



DEPARTMENT OF THE AIR FORCE

HEADQUARTERS SACRAMENTO AIR LOGISTICS CENTER (AFLC)
MCLELLAN AIR FORCE BASE, CALIFORNIA 95833-5000

23 JUL 1991

REPLY TO
ATTN OF: EMR

SUBJECT: Soil Vapor Extraction Treatability Investigation at Site S Within Operable Unit D, McClellan AFB: Draft Final Copies of Sampling and Analysis Plan, Addendum to Quality Assurance Project Plan, and Health and Safety Plan
TO: SEE DISTRIBUTION

1. The above mentioned documents, along with formal response to regulatory agency comments, are attached for your records.

2. These documents are identified as secondary documents to the primary Operable Unit (OU) B Remedial Investigation/Feasibility Study (RI/FS) Proposed Plan according to the guidelines promulgated in our Interagency Agreement (IAG). These documents have been prepared for the United States Air Force for the purpose of aiding in the implementation of a final remedial action plan. The ongoing nature of the RI/FS, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating these documents since subsequent facts may become known, which make these documents premature or inaccurate. Acceptance of these documents in performance of the contract under which they were prepared, does not mean that the United States Air Force or the Department of Defense adopts the conclusions, recommendations, or other views expressed herein which are those of the contractor only, and do not necessarily reflect the official position of either department. The attached CH2M Hill documents have been reviewed as a matter involved in litigation, and have been approved for release to the general public.

3. If you have any questions, please contact me at (916) 643-1250.

FRANCIS E. SLAVICH
Project Officer

3 Atch

- 1. Sampling & Analysis Plan - AD
- 2. Addendum to Quality Assurance Project Plan - AD
- 3. Health & Safety Plan - AD
- 4. Response to Agency Review - AD
Comments Regarding the
Draft Copy of the
Health & Safety Plan

Return to
FDAC

PREFACE

CH2M HILL is a contractor for the RD/RA alternate technology program at the McClellan AFB in California. The specific technology addressed is soil vapor extraction. This document is a secondary document to the primary OUB RI/FS Report/Proposal Plan. The work is being conducted under Air Force Contract No. F04699-90-0035, Delivery Order No. 5019.

Key CH2M HILL project personnel are:

Starr J. Dehn--Program manager
Gerald R. Tracy--Project manager
Joseph P. Danko--SVE technical coordinator
Donna Morgans--Data validation
Michael McCann--Data coordinator
David Myers--Field task leader
Kathy Brewer--Health and safety

CH2M HILL would like to acknowledge the cooperation of the McClellan AFB Office of Environmental Management for assistance in expediting this project. In particular, CH2M HILL acknowledges the assistance of Captain Fran Slavich.

The work discussed in this document is being conducted between June 1991 and April 1992.

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Section 1 INTRODUCTION

→ This sampling and analysis plan (SAP) describes procedures developed for the treatability investigation of soil vapor extraction (SVE) at Site S, in Operable Unit (O.U.) D at the McClellan Air Force Base near Sacramento, California. The purpose of the treatability investigation is to develop sufficient field and operational data to assess the applicability of SVE technology in removing site-specific contaminants at the base. This information is then fed into the ongoing Remedial Investigation/Feasibility Study (RI/FS) efforts to aid in selection of cost-effective remediation procedures for specific types and locations of contaminants.

Previous investigations at Site S in O.U. D indicate that contaminants were derived from disposal of spent solvents and fuels. Contaminants at Site S are typical of those at many locations across the base. SVE technology has been successful at other off-base sites in removing similar contaminants in similar soil matrices. The treatability investigation at Site S will allow assessment of the effectiveness of SVE in removing volatile contaminants and less-mobile compounds from the waste pit and from the native soils below the pit. The result will also be useful in assessing SVE applications to other similar on-base sites.

BACKGROUND INFORMATION

The SVE treatability investigation will be carried out in Site S of O.U. D at McClellan AFB, located near Sacramento, California. An area map showing the general location of the McClellan AFB is presented as Figure 1-1.

Operable Unit D consists of approximately 140 acres located in the northwest portion of McClellan Air Force Base (Figure 1-2). The area was first used for waste disposal in the 1940s and was most recently used in 1981. Past disposal practices in O.U. D included landfills, disposal pits, open burning, incineration, sludge drying beds, and landfarms. Materials disposed of within O.U. D include industrial sludge, waste solvents, fuel, and oil. Approximately 38,000 cubic yards of waste sludge are known to be present in O.U. D. There are varying levels of volatile organics, organic acids, base/neutral compounds, trace metals, and cyanides present in both the sludge and the surrounding soil. Some of these contaminants have also been detected in the groundwater beneath O.U. D.

→ Site S is one of 12 waste disposal sites identified in O.U. D (see Figure 1-3). It has been identified as a former fuel and solvent disposal pit. Site S encompasses approximately 9,200 square feet, and the waste disposal zone extends from about 4 to 15 feet below the ground surface.

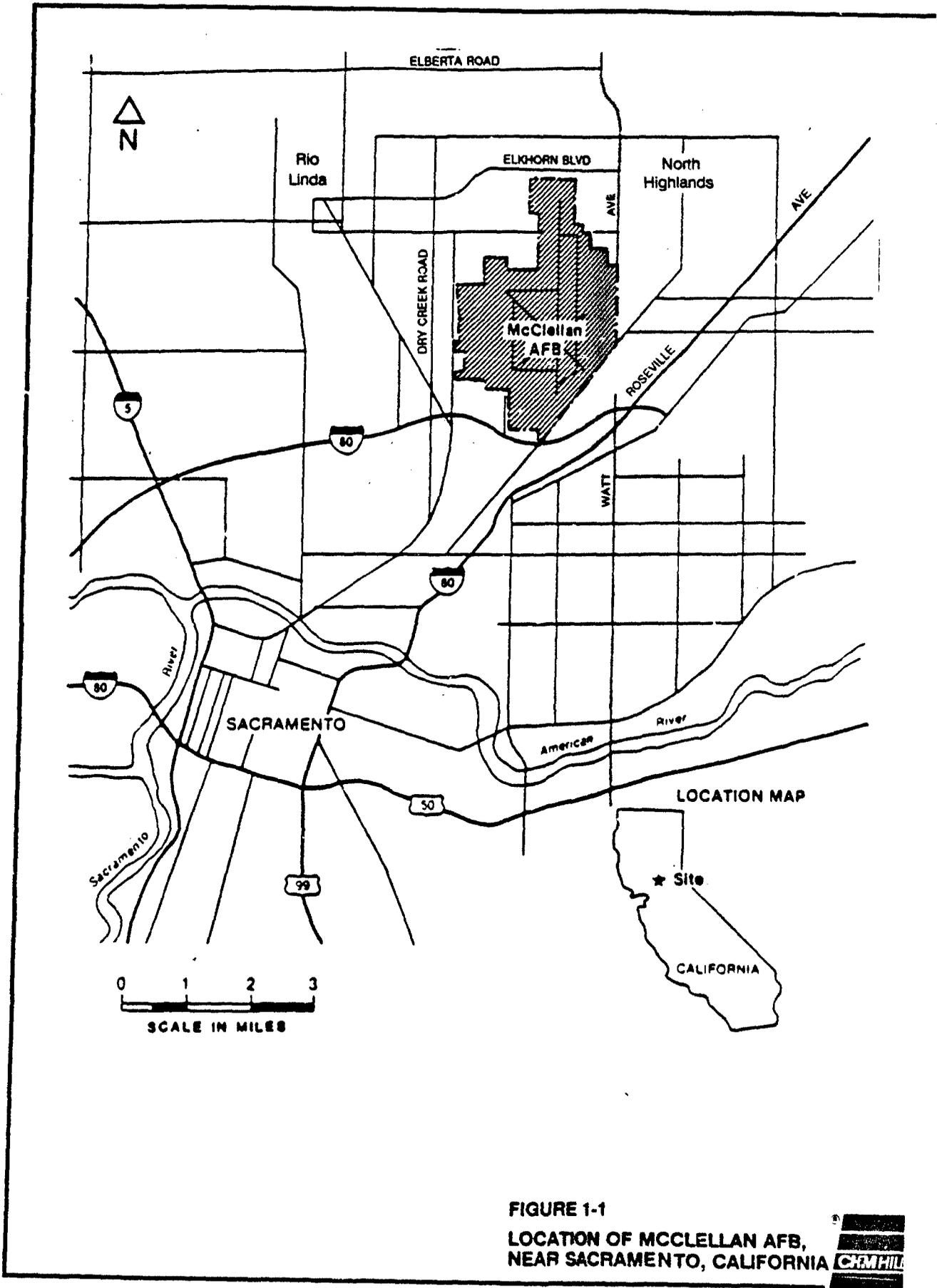


FIGURE 1-1
LOCATION OF MCCLELLAN AFB,
NEAR SACRAMENTO, CALIFORNIA



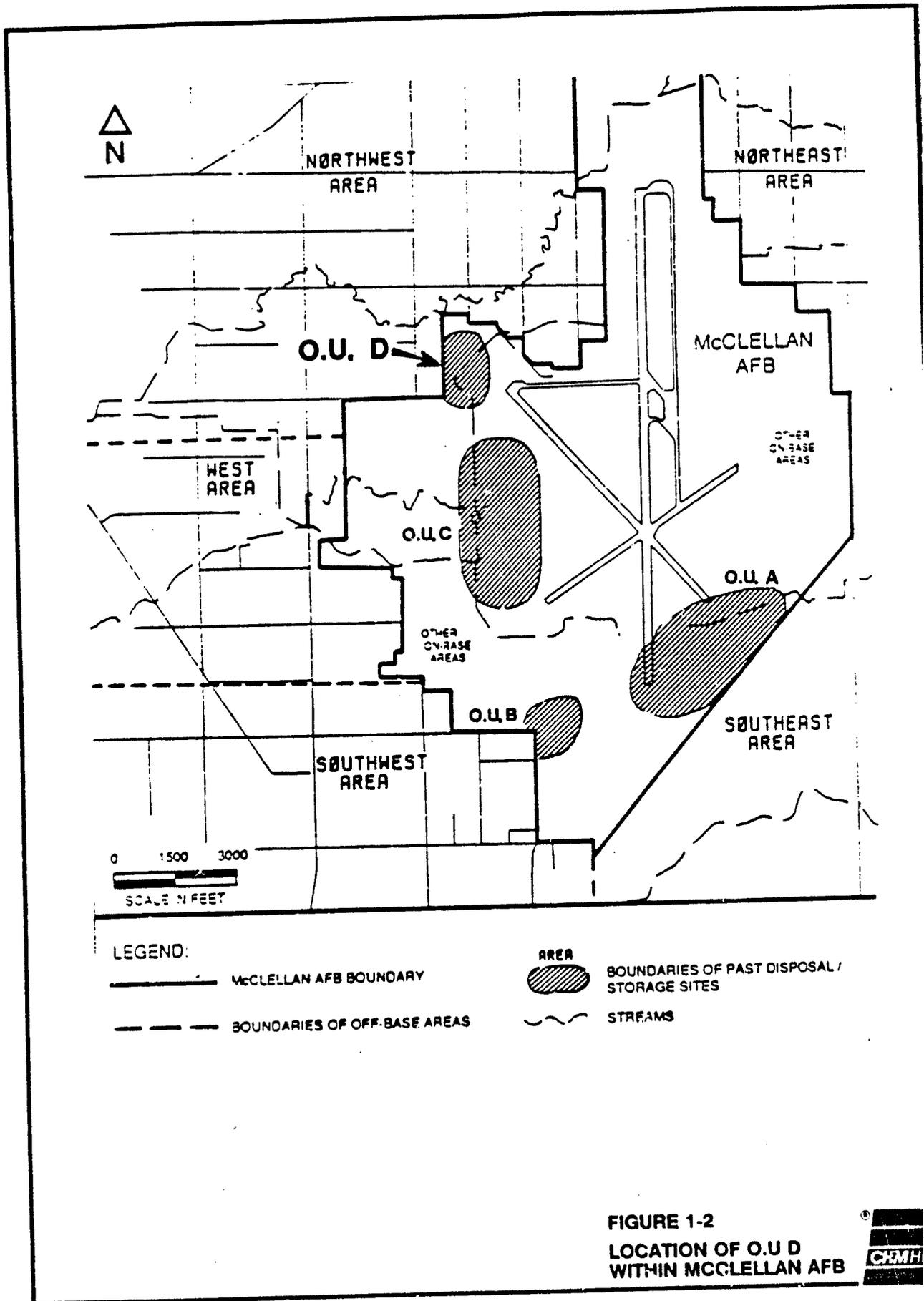
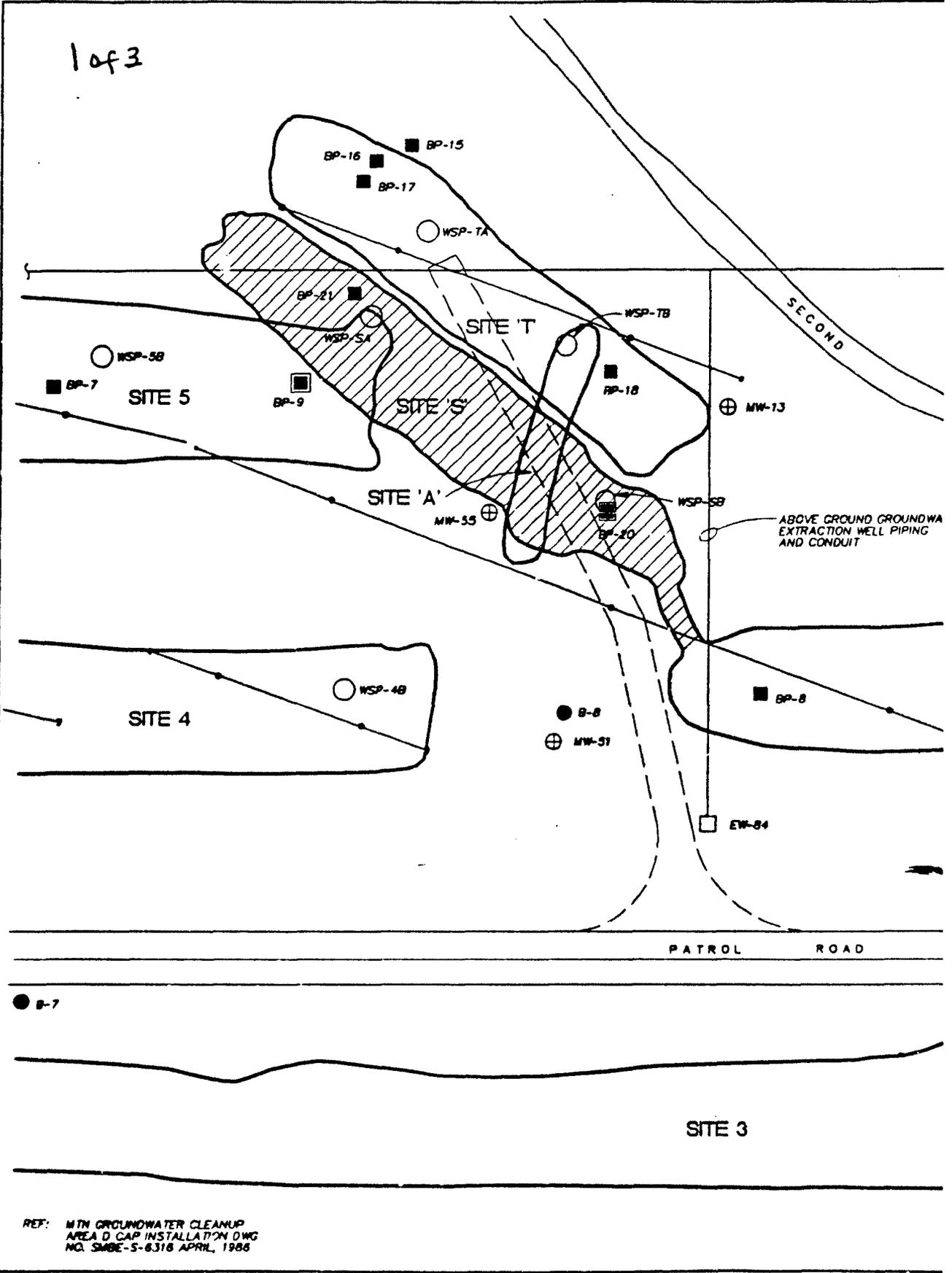


FIGURE 1-2
LOCATION OF O.U. D
WITHIN MCCLELLAN AFB



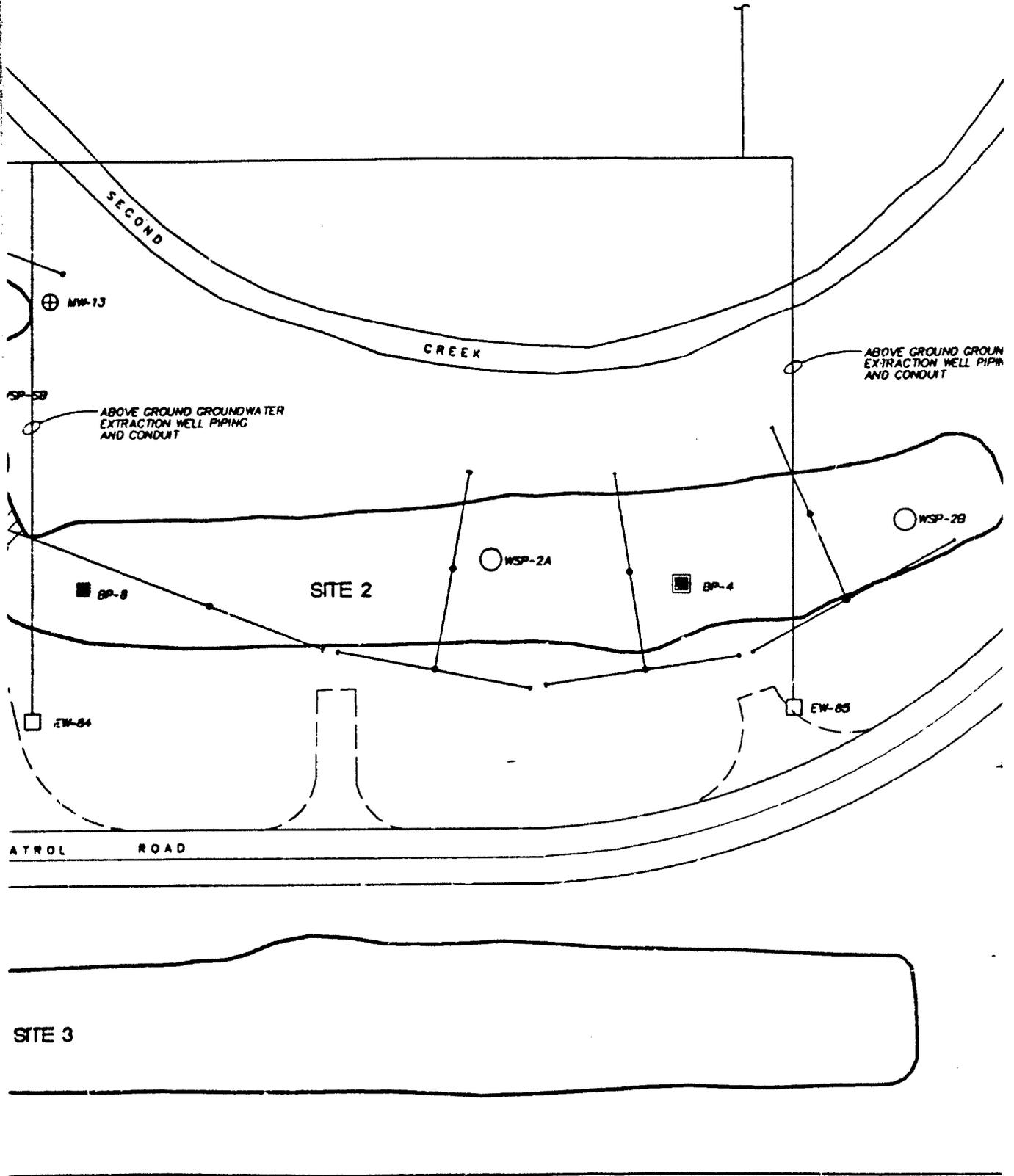
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 AREA D CAP INSTALLATION DWG
 NO. SMGE-S-8316 APRIL, 1986

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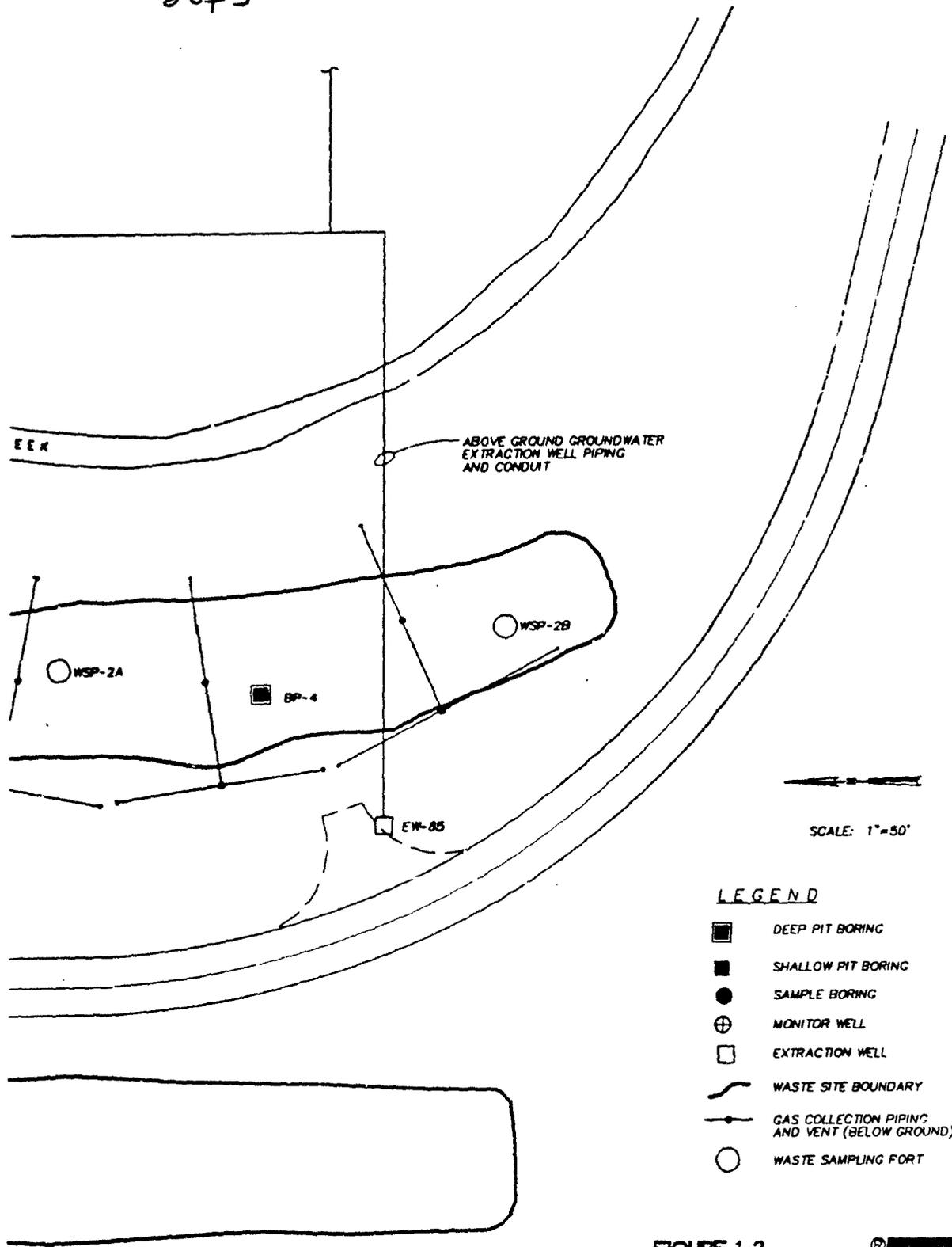


FIGURE 1-3
SITE S, O.U. D
LOCATION MAP



In 1985, two investigation borings were installed in Site S at locations shown in Figure 1-3. Soil boring logs are included in Appendix C. Figure 1-4 shows a geologic cross section through Site S and provides a list of detected contaminants. The soil contaminants found at the site are primarily volatile organic compounds, including ethylbenzene, toluene, xylene, dichlorobenzene, acetone, and 4-methyl-2-pentanone. Some semivolatile compounds were also detected. The water table in this area is approximately 100 feet below ground surface. The data collected during the 1985 investigation has been used to select Site S within O.U. D as the site for the SVE treatability investigation. The data collected during the 1985 investigation confirmed that the pit was in fact used mainly for disposal of spent solvents and fuels, rather than for mainly burn materials or industrial solids.

In 1985, as part of the McClellan AFB IRP, a multilayer cap was installed over the entire surface of O.U. D. The purpose of the low-permeability cap was to prevent rainwater infiltration and soil gas migration. Thirty-two vent risers were installed in the cap to allow for venting or collection and disposal of soil gas that might accumulate under the cap. The majority of invasive actions taken as part of the SVE treatability investigation will require penetrating the cap. Details of the cap penetration are discussed in Section 5.

