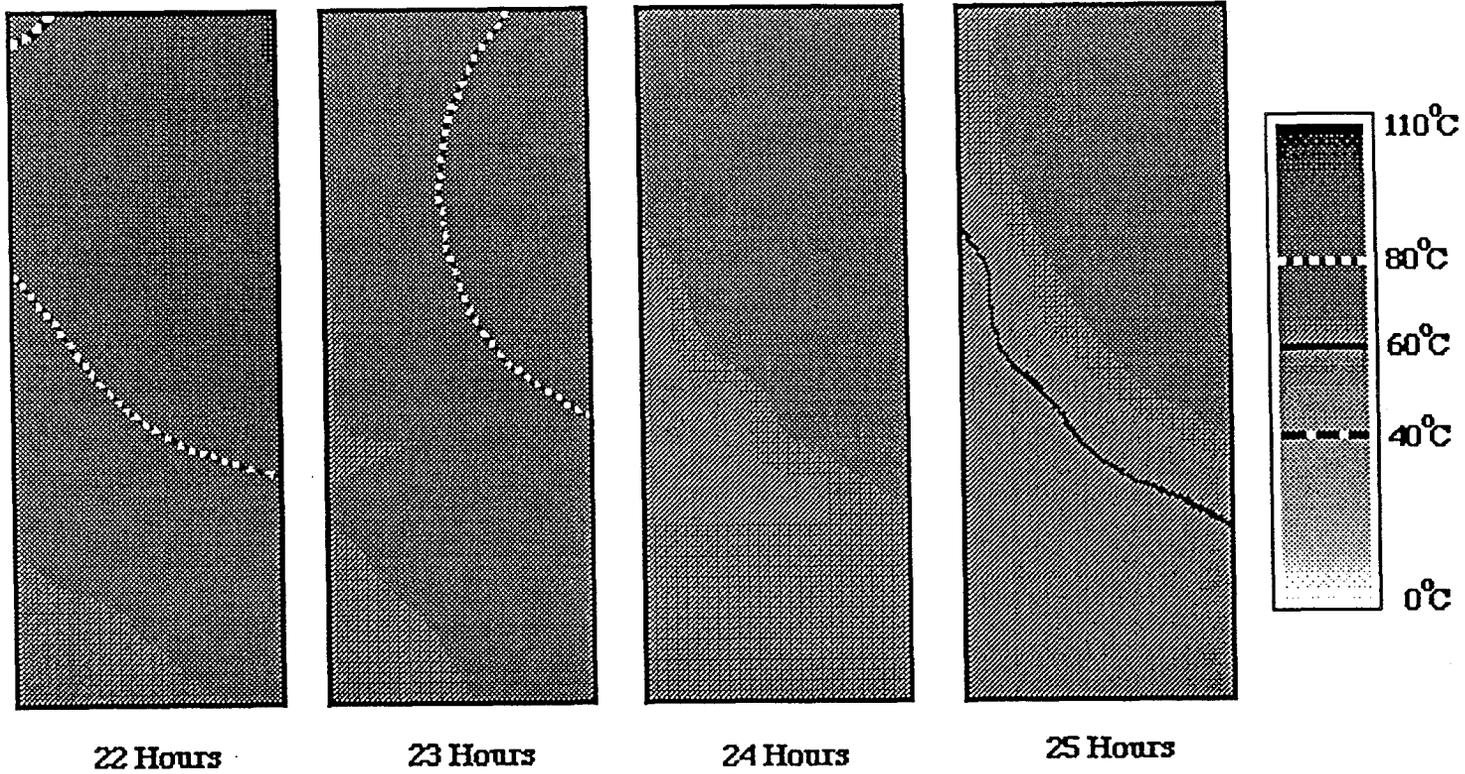
TCE Saturation Profile – 30% Initial TCE Saturation. First Vacuum Cycle after 22 hours of Continuous Steaming

figure 11a



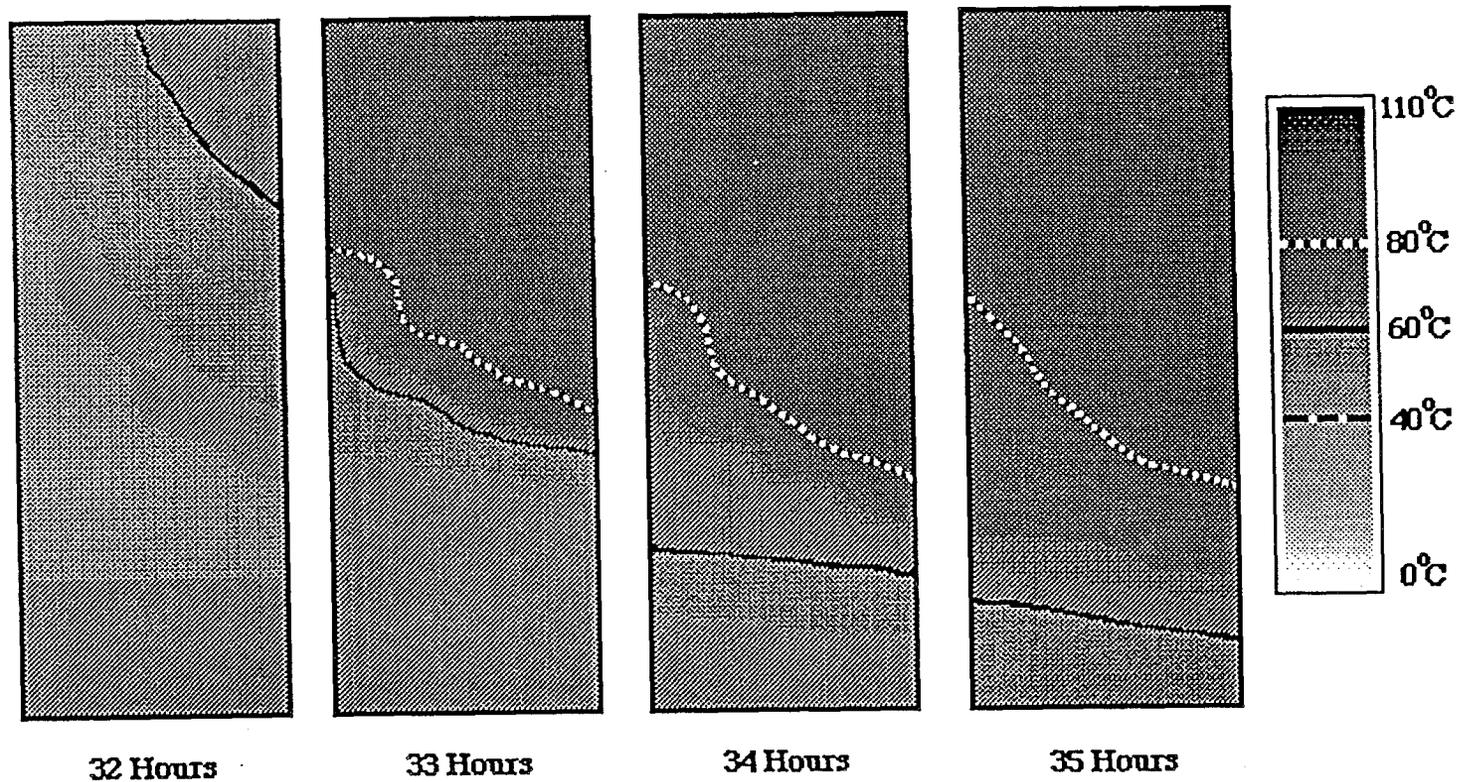
TCE Saturation Profile – 30% Initial TCE Saturation Steam injection starting
 at 32 Hours after 10 hours of Vacuum

Figure 11b.



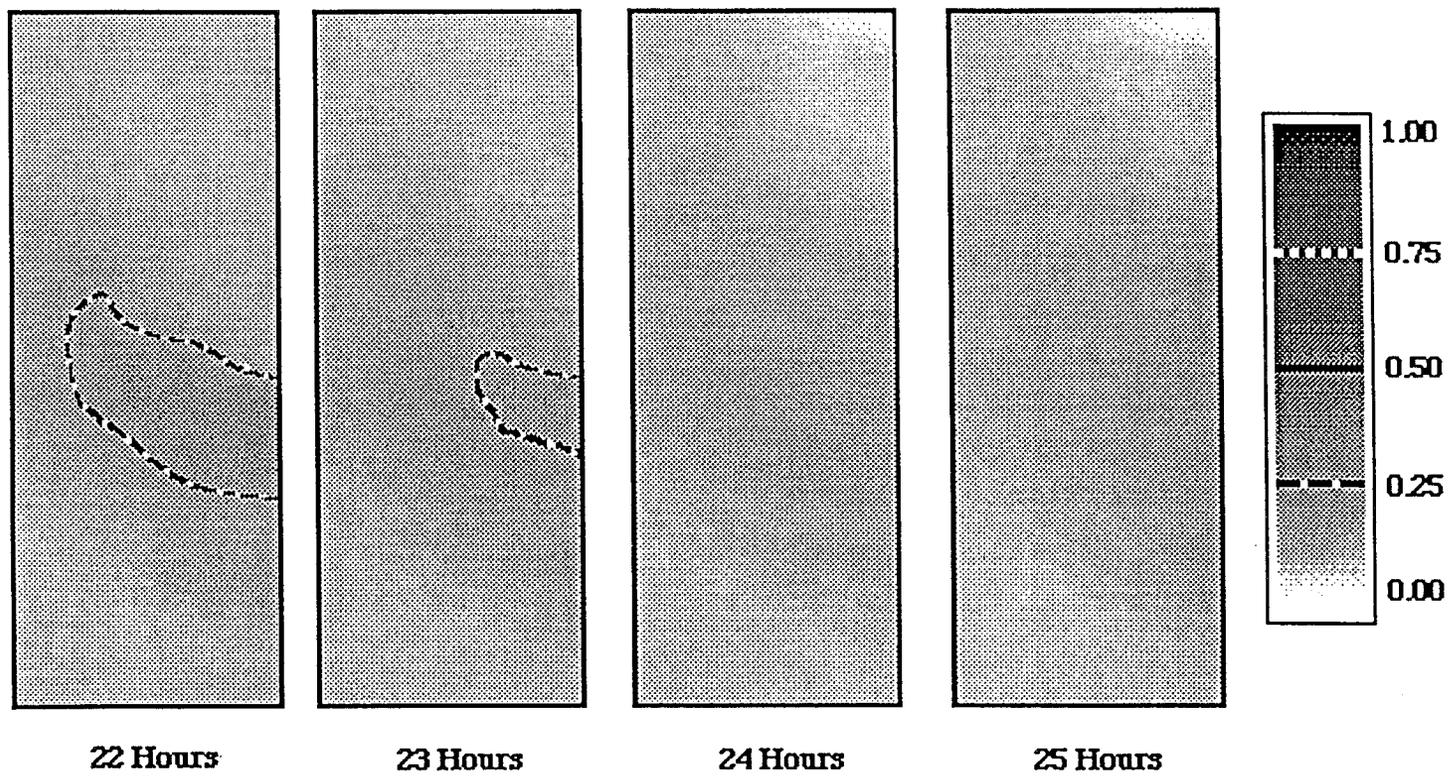
Temperature Profile — 30% Initial TCE Saturation. Vacuum after a period of 22 Hours of Steam Injection