(cont)

TREATABILITY INVESTIGATION COMPONENTS

→ Primary

The SAP has been developed to provide operating guidelines for field personnel associated with each component of the treatability investigation. The SVE treatability investigation will include two separate field efforts: a site characterization study and an SVE pilot test. The treatability investigation will be carried out in Site S. The primary objectives of the sampling and analysis efforts are to:

- 1) Assess the nature and extent of vadose zone soil contamination within the treatability investigation area
- 2) Evaluate the in situ permeability of vadose zone soils within the treatability investigation area
- 3) Obtain site-specific field data for design of the pilot-scale SVE system; and
- 4) Evaluate the effectiveness and implementability of SVE for site remediation and recovery.

The first phase of fieldwork will involve the installation of approximately nine soil borings and completion of each of the borings as either a soil vapor extraction well, or air injection well, or piezometer nest. This will be the first phase of vertical and areal characterization of waste deposited in the pit at Site S and subsurface soils below the

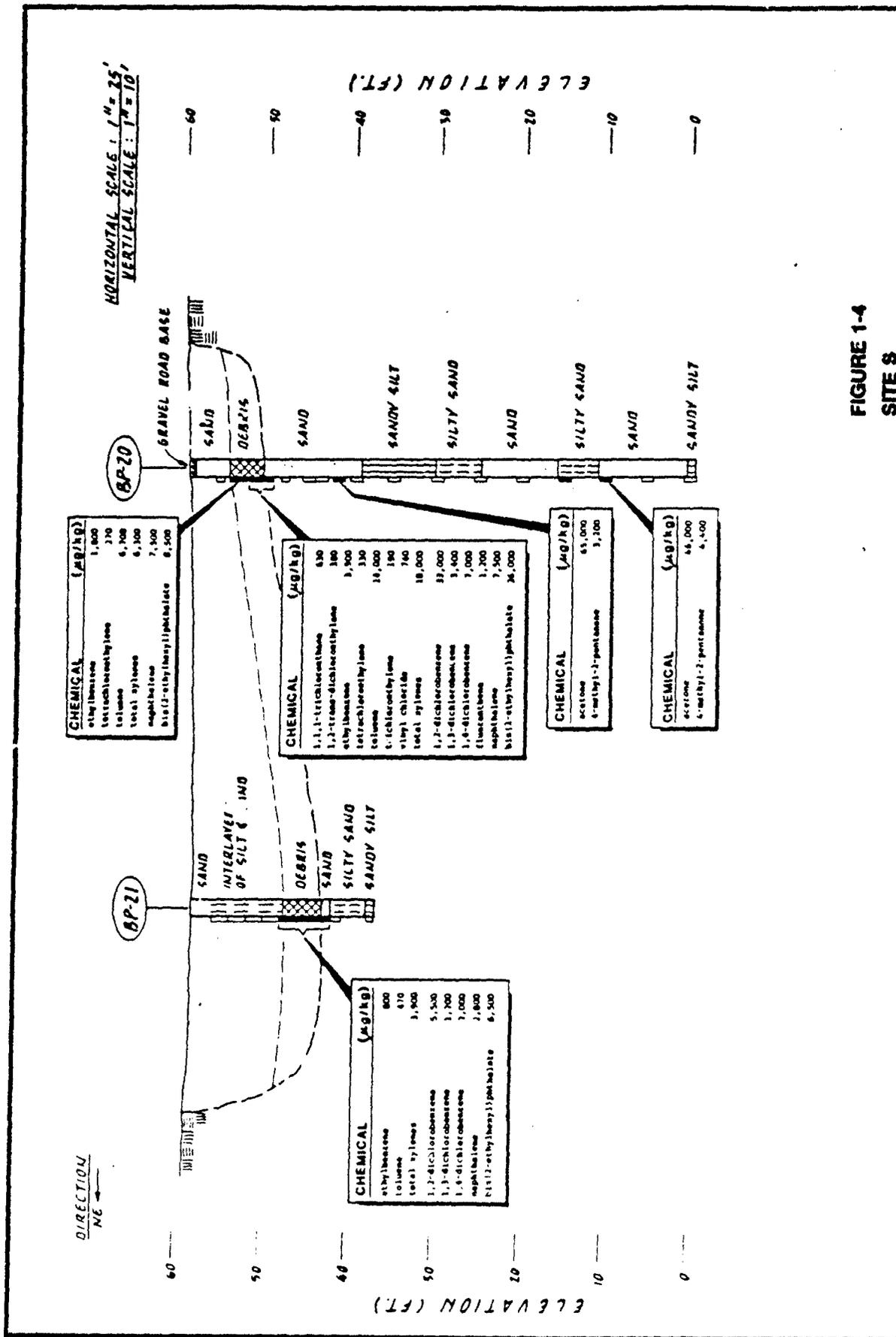


FIGURE 1-4
SITE 8
GEOLOGIC CROSS-SECTION
PHASE III/IV
MCCLELLAN AFB, IRP



waste pit. Within each boring, soils will be analyzed for VOCs, semi-VOCs, total petroleum hydrocarbons, dioxins, cyanide, metals, PCBs, and pesticides. The level of laboratory QA/QC will be consistent with the methodology described in the IRP QAPP so that the data can be used in the final O.U. D RI to be conducted at McAFB.

The areal locations for soil borings (shown on Figure 5-1) were selected to provide adequate radial and vertical negative pressure gradients as a function of system flow during the air permeability testing. It is critical that permeability be assessed in each of the contaminated strata encountered to design an SVE pilot system capable of removal of contaminants from each contaminated zone encountered.

Installation of approximately nine soil borings as part of this treatability investigation is not meant to completely characterize the nature and extent of contamination at Site S in O.U. D. Data from the nine borings should define the general nature of contaminants to be encountered and the waste matrix that the contaminants are partitioned in. This information will be used to design additional pilot test SVE wells, air injection wells, and piezometer nests to be installed as part of the pilot test construction in 1992. Pilot test SVE wells will be installed in a grid-like layout to facilitate sufficient flow through the contaminated media encountered at the site, and to provide additional characterization at every borehole that is drilled. Lithologic logs will be compiled to define the stratigraphic profile at each boring location in order to select the screened zone for each SVE well. This second phase of areal and vertical investigation will provide a thorough pretest site characterization of subsurface materials before the SVE pilot test is operated within Site S. A post-test round of soil sampling will be completed to evaluate the percent reduction of the concentration and mass of contaminants. In addition, the effectiveness of SVE will also be evaluated by analyzing SVE exhaust gas samples throughout the operation of the SVE system. The evaluation of performance of SVE at Site S is discussed further in Section 2 of the SAP. An addendum to this SAP and QAPP will be submitted for agency review during the design phase. The addendum will describe the objectives and approach in collection and analysis of samples during installation of pilot test wells, collection and analysis of SVE inlet and exhaust gas during the pilot test, and selection and analysis of post-treatment soil samples.

COMPANION DOCUMENTS

This SAP was developed in conjunction with a project-specific addendum to the base-wide installation restoration program (IRP) quality assurance project plan (QAPP). The QAPP addendum describes the project organization and responsibilities, quality assurance objectives, laboratory analyses, equipment calibration, technical reporting, and review procedures to be followed throughout the treatability investigation.

A separate health and safety plan (HASP) addendum has also been prepared for the SVE treatability investigation work.

Section 2
SVE SYSTEM DESCRIPTION AND
PERFORMANCE EVALUATION

SVE DESCRIPTION

Soil vapor extraction is a physical means of removing VOCs from contaminated soil. The SVE system will consist of a network of vacuum extraction wells screened in contaminated zones identified during installation of pilot test SVE wells. The extraction wells will be joined together by a common header pipe(s) which will be connected to an air water separator where water is removed. The separator will be connected to a positive displacement blower, which provides a negative pressure gradient in the subsurface. Discharge from the blower will be connected to a thermal incinerator, catalytic oxidation system, or GAC adsorption system, depending upon air emissions requirements and the nature and extent of VOC contamination. Wastewater from the air water separator will probably be transported to the on-base Industrial Wastewater Treatment Plant for treatment. Refer to Figure 2-1 for a schematic of the SVE system.

The subsurface vacuum created by the blower pulls VOC-laden vapors through the subsurface into the extraction wells. Pulling air through soil voids disrupts the equilibrium concentration between liquid or sorbed contaminants and VOCs in the gas phase. A concentration gradient is established from liquid or sorbed contaminants in soil interstices and micropores and VOCs present in the gas phase. Evaporation of contaminants to the gas phase occurs in the same manner in which air stripping removes contaminants from groundwater. The vacuum also decreases pressure in soil voids, thereby causing the release of additional VOCs (1).

ADVANTAGES OF SVE

The current increase in the use of SVE stems from the advantages, including ones related to regulatory factors, associated with the in situ nature of the technology. These advantages include the following (1):

- Biodegradation of hydrocarbons as a result of increased vadose zone oxygen supplied by the SVE system.
- SVE is minimally intrusive to contaminated soils. The potential release of VOCs to onsite and offsite receptors is insignificant when compared to excavation and removal of contaminated soils.
- SVE is not a complicated technology to implement. However, optimal sizing and operation of this equipment on a medium-sized or larger site does require assistance from experienced personnel. Also, if flammable

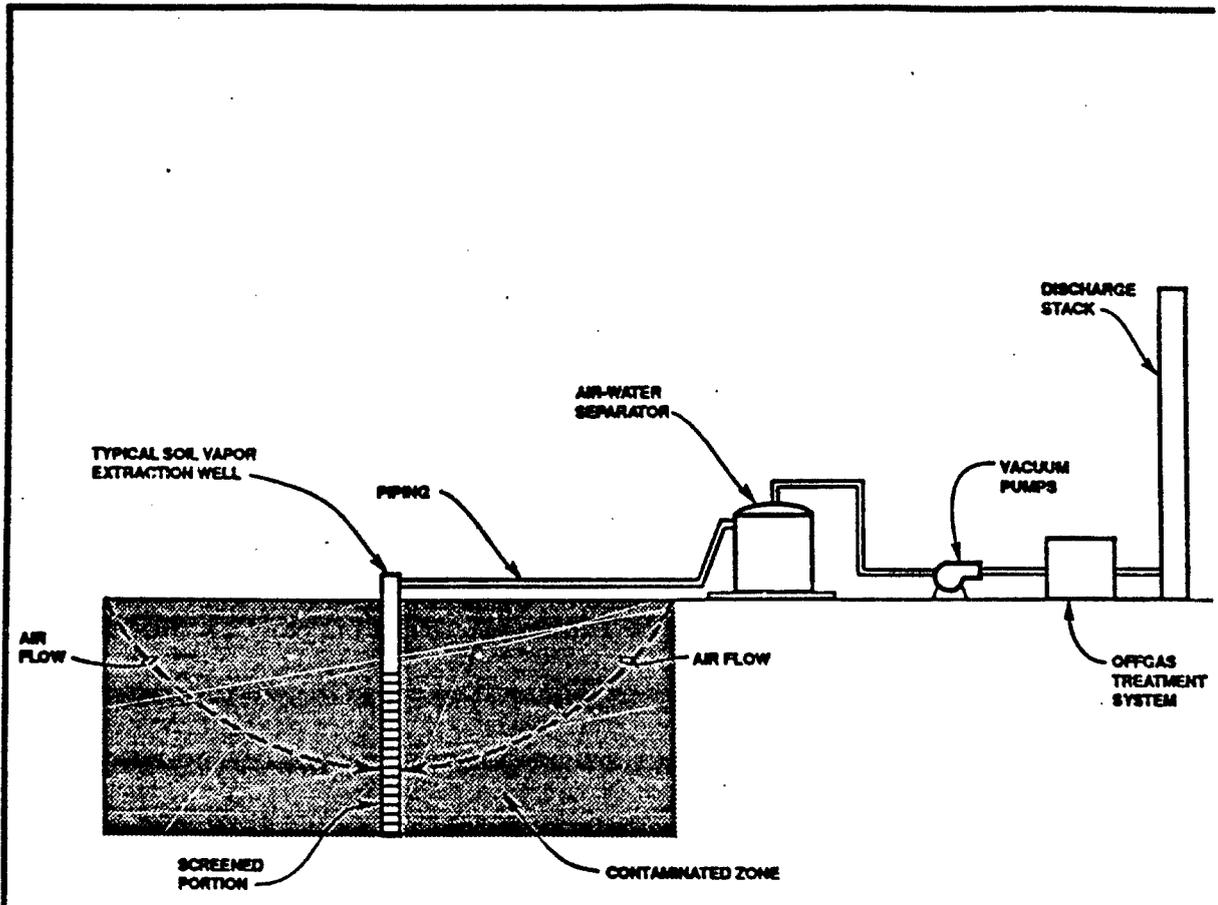


FIGURE 2-1
SCHEMATIC OF SOIL VAPOR
EXTRACTION SYSTEM

McCLELLAN AIR FORCE BASE
 SVE TREATABILITY INVESTIGATION



VOCs are present, care must be taken to avoid fire and/or explosion in the SVE system.

- The use of SVE can result in a relatively quick reduction of VOCs.
- SVE can reduce the vadose zone source input, thereby drastically decreasing the time required for saturated zone pump-and-treat alternatives.
- SVE, when applicable, is usually more cost-effective than other in situ technologies. When compared to excavation costs (with subsequent disposal or treatment), its costs can easily be an order of magnitude lower.
- With the land ban on solvent tainted soils, SVE offers a viable alternative technology to excavation with disposal or treatment.

LIMITATIONS OF SVE

VOLATILITY OF CONTAMINANTS

SVE is applicable if VOCs are the primary contaminants in the soil. As a guideline, a compound is a likely candidate if it has both of these characteristics:

- Vapor pressure (P^*) of 1.0 mm or more of mercury at 20°C
- Henry's Law constant greater than 100 atmospheres/mole fraction (in the moderate range), or dimensionless Henry's Law constants greater than 0.01.

Examples of VOCs amenable to SVE are: 1,1,1-trichloroethane, tetrachloroethylene, 1,2-dichloroethane, benzene, and toluene. Trichlorobenzene and diesel and other large-molecular-weight petroleum fuels are more difficult to extract. In spite of low volatility of large-molecular-weight hydrocarbons soil venting has been documented to stimulate biodegradation of these and other smaller chain hydrocarbons (Miller et al., 1990, and Elliott et al., 1989).

GROUNDWATER DEPTH

SVE usually is a good alternative for sites where the majority of contamination is in the vadose zone. Sites where the majority of contaminants are in the saturated zone must be evaluated to compare dewatering and subsequent SVE with groundwater pumping and treatment in conjunction with SVE. This evaluation should consider the saturated zone characteristics, the overall cleanup schedule, and the regulations governing discharge.

CHARACTERISTICS OF CONTAMINATED SOIL

SVE is typically more applicable to cases where the contaminated unsaturated zone is relatively permeable (hydraulic conductivities in excess of 10^{-3} or 10^{-2} $\text{cm}^3/\text{cm}^2\text{-sec}$) and uniform. Sands and gravels are especially amenable to SVE. However, the technology has been used in less permeable clayey or silty soils with some success. Agrelot et al., 1985 and Applegate et al., 1988, demonstrated removal of contaminants in soils with conductivities ranging from 10^{-3} to 10^{-6} . This success could be due to the presence of more permeable sand and gravel strata typically found in alluvial settings or the relatively low moisture contents in the finer-grained soils (Bennedsen, 1987).

Michaels and Stinson (1989) have found that porosity appears to be a more important characteristic to consider when evaluating the applicability of SVE. These conclusions are based on the results of the SITE program demonstration test of Terra Vac's vacuum extraction system in Groveland, Massachusetts. Significant VOC removal rates were achieved in relatively impermeable clays (hydraulic conductivities of 10^{-7} $\text{cm}^3/\text{cm}^2\text{-sec}$) and more permeable sands (hydraulic conductivities of 10^{-3} $\text{cm}^3/\text{cm}^2\text{-sec}$). Both soil strata had porosities between 40 and 50 percent.

PRELIMINARY REMEDIATION GOALS

The first step in establishing protective remedial action objectives is the development of preliminary remedial goals (PRGs). PRGs are initially based on readily available chemical-specific ARARs (e.g., MCLs) or health-based levels of concern. The PRGs developed will be refined using site-specific data generated during the RI.

As the treatability investigation and RI/FS progresses, site specific information will be used to set final remediation goals. Some of the major factors (from the baseline risk assessment) that will result in the modification of initial calculated PRGs are: the presence of sensitive and site worker populations, local climate and terrain (and their influence on exposure frequency assumptions), the physical characteristics of the chemical (i.e., volatility, partitioning behavior, etc., which will determine the importance of other pathways), and the presence of background contaminants. In addition, the environmental evaluation may have a significant impact on final remedial goals. The importance of these factors cannot be overstated. Final goals may be quite different from preliminary goals first determined from the standardized equations for some sites or contaminants. Close contact throughout the treatability and RI/FS process between risk assessors and persons developing remediation strategies will be necessary to achieve final remediation goals that are protective and addressed by appropriate remedial actions.

The NCP states that "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or

multiple pathways of exposure..." (Section 300.430(e)(2)(i)(A)(2)(55 *Federal Register* 8848)). Therefore, this value is used in the initial PRG equations (when chemical-specific ARARs are unavailable). Noncancer risk is expressed in terms of the hazard quotient. A value of 1 is used in these equations, where the intake equals the reference dose.

Table 2-1 lists both ingestion and leaching PRGs for all contaminants previously identified at the site. The PRGs were developed following the draft *EPA Risk Assessment Guidance for Superfund: Volume I--Human Health Evaluation Manual (Part B)*, April, 1990. To provide PRGs for chemicals with no available ARARs, medium specific risk-based equations have been developed for cancer and non-cancer risks to account for some common exposure pathways for Site S. The PRGs have been calculated assuming an incidental ingestion pathway and a leaching pathway. The risk-based equations have been developed by using reasonable maximum exposure (RME) assumptions for a scenario of future residential use of the site. These equations cover a small fraction of the possible exposure scenarios possible at the site. Leaching PRGs were determined by multiplying the MCL by an assumed attenuation factor of 100 to develop a soil level of concern. The attenuation factor was based on California Regional Water Quality Control Board published guidelines (October 1986). If no MCLs existed, the risk-based groundwater level of concern was multiplied by the assumed attenuation factor of 100. The site-specific baseline risk assessment will identify the most relevant exposure assumptions (based on RME conditions) to be used in identifying final remediation goals. In addition, levels acceptable for delisting the waste and levels set at other similar sites will be evaluated during the RI, and will be considered when establishing final remediation goals.

SVE PERFORMANCE EVALUATION

The effectiveness of the SVE system will be evaluated by comparing concentration levels of contaminants and the reduction in the mass of contaminants before, during, and after the pilot testing. The three main approaches to assessing the effectiveness of SVE include:

- Determine the average concentration of contaminants in the waste pits and subsurface materials. This data will be combined with the volume of Site S and average soil density to determine the approximate mass of contaminants before the pilot test and after the pilot test has been completed. This is planned to provide only a rough approximation of the mass of contaminants. No statistical kriging is planned for these mass estimates. Close agreement between pre- and post pilot test sampling could reinforce the measured effectiveness of SVE at the site.

Table 2-1
PRELIMINARY REMEDIATION GOALS AND PROPOSED DETECTION LIMITS
Levels of Concern for Soil and Solid Waste.
McClellan Air Force Base

Chemical	Analytical Method f	Method Detection Limit e (mg/kg)	U.S.EPA Carcinogen Classification	Ingestion Pathway a,b (mg/kg)	Leaching Pathway (mg/kg)
Acenaphthene	8270	0.19		42000	210.0
Acetone	8240	0.10		70000	350.0
Acetophenone	8270	0.28		70000	350.0
Aniline	8270	1.0	B2	298	1.5
Anthracene	8270	0.19		210000	1050.0
Arsenic	200	0.2	A	1	5.0
Benzene	8240	0.005	A	59	0.5
Benzo[a]anthracene	8270	0.78	B2	0	0.0
Benzo[a]pyrene	8270	0.25	B2	0	0.0
Benzo[b]fluoranthene	8270	0.48	B2	0	0.0
Benzo[k]fluoranthene	8270	0.25	B2	0	0.0
bis(2-Ethylhexyl)phthalate	8270	0.25	B2	121	0.5
2-Butanone (MEK)	8240	0.10		35000	175.0
Butylbenzylphthalate	8270	0.25	C	140000	520.0
Cadmium	200	0.5		350	2.0
Chlorobenzene	8240	0.005		14000	70.0
Chloroform	8240	0.005	B2	278	1.5
Chromium III	200	0.20		700000	3500.0
Chromium VI	200	0.5		3500	17.5
Chrysene	8270	0.250	B2	0	0.0
Cyanide	200	0.20		14000	70.0
DDT	8080	0.002	B2	5	0.0
Dibenz[a,h]anthracene	8270	0.25	B2	0	0.0
1,2-Dichlorobenzene	8270	0.19		63000	315.0
1,3-Dichlorobenzene	8270	0.19		63000	315.0
1,4-Dichlorobenzene	8270	0.44	C	71	60.0
1,1-Dichloroethane	8240	0.005	C	70000	350.0
1,1-Dichloroethene	8240	0.005	C	3	0.5
Diethyl phthalate	8270	0.19		560000	2800.0
2,4-Dimethylphenol	8270	0.27		14000	70.0
Di-n-butylphthalate	8270	0.25		70000	350.0
2,6-Dinitrotoluene	8270	0.19	B2	2	0.0
Ethylbenzene	8240	0.005		70000	350.0
Fluoranthene	8270	0.22		28000	140.0
Fluorene	8270	0.19		28000	140.0
Heptachlor epoxide	8080	0.001	B2	0	0.0
Hexachlorobutadiene	8270	0.09	C	22	0.0
Indeno[1,2,3-cd]pyrene	8270	0.37	B2	0	0.0
Isophorone	8270	0.22	C	414	2.0
Lead	200	0.20	B2	----	----
Mercury, inorganic	200	0.02		210	1.0
Methylene Chloride	8240	0.005	B2	226	1.0
4-Methyl-2-pentanone (MIBK)	8240	0.05		35000	175.0
Naphthalene	8270	0.16		2800	14.0
Nickel	200	0.20		14000	70.2
Nitrobenzene	8270	0.19		350	2.0

Table 2-1
PRELIMINARY REMEDIATION GOALS AND PROPOSED DETECTION LIMITS
Levels of Concern for Soil and Solid Waste
McClellan Air Force Base

Chemical	Analytical Method f	Method Detection Limit e (mg/kg)	U.S.EPA Carcinogen Classification	Ingestion Pathway a,b (mg/kg)	Leaching Pathway (mg/kg)
N-Nitrosodiphenylamine	8270	0.19	B2	347	1.5
N-Nitrosodi-n-propylamine	8270	1.0	B2	0	0.0
PCBs	8080	0.02	B2	0	0.0
Pentachlorophenol	8270	0.36	B2	14	20.0
Phenol	8270	0.15		420000	2100.0
Pyrene	8270	0.19		21000	105.0
Styrene	8240	0.005	B2	57	0.5
2,3,7,8-TCDD (Dioxin)	8280	0.01	B2	0	0.0
1,1,2,2 Tetrachloroethane	8240	0.005	C	8	0.0
Tetrachloroethene	8240	0.005	B2	33	0.5
Toluene	8240	0.005		140000	700.0
trans-1,2-Dichloroethene	8240	0.005		14000	70.0
1,2,4-Trichlorobenzene	8270	0.19		910	4.5
1,1,1-Trichloroethane	8240	0.005		63000	315.0
1,1,2-Trichloroethane	8240	0.005	C	30	0.5
Trichloroethene	8240	0.005	B2	154	1.0
Trichlorofluoromethane (F-11)	8240	0.01		210000	1050.0
2,4,5-Trichlorophenol	8270	1.0		70000	350.0
Vinyl Chloride	8240	0.01	A	1	0.0
Xylenes	8240	0.005		1400000	7000.0
EXPOSURE ASSUMPTIONS					
Exposure Setting					Resident
Exposed Individual					Ad
Daily Soil Ingestion Rate (milligrams/day)					1.000E+
Body Weight (kilograms)					7.000E+
Number of Days/Week Exposed					7.000E+
Number of Weeks/Year Exposed					5.000E+
Number of Years Exposed					3.000E+
Lifetime (yrs)					7.000E+
Excess Lifetime Cancer Risk					1E-
<p>a. Risk assessment-based values estimated for an assumed incidental ingestion pathway using the following exposure assumptions. Values are intake levels which equal 1E(-6) excess cancer risk for carcinogens or RfD intake levels for noncarcinogens.</p> <p>b. Source of toxicity values: U.S. EPA Health Effects Assessment Summary Tables, Annual, FY1991, and U.S. EPA IRIS data</p> <p>c. Values are based on groundwater protection and assume a leaching pathway. Either the MCL or risk-based groundwater level concern was multiplied by an assumed attenuation factor of 100 to develop a soil level of concern.</p> <p>d. Based on Federal MCL.</p> <p>e. The method detection limits are based on the analysis of clean soil. Actual reported detection limits will vary depending upon sample dilution required to maintain the sample within the linear calibration range of the analytical instrument.</p> <p>f. Analytical methods are from "US EPA SW-846", Third Edition (1986), except for the analytical methods for metals (200 series) which are from "EPA Methods for Chemical Analysis of Water and Waste", US EPA-600/4-79-020 (1983).</p>					
<p>NOTE: The "target" concentrations presented in this table do not represent a determination by CH2M HILL of "safe levels". Target levels are for reference purposes only. They can serve as a first cut at clean up goals. The target levels are provided for individual chemicals and do not account for joint effects of mixtures. A site-specific exposure assessment could change these</p>					

- Calculate the average percent reduction in the concentration of contaminants from pre- and post-treatment boreholes and in separate waste matrices where possible. While similar to the first approach described above, this method would not plan to extrapolate concentrations across the site, but instead focus the evaluations on specific boreholes within the site.
- Monitoring the rate of decrease of contaminants in the SVE offgas by obtaining SUMMA canister samples and/or conducting process monitoring with an onsite GC as the pilot test proceeds. Canister samples would be analyzed following Method TO-14, and onsite GC analysis would quantitate a target list of the most prevalent VOCs identified during the air permeability test. Process monitoring, including speciation of VOCs, tracking process flows, temperature, and system pressures, will provide data required to:
 - Calculate cumulative pounds removed
 - Track temporal variation of individual VOCs during the test.