Figure 12a.



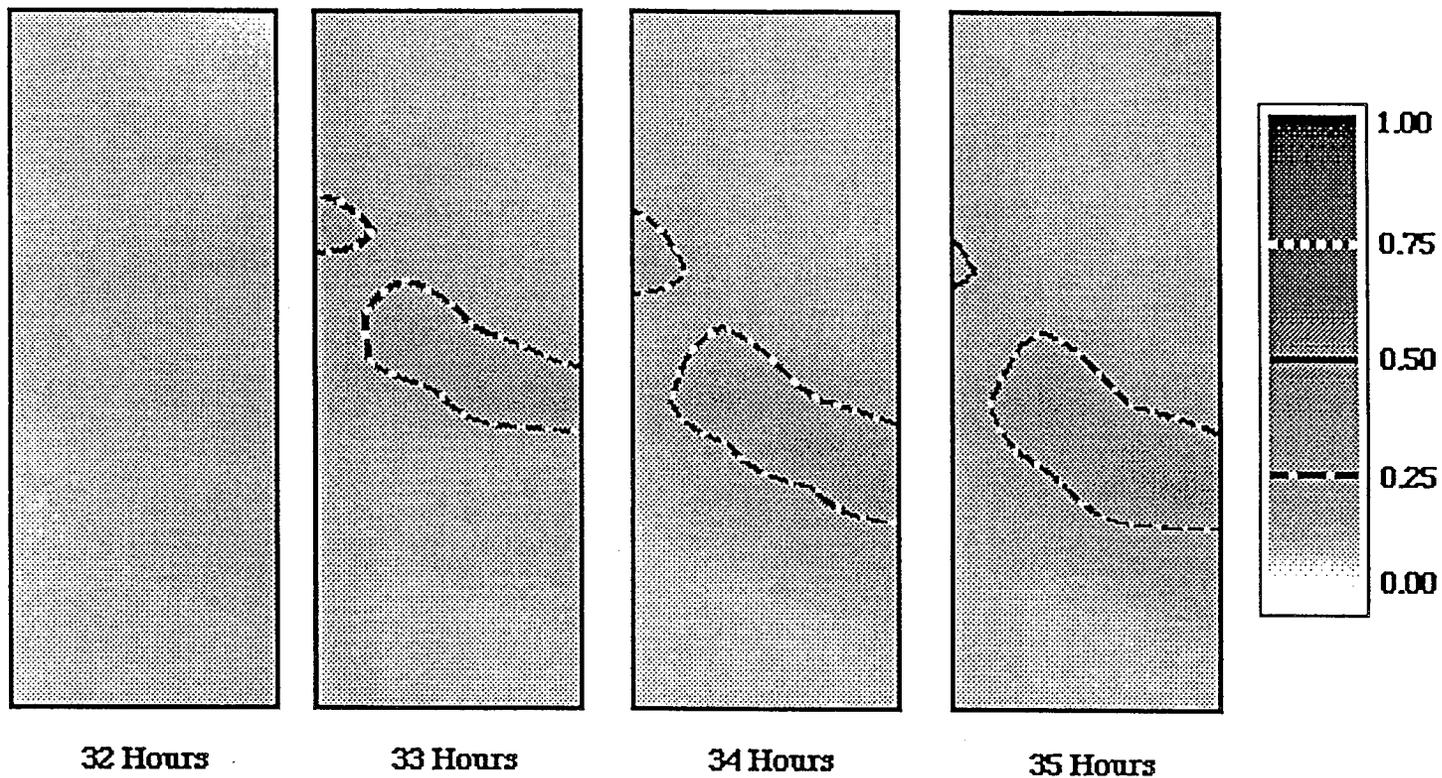
Temperature Profile — 30% Initial TCE Saturation. Steam Injection after 10 Hours of vacuum

Figure 12b.



Water Saturation Profile – 30% Initial TCE Saturation. Start of Vacuum after 22 hours of Continuous Steam

Figure 13a.



Water Saturation Profile — 30% Initial TCE Saturation. Start of Steam Injection after 10 hours of Vacuum

Figure 13b.

TCE Phase Saturation

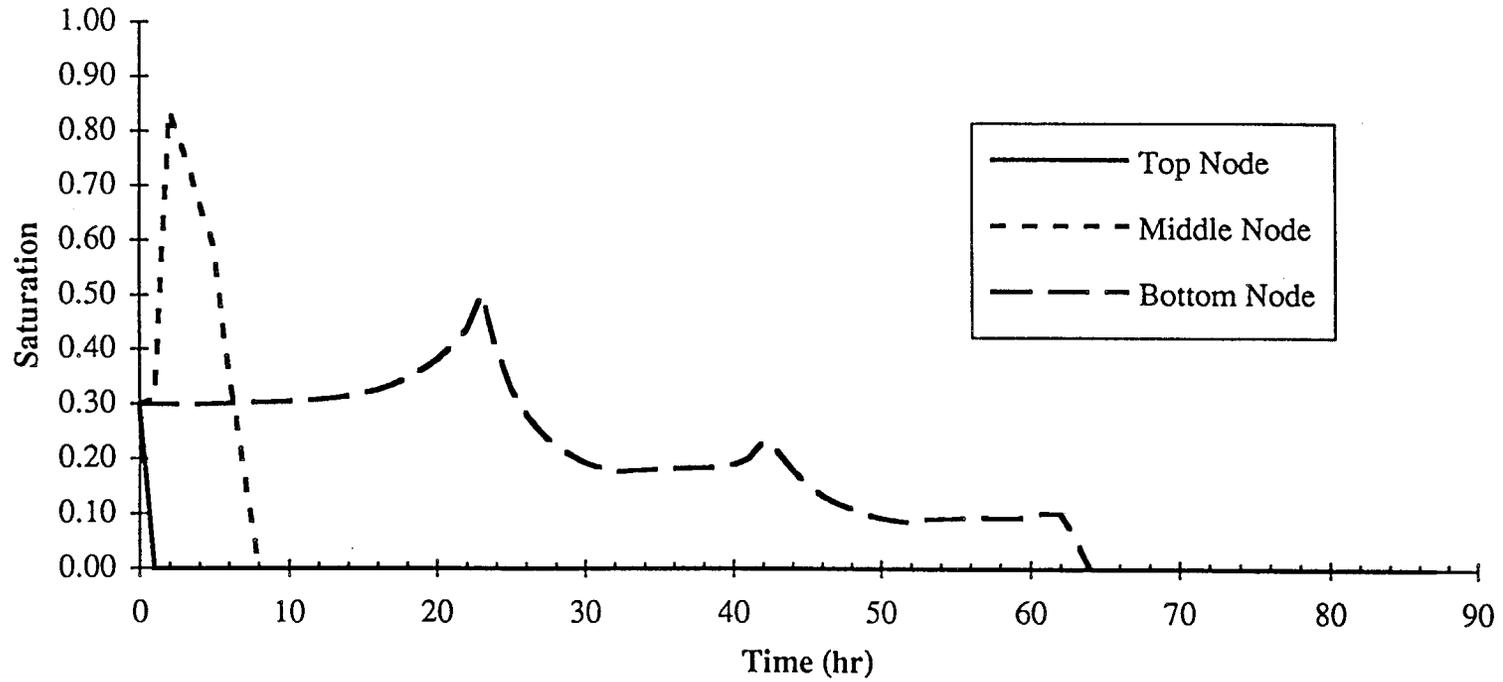


Figure 14. TCE phase saturation for three nodes during computer simulation of a 10 hour cycle time starting at 22 hours.