The system will be shut down and restarted periodically to evaluate the restart spike and hence the progress of source strength reduction. The TO-14 analyte list does not and will not include all compounds detected at Site S. The method includes speciation of only volatile organics. The effectiveness of SVE at removing semivolatiles will be evaluated by comparing percent reduction of semivolatiles as measured by before and after soil analysis by method SW8270. SVE has reduced the concentration of semivolatiles at other sites, however the effectiveness of the technology in reducing the concentration of these less volatile compounds is highly waste-specific and will be evaluated during the pilot test.

It can be argued that SVE offgas concentrations represent preferential flow paths and may not provide indication of the effectiveness of the technology in less permeable strata. Therefore, it is planned to measure the rate of change of VOCs from soil gas monitoring probes (piezometers), since they have been installed mainly in less permeable silty strata. Canister sampling and field screening methods will be used to measure the percent reduction of VOCs from soil gas monitoring probes.

Section 3
PROJECT SCHEDULE

An initial project schedule is presented as Figure 3-1. The site characterization portion of the treatability investigation is scheduled to occur between mid-June 1991 and August 1991. The SVE pilot test is currently scheduled to begin in mid-1992 and continue for at least 6 months.

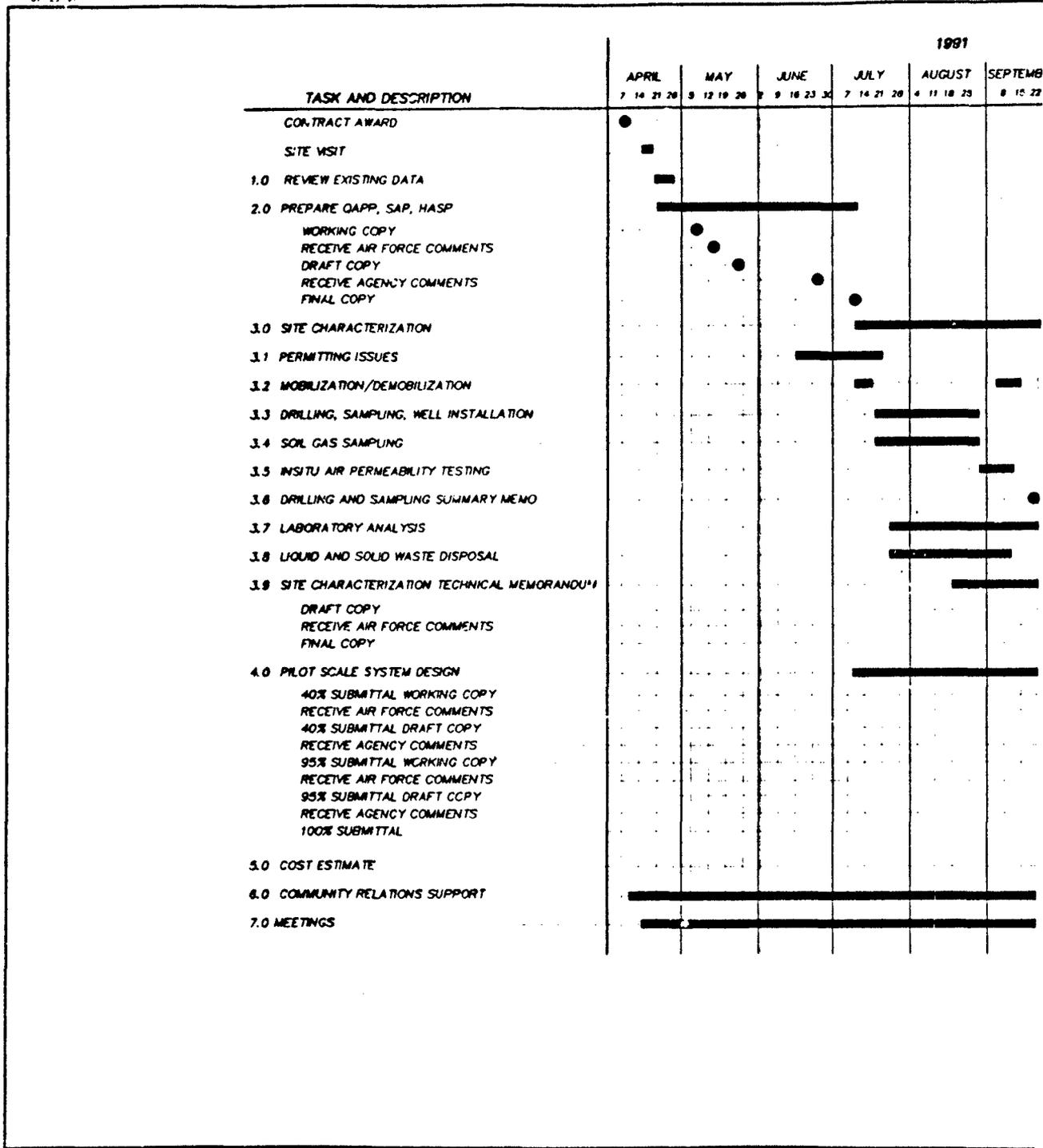


Table 4-1
Characterization Sampling and Analysis Program

Sample Matrix	Field Parameter	Laboratory Parameter	Analysis Level	Samples			Duplicates			
				No.	Frequency	Total	No.	Frequency	Total	
Soil Boring Samples										
Soil	HVs or equivalent	N/A	I	300	1	300				
	N/A	SW 8240	IV	50	1	50	5	1	5	
		MM SW 8015	IV	40	1	40	5	1	5	
		SW 9010	IV	100	1	100	10	1	10	
		PP	IV	7	1	7	1	1	1	
	Dry sieve	N/A		I	30	1	30			
	N/A	TOC 415.1		III	10	1	10			
N/A	Grain size distribution, porosity, permeability, and percent saturation		III	12	1	12				
Air Permeability Test Samples										
Air	N/A	Modified TO-14	III	4	1	4	1	1	1	
SVE Pilot Test Sampling and Analysis Program^c										
Air	HVs	N/A	I	6	78	468				
	O ₂	N/A	I	6	26	156				
	Relative humidity	N/A	I	6	26	156				
	Temperature	N/A	I	6	26	156				
	N/A	TO-14	III	6	3	18	1	3	3	
	N/A	CO	III	1	4	4	1	4	4	
	N/A	HCl	III	1	4	4	1	4	4	
^a Field blanks will be collected at a 5 percent frequency. One equipment blank will also be collected and analyzed for each analytical parameter. ^b Trip blanks will be submitted at a one-per-shipment rate for analysis. ^c Preliminary estimate. This phase will be further developed and detailed in an Addendum to this QAPP submittal during the design phase.										
Notes: MM 8015 = Total petroleum hydrocarbons; modification as described in Section 8 of this QAPP Addendum. PP = Analyzed for volatile compounds (SW 8240), base neutral and acid-extractable organic compounds (SW 8270), metals (EPA 200 or cyanide (SW 9010). Sample numbers are approximate; actual number of samples will be determined in the field. SVE pilot test sample numbers are based on a 6-month pilot test.										

CVOR146/003.51

Table 4-1
 Environmental Sampling and Analysis Program

Total	Duplicates			Field Blanks ^a			Trip Blanks ^b			Matrix Spike Duplicates			Total
	No.	Frequency	Total	No.	Frequency	Total	No.	Frequency	Total	No.	Frequency	Total	
300													300
50	5	1	5	3	1	3	5	1	5	5	1	5	68
40	5	1	5	2	1	2	4	1	4	5	1	5	56
100	10	1	10	3	1	3	10	1	10	10	1	10	133
7	1	1	1	1	1	1				1	1	1	10
30													30
10				1	1	1				1	1	1	12
12													12
4	1	1	1	1	1	1							6
468													468
156													156
156													156
156													156
18	1	3	3	2	1	2				2	1	2	25
4	1	4	4	1	1	1							9
4	1	4	4	1	1	1				1	1	1	10

analyzed for each analytical parameter.

submitted during the design phase.

collected.

compounds (SW 8279), metals (EPA 200 series), dibenzo-p-dioxins and dibenzofurans (SW 8280), organochlorine pesticides and PCBs (SW 8080), and

8

reduction. Inclusion of this microbiological analysis will be included in the SAP/QAPP addendum slated to be issued during design of the pilot test system.

Table 4-2
Guidelines for Selecting Samples for Fixed Laboratory Analysis

Analysis	Criteria
8240 or 8010	<p>Obtain a sample every 20 to 25 feet vertically to provide vertical characterization of VOCs from waste pit to the water table.</p> <p>In addition, select the most contaminated sample from each separate lithologic zone encountered (i.e., less permeable silt to more permeable poorly graded fine sand) as determined by onsite HNu screening.</p>
PP Scan (includes 8240, 8270, 8280, 8080, 9010, 200 Series)	<p>Obtain one sample from the waste pit at each boring to identify quantity of semivolatiles, pesticides, PCBs, dioxins, metals, and cyanide present in the pit. Also, obtain additional random samples below the pit to characterize the extent of migration of priority pollutants below the pit, particularly semivolatiles, which impact the fate and transport of VOCs.</p>
Modified Method 8015	<p>Obtain approximately four samples per borehole from the waste pit to the water table to vertically characterize TPH as gasoline and as diesel. More volatile short chain hydrocarbons affect Btu content of extracted off gas and hence the selection of emission control equipment for the pilot test. Extractable TPH affect the fate and transport of VOCs and the quantity of extractable TPH impacts the amount of biodegradation that could occur.</p>
TOC 415.1	<p>One per borehole, mainly in the waste pits to identify total organic carbon. TOC affects the fate and transport of VOCs.</p>

Section 5 SAMPLING EQUIPMENT AND PROCEDURES

This section describes the equipment and procedures that will be used in the collection of samples during the SVE treatability investigation. A listing of sample containers and preservation methods is presented in Section 7.

SOIL BORING LOCATIONS

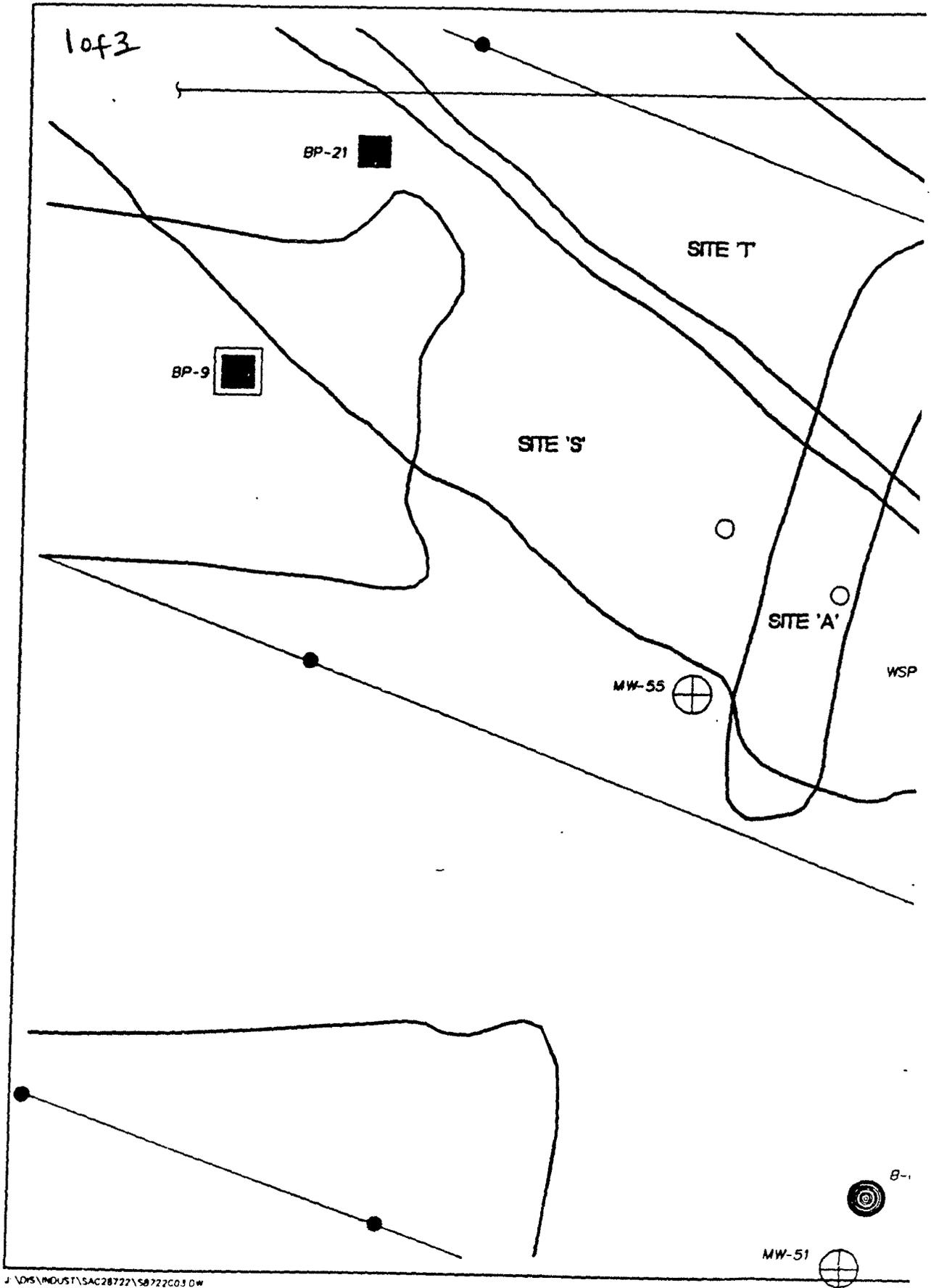
Figure 5-1 presents preliminary boring and test well locations. Soil borings and air permeability test wells will be placed in areas of suspected contamination based on past studies at the site. The test wells will be focused in the southwestern portion of Site S near existing Boring BP-20. Soil borings will be located throughout the southwestern end of Site S. The actual locations will be established following a thorough field reconnaissance.

CAP PENETRATION

All soil borings will be located within the area of the existing multilayer cap. The cap consists of 24 inches of silty sand/sandy silt cover material overlying a 40-mil HDPE synthetic membrane. The membrane is underlain by 18 inches of low permeability soil (clay) which in turn is underlain by 6 inches of granular drain material and a variable thickness of site grading material. Waste sampling ports consisting of 5-foot-long segments of 5-foot-diameter reinforced concrete pipe were installed through the cap during the original cap construction to facilitate future sampling of the contaminated materials. The sampling ports are sealed at the top with gasketed aluminum plate covers. Some of the new soil borings will be installed through the existing sampling ports. Other borings will require new penetrations directly through the multilayer cap. Cap penetration and sealing procedures are discussed below. These procedures are the same whether the final installation is an extraction well, an injection well, or a piezometer.

At the conclusion of the treatability investigation, the wells and piezometers will be left intact for use during site remediation, assuming that soil vapor extraction is selected for such remediation. If soil vapor extraction is not implemented at Site S after the pilot-scale testing is complete, then the wells and piezometers should be abandoned in accordance with applicable regulatory requirements. Such procedures typically require that the well or piezometer be fully grouted in place.

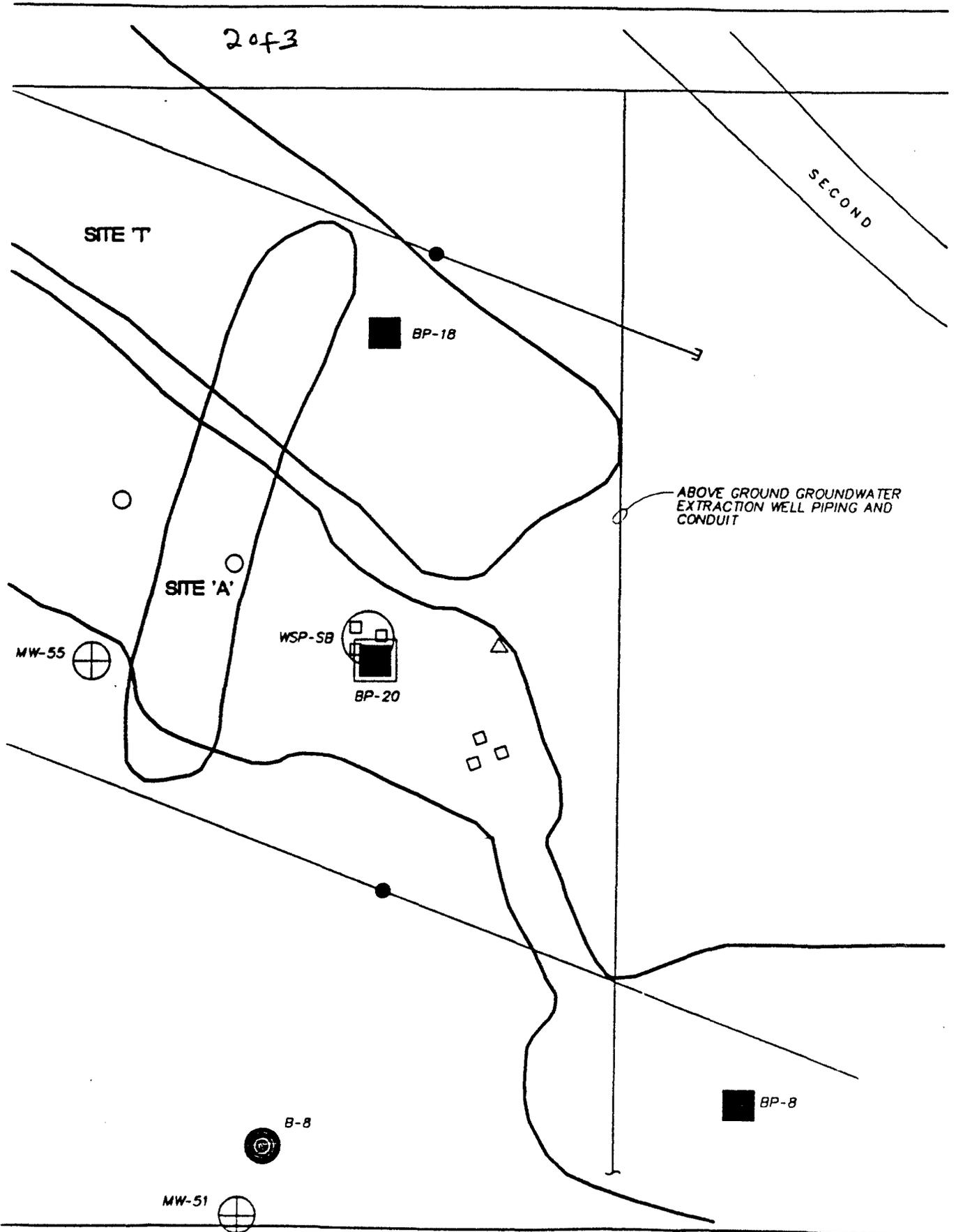
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2 of 3



SITE 'T'

BP-18

SECOND

ABOVE GROUND GROUNDWATER EXTRACTION WELL PIPING AND CONDUIT

SITE 'A'

MW-55

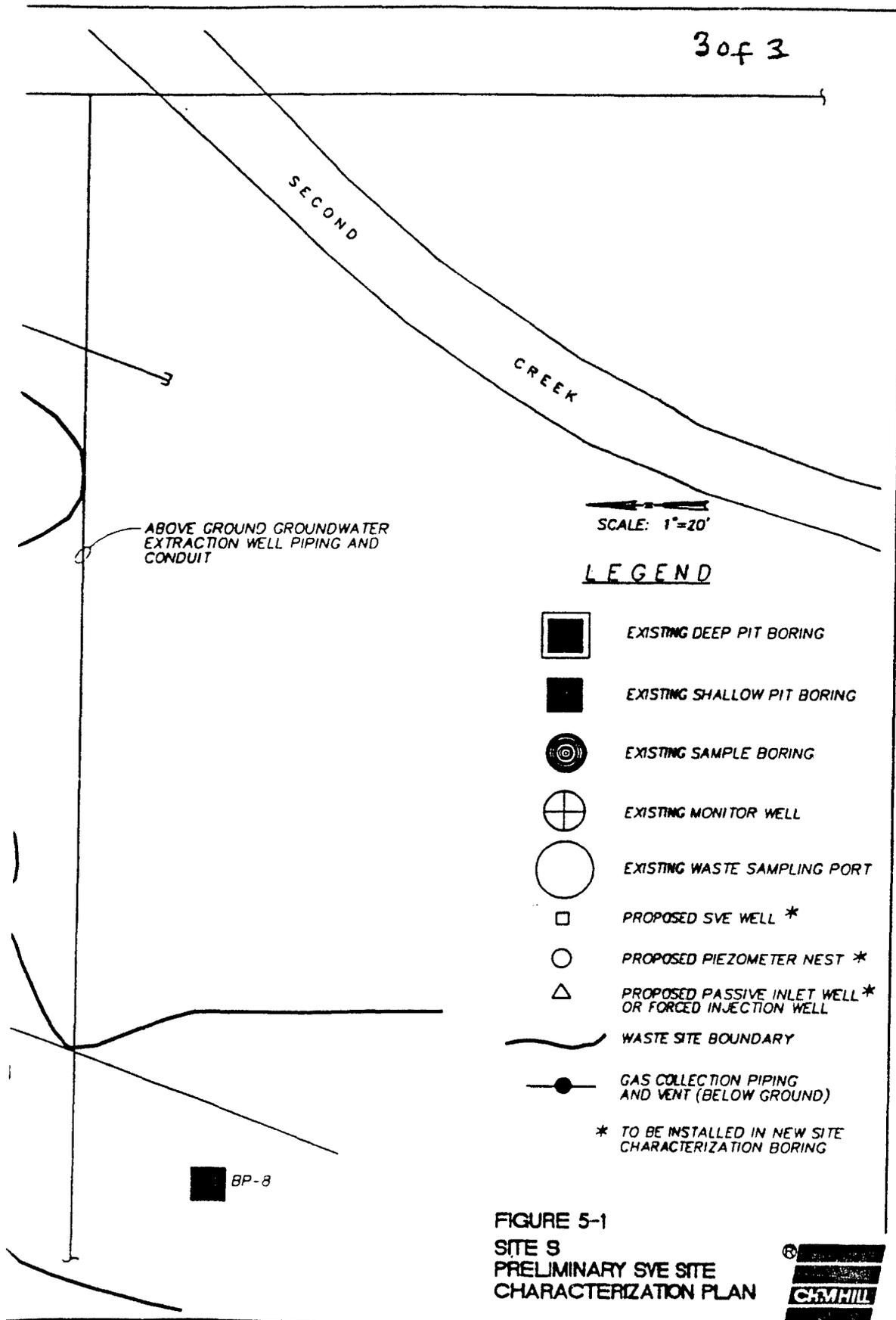
WSP-SB

BP-20

B-8

MW-51

BP-8



ABOVE GROUND GROUNDWATER EXTRACTION WELL PIPING AND CONDUIT

SCALE: 1"=20'

LEGEND

-  EXISTING DEEP PIT BORING
 -  EXISTING SHALLOW PIT BORING
 -  EXISTING SAMPLE BORING
 -  EXISTING MONITOR WELL
 -  EXISTING WASTE SAMPLING PORT
 -  PROPOSED SVE WELL *
 -  PROPOSED PIEZOMETER NEST *
 -  PROPOSED PASSIVE INLET WELL * OR FORCED INJECTION WELL
 -  WASTE SITE BOUNDARY
 -  GAS COLLECTION PIPING AND VENT (BELOW GROUND)
- * TO BE INSTALLED IN NEW SITE CHARACTERIZATION BORING

FIGURE 5-1
SITE 3
PRELIMINARY SVE SITE
CHARACTERIZATION PLAN



PENETRATIONS THROUGH THE EXISTING SAMPLING PORTS

A cross-section through a typical existing sampling port is shown on Figure 5-2. Prior to drilling, the aluminum cover will be removed and the sampling port will be filled with compacted, noncontaminated, low permeability material similar to that placed in the original multilayer cap. The material will consist of a mixture of silty sand/sandy silt and bentonite. The mixture will be proportioned as one part bentonite to four parts soil prior to placement within the sampling port. The mixture will be moisture conditioned and then placed in maximum 6-inch-thick lifts. Each lift will be compacted with at least six passes of a Wacker manually operated pneumatic compactor, or similar equipment in good condition. Backfilling will continue to the top of the sampling port. The finish surface will be graded such that the material in the center of the sampling port is higher than that at the edges of the port to ensure that rainfall will run off rather than soak into the backfill.