TCE Simulation Temperatures

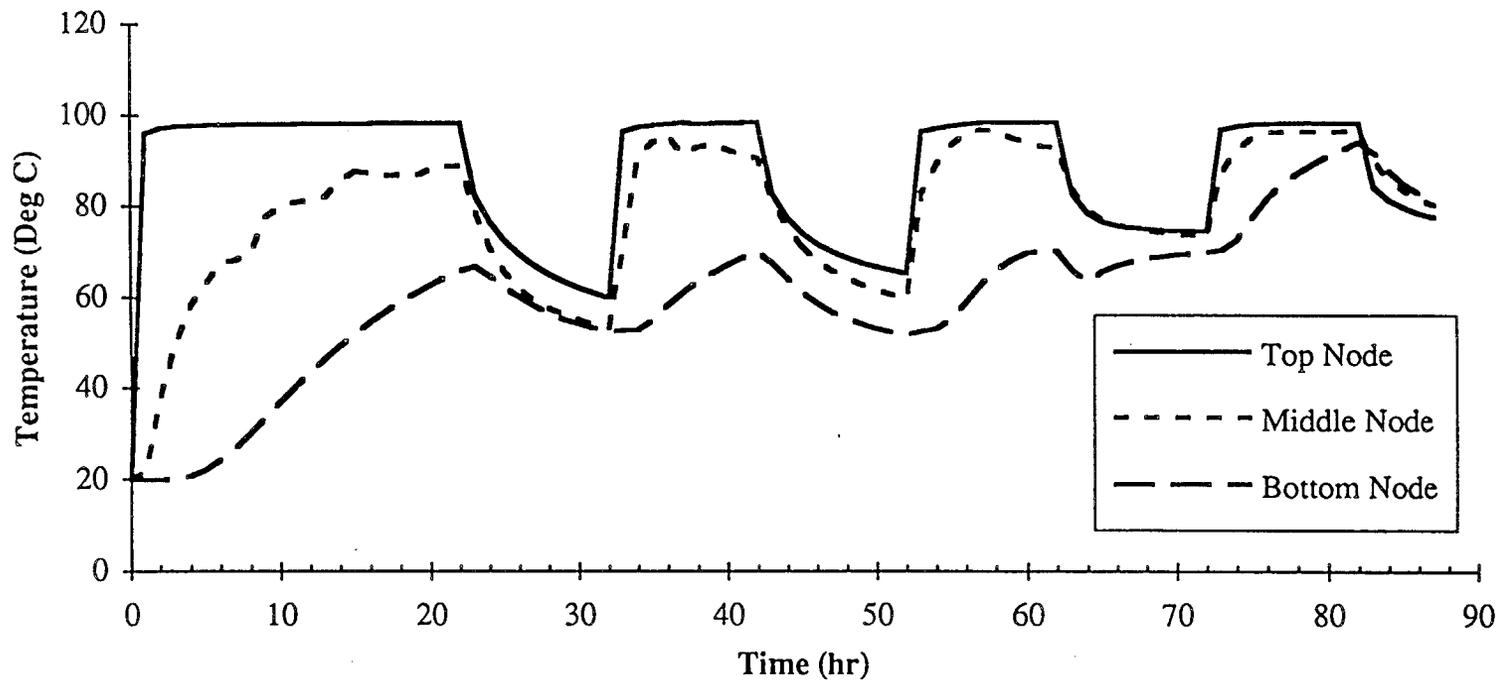


Figure 15. Temperature profiles for three nodes during computer simulation of a 10 hour cycle starting at 22 hours.