Specifications for placement of the low permeability material in the original multilayer cap construction required compaction to at least 90 percent relative compaction as defined by the American Society of Testing Materials (ASTM) Method D-1557. Field compaction tests will be conducted on the new backfill as necessary to verify that the procedure specified for compaction of the soil/bentonite mixture within the sampling port results in a compacted mass that meets or exceeds that required in the original liner construction.

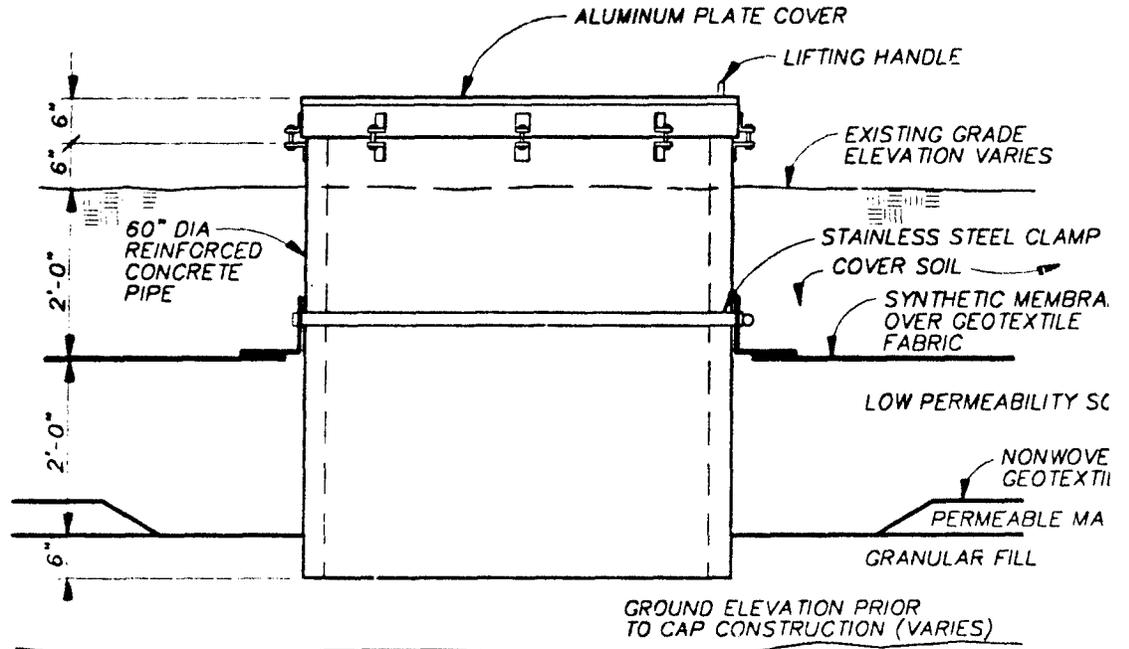
One or more wells or piezometers will be constructed through the backfilled sampling port. Figure 5-3 depicts a sampling port after well construction. If only one well or piezometer is constructed through an existing sampling port, then consideration will be given to modifying the plate aluminum port cover such that it can be reused to seal the top of the sampling port. However, if multiple wells or piezometers are constructed through a single sampling port, then the plate aluminum cover will not be reused.

PENETRATION THROUGH THE MULTILAYER CAP

Figure 5-4 depicts a cross-section through the existing multilayer cap and schematically illustrates the procedure for penetrating and resealing the multilayer cap at locations other than the existing waste sampling ports.

The existing cover material will be carefully hand excavated down to the HDPE liner at each new boring location. The excavation will be large enough to cut a circular hole in the liner 6 inches larger than the outside diameter of the largest drill auger to be used. After the initial section of drill auger is positioned within the hole in the liner, the remainder of the hole will be temporarily backfilled to allow the drill cuttings to be deposited at the ground surface for removal. The boring will then be advanced to the desired depth and the well or piezometer constructed.

After installation of the well or piezometer screen, the remainder of the boring will be filled with a bentonite seal and cement/bentonite grout up to the HDPE liner. Once

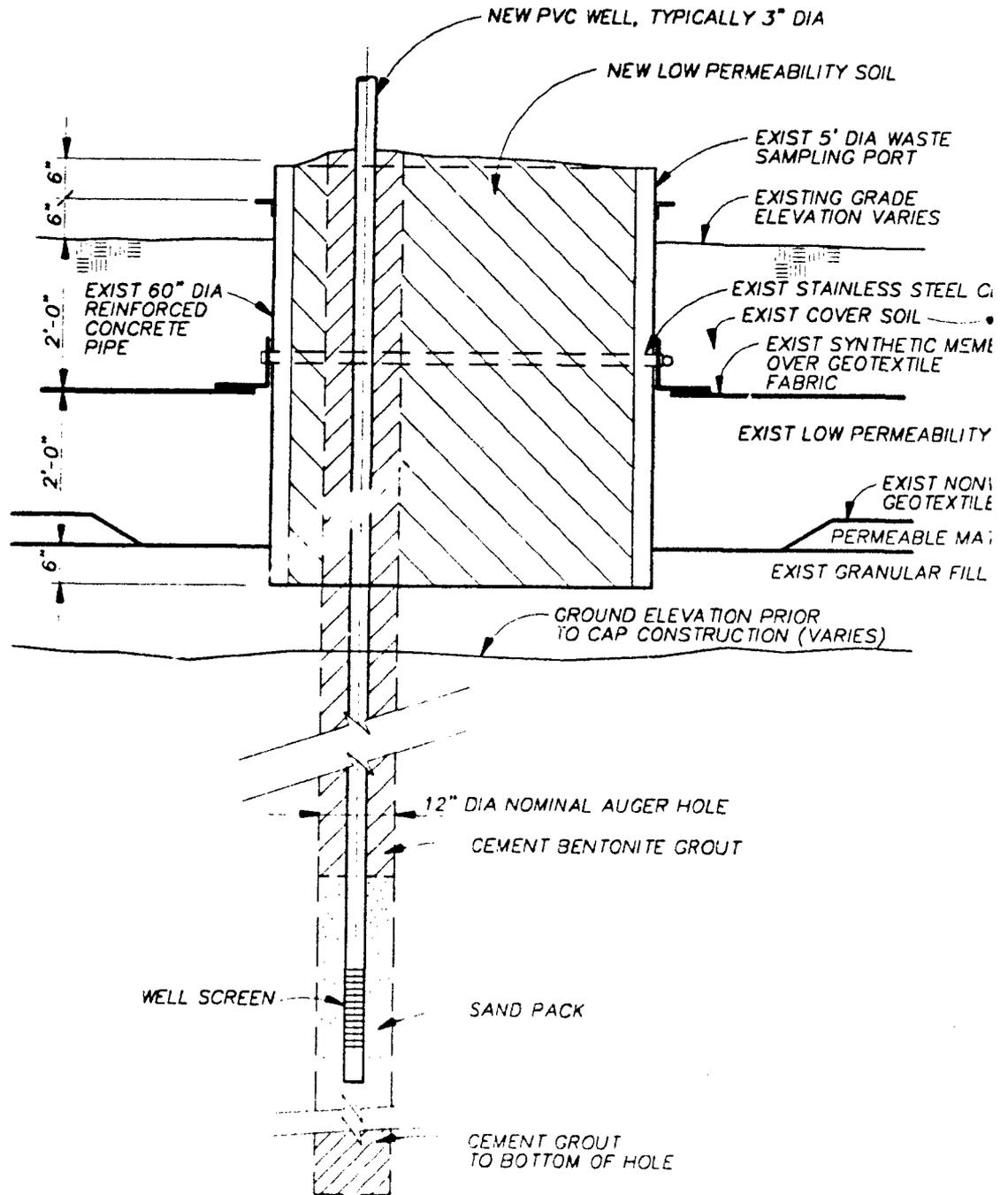


SECTION
NTS

REFERENCE: "MIN GROUNDWATER CLEANUP
AREA D CAP INSTALLATION"
DWG NO. SMBE-S-6316, SHT 12 OF 13
APRIL, 1985

FIGURE 5-2
EXISTING WASTE
SAMPLING PORT





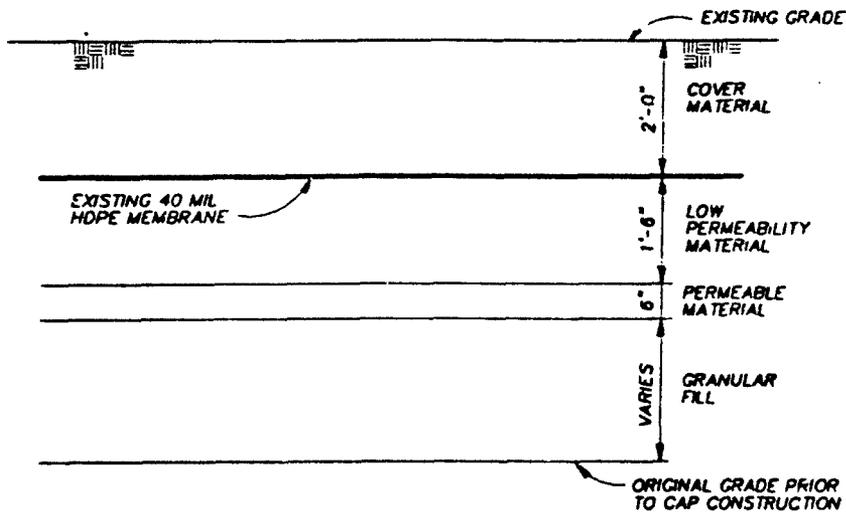
SECTION
NTS

NOTE: DETAILS OF EXISTING WASTE SAMPLING PORT TAKEN FROM "MTN GROUNDWATER CLEANUP AREA D CAP INSTALLATION" DWG NO. SMBE-S-6316, SHT 12 OF 13 APRIL, 1986

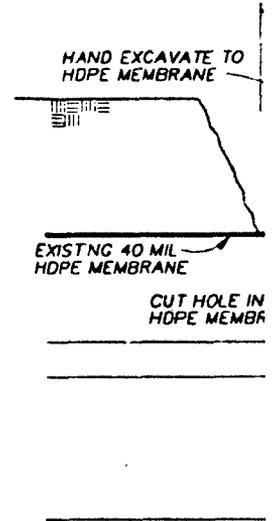
FIGURE 5-3
NEW WELL
INSTALLED THROUGH
EXISTING WASTE
SAMPLING PORT



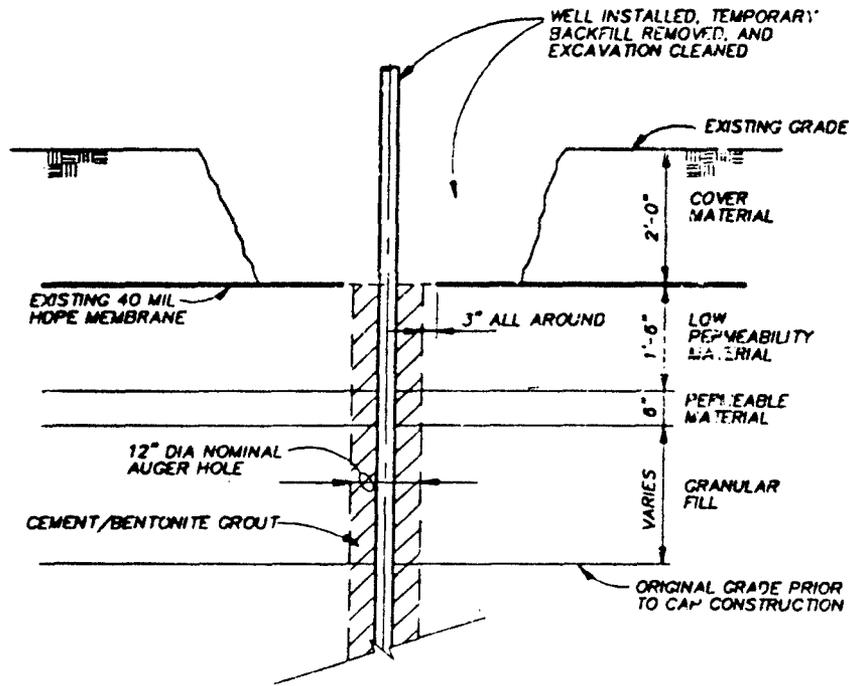
1 of 3



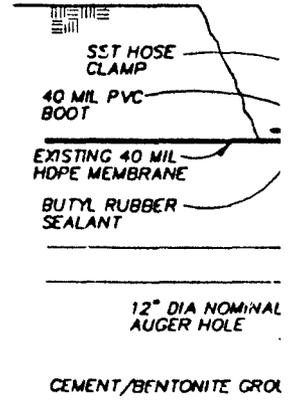
TYPICAL SECTION THROUGH EXISTING CAP



STEP 1: EXPOSURE HOLE

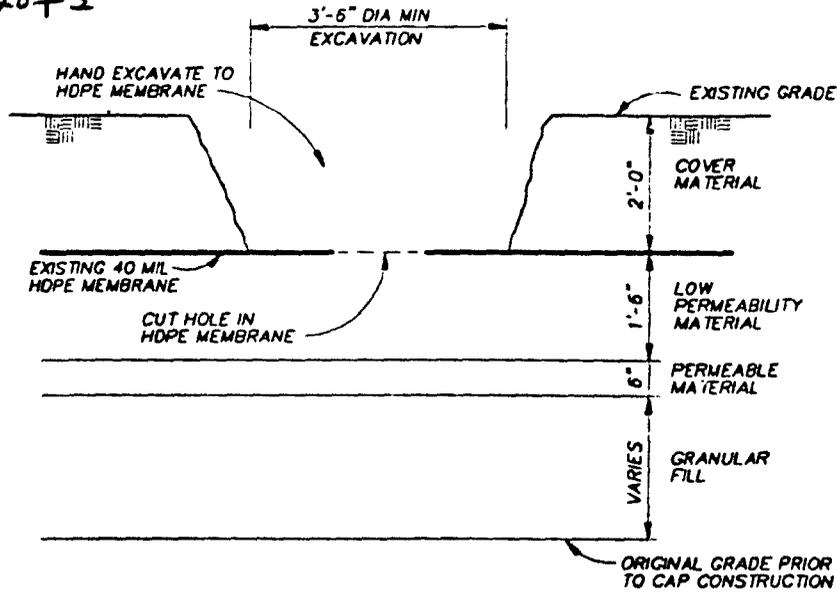


STEP 3: INSTALL WELL OR PIEZOMETER, THEN REMOVE TEMPORARY FILL AND CLEAN THE HDPE MEMBRANE SURFACE

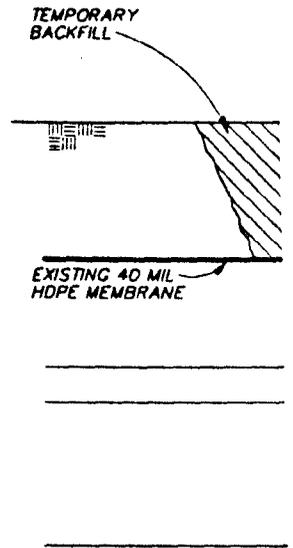


STEP 4: PLACE HDPE BOOT

20 of 3

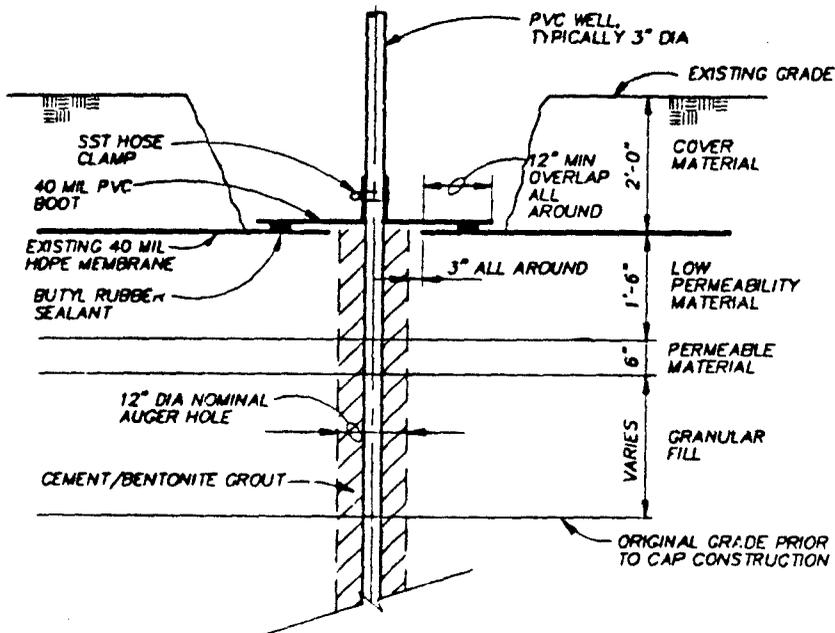


STEP 1: EXPOSE HDPE MEMBRANE AND CUT HOLE FOR AUGER PENETRATION

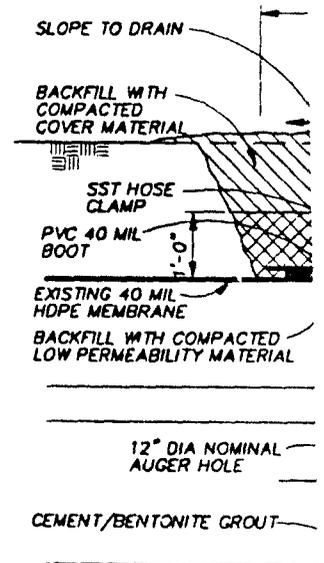


STEP 2: PLACE BEGIN I

DE

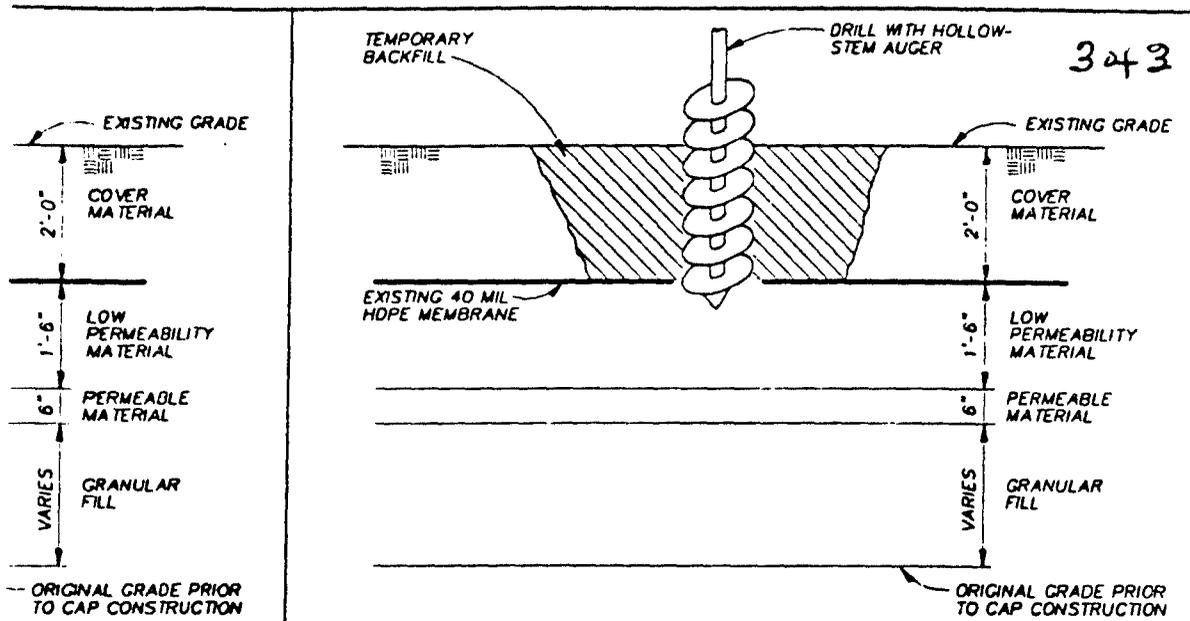


STEP 4: PLACE BUTYL RUBBER SEALANT BETWEEN HDPE MEMBRANE AND PVC, AND CLAMP BOOT TO WELL CASING



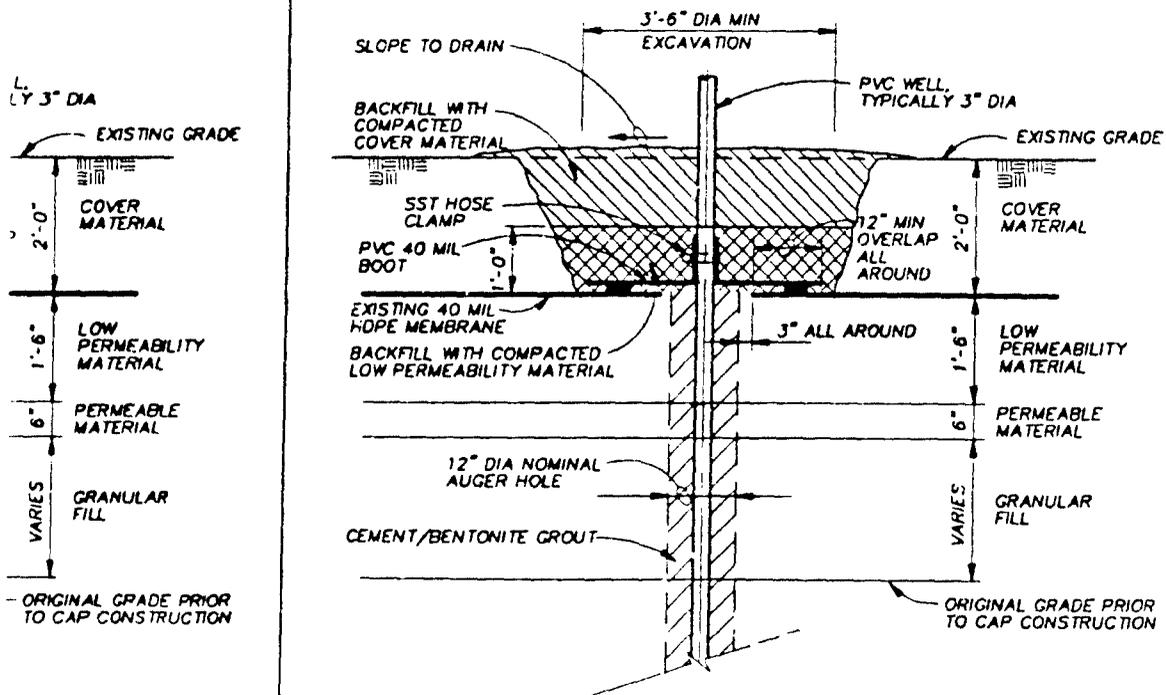
STEP 5: PLACE COI AND COVER

JR
DN



UT

STEP 2: PLACE TEMPORARY BACKFILL AND BEGIN DRILLING



BETWEEN CLAMP

STEP 5: PLACE COMPACTED SOIL/BENTONITE MIXTURE AND COVER MATERIAL OVER THE PVC BOOT

FIGURE 5-4
CAP PENETRATION



the grout has cured, the cover material will be re-excavated to expose the HDPE liner. A 40-mil-thick segment of PVC will be fashioned into a "boot" and placed over the well or piezometer casing. The "boot" will be sized such that the skirt of the "boot" will overlap the circular cut in the HDPE liner by at least 12 inches all around. The neck of the "boot" will be secured to the casing with a stainless steel hose clamp.

Prior to placing the "boot", the exposed surface of the HDPE liner will be brushed clean of soil. Then a strip of black butyl tape, as manufactured by Biddle Co., will be placed on the HDPE surface in a circular ring approximately 3 to 5 inches away from the edge of the PVC "boot." The butyl tape is 1/4-inch thick by 3/4-inch wide, and is supplied in 18-foot-long rolls. The butyl rubber compound will remain flexible and aid in sealing the two materials together.

After the PVC "boot" is placed over the HDPE liner and the butyl tape, any resulting wrinkles in the "boot" skirt will be smoothed out. A strip of butyl tape will be placed beneath any wrinkles that cannot be removed. Once the PVC "boot" has been satisfactorily prepared, soil/bentonite mixture as defined for use in the sampling ports will be placed in the excavation in maximum 6-inch thick lifts and compacted with at least 6 passes of the manually operated pneumatic compactor, taking care not to damage the neck of the "boot" that is attached to the casing pipe. At least 12 inches of the compacted soil/bentonite mixture will be placed over the PVC "boot". The remaining portion of the hand excavation will be backfilled with compacted cover material from the initial excavation. The cover material will be compacted similar to the soil/bentonite mixture. The finish surface of the compacted cover material will be sloped away from the well or piezometer casing to minimize the potential for rainwater to infiltrate around the piezometer or well installation.

SOIL BORING SAMPLE COLLECTION

Soil borings will be drilled to total depth with hollow stem augers. Representative formation samples will be collected by driving split spoons ahead of the augers in general accordance with ASTM D-1586 procedures for standard penetration resistance test in soils. Field logging will be completed by the onsite staff under the direction of a registered engineer or geologist.

Samples will be obtained at 2.5-foot intervals from grade to total depth in approximately five borings and at 5-foot intervals in the remaining borings. The samples will be collected using a modified 2-inch-diameter split-spoon sampler fitted with four 6-inch-long brass sleeves (Figure 5-5). Sampling procedures include:

- Prior to each sampling, the split-spoon and brass sleeves will be thoroughly decontaminated as outlined in the decontamination section.