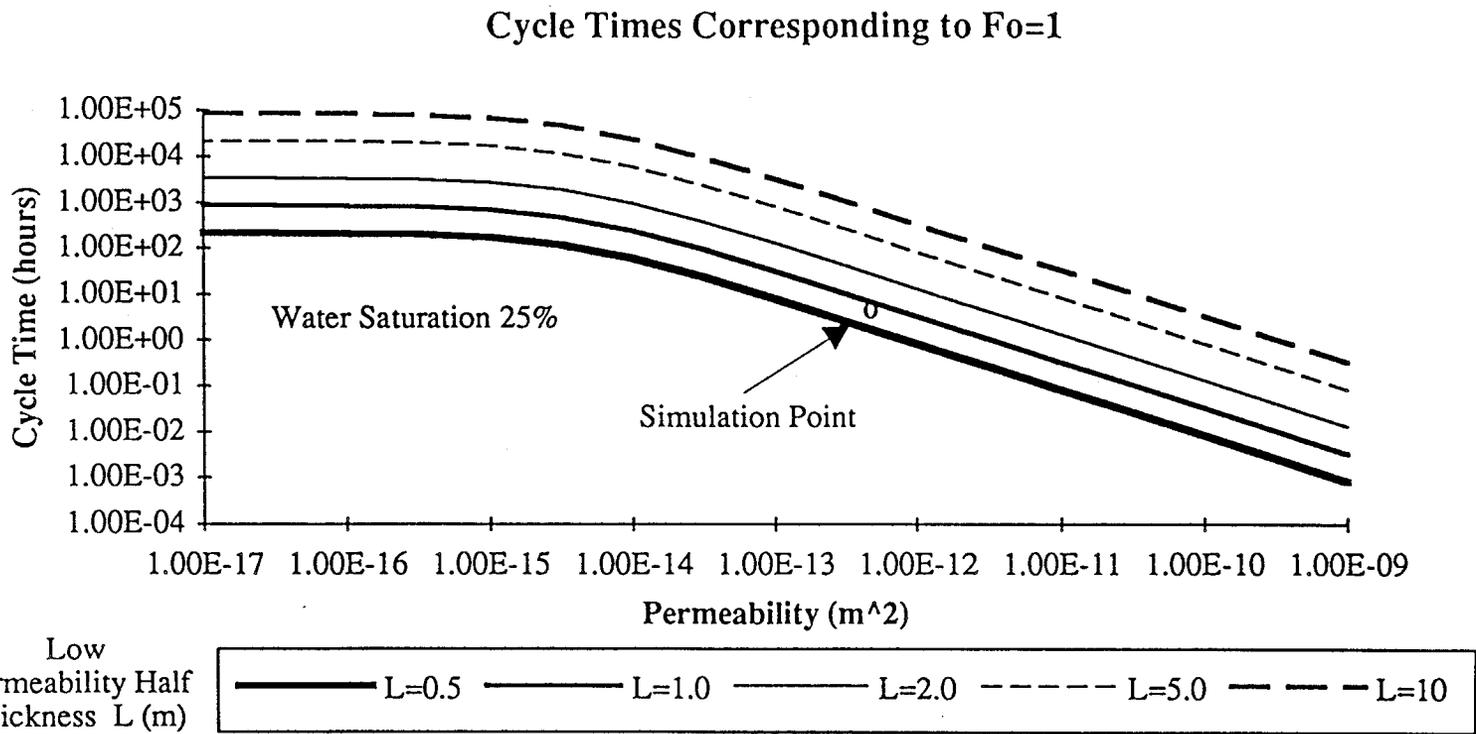


Figure 16. Optimal cycle times for layer of thickness $2L$ for various bulk permeabilities

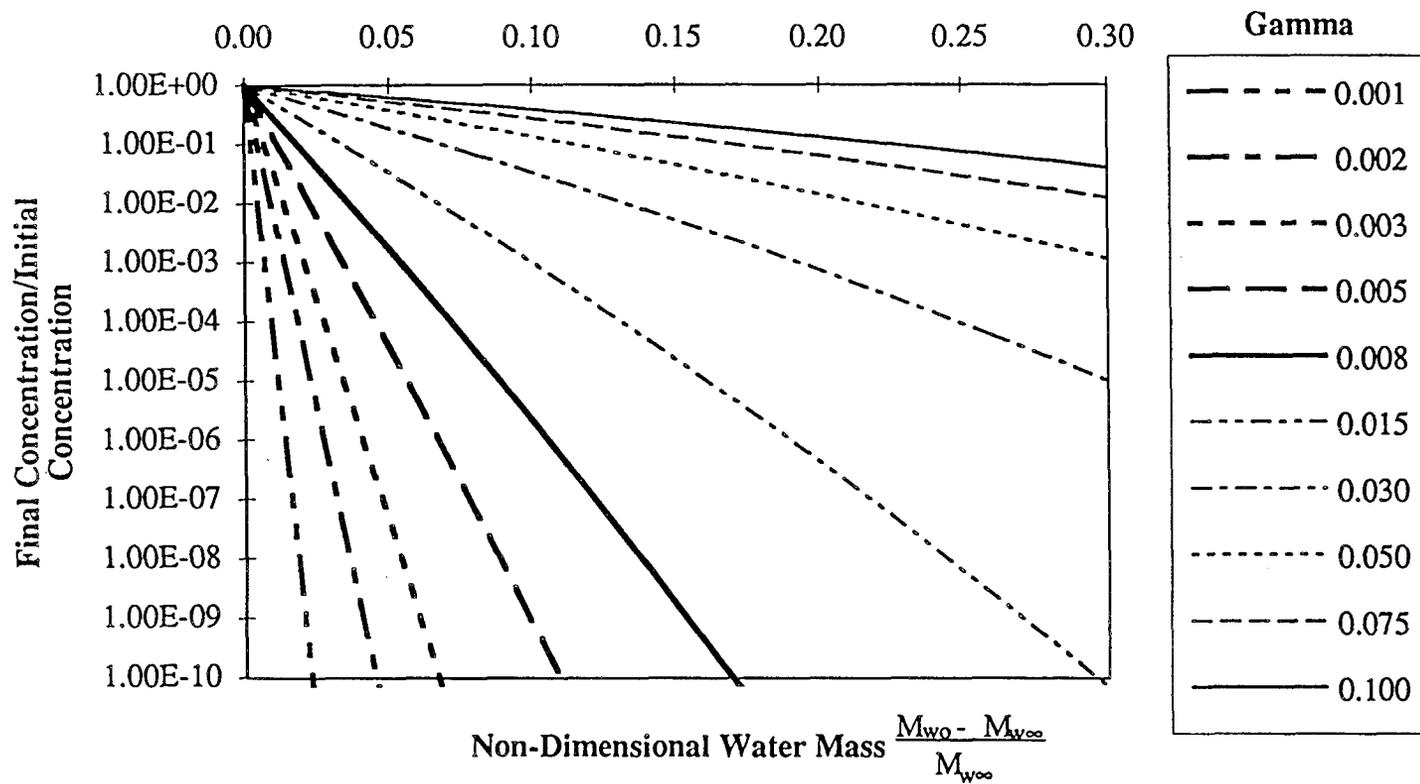


Figure 17. Ratio of final concentration to initial concentration of dissolved NAPL for different values of gamma as a function of non-dimensional water mass