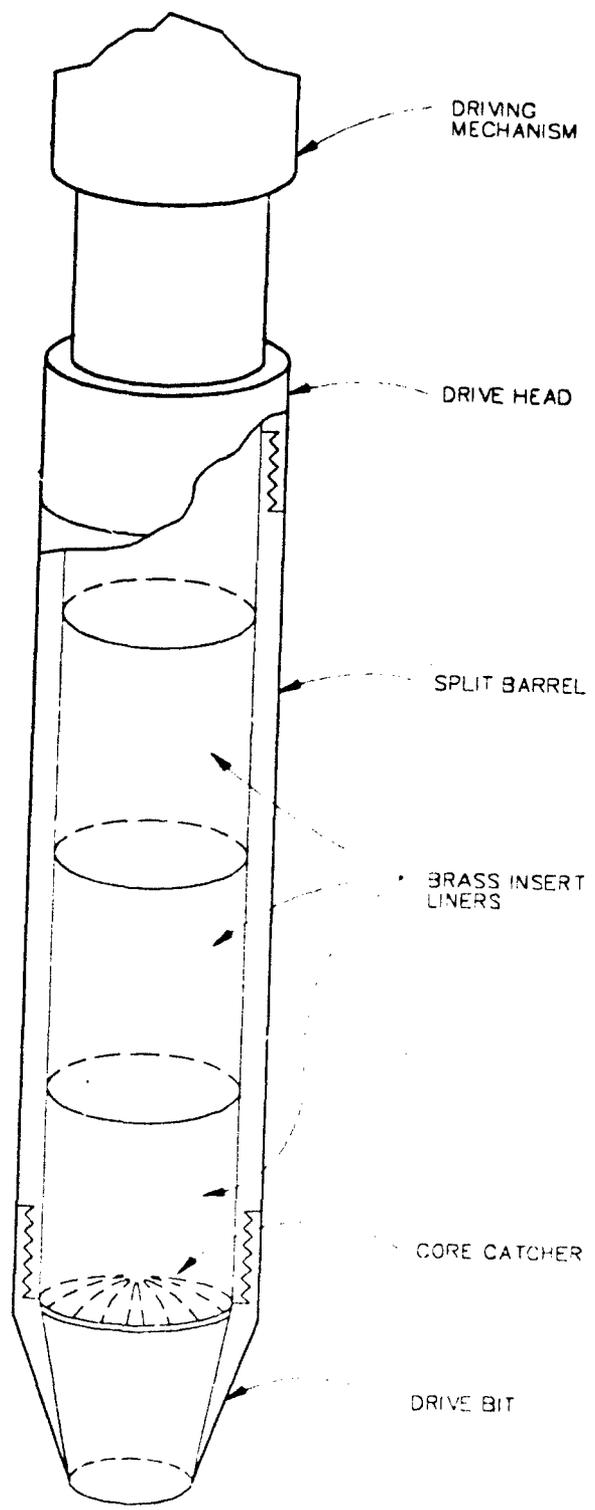


FIGURE 5-5
SPLIT-SPOON SAMPLER



- The sampler will be driven 24 inches into the undisturbed soil, or until refusal, and blow counts will be recorded (ASTM D-1586).
- Upon opening the sampler, the two center liners (the second and third of the four liners from the top) will immediately be trimmed and removed from the spoon and capped with teflon tape and PVC slip caps. The liners will be numbered and labeled with the top-center liner designated for onsite headspace analysis and the bottom-center liner reserved for offsite analysis.
- Immediately upon capping and labeling, the two center liners will be placed in an iced cooler. The samples designated for offsite analysis will later be shipped under chain of custody to the analytical laboratory.
- The remaining soil in the top and bottom liners will be used for soil logging per CH2M HILL Soil Boring Log Guidelines (Appendix B) and Air Force data management requirements.

AIR PERMEABILITY TESTING

DESCRIPTION

The air permeability test will be conducted using a nest of SVE wells installed in the vicinity of SB-20 (see Figure 5-1). The screened interval of each SVE well will be selected by considering subsurface stratigraphic and contaminant variations. The HNu will be used to identify if a sample is contaminated or not. It provides a nonspecific indication of total VOCs. At least one SVE well will be screened in the waste pit due to the nonuniform physical and chemical characteristics of sludge mixed with industrial solids. It is important to isolate this matrix during testing to determine the effective permeability in it and the composition and concentration of contaminants from it.

Below the waste pit, the objective is to install separate SVE wells screened in the most permeable, least permeable, and medium permeable stratigraphic zones, that also appear to be contaminated based on HNu results. Categorization of most permeable to least permeable will be accomplished by visual inspection of soil samples by a registered field geologist. Preliminarily, least permeable zones are assumed to consist of silts and clays, and the most permeable zones will likely be the poorly graded fine sands. At this time, there is no minimum limit for the concentration of total VOCs that will dictate if an SVE well is to be installed. For example, if a lithologic zone identified as mainly silt is correlated between borings, and this zone is contaminated as determined by onsite HNu headspace screening analysis, then an SVE well would be screened over this zone. Once again, the objective would be to evaluate the permeability in this zone and the concentrations of contaminants from it. If a zone of poorly graded contaminated sands is correlated between borings, then a screen would probably

be installed over this zone to evaluate the permeability and contaminant characteristics in it. The possibility exists that we could encounter a zone of sandy silt and clays just above the water table that can be correlated between borings. Following the same approach, a separate SVE well would be installed in this regime for the same reasons cited above. When installing a screen or piezometer in a less permeable zone, as identified by onsite logging, care would be taken to install the screen and sand filter pack only in the less permeable zone, so as to minimize communication with more permeable sands lying just above or below the zone. Each SVE well will contain a sand filter pack around the annulus throughout the screened zone, followed by a bentonite seal and bentonite/cement grout to the ground surface.

Approximately two nested vacuum piezometers/monitoring probes would also be installed (see Figure 5-1) at approximately 25 and 50 feet from the SVE well cluster. Piezometer screen lengths will be approximately 2 feet, and locations will be selected to match the lithologic zones that SVE wells are screened in to enable measurement of vacuum pressure while pulling a constant air flow on the SVE well being tested. The effective radius of influence will be determined by evaluating the vacuum levels obtained throughout the subsurface as a function of the wellhead vacuum and vapor flow from the SVE well. Each SVE well in a cluster will be tested separately to evaluate variations in subsurface vacuums apparent in each strata being tested.

Approximately four in situ, steady-state air permeability tests will be conducted (one on each of the SVE wells) by connecting a skid mounted vacuum extraction unit to the SVE well being tested. The tests will be conducted over a 5-day period. It is anticipated that water manometers will be installed on each vacuum piezometer to obtain subsurface vacuums, while a vacuum pressure gauge will be used to obtain vacuum at the SVE well. Flow will be measured at discharge of the vacuum extraction unit using an annubar or other equivalent device.

Data obtained from the permeability test will include: vacuum pressures from each piezometer as a function of time, vacuum pressure at the SVE well head, flow rate from the SVE well, barometric pressure, and extraction well temperature. Additional data collected during installation of the nine soil borings includes: porosity, percent saturation by water, grain size distribution, and vertical and horizontal permeabilities via method API RP40.

Flow rate and transient pressure distribution data are used to estimate the soil permeability to vapor flow. The expected change in the subsurface pressure distribution with time $P'(r,t)$ can be approximated by (Johnson et al., 1989):

$$P' = \frac{Q}{4\pi m(k/\mu)} \left[-0.5772 - \ln\left(\frac{r^2 e \mu}{4kP_{atm}}\right) + \ln(t) \right] \quad (1)$$

where:

- P' = gauge pressure measured at distance r and time t
- m = stratum thickness
- r = radial distance from vapor extraction well
- k = soil permeability to air flow
- μ = viscosity of air (g/cm-s)
- e = air-filled soil void fraction = $e_i(1-S)$
- t = time
- Q = volumetric vapor flow rate from extraction well
- P_{Atm} = ambient atmospheric pressure (g/cm-s²)
- S = degree of saturation

Equation 1 predicts that a plot of P' versus $\ln(t)$ should be a straight line with slope A and y-intercept B equal to:

$$A = \frac{Q}{4\pi m(k/\mu)} \quad B = \frac{Q}{4\pi m(k/\mu)} \left[-0.5772 - \ln\left(\frac{r^2 e \mu}{4kP_{Atm}}\right) \right] \quad (2)$$

The permeability to vapor flow can then be calculated from the data by one of two methods. The first is applicable when Q and m are known. The calculated slope A is used:

$$k = \frac{Q\mu}{4A\pi m} \quad (3)$$

The second approach must be used whenever Q or m is not known. In this case the values A and B are both used:

$$k = \frac{r^2 e \mu}{4P_{Atm}} \exp\left(\frac{B}{A} + 0.5772\right) \quad (4)$$

The above approach will be used to estimate in situ permeabilities where possible. For example, if an SVE well is screened in an upper silt lens, data from nearby piezometers screened in the same or a similar silt lens will be used to estimate the in situ permeability. However, if one of the wells is screened over variable poorly graded sands and silty zones, then it will be difficult to determine an accurate estimate of the permeability. The results of these calculations will be compared to lab permeability estimates following API RP40 obtained for each different lens identified at the site.

Gas permeability can also be estimated from grain size analyses performed on soil samples. Equation 5 presents permeability as a function of pore radius (Massmann, 1989):

$$k = 0.125r^2 \quad (5)$$

Pore permeability k is in units of (length)² and pore radius r in units of length. For k in darcies and r in millimeters, Equation 5 can be rewritten as

$$k = 125,000r^2 \quad (6)$$

Relationships have been developed to estimate the average pore radius of sands and gravels from the results of grain size analyses. These estimates, which should be viewed as order-of-magnitude approximations, are generally of the form

$$r = cD_{15} \quad (7)$$

where c = empirical constant; and D_{15} = grain size for which 15% by weight of particles are smaller. Sherard et al. (1984) have found that a c value of 0.1 gives reasonable approximations for sand and gravel soils.

Combining Equations 6 and 7 gives an expression for gas permeability as a function of the grain size parameter:

$$k = 1.250D_{15}^2 \quad (8)$$

where the permeability, k , is in darcies and the grain size parameter, D_{15} , is in millimeters. It should be emphasized that the permeability value predicted by Equation 8 is a gross approximation that should be viewed as an order-of-magnitude estimate, at best.

The radius of influence (R_1) can be defined as the maximum radius that an SVE well is considered to be effective at removing VOCs from the subsurface. The radius of influence is approximated by measuring the steady state vacuum pressure in piezometers at constant flow from the SVE well. An estimate of R_1 , which defines the zone in which vapor flow is induced will be obtained for each different strata at the site (as appropriate) (i.e., R_1 (waste fill) R_1 (lower silt), etc.). In general, R_1 depends on soil properties of the vented zone, properties of surrounding soil layers, the depth at which the well is screened, and the presence of any impermeable boundaries (water table, clay layers, surface seal, building basement, etc.). Steady-state pressure distribution results from each of the five SVE wells will be analyzed to estimate the radius of influence.

The results of permeability data and R_1 data will both be used to estimate the number and spacing of SVE wells required to successfully effect each contaminated strata encountered at the site. The feasibility and usefulness of utilizing a numerical model to

assist in designing the number and location of SVE air injection and extraction wells will be considered after review of the air permeable test data.

Upon completion of the pilot test, additional physical testing such as percent moisture and permeable testing, will be considered to evaluate the impact SVE has had on subsurface physical characteristics. Additional plans for physical testing will be described in the SAP/QAPP addendum to be submitted during design.

AIR PERMEABILITY OFFGAS SAMPLING

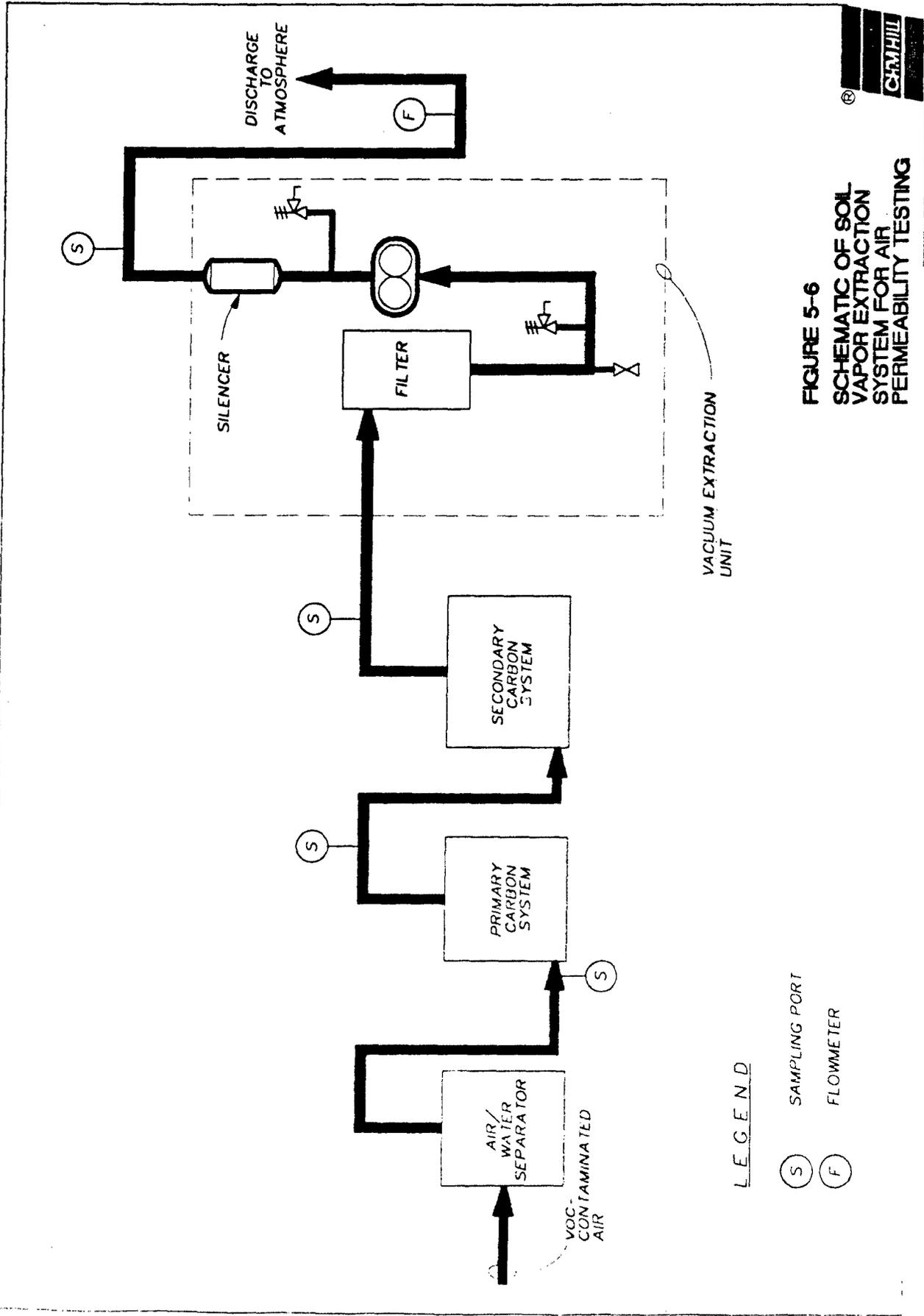
The offgas from the air permeability testing will be treated using canisters of granular activated carbon. Carbon canisters will be connected in series so that a primary carbon unit will adsorb the majority of the VOCs and the secondary carbon unit would serve primarily as a backup. Offgas between the carbon units will be monitored using an HNu or OVA on a frequent basis to identify when breakthrough occurs. Upon breakthrough, the primary carbon unit will be shipped offsite for regeneration and the secondary carbon unit moved to the primary position. A new carbon unit will be installed in the secondary position. See Figure 5-6 for a schematic of the SVE system to be used during air permeability testing.

Up to 10 stainless steel canister air samples will be collected during the air permeability test for offsite chemical analysis. The analytical results from the air permeability testing canister samples will be used in the design of the SVE pilot test air treatment system. The procedure for collection and analysis is listed below under the soil vapor section.

SOIL VAPOR CANISTER SAMPLE COLLECTION/ANALYSIS

Soil vapor samples for both the air permeability testing and the SVE pilot test will be collected. Canister samples will be collected following the guidance offered in EPA's "*Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*," EPA 4-84-041-April 1984. The specific method to be used is T0-14, "Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Passivated Canister Sampling and Gas Chromatography Analysis."

Evacuated, 6-liter SUMMA polished canisters will be used to collect soil gas samples from the vacuum extraction system at approximately -10 inches Hg and at 55°F. The exact location for sample collection will be determined in the field by the field team leader, but in principal a sample port/tap will be placed in the gas exhaust line after the gas has exited the soil vapor extraction well and prior to the vacuum blower. After passing the sample tap the gas enters the carbon canister exhaust gas treatment system. Figure 5-6 presents a simplified graphic of the SVE system to be used during the permeability test phase. The line at the sample tap will be pressurized to approximately -10 inches Hg vacuum.



LEGEND

- (S) SAMPLING PORT
- (F) FLOWMETER

FIGURE 5-6
SCHEMATIC OF SOIL
VAPOR EXTRACTION
SYSTEM FOR AIR
PERMEABILITY TESTING

The canisters will be used and samples collected in the vacuum mode. That is to say, the vacuum in the clean canister (near 30 inches Hg) will be used to pull the sample out of the SVE duct and deliver it to the canister. A flow regulator will be used to control the sample rate and maintain it near constant over the prescribed course of the sample collection period. The desired sample rate, determined by the size of the canister and the length of sample period, will be preset using a Mini-Buck calibrator or calibrated rotometer by the laboratory prior to shipment to the field. The preset rate will be confirmed during sample collection at various time intervals by checking the canister pressure gauge and comparing that value to the elapsed time. These samples will be collected at a rate of 30 cc/min over a 30-minute time duration. This period will be used rather than shorter grab types to allow for spikes or peaks in the stream to average out thus providing more representative samples.

The final canister pressure will always be less than that of the pressure in the SVE line to maintain canister integrity. The line pressure will be approximately -10 inches Hg and the sample will be stopped with the canister at approximately -12 inches Hg. This procedure allows monitoring of the canister for leaks after sampling and during shipment and also preserves/stabilizes the sample in the gas phase prior to analysis.

Prior to sample collection, each canister will be cleaned in the lab as follows:

- Using exponential dilution, each canister will be rinsed several times with ultra high purity nitrogen.
- Each canister will be subsequently placed in an oven (125°C) and connected to a high vac. pump. Heat and vac. will be applied until the canister pressure is <5mTorr (EPA spec: 50mTorr).
- Certification will be done using GC/MS with surrogate spikes. At least one canister from every batch will be certified.

Following cleaning, the canisters will be evaluated and evacuated in the laboratory. Additionally, those containers to be used for spike sample preparation and blanks will be humidified. All canisters used on the project will be prescreened and verified clean to a level of <0.2 ppbv of any target organic species or 20 ppbv total chromatographical organics. After analysis, the canisters will be evacuated to a level of at least -27 inches Hg and the absolute pressure recorded. A stainless steel 2-micron filter will be attached to each flow controller prior to shipment to remove particulate material in the gas stream prior to entering the canister.

To collect a SVE canister VOC sample, the following procedure shall be followed:

1. The canister and flow controller to be used for sampling is removed from the shipping container and inspected for damage. The laboratory-assigned tracking reference numbers are checked to ensure they match those listed on the

shippers chain of custody form. The flow controller reference number is noted and the unit flagged as an inlet sample stream component.

2. The sampling system is assembled as shown in Figure 5-7 by removing the protective cap from the canister and flow controller and attaching the flow controller to the inlet of the canister. The probe section is unpacked, labeled as inlet SVE and inspected for damage. A wrench should be used to securely tighten the connections but not tightened too much as this can cause leaks or jam the threads. Conduct a negative pressure system leak check using a dummy canister to supply the vacuum air. Remove the leak check canister and replace with a sample canister. Conduct the leak test again with the actual field canister.
3. The assembly is transported to the sample station and the probe end caps are removed. The probe is inserted in the duct and allowed to extend upstream into the flowing gas stream. The probe position should be at least 4 inches upstream of the access port to ensure in-leakage of ambient into the negative pressure duct will not dilute the sample stream.
4. Ensure the sample probe and flow controller connection is secure by tightening with a wrench. If the SVE system is operational, activate the sampling system by fully opening the canister valve. Record the required information on the field data sheet, as shown in Figure 5-8.
5. Every 5 to 7 minutes record the canister system pressure and calculate the pressure decrease as a function of time to ensure proper operation of the flow controller.
6. At the conclusion of the desired time period, or when the canister pressure reaches -12 inches Hg or at least 2 inches Hg less than the line pressure, stop the sample. To do this simply close the canister valve and remove the sample probe. Transport the assembly back to the operations facility and disassemble the sample for canister recovery.
7. Once the canister is recovered, replace the end caps, attach a canister label or seal around the neck of the valve and complete the appropriate canister chain of custody form.
8. Repackage the sample canisters in the original containers and ship to the contracted laboratory. For the purposes of this phase of the study all canisters will be analyzed by Air Toxics Limited, Sacramento, California. All samples will be personally delivered.

Duplicate sample collection: to collect a duplicate sample, the following steps shall be follows.

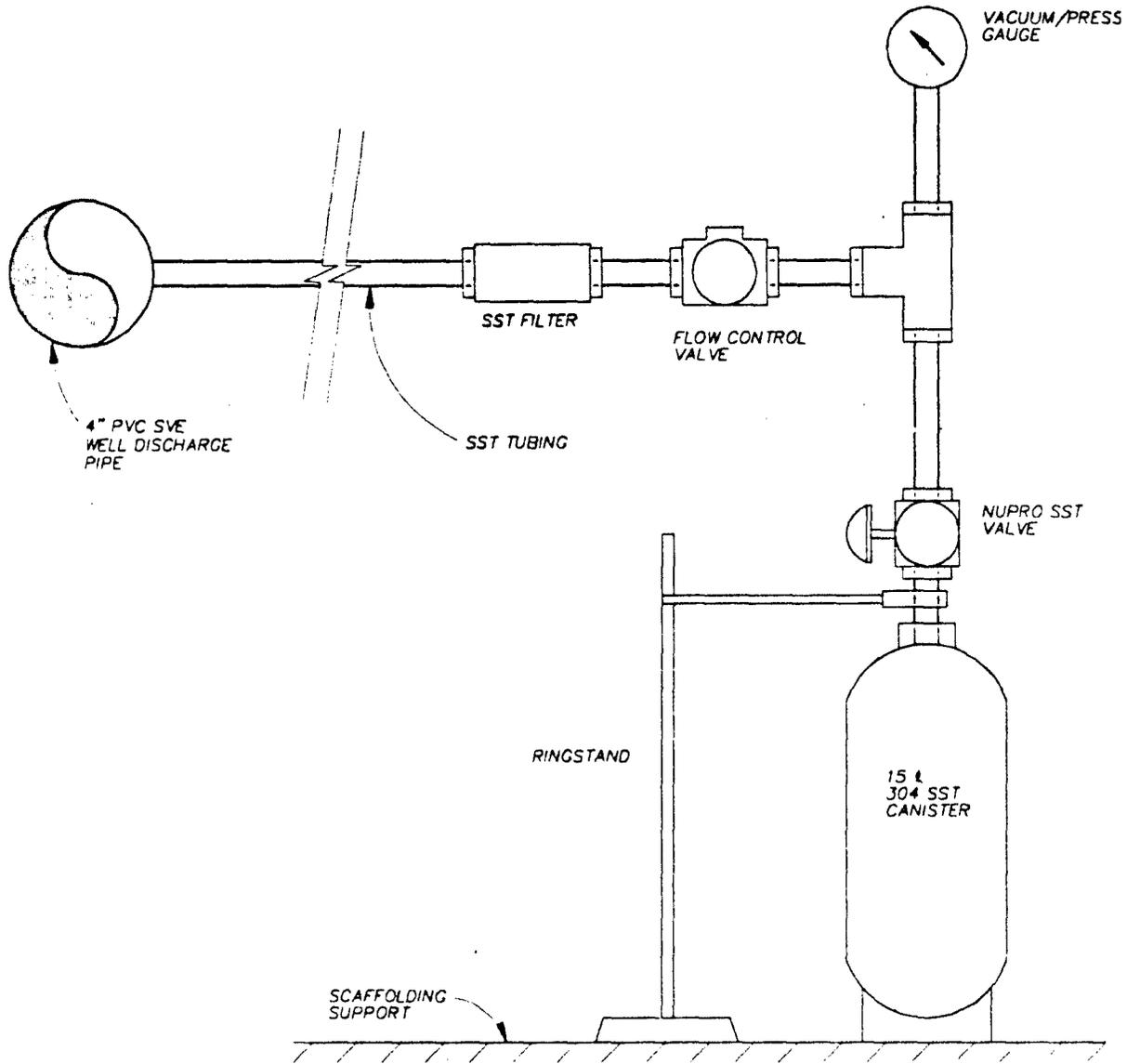


FIGURE 5-7
SAMPLE CONFIGURATION FOR
SUBATMOSPHERIC PRESSURE SAMPLING



W-30-1188124727-12/04 SW

Soil Vapor Extraction- Permeability Data

Project Number _____
 Date _____

Names and Company of Personnel _____

- 1 _____
- 2 _____
- 3 _____
- 4 _____

NO. _____
 Project Equipment Description _____
 Size/Capacity _____

Extraction Wells Evaluated

Canister Data

Lab ID No. _____
 Initial Pressure _____
 5 minute Pressure _____

CH2M HILL ID No. _____
 Initial Pressure _____
 5 minute Pressure _____

Probe Data

Equipment Readings

Time _____

Sample Point Temp. F _____
 Well Head Vacuum inHg _____
 Carbon Unit Vacuum inHg _____
 H-NU Readings
 HC Primary inlet _____
 HC Secondary inlet _____
 HC Blower outlet _____
 Span Settings _____

Sample Start Time _____
 Sample End Time _____

CH2M HILL Sample ID _____

FIGURE 5-8

1. Assemble the sampling train (i.e., canister, flow controller, probe) as described for sample collection.
2. Transport both duplicate and actual sample train to collection point on SVE duct.
3. Using several small pieces of wire, secure together the two probe sections at exact lengths and insert into the SVE duct.
4. Fill in appropriate line data on field data collection sheet and start each sampling train simultaneously by fully opening the canister valves.
5. Record the start time and each canister pressure reading (initial pressure).
6. Monitor each trains pressure throughout the desired sample run and record on field data sheet.
7. When the sample time has expired or the trains have reached ending target pressure, stop the runs by simultaneously closing each canister valve.
8. Remove sampler probes from SVE duct, and recover sample canisters by removing the wire attaching the probes. Replace probe end caps and transport assemblies back to sample recovery station.
9. Complete sample recovery and sample chain-of-custody forms.

NOTES TO FIELD STAFF:

1. The probes and flow controllers shall be used only once. All sample assemblies will be dedicated to the well in service and not decontaminated in the field.

Sample Analysis

This section presents an overview of the prescribed sample analysis to be conducted on the SVE canisters. Upon arrival at the contracted laboratory, the canister sample information is recorded from the Chain-Of-Custody form and logged into the laboratory sample tracking system. To analyze a canister sample, the container is pressurized to a known pressure and the pressure recorded. This pressure value is again used to calculate the final sample concentration after analysis.

The pressurized canister is then attached to the analytical instrument. The instrument extracts a known volume of air from the canister to be analyzed. The air is then passed through a drier to remove entrained moisture and concentrated by collection in a cryogenically cooled trap. The trap temperature is then raised and the collected compounds are volatilized back into the gas phase and directed to a high resolution gas chromatographic analytical instrument. The individual species are separated on the GC

column, identified and quantified using a mass spectrometer (MS-specific detector) operated in the full scan mode.

For the purposes of this study, the standard list of TO-14 compounds plus acetone and MIBK will be evaluated. Total petroleum hydrocarbons (TPH) will also be evaluated and reported for each canister. The GC/MS scan mode evaluations will be reported in their entirety, including any nontarget list compounds detected and up to 10 tentatively identified compounds (TICs). All samples collected will be analyzed for TPH by summation of the integrated area on the chromatogram in the TPH region (C4 to C12) and quantified and reported as heptane (C7). The quantification is based on a heptane standard calibrant gas.

The target compound list for full scan GC/MS volatile TO-14 analyses is presented in Table 5-1. The listed compounds have a method detection limit (MDL) of approximately 1 part per billion (ppb) volume basis with the exception of acetone at approximately 10 ppbv.

Freon 12	1,1,2-Trichloroethane
Freon 114	Tetrachloroethane
Chloromethane	Ethylene dibromide
Vinyl chloride	Chlorobenzene
Bromomethane	Ethyl benzene
Chloroethane	m,p-Xylene
Freon 11	o-Xylene
1,1-Dichloroethene	Styrene
Freon 113	1,1,2,2-Tetrachloroethane
Methylene chloride	1,3,5-Trimethylbenzene
1,1-Dichloroethane	1,2,4-Trimethylbenzene
cis-1,2-Dichloroethene	1,3-Dichlorobenzene
Chloroform	1,4-Dichlorobenzene
1,1,1-Trichloroethane	Chlorotoluene
Carbon Tetrachloride	1,2-Dichlorobenzene
Benzene	1,2,4-Trichlorobenzene
1,2-Dichloroethane	trans-1,2-Dichloroethene
trans-1,3-Dichloropropane	Acetone
Toluene	4-methyl,2-pentanone (MIBK)
cis-1,3-Dichloropropene	Total petroleum hydrocarbons

SVE PILOT TESTING

Pilot testing of an SVE system will be conducted for a minimum of 6 months following installation of the system. The pilot-scale SVE system will include SVE wells connected through a common header to a portable skid-mounted vacuum extraction unit. Offgas from the pilot test will be treated using onsite catalytic oxidation, or thermal incineration.

Sampling during the pilot test will include onsite monitoring using qualitative, nonspeciating vapor analyzers (HNU or equivalent) and the collection of canister samples for offsite analysis of VOCs, total petroleum hydrocarbon, and fixed gases such as CO and CH₄. Treated offgas samples will also be collected for HCl analysis. Onsite monitoring will be conducted an average of three times per week for the duration of the pilot test from each of the test wells, the combined SVE header, and the treated offgas. More samples will be collected in the beginning of the pilot test when SVE offgas concentrations are the highest and decreasing steadily. Less samples will be obtained near the end of the pilot test when SVE offgas concentrations are fairly constant.

Stainless-steel canister samples and HCl samples for offsite analysis will be collected approximately three different times during the course of the pilot study from the same locations. The collection and analysis of VOCs, TPH, fixed gases, and HCL will be further detailed in an addendum to this SAP and QAPP. This addendum will be submitted for agency review during the design phase.

Process monitoring during the pilot test using an onsite GC will also be considered as a substitute for HNU analyses, and as a replacement for some of the canister sampling. The feasibility and data quality associated with onsite GC analyses will be evaluated after canister results obtained during the air permeability test have been reviewed. The selected methods will be described in an addendum to this SAP and QAPP.

Section 6 SAMPLE DESIGNATION

A CH2M HILL sample numbering system will be used to identify each sample submitted for analysis. A listing of the sample identification numbers will be maintained in the field log book by the field team leader. Each sample identification will have three components as described below.

STATION

The station code identifies the site and the physical location of the sample. The site identifier for all sample locations for the SVE treatability investigation will be VES (vapor extraction, Site S). The sample locations will be numbered sequentially 01 through 99.

SAMPLE

The sample code identifies the sampling event and sample type. For soil samples, sampling events will be identified by the month and year in which most of the samples were collected (e.g., 07/91). To uniquely identify the samples taken at different depths, the lower depth of the sample will be added to the identifier (e.g., 07/91-07.5).

A different type of code needs to be used for air samples from air permeability testing and pilot testing, since more than one sample could be collected during a single day. For these samples, the sample code will include the date the sample was taken, the sample type ("AP" for air permeability or "PT" for pilot test), and a number to indicate whether that was the first, second, third, etc., sample to be taken from that location that day. A complete sample code for an air permeability sample would therefore be: 07/02/91-AP-01. The time the sample was taken should be recorded in the field log book.

SUBSAMPLE (SS)

The subsample or SS code is used to indicate duplicate samples. If the sample is a routine one, the SS field code will be an "N1." If the sample is a duplicate, then the SS field code will be "FD1." If two duplicate samples are taken, the second duplicate will be "FD2."

Section 7
SAMPLE HANDLING, PRESERVATION, AND SHIPMENT

This section presents the methods to be followed to ensure that samples arrive at the laboratory intact, at the proper temperature, and free from external contamination.

SAMPLE HANDLING

Soil samples designated for offsite analysis will be submitted to the laboratory in the brass liners used for sample collection. Upon opening a split-spoon sample, the brass liner will be removed from the split spoon and excess soil will be trimmed from the ends of the liner. The ends of the liner will then be covered with teflon tape and PVC slip caps placed over the teflon tape. The liner will then be placed in a labeled ziplock plastic bag, which will in turn be placed in an iced cooler.

Soil vapor (air) samples will be collected in stainless steel canisters supplied by and returned to the laboratory. Dedicated shipping containers will be used to ship the canisters to and from the laboratory.

SAMPLE PRESERVATION

All soil samples collected for offsite analysis will be placed on ice in coolers immediately after collection. Coolers will be kept out of direct sunlight as much as possible and removed to the field office at least every 4 hours. The samples will be repacked with ice prior to shipping them to the laboratory. In the laboratory, samples will be stored at 4°C or less prior to analysis, and stored below 4°C between analysis and sample release for disposal.

In addition to cooling all samples to 4°C, the following equipment blanks and trip blanks collected as part of the field analysis will require preservation as indicated:

- VOAs (8010, 8240)--HCl to pH_≤2
- TOC (415.1)--H₂SO₄ to pH<2
- Metals (200 Series)--HNO₃ to pH<2
- Cyanide--NaOH to pH>12

Soil vapor canister samples do not require preservation.

SAMPLES SHIPMENT

All samples will be shipped to the laboratory via overnight or next day delivery. All applicable sample packaging and labelling requirements for interstate transport of hazardous materials will be followed as defined in 40 CFR 49, Chapter 1, Part 171. A chain of custody report will accompany each sample shipment.

Section 8

SAMPLE DOCUMENTATION

The components of the sample documentation program include the use of sample seals, logbooks, chain of custody form, photographs, and standard handling and shipping procedures. Each component is described briefly below.

SAMPLE LABELS

Each sample collected will be labelled with the sample designation number, sample type, date, and sampler's name. The sample labels will be affixed to the sample container and will accompany the samples to the laboratory. Sample descriptions are described in Section 5.

CUSTODY SEALS

Custody seals will be placed on the sample coolers anytime a cooler is not in the immediate view of the collection team. The team will sign custody seals and place one on each side of the cooler if they are required to leave the area and cannot maintain visual contact with the samples. Seals will also be affixed to containers shipped offsite for sample analysis.

FIELD LOGBOOK

The sample team will maintain a field logbook for all sampling events. The field logbook will be a bound notebook with numbered pages. All entries will be made with ink. At the start of each day, the names of sample team members, weather conditions, and reason for sampling will be recorded. The field team leader will keep custody of the field logbook at all times and sign each page.

Data obtained on all of the samples will be entered into the logbook. This includes: the sample identification, location, depth, date and time of sample collection, parameters requested for analysis, field measurement and calibration data, analysis data and methods, sample distribution and transporter, field lot control number, field observations, and crew times.

A separate logbook will be maintained for the field screening headspace analysis. The receipt, preparation, analysis, and results of all headspace samples will be recorded by the person doing the analysis. Each page will be signed and dated by the analyst.

Any corrections in the logbooks will be made by striking out the incorrect entry with a single line such that the original entry is not obliterated. The person making the correction will also initial and date the crossed out entry. The correct entry will then be made below the crossed out entry.

PHOTOGRAPHS

Photographs of sampling locations will be taken. Log entries will be made in the field notebook that identify the sampling point depicted in each photograph. Each entry will include the date, time, and site location.

CHAIN-OF-CUSTODY FORMS

Chain-of-custody forms will be used for all samples. Forms equivalent to the one shown as Figure 8-1 will be delivered with the samples to the laboratory. Each time the sample containers change custody, both the sender and receiver will sign and date the chain-of-custody form accompanying the sample set. When a sample shipment is sent to the laboratory, a copy of the chain-of-custody form will be retained. The laboratory will be instructed to sign its copy of the chain-of-custody sheet included with the samples and return a copy of the signed sheet along with the analytical results. A chain-of-custody record will be completed for each shipping container.

The following information is included on the chain-of-custody form:

- Sample number
- Signature of sampler
- Date and time of collection
- Place of collection
- Type of sample
- Number and type of container
- Inclusive dates of possession
- Signature of receiver

LABORATORY LOGBOOK

Upon receipt of each sample shipment by the laboratory, each cooler will be inspected and any problems reported to the sample coordinator or site manager. Samples will be logged and immediately placed in a refrigerator at a temperature of approximately 4°C. Only upon review and validation of the data at the end of the project will the samples be released by the project manager for return to McClellan AFB.

Following sample receipt in the laboratory, the sample custodian or laboratory personnel will clearly document the processing steps that are applied to the sample. The results of the analysis of all quality control samples will be identified specific to each batch of samples analyzed. The laboratory logbook will include the time, date, and name of the person who performed each processing step.

Section 9 FIELD QUALITY CONTROL SAMPLES

The purpose of the field quality control program is to provide a measure of data quality. Field duplicates indicate the precision of the overall sampling and analysis event, and matrix spike duplicates indicate the precision of the laboratory analyses. The following duplicate samples will be collected during the SVE treatability investigation:

- **Field Duplicates:** One field duplicate sample will be analyzed for every 10 or fewer soil samples submitted for every analysis. All soil duplicates will be identified in the field and prepared in the laboratory from soils in the selected brass liners.

One duplicate canister sample will be collected for each 10 soil vapor canister samples submitted for offsite analysis. The duplicate sample will be identified in the field and on the sample chain of custody record.

- **Matrix Spike Duplicates:** One matrix spike duplicate will be analyzed for every 10 or fewer soil samples submitted for each analysis. All matrix spike duplicates will be identified in the field and prepared in the laboratory from soils in the selected brass liners.

A matrix spike sample will be prepared in the laboratory for every 10 soil vapor canister samples collected as part of air permeability testing. The spike sample (matrix spike) will be prepared by delivering a mixture of standard gas from an audit cylinder to a premoisturized canister. The cylinder audit gas is a blend of 17 VOCs in a balance of nitrogen. The gas was prepared by Scott Marrin Specialty Gasses and preanalyzed to a tolerance of ± 5 percent for each compound. The compounds range in concentration between 96 ppbv and 110 ppbv.

The audit cylinder will be used to directly deliver gas to a six-litre canister previously requested for field use. The canister matrix spike sample will be prepared to a final pressure similar to the actual samples collected in the SVE field study (i.e., -6 ± -10^{11} Hg). The following compounds are represented in the audit cylinder:

1,2-Dichloroethane	1,1-Dichloroethane
1,1-Dichloroethylene	t-1,2-Dichloroethylene
Dichlorodifluoromethane	c-1,2-Dichloroethylene
Trichlorofluoromethane	Vinyl Chloride
Trichloromethane	Dichloromethane
1,1,1-Trichloroethane	Benzene
Tetrachloromethane	Toluene
Trichloroethylene	(Balance Nitrogen)
Tetrachloroethylene	

A number of blank samples will also be collected and analyzed. Field blanks measure the performance of sampling equipment and sampling containers. Trip blanks provide an indication of external, nonsampling effects on sample integrity. Equipment blanks help to monitor the effectiveness of equipment decontamination procedures. The following blank samples will be collected during the SVE treatability investigation:

- **Field Blanks:** One field blank will be analyzed for every 20 or fewer soil samples. All field blanks will be generated in the field using diatomaceous earth brought to the site and a clean brass soil liner.
- **Trip Blanks:** One trip blank will be analyzed with each batch of VOC samples (8010, MM8015, or 8240) submitted to the laboratory. Trip blanks will be generated in the lab using DI water and sent to the field prior to initiating the treatability investigation work.
- **Equipment Blanks:** One equipment blank will be analyzed for each analytical method employed as part of the treatability investigation. Equipment blanks will be prepared in the field by pouring DI water through a clean brass soil liner.
- **Canister Field Blanks:** One field blank canister sample will be prepared separately. The field blanks will be prepared using ultrapure-moisturized nitrogen and delivered to the canister through a standard probe and flow controller assembly. This will be done to simulate actual field equipment conditions. Because dedicated sampling equipment will be used for each well location, no decontamination checks will be made. The blank, therefore, will be a check of the laboratory cleaning and traveling process. The nitrogen stream will be moisturized using an in-line impinger filled with ultrapure HPLC water.

Notes: Moisturizing of the nitrogen introduced to the blank sampling assembly will be performed by passing/sparging the nitrogen from a pressurized cylinder through ultrapure water. The moistened stream or saturated stream will then be directed to the probe section.

The expected number of samples, duplicates, and matrix spike duplicates are listed on Table 4-1, presented in Section 4 of this SAP.

Section 10
DECONTAMINATION PROCEDURES
AND WASTE DISPOSAL

This section includes a description of equipment decontamination procedures that will be employed during the SVE treatability investigation. Decontamination procedures for field personnel are described in the site health and safety plan (HASp).

Contamination at the treatability investigation site is principally associated with volatile and semivolatile organic compounds; therefore, pressurized hot water cleaning to remove soil and contaminants will be the primary feature of the equipment decontamination process. Two levels of equipment decontamination will be implemented. The first level (Level 1) of equipment decontamination will be a general decontamination process that applies to all onsite equipment used for soil augering, soil borings, and sampling. The second level (Level 2) of equipment decontamination will be a more specific decontamination process applied to sampling equipment tools and utensils or other equipment that will contact soil samples. This decontamination protocol is based on information presented by EPA in *Protocol for Groundwater Evaluation*, OSWER DIR 9080.0-1.

LEVEL 1 GENERAL EQUIPMENT DECONTAMINATION

All equipment (including but not limited to drilling equipment, support and ancillary equipment, vehicles, drill rods, auger flights, sampling equipment, split spoons, and tools) will be given the following general decontamination before site entry. Also, sampling equipment (including all downhole and surface sampling gear) must be put in a plastic-lined "dirty-equipment" area for decontamination after each sampling event.

All drilling equipment, including the rig and associated equipment, will be decontaminated by the drilling subcontractor before entering and leaving the site. Drilling equipment will also be decontaminated between the drilling of each borehole.

The decontamination process will include:

- Removal of all loose dirt
- Thorough cleaning with a pressurized hot water spray

All air sampling equipment will be laboratory cleaned prior to mobilization to the field in accordance with TO-14 protocol. Dedicated sampling equipment will be used per sampling location and therefore no field decontamination will be required.

LEVEL 2 SAMPLING EQUIPMENT DECONTAMINATION

Sampling equipment, such as split spoons, brass liners, utensils, and other items that will contact with soil samples, will receive a second decontamination as follows:

- Scrub with Alconox and water
- Rinse with distilled water
- Rinse with methanol
- Rinse with deionized/distilled water
- Air dry

CONTAMINATED MATERIALS DISPOSAL

Disposable materials contaminated during the sampling operations (e.g., tyveks, booties, gloves) will be placed in plastic bags for disposal. Ultimate responsibility for the disposal of the accumulated materials will lie with the McClellan AFB.

INVESTIGATION DERIVED WASTE MANAGEMENT

Drill cuttings from the installation of soil borings and SVE test wells will be temporarily stored onsite in drums, rolloff bins, or other suitable containers. Two grab samples from each bin will be collected by the field team for offsite Toxicity Characteristic Leaching Procedure (TCLP) analysis. The TCLP analyses will provide information on the waste stream and potential disposal options. Ultimate disposal of the soil within the bins will be handled by the Air Force staff.

Carbon canisters used for offgas treatment during the air permeability testing will be disposed of offsite by a CH2M HILL subcontractor. McClellan AFB will be listed as the generator of this waste.

Decontaminated water will be collected by CH2M HILL in an onsite tank and disposed by McClellan AFB personnel at the base's wastewater treatment plant.

Section 11 REFERENCES

- Agrelot, Jose C., James J. Malot, and Melvin J. Visser. Vacuum Defense System for Groundwater VOC Contamination. Presented at the Fifth National Symposium on Aquifer Restoration and Ground Water Monitoring, Columbus, Ohio. May 21-24, 1985.
- Applegate, Joseph, John K. Gentry, and James J. Malot. Vacuum Extraction of Hydrocarbons from Subsurface Soils at a Gasoline Contamination Site. 1988.
- Bennedsen, M.B. et al. Use of Vapor Extraction Systems for In Situ Removal of Volatile Organic Compounds from Soil. 1987.
- California Regional Water Quality Control Board, Control Valley Region. The Designated Level Methodology for Waste Classification and Cleanup Level Determination. October 1986.
- Danko, J. 1989. Applicability and Limitations of Soil Vapor Extraction. Presented at the Soil Vapor Extraction Technology Workshop, Office of Research and Development, Edison, NJ. June 28-29.
- Elliott, M., and DePaoli, D. 1989. In Situ Venting of Jet Fuel--Contaminated Soil. Presented at the 44th Purdue Industrial Waste Conference. May 1989.
- Johnson, P.C., M.W. Kemblowski, J.D. Colthart, D.L. Byers, and C.C. Stanley. 1989. A Practical Approach to the Design, Operation, and Monitoring of In situ Soil Venting Systems. Presented at the Soil Vapor Extraction Technology Workshop, Office of Research and Development, Edison, NJ. June 18-29. [Also published (1990): Ground Water Monitoring Review, 10(2):150-178].
- Michaels, P.A. and Stinson, M.K. Technology Evaluation Report. SITE Program Demonstration Test Terra Vac In Situ Vacuum Extraction System Groveland, Massachusetts. Contract No. 66-03-3255. 1989.
- Miller, Major R. 1990. A Field Scale Investigation of Enhanced Petroleum Hydrocarbon Biodegradation in the Vadose-Zone at Tyndall AFB, Florida. Presented at the 1990 National Water Works Association Conference, Houston, TX. July 9.
- Massmann, J.W. Applying Groundwater Flow Models in Vapor Extraction System Design. *Journal of Environmental Engineering*, Vol. 115, No. 1. February 1989.

Sherard, J.L., L.P. Dunnigan, and J.R. Talbot (1984). Basic Properties of Sand and Gravel Filters. *Journal of Geotechnical Engineering*, 110(6), 684-700.

United States Environmental Protection Agency. Risk Assessment Guidance for Superfund: Volume I--Human Health Evaluation Manual (Part B). April 1990.

United States Environmental Protection Agency. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA 4-84-041. April 1984.

APPENDIX A
ONSITE HEADSPACE ANALYSIS

SCREENING ANALYSIS FOR
VOLATILE INDICATOR PARAMETERS IN SOIL SAMPLES

1. SCOPE AND APPLICATION

1.1 This method is utilized for field screening of soil samples from the Verona Well Field (VWF) site for volatile hydrocarbon parameters that are indicative of contamination at the site. It is presented as a means to rapidly characterize contamination in soil samples as part of the RI/FS field sampling plan. The method lacks specificity. It is only semi-quantitative for VWF compounds such as:

1,1,1 Trichloroethane (1,1,1--TCA)

Trichloroethylene (TCE)

Tetrachloroethylene (PCE)

Toluene

Xylene

1.2 Application of this method is limited to the screening analysis of soil for the target constituents. The test data record produced in the analyses allows the site investigation team to

examine the relative degree of soil contamination by volatile compounds.

1.3 This method is nonspecific and, as such, it will not differentiate between target constituents and contamination due to the presence of other volatile hydrocarbons.

1.4 The method detection limits (MDL) for the target constituents are estimated to be approximately 0.05 ppm. These estimates are the result of previous method development work on similar projects.

2. SUMMARY OF METHOD

2.1 The method presented here is loosely based on EPA Method 5020, headspace analysis, found in the EPA SW 846, Test Methods for Evaluating Solid Waste, second edition, July 1982. In brief, the lateral half section of a split spoon is placed in a 16-ounce polyethylene bottle. The sample headspace is analyzed using a HNu analyzer based on photoionization detection, and the results are recorded.

3. INTERFERENCES

3.1 Samples containing volatile hydrocarbons other than the target constituents may be detected in addition to the target constituents.

3.2 Any compound with an appreciable vapor pressure that ionizes at or below 10.2 electron volts in the analyzer may be detected in the analysis.

3.3 The detection limits and quality of quantification are a function of the soil moisture content and partition coefficients of the target constituents.

4. SAFETY

4.1 The target constituents are either identified as or suspected of being carcinogens. All samples are assumed to be hazardous. Stock and working calibration standards, as well as samples, shall be handled with the utmost care using good lab techniques to avoid harmful exposure.

4.2 Lab analysts shall wear lab coats, safety glasses, and surgical gloves at all times when preparing and handling standards and field and lab samples.

4.3 Standards and samples shall be prepared in a fume hood. This includes all subsampling and compositing activities.

4.4 Volatile compounds found at VWF such as perchloroethene trichloroethene, etc., are regulated by OSHA and described in NIOSH/OSHA manual Occupational Health Guidelines for Chemical Hazards, 1981. The short term exposure limit (STEL) is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a workday, even if the time-weighted average is within the TCV. The STEL's for these compounds are above 100 ppm. These compounds also have odor thresholds that are in the range of 25 ppm or less, which offers "good warning properties." Exposure pathways are oral, dermal, eyes, and airway. Short-term exposure effects include: light headedness, dizziness, and headache. Long-term exposure effects include: vomiting, fainting, and possible unconsciousness. Systemic effects result from either a large exposure or repeated smaller exposures through any of the exposure routes.

Any situation that leads to or causes noticeable odors or produces any noticeable symptoms in the

workers shall be investigated, immediately followed by appropriate corrective action.

4.5 Safety equipment including a fire extinguisher, first aid kit, eye wash, and chemical spill clean-up kit shall be available for use at all times.

5. APPARATUS AND MATERIALS

5.1 Bottles--16-ounce polyethylene wide mouth with screw caps that are drilled in a size to accept the probe of the HNu analyzer.

5.2 Lab tape--used to seal the hole in the polyethylene bottle cap immediately after depositing the sample in the bottle.