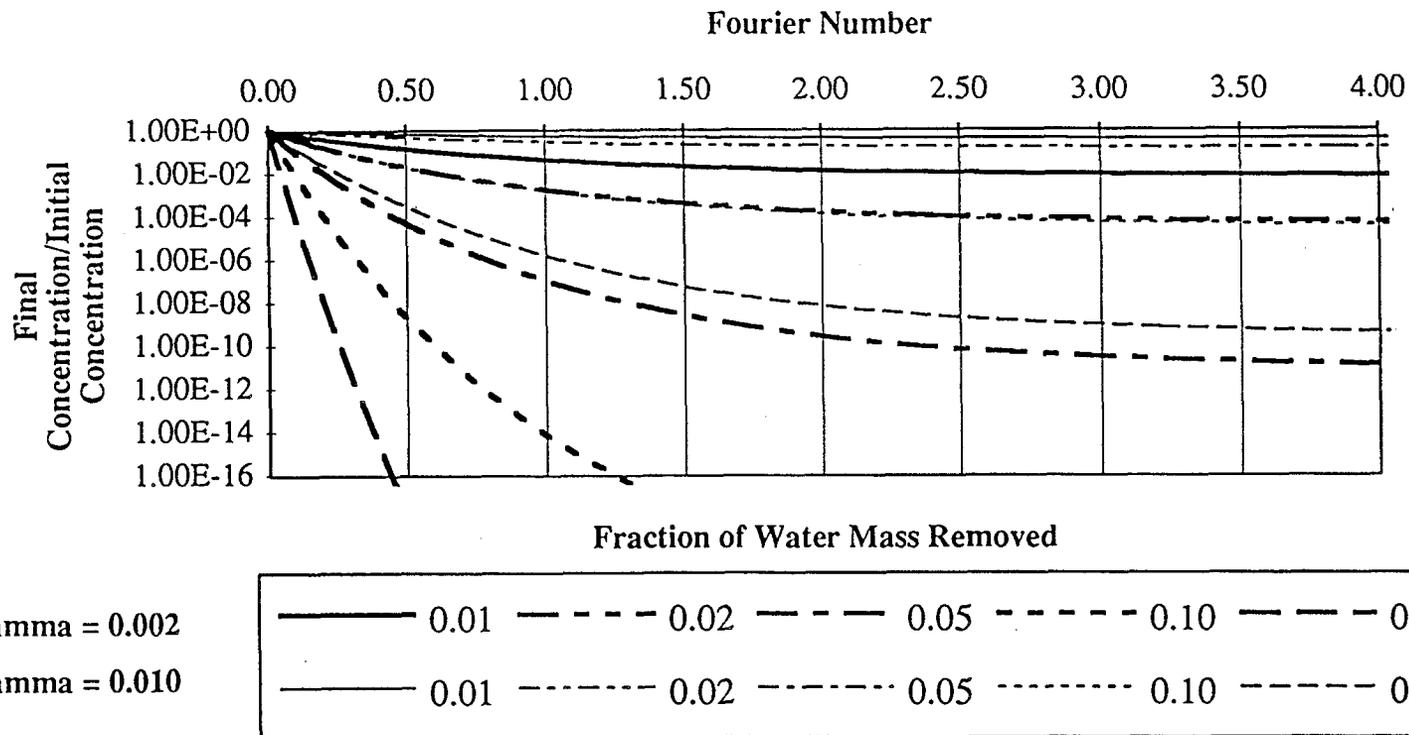


Figure 18. Reduction of the Concentration of Contaminant as a function of Gamma and Mass Fraction of Water Removed