5.3 Analyzer--HNU Model PI 101; complete with 10.2 electron volt probe and attachments.

5.4 Ringstand and clamp--used to support the probe of the analyzer.

5.5 Labware--necessary for preparation and handling of samples and standards.

5.6 Refrigerator/freezer--complete with locks as needed for storage and controlled access to samples.

6.0 CHEMICALS, REAGENTS, AND GASES

6.1 Span gas--HNU span gas or equivalent at approximately 50-ppm benzene equivalent for calibration of the analyzer.

6.2 Zero air--proper grade for zeroing the analyzer.

6.3 Methanol--reagent grade for cleaning.

7. CALIBRATION

7.1 Direct zero air to the HNU analyzer and zero it using the zero control pot.

7.2 With the analyzer on the mid-range setting (0-200), direct span gas to the analyzer and adjust the span control pot such that the meter corresponds to the stated concentration of the span gas. The span gas shall be isobutylene with a 62-ppm benzene equivalent. Instrument shall be calibrated daily.

7.3 Complete the calibration log identified as "Volatiles Screening Calibration Log."

8. SAMPLE PREPARATION AND EXTRACTION

8.1 Allow the sample to come to room temperature.

8.2 Position the sample container under the HNu probe as shown in Figure 1. Remove the tape covering the hole in the bottle cap and insert the probe to the point marked on its side (about half way into the bottle).

8.3 Observe the meter scale for upscale deflection and record the highest reading observed. Switch scales on the analyzer if necessary to obtain on-scale readings.

8.4 Record the highest reading on the sample data sheet.

8.5 Transfer the contents of the sample bottle to a soil sample disposal drum.

8.6 Clean each polyethylene bottle and its cap in this order: rinse and brush with tap water, rinse with methanol, and finally rinse with deionized water.

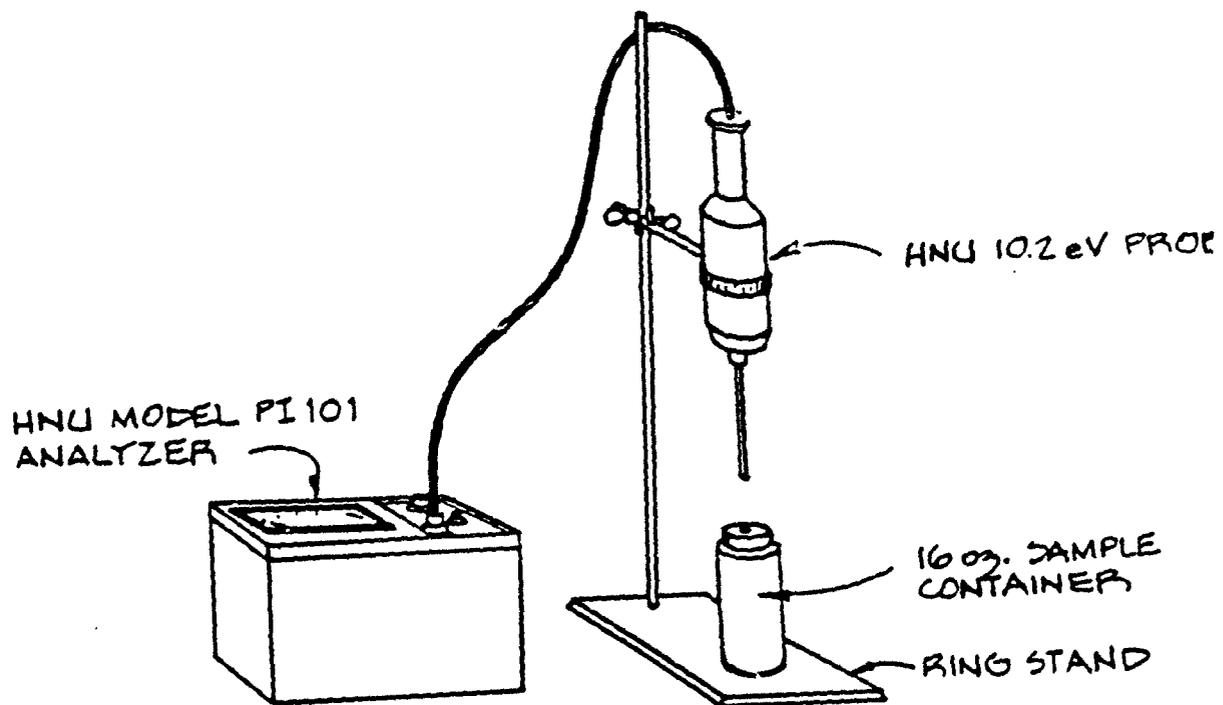


FIGURE 1
VOLATILES SCREENING APPARATUS

Allow the bottle and cap to air dry. With the cap in place, use the HNu analyzer to test each bottle to determine if each bottle is clean. Reject any bottle having a measurable reading at the lowest calibration range. Repeat the cleaning process as needed to thoroughly clean all bottles. Discard bottles that continue to give measurable readings.

9. QUALITY ASSURANCE

9.1 Span control settings of less than 5.0 on the HNu analyzer are indicative of a dirty lamp. Any time the setting approaches 5.0, clean the detector as described in the analyzer operations manual.

9.2 Quality assurance measures shall include as a minimum; daily calibration of the HNu analyzer and mid-range calibration checks prior to the analysis of each lot of samples or with each lot of 20 samples, whichever is more frequent.

CVR178/015

APPENDIX B
CH2M HILL SOIL BORING LOG GUIDELINES

CVOR146022.51-2

SOIL BORING LOG GUIDELINE

SOIL BORING LOG POLICY

This soil boring guideline will be used for all CH2M HILL projects in which soil boring techniques are used during geotechnical field exploration. The purpose of the guideline is to assist CH2M HILL staff in accurately recording and presenting all field data that are necessary to sufficiently describe, label, and package recovered soil samples in a consistent manner. The guideline establishes the minimum kinds of information that must be recorded in the field to adequately characterize recovered soil samples.

Because each of our projects is unique and because job requirements can vary widely, the minimum standards presented in this guideline may need to be supplemented with additional technical descriptions or field test results. However, all soil boring field logs, regardless of special project circumstances, must include information addressed in this guideline to achieve minimum acceptable standards required by CH2M HILL.

All CH2M HILL staff members are encouraged to present their suggestions for clarification or improvements to this guideline. Please submit all suggestions or comments in writing to the Geotechnical Discipline Group Director.

RECORDING SOIL BORING FIELD DATA

CH2M HILL Standard Form D1586, the Soil Boring Log form, will be used on all CH2M HILL projects for field logging (see Figure 1). Adherence to a standard format for recording data will help streamline our project efforts and ensure a consistent presentation of factual subsurface data. All heading information must be completely filled out on each log sheet used, and all technical items in each column must be addressed in the field.

The boring log should be completed in the field according to the attached instructions. Forms should be filled out neatly and completely. Laboratory testing, if required, should be initiated immediately after completion of the field work. Field classifications of samples should be checked against the laboratory test results, and corrections should be noted, initialed, and dated on the field log.

INSTRUCTIONS FOR COMPLETING SOIL BORING LOG, FORM D1586

Form D1586 is a standard CH2M HILL form that is available in weatherproof paper from all regional form distributors.

Following are instructions for completing the log forms in the field. See Figure 2 for an example of a field log completed according to the instructions.

Field personnel should review logs on completion for accuracy, clarity, and thoroughness of detail. Samples should also be checked to see that information is correctly recorded on both jar lids and labels and on the log sheets.

If any changes to the soil classification are made on the log forms after completion of the field work, they should be done in red, then initialed, and dated.

Heading Information

Project Number. Use standard region code, contract I.D. (5-digit), and point number designated for field exploration or geotechnical services.

Boring Number. Enter the boring number. A numbering system should be chosen that does not conflict with information recorded for previous exploratory work done at the site. Number the sheets consecutively for each boring. If rock core log sheets are also used, continue the consecutive numbering.

Project. Fill in the name of the project or client.

Location. If stationing, coordinates, mileposts, or similar project layout information is available, indicate the position of the boring with respect to that system, using modifiers such as "approximate" or "estimated" as appropriate. If this information is not available, identify the client facility (e.g., Richland STP, center of Clarifier No. 2 site) or the town and state.

Elevation. Enter the elevation. If it is estimated from a topographic map, or if it is roughly determined using a hand level, use the modifier "approximate." If the elevations are to be surveyed later, or if the elevation is unknown, enter this information.

Drilling Contractor. Enter the name of the drilling company and the city and state where the company is based.

Drilling Method and Equipment. Identify the bit size and type, drilling fluid (e.g., mud, Revert), and method of drilling (e.g., rotary, hollow-stem auger, air track). Information on the drilling equipment (e.g., CME 55, Mobile B61) should also be entered here.

Water Level and Date. Enter the depth at which groundwater is first encountered. If frequent water measurements are taken, the information should be recorded in the Comments

column. If water is not encountered during drilling, or could not be detected because of the drilling method, this information should be noted. Generally, water levels should be measured each morning before resuming drilling and at the completion of each boring. Record date and time of day (for tides, river stage, etc.) of each water level measurement.

Date of Start and Finish. Enter the dates the boring was begun and completed. Time of day may be added if several borings are performed on the same day.

Logger. Enter the first initial and full last name.

Technical Data

Depth Below Surface. Use a depth scale that is appropriate for the sample spacing and for the complexity of subsurface conditions.

Sample Interval. Draw horizontal lines at the top and bottom depth of each sample interval. These lines should extend to the soil description column. For a very short sample interval, the bottom line can be lowered after the interval column to provide room for writing the information (see Figure 2). Enter the depth at the top and bottom of the sample interval.

Sample Type and Number. Enter the sample type and number. For instance, S1 = split spoon, first sample. Number samples consecutively regardless of type. Enter a sample number even if no material was recovered in the sampler.

Sample Recovery. Enter the length to the nearest tenth of a foot of soil sample recovered from the sampler.

Standard Penetration Test Results. In this column enter the number of blows required for each 6 inches of sampler penetration and the "N" value, which is the sum of the blows in the last two 6-inch penetration intervals. A typical standard penetration test involving successive blow counts of 2, 3, and 4 would be recorded as 2-3-4 and (7). The standard penetration test will be terminated if the sampler encounters refusal. Refusal is a penetration of more than 6 inches but less than 12 inches with a blow count of 100, or a penetration of less than 6 inches with a blow count of 50. A partial penetration of 50 blows for 4 inches is recorded as 50/4".

Soil Description. The soil classification should follow the format described in the section below entitled "Field Classification of Soil."

Symbolic Log. This column is usually omitted during fieldwork.

Comments. Include all pertinent observations (e.g., changes in drilling fluid color, rod drops, drilling chatter, rod bounce as in driving on a cobble, damaged Shelby tubes, and equipment malfunctions). Also note if casing was used, the sizes and depths installed, and if drilling fluid was added or changed. You should instruct the driller to alert you to any significant changes in drilling (e.g., changes in material, occurrence of boulders, and loss of drilling fluid). Such information should be attributed to the driller and recorded in this column.

Specific information might include:

- The date and the time drilling began and ended each day
- The depth and size of casing and the method of installation
- Depth of rod chatter
- Depth and percentage of drilling fluid loss
- Depth of hole caving or heaving
- Depth of change in material
- Drilling interval through a boulder
- The results of pocket penetrometer or torvane test reported as: "PP = _____ TSF" or "TV = _____ TSF," respectively

The depth of piezometers and the results of in situ tests should be noted in the Comments column.

FIELD CLASSIFICATION OF SOIL

This section presents the format for the field classification of soil. All descriptions of soil will be done in accordance with the Unified Soil Classification System (USCS), ASTM D 2487-85 (Figures 3 and 4). The approach and format for classifying soils should conform, in general, to ASTM D 2488-84, Visual-Manual Procedure for Description and Identification of Soils.

The Unified Soil Classification System is based on numerical values of certain soil properties, which are measured by laboratory tests. It is possible, however, to estimate these values in the field with reasonable accuracy using visual-manual procedures. Also, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of

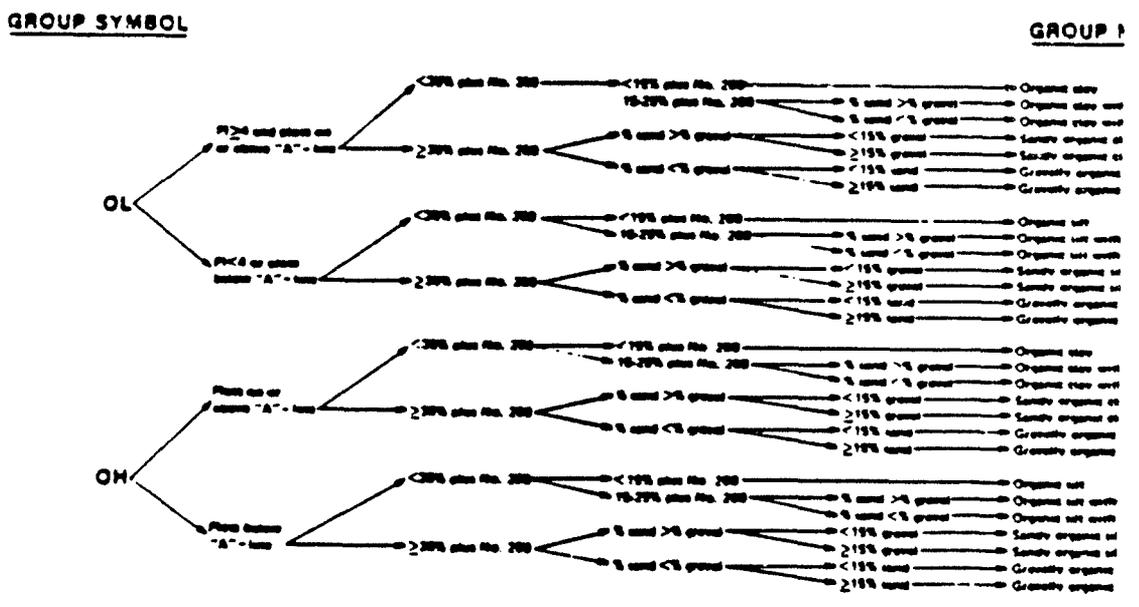
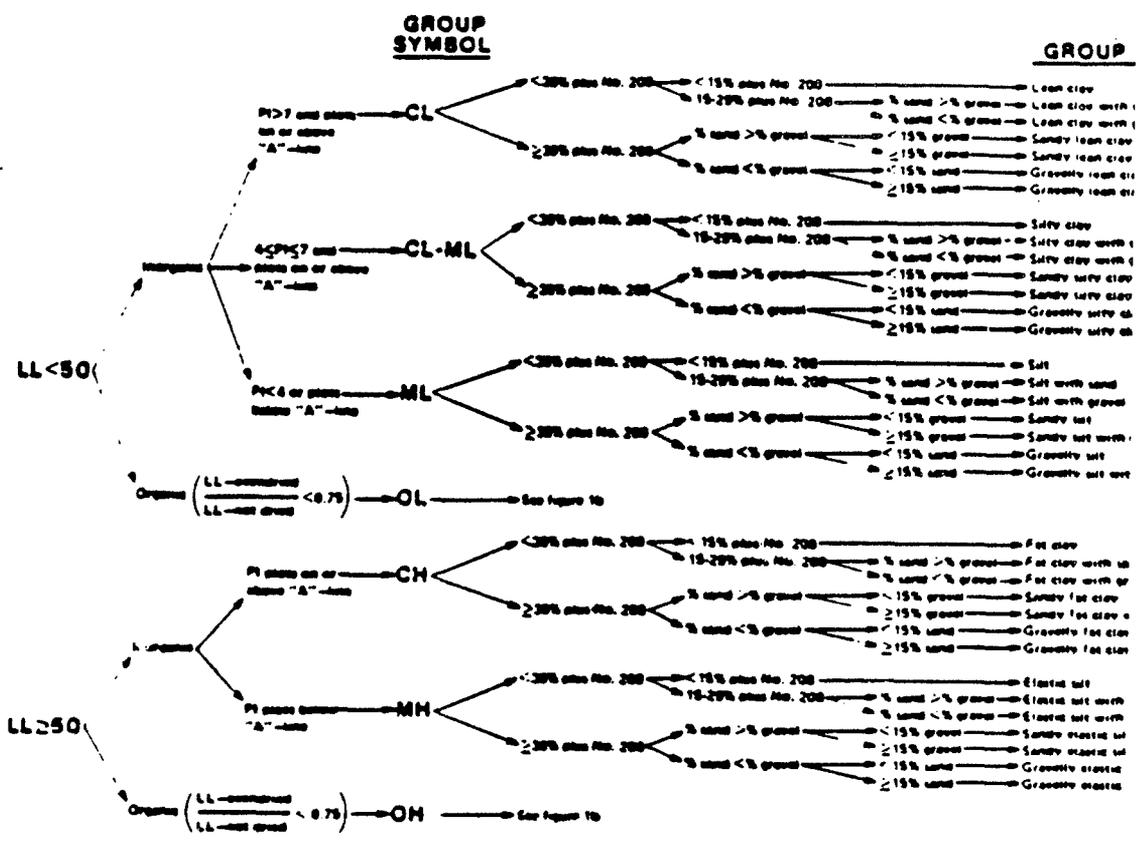
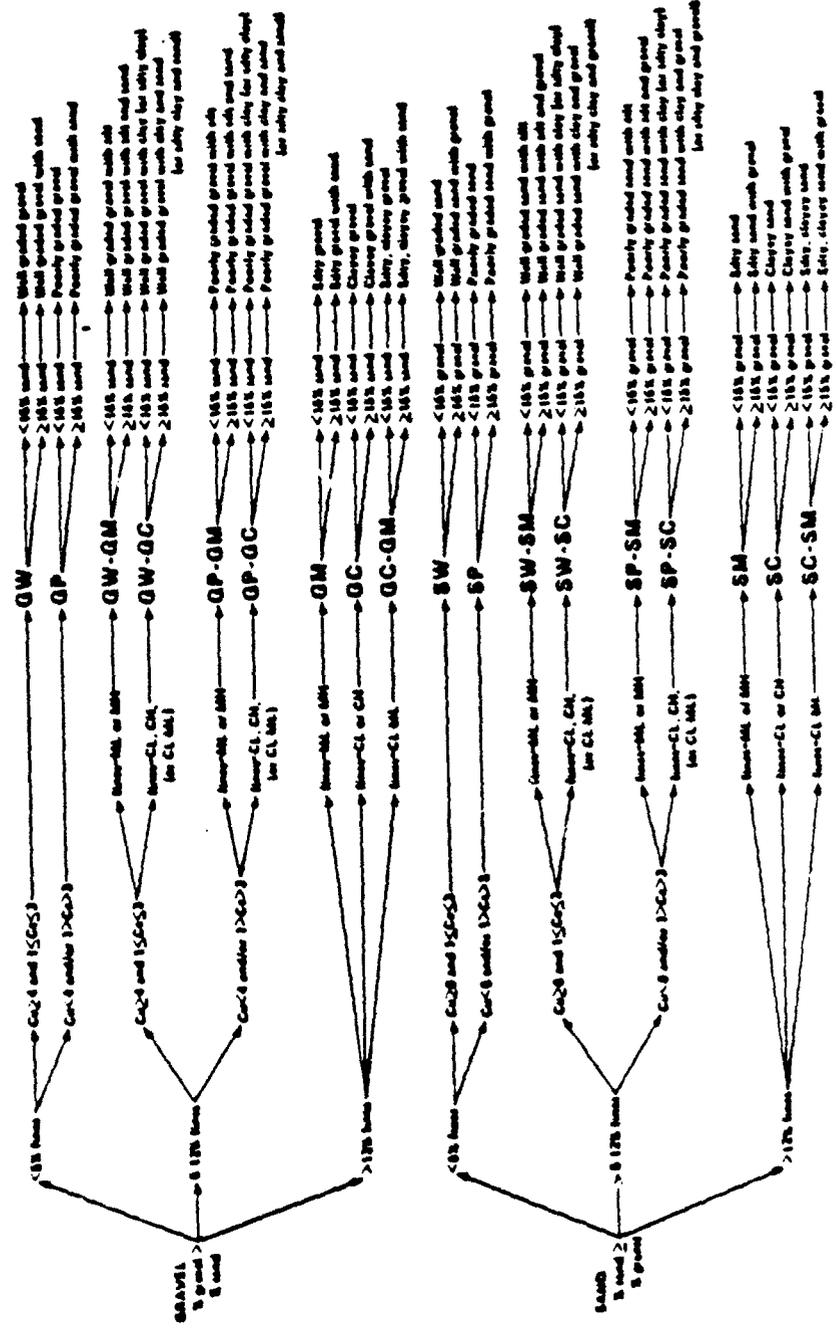


Figure 3
FLOWCHART FOR CLASSIFICATION OF FINE-GRAINED SOIL

GROUP NAME

GROUP SYMBOL



soil types in a bedded deposit, can be obtained only in the field. Corrections and additions to the field classification can be provided, when necessary, by laboratory testing of the soil samples.

Soil descriptions should be precise and comprehensive without being verbose. The correct overall impression of the soil should not be distorted by excessive emphasis on insignificant details. In general, similarities between consecutive samples should be stressed rather than differences.

Soil descriptions shall be recorded in the Soil Description column for every soil sample collected. The format and order for soil descriptions should be:

1. Soil name (synonymous with ASTM D 2487-85 Group Name) with appropriate modifiers
2. Color
3. Moisture content
4. Relative density or consistency
5. Soil structure or mineralogy
6. Group symbol

This order follows, in general, the format described in ASTM D 2488-84. Examples of soil descriptions are provided in Table 1.

Soil Name

The basic name of a soil shall be identical to the ASTM D 2487-85 Group Name based on visual estimates of gradation and plasticity. The soil name should be capitalized. The only acceptable soil names are those listed in Figures 3 and 4, which are from ASTM D 2487-85.

Examples of acceptable soil names are illustrated by the following:

A soil sample is visually estimated to contain 15 percent gravel, 55 percent sand, 30 percent fines (passing No. 200 sieve). The fines are estimated as either low or highly plastic silt. This sample is SILTY SAND WITH GRAVEL, with a Group Symbol of (SM).

Another soil sample has the following visual estimate: 10 percent gravel, 30 percent sand, and 60 percent fines (passing the No. 200 sieve). The fines are estimated as low plastic silt. This sample is SANDY SILT. The gravel portion is not included in the soil

Table 1
EXAMPLE SOIL DESCRIPTIONS

POORLY GRADED SAND, fine, well-rounded, light brown, moist, loose (SP)

FAT CLAY, dark gray, moist, stiff (CH)

SILT, light greenish gray, wet, very loose, some mica, lacustrine (ML)

WELL-GRADED SAND WITH GRAVEL, subangular gravel to 0.6 inches max, reddish brown, moist, dense, (SW)

POORLY GRADED SAND WITH SILT, white, wet, medium dense (SP-SM)

ORGANIC SILT WITH SAND, dark brown to black, wet, firm to stiff but spongy undisturbed, becomes soft and sticky when remolded, many fine roots, trace of mica (OH)

SILTY GRAVEL WITH SAND, subrounded gravel to 1.2 inches max, brownish red, moist, very dense, (GM)

INTERLAYERED SILT (60 percent) AND CLAY (40 percent): SILT WITH SAND, nonplastic, sudden reaction to shaking, medium greenish gray, layers mostly 1.5 to 8.3 inches thick; CLAY, dark gray, firm and brittle undisturbed, becomes very soft and sticky when remolded, layers 0.2 to 1.2 inches thick (ML and CH)

SILTY SAND WITH GRAVEL, weak gravel to 1.0 inches max, light yellowish brown, compact, moist, very few small particles of coal, fill (SM)

SANDY ELASTIC SILT, very light gray to white, wet, stiff, weak calcareous cementation, (MH)

SILTY CLAY WITH SAND, dark brownish gray, moist, stiff (ML-CL)

WELL-GRADED GRAVEL WITH SILT, rounded gravel to 1.0 inches max, brown, moist, very dense (GW-GM)

name because the gravel portion was estimated as less than 15 percent. The Group Symbol is (ML).

The gradation of coarse-grained soil (more than 50 percent retained on No. 200 sieve) is included in the specific soil name in accordance with ASTM D 2487-85. There is no need to further document the gradation. However, the maximum size and angularity or roundedness of gravel and sand-sized particles should be recorded. For fine-grained soil (50 percent or more passing the No. 200 sieve), the name is modified by the appropriate plasticity/elasticity term in accordance with ASTM D 2487-85.

Interlayered soil should each be described starting with the predominant type. An introductory name should be used such as "Interlayered Sand and Silt." Also, the relative proportion of each soil type should be indicated (see Table 1 for example).

Where helpful, the evaluation of plasticity/elasticity can be justified by describing results from any of the visual-manual procedures for identifying fine-grained soils, such as reaction to shaking, toughness of a soil thread, or dry strength as described in ASTM D 2488-84.

Color

The basic color of a soil, such as brown, gray, or red, shall be given. The color term can be modified, if necessary, by adjectives such as light, dark, or mottled. The color description should be kept simple and should not emphasize unimportant color aspects or shades.

Moisture Content

The degree of moisture present in a soil sample should be defined as dry, moist, or wet. Moisture content can be estimated as follows:

Dry	Requires addition of considerable moisture to obtain optimum moisture content
Moist	Near optimum moisture content
Wet	Requires drying to obtain optimum moisture content

Relative Density or Consistency

Relative density of a coarse-grained (cohesionless) soil is based on N-values (ASTM D 1586-84). If the presence of large gravel or disturbance of the sample makes determination of the in situ relative density or consistency

difficult, then this item should be left out of the description and explained in the Comments column of the soil boring log.

Consistency of fine-grained (cohesive) soil is properly based on results of pocket penetrometer or torvane results. In the absence of this information, consistency can be estimated from N-values. Relationships for determining relative density or consistency of soil samples are given in Tables 2 and 3.

Soil Structure or Mineralogy

Discontinuities and inclusions are important and should be described. Such features include joints or fissures, slickensides, bedding or laminations, veins, root holes, and wood debris.

Significant mineralogical information should be noted. Cementation, abundant mica, or unusual mineralogy should be described, as well as other information such as organic debris or odor.

Residual soils have characteristics of both rock and soil and can be difficult to classify. Relict rock structure should be described and the parent rock identified if possible.

Group Symbol

Each soil description is concluded with the appropriate group symbol from ASTM D 2487-85 (see Figures 3 and 4). The group symbol should be placed in parentheses at the end of the description to indicate that the classification has been estimated.

In accordance with ASTM D 2488-84, dual symbols (e.g., GP-GM or SW-SC) can be used to indicate that a soil is estimated to have between 5 and 12 percent fines. Borderline symbols (e.g., GM/SM or SW/SP) can be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. The use of a borderline symbol should not be used indiscriminately. Every effort should be made to first place the soil into a single group.

STANDARD PENETRATION TEST PROCEDURES

Standard Penetration Tests (SPT) are conducted to obtain a measure of the resistance of the soil to penetration of the sampler and to recover a disturbed soil sample. Standard Penetration Tests should be conducted in accordance with ASTM D 1586-84, Penetration Test and Split Barrel Sampling of Soils.

Table 2
RELATIVE DENSITY OF COARSE-GRAINED SOIL
(Developed from Sowers, 1979)

<u>Blows/Ft</u>	<u>Relative Density</u>	<u>Field Test</u>
0-4	Very loose	Easily penetrated with 1/4-in. steel rod pushed by hand
5-10	Loose	Easily penetrated with 1/4-in. steel rod pushed by hand
11-30	Medium	Easily penetrated with 1/4-in. steel rod driven with 5-lb. hammer
31-50	Dense	Penetrated a foot with 1/4-in. steel rod driven with 5-lb. hammer
>50	Very dense	Penetrated only a few inches with 1/4-in. steel rod driven with 5-lb. hammer

Table 3
CONSISTENCY OF FINE-GRAINED SOIL
(Developed from Sowers, 1979)

<u>Blows/Ft</u>	<u>Consistency</u>	<u>Pocket Penetrometer (TSF)</u>	<u>Torvane (TSF)</u>	<u>Field Test</u>
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumb but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
>30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

Equipment and Calibration

Before starting the testing, the necessary equipment should be inspected for compliance with the requirements of ASTM D 1586-84. The split-barrel sampler should measure 2 inches O.D., with 1-3/8 inches I.D., and should have a split tube at least 18 inches long. The dimensions should conform with those indicated on Figure 1 of ASTM D 1586-84. The minimum size sampler rod allowed is "A" rod (1-5/8 inches O.D.). A stiffer rod, such as "N" rod (2-5/8 inches O.D.), is required for depths greater than 50 feet. The drive weight assembly should consist of a 140-pound hammer weight, a drive head, and a hammer guide that permits a free fall of 30 inches.

Procedures

Standard Penetration Tests should be conducted at every change of strata or, within a continuous stratum, at intervals not exceeding 5 feet. Before driving the split-barrel sampler, all loose and foreign material should be removed from the bottom of the borehole. It may be helpful to measure the rod "stickup" to ensure that the sampler is being driven from the bottom of the borehole. The Standard Penetration Test should be performed by driving a standard split-barrel sampler 18 inches into undisturbed soil at the bottom of the borehole by a 140-pound guided hammer or ram, falling freely from a height of 30 inches.

The number of blows required to drive the sampler for three 6-inch intervals, for a total of 18 inches, should be observed and recorded on the soil boring log. The sum of the number of blows required to drive the sampler the second and third 6-inch intervals is considered the Standard Penetration Resistance (N) or the "blow-count." If the sampler is driven less than 18 inches, but more than 1 foot, the penetration resistance (N) is that for the last 1 foot of penetration. If less than 1 foot is penetrated, the log shall state the number of blows and the fraction of 1 foot penetrated. If possible, the field logger should observe the sampler being driven and count the blows for each sample attempt.

General Considerations

The following comments and suggestions should be considered when performing Standard Penetration Testing:

1. The borehole should be cleaned out before every sample attempt. Because a minor amount of caving can be expected, the borehole can be considered to be adequately cleaned if no more than 4 inches of loose or foreign material has collected at the bottom of the borehole. A greater amount of caving is sufficient cause to require the hole to be cleaned again.

2. The ball check valve in the split-barrel sampler should be cleaned and working properly for each sample. Bent, chipped, or damaged shoes should be replaced. The split-barrel halves should not be warped. In case of zero sample recovery (i.e., if the sample is lost during first attempt), a spring catcher should be used during subsequent attempts to facilitate recovery.
3. During SPT sampling, it is important that all rod connections be tight and that the hammer guide be connected securely to the drill rods. If the hammer guide connection becomes loose, much of the hammer energy may be lost because of deflection of the hammer coupling. The lifting rope should not rub against the mast. Each hammer fall should be 30 inches.
4. During SPT sampling, it is important that the drill rods be positioned at the center of the drill hole. This is necessary to preclude the development of friction between drill rods and the walls of the borehole or casing.
5. If the hammer weight is raised by means of a cathead, generally two wraps on the cathead should be used. The optimum number of wraps will vary with the condition of the rope and cathead and the weather. Most importantly, the driller should exercise care to prevent friction of the rope on the cathead during the fall of the hammer.
6. Occasionally, nonstandard procedures or equipment are used for obtaining samples (such as 3-inch O.D. split-barrel samplers, or 300-pound hammers). Any nonstandard practice should be described on the boring log form. Also, the blow counts should be clearly marked as not conforming to SPT values.

SAMPLE LABELING AND PACKAGING

The samples recovered from the borehole are an important part of the boring record and must be properly packaged and labeled. Samples that are improperly or inadequately labeled are useless. The following description outlines the minimum requirements for packaging and labeling of samples.

Disturbed samples should be placed in jars that are marked both on the jar lid and on a label on the side of the jar. Standard CH2M HILL jar labels are available (Form No. 131, Soil Sample Labels) for this purpose. The following information should be clearly marked on the jars: job number, boring number, sample number, sample depth, blow counts, sample recovery, and date. Use an indelible marker or a metal scribe on the jar lid. If moisture content tests are anticipated, jar samples should be tightly sealed, then sent

to the laboratory and the testing initiated as soon as possible (within one week). See Figure 5 for labeling details.

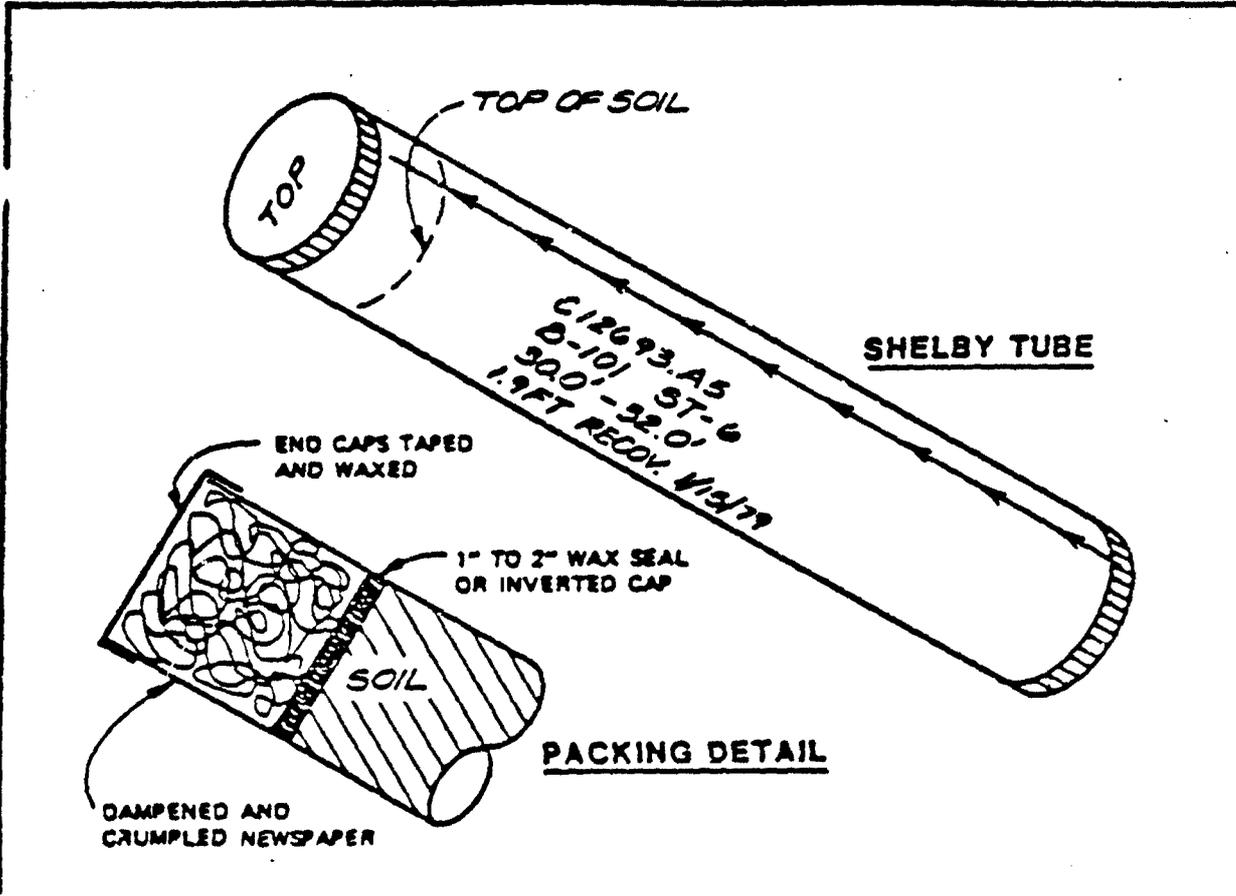
Boxes containing the jars should be labeled on top and on one end with the following information: job name, job number, boring number, sample numbers and sample depths, date, and name. It is helpful to start a new box for each new boring if the boxes are at least one-half full.

Shelby tubes should be cleaned of mud and moisture. When dry, use an indelible marker to label them with the following information: an arrow indicating which way is up, job number, boring number, sample number and depth, amount of recovery, and date. The top and bottom of the sample can be circumscribed on the outside of the tube with a marker.

Waxing of Shelby tubes is essential if sample testing will not occur within a few days. In all cases, lids should be placed on the ends and taped with airtight tape. Make certain that the holes in the top of the tube are sealed. The open portion of the tube, above the sample, should be packed to prevent shifting of the soil. Dampened newspaper is generally adequate for this purpose, but it should be separated from the soil sample by a wax seal or an inverted cap. See Figure 5 for labeling and packing details.

FIELD EQUIPMENT CHECKLIST

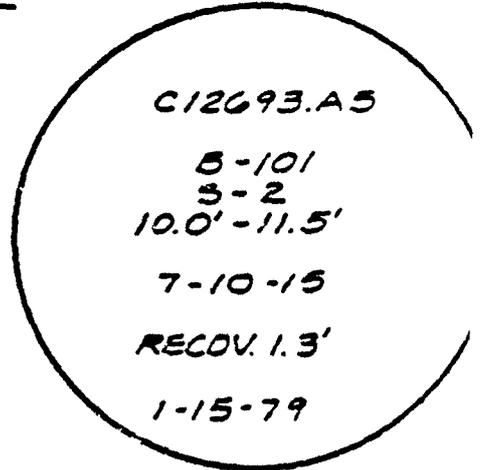
Table 4 lists equipment and supplies that are necessary or useful for soil boring exploration.



JAR SAMPLES

OFFICE <u>CVD</u>				
PROJECT NO <u>C12693.A5</u>				
T.H. <u>B-101</u>	SAMPLE <u>S-2</u>			
DEPTH	BLOWS	7	10	15
10.0' -	INCHES	6	6	6
11.5'				
DATE <u>1-15-79</u>		RECOV. <u>1.3'</u>		
FORM # 131				

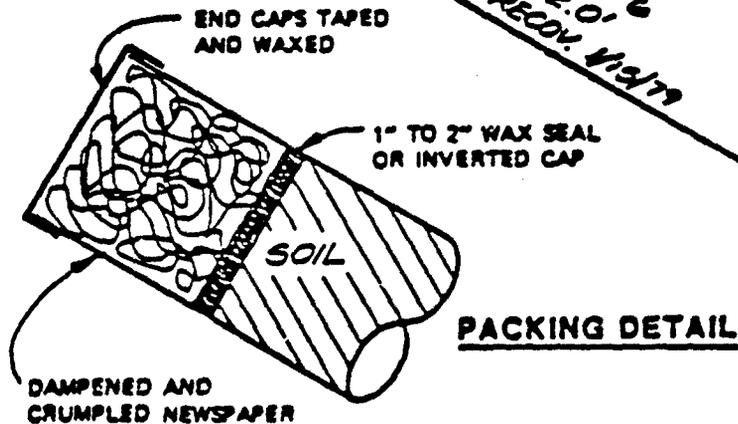
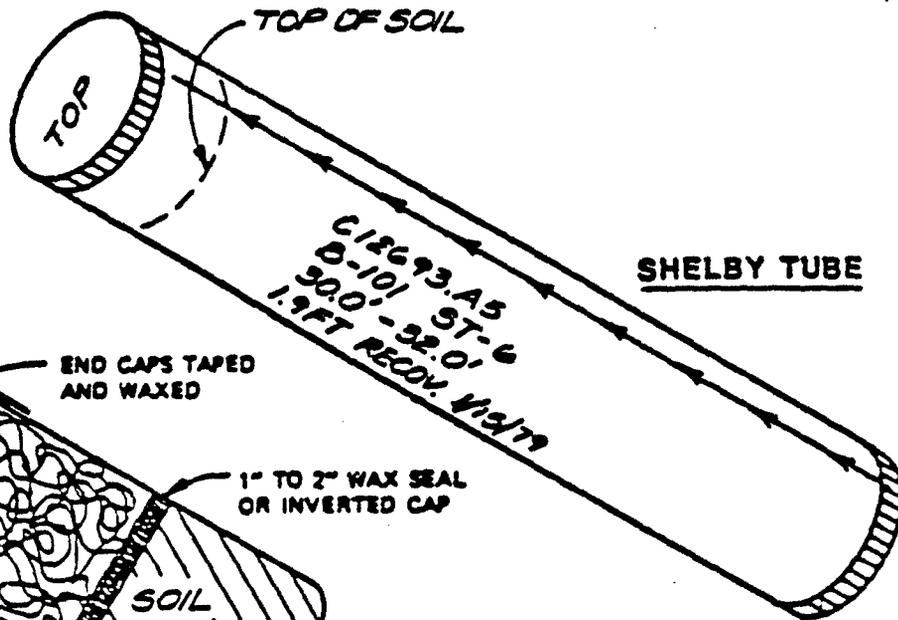
SIDE LABEL



LID

Figure 5
SAMPLE LABELING DETAILS

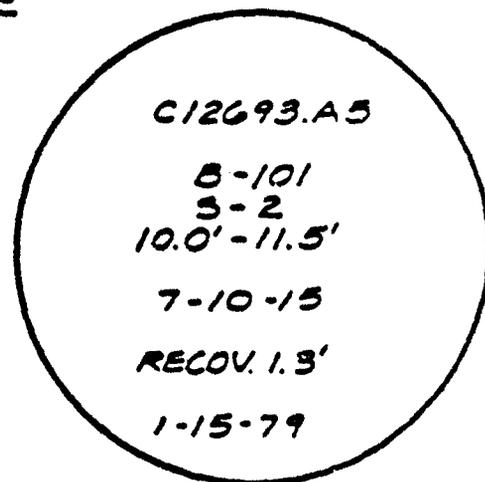




JAR SAMPLES

OFFICE <u>GYD</u>				
PROJECT NO. <u>C12693.A5</u>				
T.N. <u>B-101</u>	SAMPLE <u>S-2</u>			
DEPTH	BLOWS	7	10	15
<u>10.0'</u>	INCHES	6	6	6
<u>11.5'</u>				
DATE <u>1-15-79</u>		RECOV. <u>1.3'</u>		
FOAM # 131				

SIDE LABEL



LID

Figure 5
SAMPLE LABELING DETAILS



Table 4
FIELD EQUIPMENT CHECKLIST FOR SOIL BORING LOGGING

Siting

- Lath, flagging, and orange spray paint
- Lumber crayon
- 100-foot tape
- Brunton or Silva compass

Logging Equipment

- Soil Boring Guideline
- Clipboard
- Form-D1586 on all-weather paper
- Pens/pencils
- Engineer's pocket tape measure with tape lock
- Field notebook on all-weather paper
- Squirt bottle with water
- Spatula
- HCL, 10 percent solution

Sampling and Packaging

- Jars with lids and labels (Form #131)
- Shelby tubes and plastic end caps
- Airtight tape (e.g., electrical)
- Newspaper
- Wax, stove, melting pot, and matches
- Indelible fine felt-tipped markers (e.g., "Sharpie" brand)

Test Equipment

- Pocket penetrometer
- Torvane
- Well sounder

Other

- Camera, film
- Hand lens
- Rags
- Ear protectors
- Screwdrivers
- Hard hat
- Sunscreen
- Insect repellent

SELECTED REFERENCES

- American Society for Testing and Material. 1986. ASTM D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. Annual Book of ASTM Standards, Section 4, Vol. 4.08, pp. 298-303.
- American Society for Testing and Material. 1986. ASTM D 1587, Standard Method for Thin-Walled Tube Sampling of Soils. Annual Book of ASTM Standards, Section 4, Vol. 4.08, pp. 304-307.
- American Society for Testing and Material. 1986. ASTM D 2487, Standard Test Method for Classification of Soils for Engineering Purposes. Annual Book of ASTM Standards, Section 4, Vol. 4.08, pp. 397-410.
- American Society for Testing and Material. 1986. ASTM D 2488, Standard Practice for Description of Soils (Visual-Manual Procedure). Annual Book of ASTM Standards, Section 4, Vol. 4.08, pp. 411-425.
- American Society of Civil Engineers. 1976. Subsurface Investigation for Design and Construction of Foundations of Buildings. American Society of Civil Engineers Manual on Engineering Practice, No. 56, 53 pp.
- Bell, F. G. 1981. Engineering Properties of Soils and Rocks. London: Butterworth Publishers, Inc.
- Burmister, D. M. 1949. Principles and Techniques of Soil Identification. Proceedings of the Highway Research Board, pp. 402-433.
- Casagrande, A. 1947. Classification and Identification of Soils. American Society of Civil Engineers Transactions, pp. 901-991.
- Kovacs, W. D., L. A. Salomone, and F. Y. Yokel. 1981. Energy Measurement in the Standard Penetration Test. U.S. Dept. of Commerce, National Bureau of Standards, Building Science Series 135.
- Matula, M. 1981. Rock and Soil Description and Classification for Engineering Geological Mapping, Report by the IAEG Commission on Engineering Geological Mapping. Bulletin of the International Association of Engineering Geology, No. 24, pp. 235-274.
- Sowers, G. F. 1979. Introductory Soil Mechanics and Foundations: Geotechnical Engineering. MacMillan Publishing Co., New York, 4th edition. 621 pp.
- U.S. Bureau of Reclamation. 1974. Earth Manual. 2nd ed. Washington, D.C.: U.S. Government Printing Office.

APPENDIX C

**SOIL BORING LOGS FROM 1985 INVESTIGATION
AT SITE S IN OPERABLE UNIT D**

CVOR146022.51-3



	PROJECT NUMBER M17322.CO
SOIL BORING LOG	

PROJECT McClellan Air Force Base, IRP LOCATION South end of "S" Pit
 DRILLING METHOD 8-inch hollow stem auger DRILLERS & EQUIPMENT Diamond Core Drilling
 ELEVATION 59.5 feet BORE HOLE: BP-20
 WATER LEVEL _____ DATE: 2-28&3-1-84 START: 4:20 p.m. FINISH: 5:40 p.m. INSPECTOR CYC

DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS		SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
	INTERVAL AND TYPE	NUMBER	RECOVERY (INCHES)	BLOWS	BPF				
				8"-6"-6"	"N"				
						6 in. roadbase gravel <u>Fine to medium sand, slightly moist, brown</u>	2 2	GW SW	HNu reading above background
5	SS 1			6-5-4-6	9	Top 6 in. same <u>Fine sand, slightly moist, dark gray</u>			40 Changed to Level C 26
	SS 2	4		1-1-1-2	2	Same, moist, <u>sludge</u> in sampler	X X	SW LF	130* 60
	SS 3			11-10-7-10	17	Same, moist, black, <u>sludge</u> , wet at top 4 in.	X X		130* 80
10	SS 4			21-50/5"	>71	<u>Fine to medium sand, moist, dark gray</u>		SW	200 50
	SS 5			22-50/5"	>72	Same			280 70
	SS 6			24-40-55/5"	>95	<u>Medium to coarse sand, moist, dark gray, cemented</u>			280 330
15	SS 7			21-32-50/5"	>82	Same			Wet soil off cuttings 66
	SS 8			17-28-32	60	<u>Fine to medium sand, moist, dark gray</u>			330* 54
20	SS 9			19-25-50	75	<u>Fine to very fine sand, slightly moist, dark gray</u>			300
									Casing installed to 17 ft; deep drilling on 3-1-84, 11:15 a.m. to 1:55 p.m. 20
25	SS 10			6-12-34	46	<u>Sandy silt, slightly moist, gray; hard silt at bottom 6 in.</u>		ML	50
	SS 11			9-36-50/3"	>86	Same <u>Silty sand, slightly moist, dark brown, cemented</u>		ML SM	60 25
30									



PROJECT NUMBER
M17322.CO

SOIL BORING LOG

PROJECT McClellan Air Force Base, IRP LOCATION South end of "S" Pit
 DRILLING METHOD 8-inch hollow stem auger DRILLERS & EQUIPMENT Diamond Core Drilling
 ELEVATION 59.5 feet BORE HOLE: BP-20
 WATER LEVEL _____ DATE: 2-28-83-1-84 START: 4:20 p.m. FINISH: 5:40 p.m. INSPECTOR CYC

DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS		SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)	
	INTERVAL AND TYPE	NUMBER	RECOVERY (INCHES)	BLOWS	SPT					
				8"-8"-8"	"N"					
									HNu reading above background	
35	SS 12			8-15-32	47	Same Very fine to fine clean sand, slightly moist, dark gray		SM	Changed to Level C at 15-33 ft	
								SW	90	
40	SS 13			9-16-38	54	Same, cemented		SW	130	
45	SS 14			7-37-50/ 5"	>97	Interlayered <u>sandy silt</u> and <u>silty sand</u> , slightly moist, gray		ML / SM	175*	
50	SS 15			13-42-50 /4"		<u>Sandy silt</u> , slightly moist, gray-brown <u>Fine sand</u> , well cemented, slightly moist, gray-brown		ML SW	155	
55	SS 16			9-13-29	42	<u>Fine clean sand</u> , slightly moist, brown at tip <u>Fine to very fine clean sand</u> , slightly moist, dark brown to dark gray		SW	42	
60	SS 17			7-35-50/ 5"		<u>Fine clean sand</u> , slightly moist, dark gray <u>Sandy silt</u> , slightly moist, gray-brown		SW ML	HNu reading after pulling out augers: 0 ft: 180 ppm 140	
						Total depth = 39.3 ft				



	PROJECT NUMBER M17322.CC
SOIL BORING LOG	

PROJECT McClellan Air Force Base, IRP LOCATION North middle "S" Pit
 DRILLING METHOD 8-inch hollow stem auger DRILLERS & EQUIPMENT Diamond Core Drilling
 ELEVATION 58.5 feet BORE HOLE: BP-21
 WATER LEVEL _____ DATE: 3-1-84 START: 4:10 p.m. FINISH: _____ INSPECTOR RLO

DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS		SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
	INTERVAL AND TYPE	NUMBER	RECOVERY (INCHES)	BLOWS	SPP				
				6"-6"-6"	"N"				
								SW	HNu reading above background
5	SS	1	24	6-5-4-4	9	Fine to medium sand, slightly silty, brown, slightly moist			Fill over pit extends to about 11 ft
	SS	2	24	3-3-4-30/4"	7	Same			0
	SS	3	24	27-10-8-13	18	Same, interlayers of brown-gray silt		SW /MI	3
10	SS	4	24	3-5-5-5	10	Same, small flakes of charcoal-like material			5 24*
	SS	5	24	3-4-9-15	13	Top 12 in. fine sand, brown, slightly moist; bottom 12 in. black charcoal-like material		LF	Charcoal, with misc debris out of hole 10
	SS	6	12	4-5-5-19	10	Same			Changed to Level C 58*
15	SS	7	24	9-16-19-40	31	Top 12 in. soft sludge, black, fluid; bottom 12 in. gray-green fine to medium sand		SW	64*
	SS	8	24	26-56/5"	>70	Silty fine sand, gray, slightly moist		SM	135
20	SS	9	12	34-50/3"		Top 6 in. fine sand, gray, nearly dry; bottom 6 in. silt, gray, slightly moist, firm to hard		SP /MI	140
25									
30									