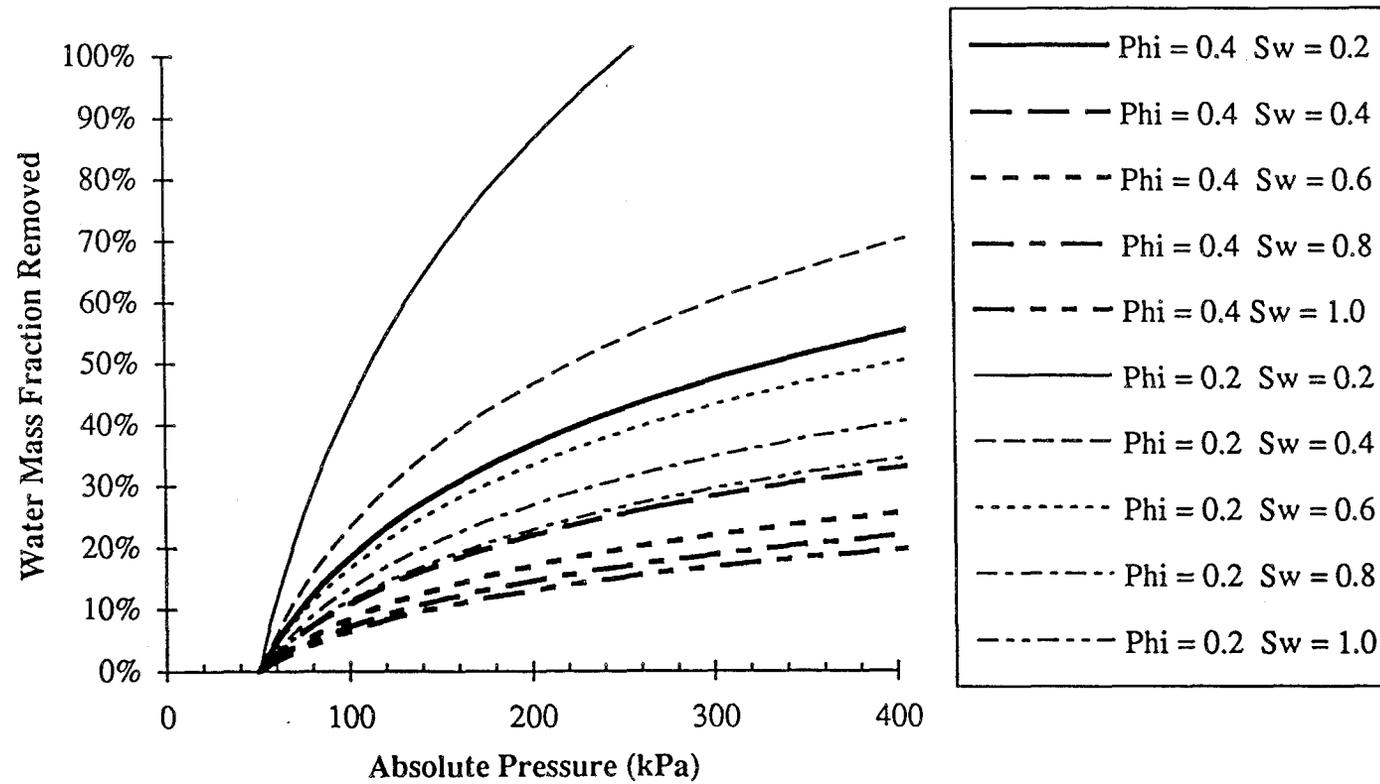


Figure 19. Water mass fraction removed due to an absolute pressure decrease from indicated values to 50 kPa for different porosities and initial water saturations.

PCE-30%			
	Steam Only	44 Hour Cycle	10 Hour Cycle
0.99% clean	162	195	112
1 ppb	184	221	128
Steam time to 1 ppb	184	132	84
Fourier No	-	7.28	1.65

PCE-85%			
	Steam Only	22 Hour Cycle	10 Hour Cycle
0.99% clean	*	*	*
1 ppb	*	*	*
Steam time to 1 ppb	*	*	*
Fourier No	-	3.64	1.65

TCE-30%				
	Steam Only	22 Hour Cycle	10 Hour Cycle	6 Hour Cycle
0.99% clean	90	73	64	61
1 ppb	113	111	84	73
Steam time to 1 ppb	113	66	52	46
Fourier No	0	3.64	1.65	0.99

TCE-85%			
	Steam Only	22 Hour Cycle	10 Hour Cycle
0.99% clean	190	156	124
1 ppb	*	199	144
Steam time to 1 ppb	*	110	82
Fourier No	-	3.64	1.65

* Simulation not completed

Table 1. Steam cycle efficiencies for various initial conditions.

	Molecular Weight [g/mole]	Vapor Pressure [kPa]	Solubility [ppm]	Mass Fraction Water Phase	Mass Fraction Vapor Phase	Gamma []
Benzene	78.11	12.7	1780	0.18%	28%	0.00639
Toluene	92.13	3.80	510	0.05%	11%	0.00463
Ethylbenzene	106.2	1.27	160	0.02%	4%	0.00360
p-Xylene	106.2	1.17	190	0.02%	4%	0.00463
TCE	131.40	10.0	1100	0.11%	33%	0.00332
PCE	165.83	2.5	140	0.01%	13%	0.00112
Carbon Tetrachloride	153.80	15.1	1160	0.12%	48%	0.00241
Chloroethane	64.90	100.7	5710	0.57%	100%	0.00573
Dichloromethane	84.90	58.4	19400	1.94%	80%	0.02427

Table 2. Values for the Mass Fraction Ratio Γ for various chemicals at 20°C